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VOL. XI.

MITCHELL'S
MANUAL OF PRACTICAL ASSAYING.

LONDON:
HIPPOLYTE BAILLIERE, 219, REGENT STREET,
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1854.

LONDON:
WILSON and OGILVY,
Skinner Street.

MANUAL
OF
PRACTICAL ASSAYING,

INTENDED FOR THE USE OF

METALLURGISTS, CAPTAINS OF MINES,
AND
ASSAYERS IN GENERAL.

WITH

Copious Tables

FOR THE PURPOSE OF ASCERTAINING IN ASSAYS OF GOLD AND SILVER,
THE PRECISE AMOUNT, IN OUNCES, PENNYWEIGHTS, AND GRAINS, OF NOBLE METAL,
CONTAINED IN ONE TON OF ORE FROM A GIVEN QUANTITY.

BY

JOHN MITCHELL, F.C.S.

AUTHOR OF
"MANUAL OF AGRICULTURAL ANALYSIS," "TREATISE ON THE ADULTERATIONS OF FOOD,"
"METALLURGICAL PAPERS," ETC. ETC.

SECOND EDITION, ENTIRELY REVISED AND GREATLY ENLARGED.

WITH 360 ILLUSTRATIONS.

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PREFACE

TO THE FIRST EDITION.

When the rank our country holds among nations, as regards her mining interest, is taken into consideration, it must be with all a matter of surprise that no work especially devoted to the elucidation of the processes to be employed in ascertaining the richness in metal of any sample of ore (that is, in other terms, its assay) has of late years appeared before the British public. Indeed, the only work at present known in England is Berthier's "Traité des Essais par la Voie Sèche," which, for the mere purpose of inculcating the principles of assaying, has many disadvantages,—not the least of which is its being written in a foreign tongue; and although a knowledge of French is now so very general, yet many are prevented from buying scientific works in that language on account of the difficulties of finding equivalents for the technicalities which must necessarily be employed. It is also a very large work, and one containing much matter which the assayer does not need,—matter relating to the composition of wood and coal ashes, furnace products, &c., which are more especially adapted for the metallurgist.

These considerations, coupled with the paucity of any knowledge of assaying, excepting that confined to a very limited number of persons, induced the author of the following pages to turn a considerable amount of his attention to this subject, more especially as much difficulty was experienced in not having a suitable text-book for the use of his pupils. A portion of the following pages was drawn up as a Manual for such a purpose; but on consideration, it was thought the extension of such a work was so much needed, that it was determined to alter the original plan as far as was consistent with the complete carrying out of the object in view, viz.: the production of a Manual embodying information in every branch of assaying, either by the wet or the dry processes.

The following is a sketch of the manner in which this is accomplished; the author having followed the excellent arrangement of Berthier as closely as possible, from whose work also much matter that suited these pages, and which it would have been useless to re-write, has been inserted. Firstly, the Mechanical and Chemical Operations of Assaying are treated in full, inclusive of a description of the apparatus required, their mode of use, &c. Secondly, Furnaces, Fuel, and Crucibles, together with a description of the best Pyrometers and their applications. Thirdly, the Fluxes, their properties, preparation, use, &c. Fourthly, an Essay on the use of the Blow-pipe, and all its appurtenances; as Fluxes, Supports, &c. Fifthly, the action of the Fluxes on some Mineral Substances. Sixthly, a method of discriminating many Minerals by means of the Blow-pipe, aided by a few tests by the humid method. Seventhly, the Humid Analysis of many Mineral Substances, their composition, locality, &c. (All the minerals mentioned in the three last heads comprehend such only as generally come under the notice of the Assayer). Eighthly, the complete Assay of all the common

Metals, in addition to which the Assay of Sulphur, Chromium, Arsenic, Heating power of Fuel, &c. is fully discussed; and ninthly, and lastly, a copious Table drawn up for the purpose of ascertaining in Assays of Gold and Silver the precise amount, in ounces, pennyweights, and grains, of Noble metal contained in a Ton of Ore from the assay of a given quantity. This Table is the most complete and copious yet published.

Not only has it been endeavoured to collect all that is generally known on the subject of Assaying, but many new facts have been added, and such matter entered into, that the success of an assay is rendered much more certain; and most assays are conducted more rapidly and with greater exactitude than heretofore.

It has also been endeavoured to introduce a new system, in which is pointed out the rationale of each process, with the chemical action taking place between the fluxes and the ores in course of assay, so that by paying a careful attention to the matters discussed, so much of the chemical nature of all ores that can come under the assayer's hand may be known, that the practice by "rule of thumb" (a rule on which very little dependence is to be placed, excepting after years of the most laborious practice, and a rule which cannot be imparted, excepting the pupil pursue the same unprofitable course) must, it is hoped, be speedily abandoned, when, by knowing the chemical properties of the body operated on, the necessary fluxes and processes might be at once indicated, and with a certainty of perfect success.

Having premised thus much, the author must beg to express his thanks to his friend Mr. F. Field for the kind assistance he afforded him whilst experimenting on the various modes of assay described in the body of the work; and trusting that any little imperfections which may be detected will not be harshly criticised, but that it may be taken into consideration that the author has attempted to improve a branch of mining knowledge to which unfortunately too little attention has been devoted, and to which, if he has added anything useful, he is indebted for the first principles of such knowledge to Berthier's "Traité des Essais," for which, to the talented writer of the above work, he is under the most lasting obligation.

23, Hawley Road, Kentish Town,
London.

PREFACE

TO THE SECOND EDITION.

In presenting this the Second Edition of the "Manual of Practical Assaying" to his mining friends and the public in general, the author has to tender his sincere thanks for the very favourable opinion expressed of the former edition, which was honoured with a most extensive circulation, not only in the United Kingdom, but in all the Colonies, the United States, and South America; in addition to which it was translated into Spanish, for the use of the Government School of Mines at Madrid.

The former edition having been out of print for some time, repeated calls have been made on the author for a Second Edition; and, in compliance with this general request, the present volume has been prepared. The same arrangement (as far as practicable) has been adhered to as in the first edition, but a considerable portion has been entirely re-written, and much new matter added. It is also embellished with nearly 400 engravings illustrative of crystallography, and the various apparatus described in the body of the work.

In its preparation, the author has been greatly influenced by a desire to extend the sphere of utility of the former edition, by introducing, in the smallest possible space, and in the simplest form, such instructions in elementary chemistry, chemical notation, the use of chemical symbols, &c., as will enable the assayer or metallurgist to trace the varied re-actions occurring either in the crucible or the furnace during the progress of an experiment.

Crystallography has also been made the subject of attention, with a view to the discrimination of mineral substances by crystalline forms, aided by a few chemical tests.

Under the assay of Silver, there is added a full and complete description of the mode of assay employed in the Paris Mint, together with engravings of the apparatus in use.

A chapter has also been introduced, containing full instructions for the discrimination of all the more commonly occurring Gems and Precious Stones; and in the Appendix will be found copious Tables for the Valuation of Gold of every degree of fineness, expressed either in carats or thousandths; following which is an Assay Table, for calculating the number of ounces, pennyweights, and grains of gold or silver in a ton of mineral, when a given quantity has been submitted to assay.

In conclusion, the astounding discoveries of mineral wealth which are now daily being made, not only in this country, but in every other to which a due amount of diligence and information has been turned, renders the appearance of a complete Manual of the more closely allied branches of knowledge involved in the successful cultivation of such researches a desideratum of considerable importance.

The present volume, it is hoped, will fill the existing void in the literature subservient to this branch of our knowledge.

Assay Office,
Dunning's Alley,
Bishopsgate Street Without.

PRACTICAL ASSAYING.

CHAPTER I.

CHEMICAL NOMENCLATURE.—LAWS OF COMBINATION, &c.

Chemical Nomenclature.—Every substance, either mineral or otherwise, with which we are acquainted, consists of one or more of the bodies termed *simple* or *elementary*,—such bodies being so called from the fact that, with our present means of research, we are not enabled to reduce them to a more simple form. Thus, if a piece of common iron pyrites or mundic, as it is more commonly called, be submitted to a certain series of operations, the chemist will find that he can obtain from it two substances, totally distinct in properties both physical and otherwise, from each other, and from the substance from which they were obtained. One body is *sulphur*, which, as is well known, is an opaque yellow substance, fusing at a very low temperature, igniting readily, and exhaling when burning a peculiar and suffocating odour. The other constituent of the pyrites is *iron*, a metallic substance of a greyish appearance, requiring an intense heat for fusion, and becoming red-hot without burning. If the chemist now perform any experiment which, in the present state of his knowledge, ingenuity can suggest, he is totally unable to obtain either the sulphur or the iron in a less simple or elementary state of existence. He can with ease cause either of them to enter into new combinations with other bodies, which compounds he can decompose,—as in the case of the pyrites,—and both sulphur and iron can be again obtained in their separate forms with all their characteristic properties; but nothing more than this can be effected: hence he is led to the belief that both sulphur and iron are simple bodies, or bodies containing only one kind of matter.

The following is a list of the simple substances discovered up to the present time; it is accompanied by certain symbols and numbers, the use and nature of which will be hereafter pointed out. Those substances marked with an asterisk (*) have either only just been discovered, or they or their compounds have hitherto found no practical use; and those marked thus (†) are found native, or unassociated with other elements.

Non-Metallic Elements or Metalloids.

Name.	Symbol.	Equivalent H = 1.
Boron	B	10·90
Bromine	Br	78·26
†Carbon	C	6·00
Chlorine	Cl	35·50
Fluorine	F	18·70
Hydrogen	H	1·00
Iodine	I	126·36
†Nitrogen	N	14·00
Oxygen	O	8·00
Phosphorus	P	32·02
Selenium	Se	39·57
Silicon	Si	21·35
†Sulphur	S	16·00

Metallic Elements.

Name.	Symbol.	Equivalent H = 1.
Aluminum	Al	13·69
†Antimony	[1]Sb	129·03
†Arsenic	As	75·00
Barium	Ba	68·64
†Bismuth	Bi	70·95
Cadmium	Cd	55·74
Calcium	Ca	20·00
*Cerium	Ce	46·00
Chromium	Cr	28·15
Cobalt	Co	29·52
†Copper	[2]Cu	31·66

---

[1] From Stibium. [2] From Cuprum.

Name.	Symbol.	Equivalent H=1.
*Didymium	Di	?
*Erbium	Er	?
Glucinum	Gl	26·50
†Gold	[1]Au	98·33
*Ilmenium	Il	?
Iridium	Ir	98·68
†Iron	[2]Fe	28·00
*Lanthanum	Ln	48·00 ?
Lead	[3]Pb	103·56
*Lithium	Li	6·43
Magnesium	Mg	12·67
Manganese	Mn	27·67
†Mercury	[4]Hg	100·07
Molybdenum	Mo	47·88
Nickel	Ni	29·57
*Niobium	Nb	?
Osmium	Os	99·56
†Palladium	Pd	53·27
*Pelopium	Pe	?
†Platinum	Pt	98·68
Potassium	[5]K	39·00
Rhodium	R	52·11
*Ruthenium	Ru	52·11 ?
†Silver	[6]Ag	108·00
Sodium	[7]Na	22·97
Strontium	Sn	43·84
*Tantalum	Ta	92·30
†*Tellurium	Te	66·14
*Thorium	Th	59·59
†Tin	[8]Sn	58·82
*Titanium	Ti	24·29
Tungstenum	[9]W	94·64
Uranium	U	60·00
*Vanadium	V	68·55
Yttrium	Y	32·20
†Zinc	Zn	32·52
*Zirconium	Zr	33·62

[1] From Aurum. [2] From Ferrum. [3] From Plumbum. [4] From Hydrargyrum.
[5] From Kalium. [6] From Argentum. [7] From Natrium. [8] From Stannum.
[9] From Wolfram.

In the above arrangement the first column contains the common name of the element; the second the symbol, or chemical short-hand character in which all chemical decompositions are most readily written and understood; and the third the equivalent, or combining proportion. Of the compounds of the above-mentioned elements, only those will be discussed which fall under the notice of the assayer, whether found native or formed artificially.

The principal compound bodies are acids, oxides, salts, and binary substances, into whose constitution oxygen does not enter.

Acids.—All those substances which redden litmus, and form salts with bases, are called acids, and are divided into two principal groups —*oxacids* and *hydracids.*

Oxacids.—The oxacids are formed by the combination of an elementary body with oxygen, and their names are fixed according to the following rules, thus:—

The oxacid formed by the combination of silicon with oxygen is silicic acid, existing abundantly as quartz, flint, and sand.

When a body combines in more than one proportion with oxygen, that compound containing the least oxygen takes the termination *ous,*—that the most *ic*: thus sulphurous acid, sulphuric acid; arsenious acid, arsenic acid.

Hydracids are formed by the combination of hydrogen with a non-metallic substance,—as chlorine. The name is made up of the simple body, or a portion of it: thus chlorine and hydrogen form hydrochloric acid,—commonly known as muriatic acid, or spirit of salts.

Oxides are binary oxygen compounds which have no action on blue litmus; they may be divided into two series. The first comprises those oxides which do not possess the property of combining with acids to form salts,—they are termed *indifferent oxides*; the second series contains those capable of uniting with acids to form salts, and are called *salifiable oxides* or *bases.*

When a simple body, in combining with oxygen, forms but one oxide, it is simply called an *oxide,* followed by the name of the simple body,—thus, *oxide of zinc.*

If the body is capable of combining with oxygen in many proportions, the compounds resulting from this combination are thus called: the words *prot, sesqui, deut,* or *bin* and *per,* &c., precede the term oxide, and the progressive amounts of oxygen are thus expressed—protoxide of lead, iron, copper, or tin; sesquioxide of aluminum, iron, or chromium; deutoxide, binoxide, or peroxide of manganese, copper, or mercury.

There are still higher degrees of oxidation of some metals, which are nearly always true acids,—as chromic, stannic, and antimonic acids.

Salts are formed when an acid reacts on a base; and usually the properties of the acid and the base are reciprocally neutralized: thus the acid which before combination possessed the power of reddening blue litmus, loses it in proportion as it combines with the base: in this case the acid and base have been combined to form a salt.

In naming salts, we have to consider—1stly, the nature of the acid; 2dly, the salifiable nature of the base; and 3dly, the proportions in which the acid and base are combined.

Every acid terminating in *ic* forms a salt terminating in *ate.*

Acids terminating in *ous* form salts terminating in *ite*; and the new names terminating in *ate* and *ite* are followed by the name of the combined oxide. Thus sulphuric acid and protoxide of iron give sulphate of protoxide of iron, or, more commonly, protosulphate of iron. Arsenious acid and protoxide of iron form arsenite of protoxide of iron or prot-arsenite of iron.

When the salt formed exists in as nearly as possible the neutral state, its name is formed as above; but if the proportion of acid is larger than in neutral salts, it is termed an *acid salt:* thus we have *acid sulphate of potash.*

If the base is in excess, the name is preceded by *sub-*: thus *subacetate of lead.* This class of salt is also called *basic.* In the nomenclature of acid and basic salts, the relation of acid to base, or of base to acid, is indicated by the name: thus, supposing the quantity of acid in the neutral salt to equal 1, then, to designate the acid salts, the words *sesqui, bi, tri, quadri* are employed, according as the acid present is $1\frac{1}{2}$, 2, 3, or 4 times that existing in the neutral salt. Thus we have sesquisulphate, bisulphate, trisulphate, &c. The same rule is followed in naming the basic salts,—as *sesquibasic, bibasic,* &c.

Binary compounds containing no oxygen.—These compounds exist most largely in nature, and it is from them we draw the greater part of our copper, lead, &c.

When a metalloid combines with a metal to form a compound which is neither acid nor basic, the name is derived from the metalloid by the addition of the termination *uret* or *ide.* The latter is now more usually employed by chemists (in the case of sulphur compounds); the former by miners and mineralogists. The termination *uret*, in like compounds, will be retained in the following pages. The reader, therefore, in comparing the term here employed with that found in the more modern works on chemistry, will readily understand the nature of the compound indicated. Thus we have compounds of sulphur and chlorine with iron and silver,—as *sulphuret* or *sulphide* of iron and *chloride* of silver.

If a metalloid combines with a metal in many proportions, the same rule is followed as in the oxygen compounds:—thus we have *proto*-sulphuret of iron, *sesqui*-sulphuret of iron, and *bi*-sulphuret of iron, ordinary iron pyrites or mundic.

Laws of Combination.—On examining the variety of compounds the same substances may afford by their union in different proportions, it will be discovered that the proportions of each element in each compound are fixed and definite; a certain weight of one substance will only combine with a certain weight or weights of another substance, and the lowest combining weight of any of the elementary bodies is termed its *equivalent* or *atomic* weight, and is represented by the numbers in the third column of the table of elementary substances (pp. 2 & 3).

As before stated, all substances combine in fixed or definite proportions: thus, if 111·56 parts of oxide of lead were analysed, they will be found to consist of 103·56 parts of lead and 8 parts of oxygen. Again, the analysis of 9 parts of water or oxide of hydrogen would give one part of hydrogen and 8 of oxygen; now, assuming, as in the table of equivalents, hydrogen as unity, we have 103·56 as the equivalent of lead, and 8 as that of oxygen. Now, if we follow oxygen further in its combinations, it will be seen that it combines thus—

Oxygen 8 combines with	Hydrogen	1
„ „ „ „	Lead	103·56
„ „ „ „	Calcium	20·00
„ „ „ „	Silver	108·00
„ „ „ „	Potassium	39·00

The above numbers, therefore, represent the equivalents of the substances to which they are appended.

Again, the equivalent of sulphur is 16, and that weight of sulphur combines with the above weights of hydrogen, lead, calcium, silver, and potassium to form sulphurets of the respective bases. 35·5 parts of chlorine, or 39·57 parts of selenium, also combine with all the same weights, viz., hydrogen 1, lead 103·56, &c., to form chlorides and seleniurets.

Such compounds are of the simplest class, consisting of single equivalents only; there are, however, many bodies containing more equivalents than two, in which case the following laws are followed.

In one class of compounds a single equivalent remains constant, while the equivalent of the other substance entering into composition gradually increases. The following views of compounds of oxygen and nitrogen will illustrate these cases.

One equivalent or 14 grs. of nitrogen combine with 8 grs. of oxygen
” ” ” ” 16 ”
” ” ” ” 24 ”
” ” ” ” 32 ”
” ” ” ” 40 ”

Thus it will be seen that each new compound is formed by the gradual addition of one equivalent of oxygen to the compound preceding it; and it must be borne in mind that no element combines with another in less quantity than its equivalent proportion, but that every addition is made by a simple multiple of the increasing element.

Another series of compounds commences with two equivalents of an element united with some uneven number of equivalents of another element. This may be illustrated by the compounds of antimony and oxygen.

Two equivalents or 258·06 antimony combine with 24 grs. of oxygen
” ” ” 40 ”

In this case the ratio is as 2 to 3 and 2 to 5.

The equivalent of a compound body is the sum of the equivalents of the elements forming it: thus sulphuric acid is composed of one equivalent or 16 parts of sulphur, and three equivalents or 24 parts of oxygen; its equivalent is therefore 40. Potash is composed of 39 parts of potassium and 8 of oxygen = 47. Now, sulphuric acid combines with potash to form sulphates of potash, the equivalent of which is 87. In this manner the equivalent of any compound body may be ascertained by adding together the equivalents of the substances forming it.

From that which has just been stated concerning the constancy of composition of chemical compounds, we are enabled to state the reaction occurring between two or more bodies when decomposition takes place; thus, 87 parts of sulphate of potash contain 40 parts of sulphuric acid and 47 parts of potash; and if it were desired to obtain sulphate of lead by the decomposition of nitrate of lead by the above amount of sulphate of potash, the exact amount of nitrate required can be readily found—thus: add together the weights of the elements forming nitric acid and oxide of lead, and the amount required will be given. Thus, nitric acid is composed of 14 nitrogen and 5 equivalents of oxygen or 40—together 54; oxide of lead of 103·56 of lead, and 8 oxygen, together 111·56, which with the nitric acid form 165·56. Now, on the addition of 165·56 parts of nitrate of lead in solution to 87 parts of sulphate of potash also dissolved in water, 151·56 parts of sulphate of lead will be precipitated in the insoluble form, and 101 of nitrate of potash remain in solution.

Chemical symbols: their use.—The symbol of an element standing alone signifies one equivalent or atom of the substance; thus, S implies 16 parts of sulphur: a small figure on the right hand side of the symbol indicates the number of equivalents to be represented, as S_2 equal to two equivalents or 32 parts of sulphur.

Two symbols placed thus, FeS, indicate a compound of iron and sulphur, one equivalent of each; they may also be separated by the sign + or a comma, thus, Fe + S or Fe , S. This mode of writing is, however, not usual with a body formed of two elements only; it is chiefly employed to show the union of two compound bodies, as sulphuret of silver and sulphuret of lead, which compound may be thus written, Ag S + Pb S, or Ag S , Pb S.

A large figure on the same line as the symbol, and on its left side, multiplies the whole of the symbols to the first comma or + sign: thus, 2Ag S , Pb S or 2Ag S + Pb S is equal to 2 equivalents of sulphuret of silver, and 1 only of sulphuret of lead; if, however, it be thus written 2(Ag S , Pb S) it means two equivalents of each sulphuret.

There are two very important uses to which symbols may be applied. One has already been mentioned, viz., the calculation of the quantities of materials to be employed in certain decompositions, and the other in rendering intelligible the reaction of one body on another. This will be readily shown by a single example, the reaction of common salt (chloride of sodium) on nitrate of silver, as in the assay of the alloys of silver and copper in the humid way. $\mathrm{Na\,Cl} + \mathrm{Ag\,O}, \mathrm{NO_5} = \mathrm{Ag\,Cl} + \mathrm{NaO}, \mathrm{NO_5}$: which shows that before the action we have 22·97 parts of sodium united to 35·5 of chlorine and 108 of silver to 8 of oxygen and 14 of nitrogen with 40 of oxygen; or, to commence with chloride of sodium and nitrate of silver, after the action we have the 108 of silver combined with the 35·5 of chlorine, and the 22·97 of sodium with the 8 of oxygen previously in combination with the silver, and the nitric acid ($\mathrm{NO_5}$), giving as a result, chloride of silver which is insoluble, and soluble nitrate of soda.

CHAPTER II.

CRYSTALLOGRAPHY.

When liquid or gaseous bodies pass slowly into the solid state, they generally take very regular polyhedral forms, called *crystals;* and the science devoted to the study of these different forms, and the laws to which they are subject, is termed *Crystallography*.

A knowledge of this science is highly useful to those engaged in mining pursuits, as the mere form of a crystal very often suffices to determine the nature of any apparently new substance, or the detection of any gem amongst a quantity of crystallized common earthy matters otherwise alike in colour, transparency, &c.

From time immemorial it has been remarked that certain minerals presented regular forms; and those of the rock crystal, diamond, and others, had excited the admiration of the ancients; but up to the middle of the last century they had been looked at as accidental, or mere freaks of nature. Linnæus first remarked that, far from being due to chance, they were so constant that they might be employed to characterise certain minerals; but the number then known was so limited that it was of scarcely any use.

It is to Romé de Lisle, however, a French mineralogist, we owe the first work on this subject. He collected a vast number of crystals, measured their angles, and ascertained they were constant for the same mineralogical species. By comparing the most varied forms the same body could affect, he found they all depended one on the other by a very simple mode of derivation. Haüy must, however, be regarded as the father of the science. To the observations made before him, he added a vast number of others; and he arrived at a mode of expressing them by a mathematical law of remarkable simplicity. He gave, at the same time, the theory of the formation of crystals, and of their changes of form.

Forms in organised bodies seem to have been definitively determined by nature, each species possessing one common to itself. Minerals appear at first sight not to be under the influence of this law; each family, for instance, presenting sometimes one form, sometimes another; and yet all these different forms seem characteristic. Nevertheless, if any one were to be shown the various specimens of carbonate of lime (above 1400), collected in various parts of the globe, he would be struck with the multitude of configurations presented to his sight, and would certainly think that by them it would be impossible to distinguish this mineral from others, especially on viewing certain crystals of carbonate of lime, having more resemblance to crystals of other substances than to those of their own kind. But to the mineralogist these numerous forms are, so to speak, only variable habits in external appearance, but not in character, under which the same individual is constantly disguised.

The manner in which crystals increase, the cause of their changes of form, the laws to which they are subject, the various modifications they undergo by mechanical violence, heat, electricity, and those which are dependent on light, will be examined in succession.

Desiring to give in this section, in which space is limited, a satisfactory notion of crystallography, we shall follow the author Laurent, from whose work this is derived, in admitting some very simple hypotheses :—

1stly. All solid bodies are formed by the union of associated molecules.

2ndly. These molecules are of the same kind in the same body, but different from those of another body.

3rdly. Molecules have the most simple polyhedral form that can be conceived. The tetrahedron (or pyramid with three faces) and prisms with three or four sides.

4thly. These forms differ from each other in different bodies by the relative dimensions of their edges, and by the value of their angles.

5thly. All molecules possess attractive forces, whose resultants coincide with the axes or lines traversing these molecules.

6thly. The intensity of these forces varies by the influence of exterior causes,—such as heat, electricity, pressure, the presence of foreign bodies, the nature of the solvent, &c.

All these hypotheses will be established on parallelopipedal molecules, or four-sided prisms; it will then be seen how they can be applied to tetrahedra and three-sided prisms.

It is now intended to examine that which happens to such molecules in their passage from the liquid to the solid state.

In fluids, adhesion being destroyed by heat or a solvent, the molecules composing them are free to move amongst themselves. By now diminishing the heat or the quantity of solvent, these molecules will obey their reciprocal attractions, and give rise to a solid body by their association. Suppose a first molecule *a* (fig. 1) deposited on a support in the midst of a liquid, the extremity of a wire, for instance, on which it would be suspended: let *b*, *c*, *d*, *e*, be many other free molecules placed around the first; the dissolving cause decreasing these molecules will be deposited in their turn, but not in any chance manner; attracted by the molecule *a*, they will present their corresponding faces, and be deposited regularly on it. The same will happen with the two other molecules not represented in the figure,—the one in front, the other in back, and a small solid, B (fig. 2), will be the result. It will be made up of seven molecules.

FIG. 1.

Let *f f* (fig. 3) be other molecules adjoining the group B; they will be attracted by the molecules composing it, and will be regularly deposited in the re-entrant angles forming a new solid, C (fig. 4), composed in one place of 9 molecules, and altogether 27; other free molecules, *b*, *c*, *d*, (fig. 4,) will be in their turn deposited, forming a new solid, similar to the first, but larger, and containing 25 molecules in a plane, and 125 in all. The increase

FIG. 2.

B

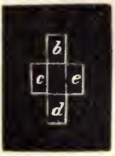
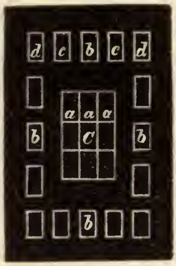


FIG. 3.

goes on continually in the same mannner by the regular juxtaposition of molecules, unless anything limits it. If the crystallization be stopped at any time whatever, the crystal always contains a cubical number of molecules—1, 27, 125, 343, &c.;—and these numbers are the cubes of the odd numbers, 1, 3, 5, 7, &c.; the symetrical union of these molecular or elementary crystals produces a crystal similar to the elementary molecule, a crystal which is termed *primitive*, or the *primitive form.*

FIG. 4.



It has been tacitly admitted, that during the whole course of the increase of a crystal the attractive forces of the molecules had remained unchanged. Supposing, however, that these forces diminish under the influence of exterior causes, such as heat, the nature of the solvent, the presence of a foreign body, &c.,—we will examine that which would happen—(that which takes place in one plane only will be noticed, for the same argument will hold good for both the anterior and posterior planes). Let *b, c, d,* (fig. 4) be free molecules placed round the crystal, they would all be submitted to the attractive forces of the crystallized molecules,—but all would not be equally attracted. The resultant of the forces of the molecules *a a a,* which attract *b,* is greater, as seen by the angle, than the resultant of the forces which attract *c c,* and still more *d d;* admitting, therefore, that the difference of these resultants is such that the four molecules *b b b b* alone are deposited, the assemblage represented by fig. 5 will be formed. By continuing the same line of reasoning, fig. 6 will be formed, and so on. It will be evident that this crystal presents at any time of its formation a rhomboidal arrangement different to the preceding, fig. 4, which is rectangular. The steps *M o M o,* formed by the invisible molecules, are themselves invisible, and must therefore be considered

FIG. 5.

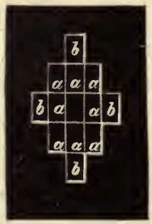
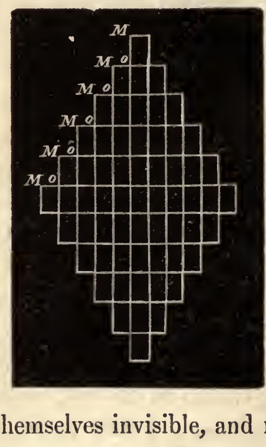


FIG. 6.



a right line, *M M*. The rhomboidal figure formed by the primitive molecules is termed a *crystal* or *secondary*, or *derived form.*

FIG. 7.

Fig. 8.

Supposing the attractive forces yet decrease, and let *a a a a a* (fig. 7) be a nucleus already formed, and *d c b c d*, free molecules placed about its upper face—(to simplify the matter, it may be taken for granted that that which takes place on one face will hold good for all the others) the five molecules *d c b c d* are attracted by the resultant of the forces of the five molecules *a*, but the molecule *b*, on account of its position, is more strongly attracted than *c c*, and those more strongly than *d d*. Admitting, as before, that the difference of these resultants is such that the molecule *b* alone is deposited, the assemblage (fig. 8) is formed; by continuing the same reasoning, fig. 9 will be produced, and so on. At any time during the crystallization, if the attractive forces do not vary, an assemblage similar to that of fig. 9 will result, but differing by the inclination of its sides from that of figure 6; it is also, however, a secondary or derived crystal.

There is nothing to prevent the admission of many other regular modes of increase by the deficiency of 1 molecule in height by 3, 4, 5, 6 molecules in breadth, or by 1, 2, 3, 4....*n* molecules in height by 1, 2, 3, 4....*n* molecules in breadth, as in fig. 10, which represents an increase produced by 3 molecules in breadth by two in height.

FIG. 9.

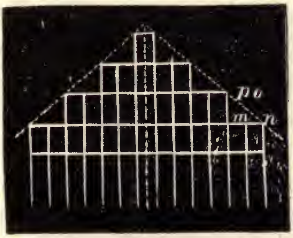
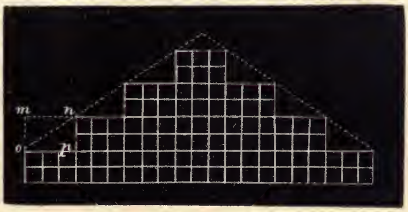


FIG. 10.



It will be hereafter proved that these unequal increments, to which the name *decrements* has been given, are sometimes produced on two or three edges of a solid, sometimes on all the edges at once. They also occur sometimes on all the solid angles, sometimes on one only. With a like body, or with a like primitive molecule whose form is invariable, a multitude of derived forms can be obtained by these regular groupings; but all these derived crystals are linked to the primitive crystal by a very simple law, which will be given.

In figure 6 the sides of the rhomboid are parallel to the diagonals of the primitive crystal, or to the diagonals of each molecule. In figure 9 they are parallel to the diagonals of the small rectangle *m n o p*, which is missing in the re-entrant angle. In fig. 10 they are parallel to the diagonals of the small rectangle *m n o p*.

If the primitive molecules were oblique prisms, as shown in fig. 11, one of the sides, *a b*, would be parallel to the great diagonal of the small quadrilateral figure *m n o p*, whilst the other side, *a c*, would would be parallel to the small diagonal of the same quadrilateral figure, or to that of the quadrilateral figure *r r t t*, formed by 3 molecules in breadth and 2 in length, wanting in the re-entrant angles.

Fig. 11.

In a word, the inclination of the sides of a derived form to the base of the primitive form is always equal to that given by the diagonals of the quadrilateral figures formed by 1, 2, 3, 4....*n* molecules in height, by 1, 2, 3, 4....*n* molecules in breadth, with the same base on the sides of these quadrilateral figures.

If derived forms met with in nature were produced by very complicated decrements of molecules in breadth and height, it would be impossible to ascertain if the law of inclination just given is true—(a law which supposes the relative dimensions of the primitive molecule known); but if we set out with the opinion that nature always employs the most simple means to produce the most varied effects, and if it be supposed that but very simple relations exist between the decrements, that is to say that *n* and *n'* are simple numbers, an hypothesis will present itself, which has been verified by observation.

Having shewn how crystals increase and change in form, it is necessary, in order to facilitate the study of crystallography, to suppose that derived crystals are formed in an inverse manner.

Let *m n o p* (fig. 12) be a derived rhomb, produced by a decrement of 1 molecule in height by 1 molecule in breadth. The same result will be arrived at (the same form), if it be supposed that the crystal were at first rectangular, *a b c d,* and 1 molecule in height and 1 molecule in breadth, to be successively removed from the angles; it would be also the same thing if it were said that the figure *m n o p*

Fig. 12.

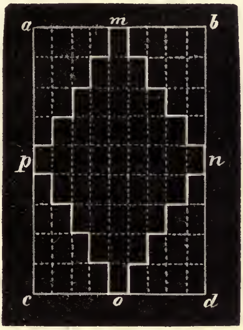
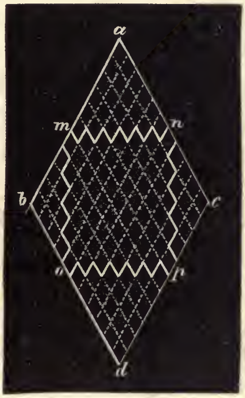


Fig. 13.



had been produced by cutting, *truncating,* or *replacing* the angles of the rectangle parallel to its diagonals.

If the primitive molecule were a rhomboidal prism it would give an assemblage or crystal *a b c d* (fig. 13). By truncating the angles of this rhomb parallel to its diagonals, the derived rectangle *m n o p* would be produced; so that it may be said indifferently that the rectangle *m n o p* is derived from the rhomb *a b c d* by truncating the angles; or, that the latter had been derived from the rectangle by a truncation of *its* angles. Although crystals are not formed in this manner (by truncation), it can, nevertheless, be said that a derived form is produced by truncations made in the angles or the edges of the primitive form, according to such and such an inclination.

CLEAVAGE.

If crystals are formed, as already supposed, by a symmetrical arrangement of associated molecules, the following inferences may be deduced:—

1stly. If any crystal be struck at random with a hammer, it ought to separate according to the planes of junction of the molecules, furnishing fragments terminated by faces plane and parallel to the faces of the form or primitive molecule.

2dly. Whatever may be the form of the derived crystals, had we a thousand differing from each other (of the same substance), if struck they would all break into fragments like the primitive form; and each of these fragments, being of itself an assemblage of primitive molecules, ought to be infinitely divided by mechanical means into other fragments all similar to the primitive form. Thus the rhomboidal crystal, *m n o p* (fig. 12), ought to break up into rectangles, and the rectangular crystal, *m n o p*, of another substance ought to subdivide into rhombs.

3dly. If the primitive form is a cube, the six faces being equal, the molecules ought to adhere to each other with the same force in the direction of the six faces. It therefore results, if such a crystal be broken, it ought not only to divide with the *same facility*, following three directions perpendicular to each other, but it ought also to present fragments whose faces have all the same aspect (shining, bright, sparkling, striated, &c.)

If the primitive form be the square prismatic, the crystal ought to break in the same manner parallel to its four vertical faces, because they are equal, and in a different manner (more or less readily with faces of a different aspect) parallel to its two bases, for the resultant of the attractive forces (adhesion), which passes through the two bases, is not equal to that of the attracting forces corresponding to the four lateral faces. In a word, the fractures are equal in any prism whatever corresponding with the four equal faces.

Experiment confirms all these conclusions; and it proves, further, that which has been before supposed, that the solids obtained by the breaking up of crystals are the most simple that can be imagined,—that is to say, solids of four, five, and six faces.

When a crystal is broken by subdividing it into regular fragments, it is said to be *cleaved*, and the solid obtained by *cleavage* represents the primitive form.

But all bodies are not susceptible of cleavage. Nevertheless, in these cases, they generally exhibit symptoms of cleavage,—such as alum, for example, which breaks in an irregular manner, but which, nevertheless, presents striæ in its fracture, which are indicative of an imperfect cleavage. Some substances cleave very readily parallel to certain faces of the primitive form,—such as mica, which crystallizes in a right prism whose base is a regular hexagon. It cleaves with wonderful facility parallel to its base, but shows no sign of cleavage in the direction of its six sides.

The law of these cleavages can be verified in gypsum and in carbonate of lime. The first is met with in large quantity at Montmartre; and it is not difficult to procure crystals as large as the closed hand which cleave in three different directions. By the aid of a penknife can be detached in one direction, with the greatest ease, perfectly plane plates, brilliant and as thin as a piece of paper. These leaves break perpendicularly to their greatest faces, according to two directions, oblique one to the other; but one of these cleavages, which is obtained by bending the plate between the fingers, is dry and brilliant, whilst the other is soft and dull. The primitive form of gypsum is then a right prism, whose base is an oblique-angled parallelogram, and not rhomboidal (four equal sides); for if the base possessed the latter form, the four vertical sides being equal, its cleavages ought to be correspondingly equal, which is not so. Carbonate of lime cleaves with the same ease in three directions (or six with the parallels), giving a primitive form,—a solid with six faces, which are equal rhombs, and equally inclined to each other.

TYPES.

To explain the transformation of forms one into the other, it has been shown that it matters little whether it be supposed that the rhomb is produced by the truncation of the angles of a rectangle, or whether the latter is obtained by truncating the angles of a rhomb.

Let *a* (fig. 14) be the base of a right prism susceptible of cleavage perpendicular to its base, and parallel to the sides *ab ac bd*, and consequently following the diagonals *af*, *be*, and *cd*. It is evident that, by six cleavages equally made on the six sides, a new hexagonal prism smaller than the original will be produced; or by cutting the prism through the centre A, following *af*, *cd*, *eb*, six new prisms with equilateral triangular bases will result. Let B (fig. 15) be one of these triangular prisms; it can be cleaved according

Fig. 14.

Fig. 15.

Fig. 16.

to the angles *a b c*, and thus subdivided into four new triangular prisms, or into three triangular prisms and an hexagonal prism, c (fig. 16). Thus the hexagonal prism may be either considered a triangular prism whose vertical edges are truncated, or the latter as resulting from the cleavage of an hexagonal prism.

In general, the construction of a building with plane surfaces is most readily represented as the resultant of the assemblage of parallelopipedons, or four-sided prisms. Suppose, then, that all the primitive molecules of different substances are parallelopipedons, the prism with rhomboidal base may be considered as made up of two triangular prisms, which would represent the primitive molecule obtained by cleavage, &c. Thus situated, it may be stated that all crystalline forms at present observed may be obtained by truncating (not arbitrarily, but according to the law of inclination already given) the solid angles or edges of the six parallelopipedons about to be described, to which the name of *type* or *crystalline* system has been given, and which are distinguished from each other by the relative size and reciprocal inclination of their edges.

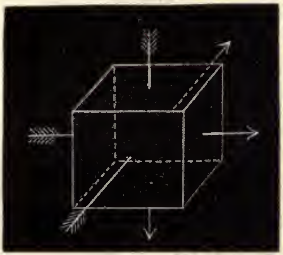
Every parallelopipedon possesses three axes or lines of symmetry passing through the centre of the two opposite faces, and consequently these three axes meet in a point which is the centre of the parallelopipedon. Any plane passing through the centre of a parallelopipedon divides that solid into two equal parts. The principal axis is that which has the greatest amount of symmetry around it. Thus, in the right prism with square base (square prism) the principal axis is the line passing through the centre of the two squares, because the similar angles and edges are similarly placed in relation to this line. If the three axes are unequal without one having more symmetry around it than the other, the solid is said to have three indifferent axes. If the three axes are equal,—as in the cube,—either one of them may be considered as the principal axis.

In studying a crystal, the observer ought always to place it before him in such a manner that the principal axis, if there be one, or any other axis, in the contrary case, is vertical. One of the other axes ought to be turned towards the observer. It is important that it be well borne in mind, which is besides very easy, the equality or inequality of the edges, faces, and angles of the six type-forms about to be described; for it is on this equality that the laws of modification about to be described rest.

SYSTEM 1.

Cubical.

FIG. 17.

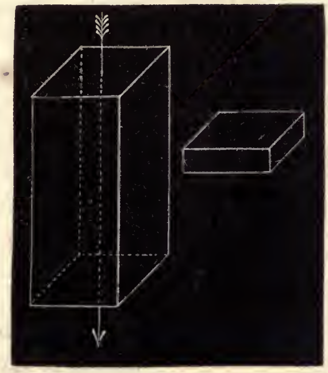


Axes, 3 equal and perpendicular.
Faces, 6 equal, square.
Solid angles, 8 equal, right.
Edges, 12 equal.

SYSTEM 2.

Right prismatic with square base (square prismatic).

FIG. 18.



Axes, 3 perpendicular. { 2 equal.
1 unequal, vertical.
(*principal axis.*)

Faces. { 4 equal, rectangular.
2 square (the upper and under faces are indifferently the base of the prism).

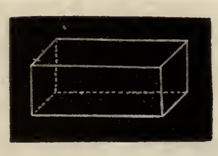
Angles, 8 right, equal.

Edges, two species. { 4 vertical.
8 horizontal.

System 3.

Right Prismatic with rectangular base (rectangular prismatic).

Fig. 19.



Axes, 3 perpendicular, unequal.

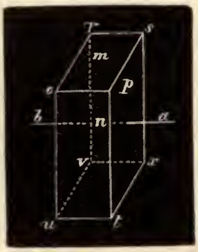
Faces, three species
- 2 rectangular.
- 2 do.
- 2 do.

Angles, 8 right, equal.

Edges, three kinds
- 4 do. do.
- 4 do. do.
- 4 do. do.

System 4.

Fig. 20.



Oblique prismatic with rectangular base
(oblique rectangular prismatic).

Either of the axes may be vertically arranged. If it be placed so that the axis *ab* is vertical, a right prism with an oblique-angled parallelogram will result. This prism is only conventionally placed, so that one of the rectangular faces *m* is inclined like a desk, whilst the other *n* is vertical.

Axes, 3, unequal, of which one, *ab,* is perpendicular to the two others.

Faces, three species
- 2 rectangles.
- 2 do.
- 2 oblique-angled parallelograms.

Angles
- 4 obtuse.
- 4 acute.

Edges
- 4 right-angled vertical.
- 4 right-angled inclined.
- 2 obtuse-angled horizontal.
- 2 acute-angled horizontal.

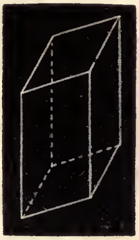
There are reckoned four kinds of edges in this solid, although, in relation to length, there are but three. But in crystallography it is not sufficient that two edges are equal that they have the same length. It is necessary that the planes of which they are the intersection should have the same angles: thus the edge *rs*, although equal to the edge *op*, is not the same kind: *rs* is equal to *tu*, and *op*=*vx*.

SYSTEM 5.

Oblique prismatic with oblique parallelogram for base.

This prism rests only on one angle.

FIG. 21.



Axes, 3 unequal, and unequally inclined to each other.

Faces, three kinds, equal 2 and 2.

Angles, four kinds, equal 2 and 2.

Edges, six kinds, equal 2 and 2

Anything whatever (face, angle, or edge), in this system, has only its opposite equal to it.

SYSTEM 6.

Rhombohedral.

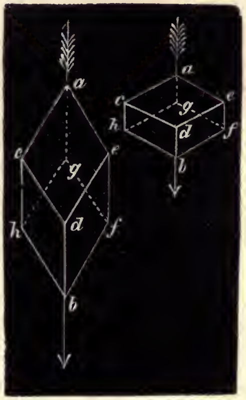
Axes, 3 equal, and equally inclined one to the other through the middle of the faces.

Faces, 6 equal rhombs.

Angles, two kinds { 2 equal, *a* and *b*.
6 equal, *c d e f g h*.

Edges, two kinds { 6 equal, passing three by three from the summits *a* and *b*.
6 equal, passing in a zigzag direction round the prism *cd de ef fg gh* and *hc*.

FIG. 22. FIG. 22 *bis*.



To understand the transformation of this system with more facility, instead of three axes it is better to assume four; one the principal, and the three others equal to each other, equally inclined to each other (60°), but all perpendicular to the principal axis: *a b* being the principal axis, imagine three other horizontal lines going—

from the middle of *cd* to the middle of *gf*
” ” *de* ” ” *gh*
” ” *ef* ” ” *ch*,

these three lines will represent the three secondary axes.

The four axes are placed like those of a right prism with regular hexagonal base. Let A and B be a section through the middle of a right prism with hexagonal base, and, perpendicular to the prism, the three lines *ab cd ef* will represent the three secondary axes passing from the middle of the opposite edge (fig. 23) or of the opposite angle (fig. 24). The vertical and principal axis is then perpendicular to the three secondary axes.

FIG. 23.

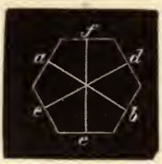


FIG. 24.

There are two varieties of rhombohedra—obtuse rhombohedra (fig. 22 *bis*), and acute rhombohedra (fig. 22). The cube placed on one of its solid angles may be considered as the limit of the obtuse and acute rhombohedra.

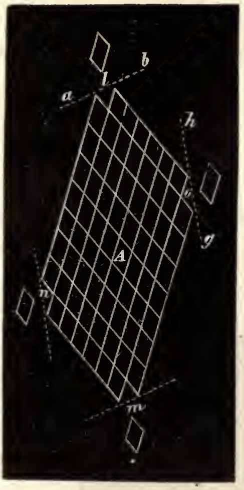
LAWS OF SYMMETRY.

If it be true that crystals change their form, as our molecular theory has led us to suppose, it is clear that whenever a decrement or truncation is effected on an edge or on a solid angle, this truncation must necessarily be repeated on all the edges and on all the equal angles; for there is no reason why a modification which has taken place on one edge, or on one angle, should not be repeated on all the edges and on all the equal angles, the attractive forces being the same on similar angles and edges.

It is also evident that, if a truncation (decrement) be made on an angle, it need not be reproduced on different angles, or if the truncation is effected it will be different.

For instance, let *a* (fig. 25) be a nucleus, one of whose faces is an oblique angled parallelogram, and *l m n o* free molecules attracted by the molecules forming the re-entrant angles. These angles are of two kinds,—two obtuse and two acute. The resultants of the attractive forces which act on *l* and *m* are equal, but different (on account of the inclination) from those acting in *o* and on *n*. The forces opposing crystallization may be sufficient to retain *o* and *n* in solution, but not sufficient to prevent the crystallization of the molecules *l* and *m* : we shall then have a parallelogram with two obtuse and equal angles truncated. Suppose that the attractive forces acting on the 4 angles of the parallelogram are not sufficient to excite the crystallization of the molecules *l m n o*, the four angles, although unequal, will indeed be truncated, but not in the same manner, for the diagonal facet, *a b*, of a molecule will be smaller than the facet *g h*, the second diagonal of the same molecule. Further, the angles *a l n, o l b*, which the facet *a b* forms with the sides of the parallelogram, are not equal to the angles *b o l, g o m,* made by the facet *g h* with the same sides of the parallelogram.

FIG. 25.



If the figure were a rectangle the four angles would be equal, and the four would be equally truncated (fig. 26), but the inclination of the facets *l i* is not the same on the edges *a b* and *c d* as on the edges *a b* and *a c.*

FIG. 26.

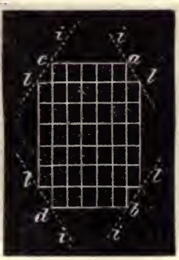


FIG. 27.

If the figure were a square (fig. 27) the four angles would be equally truncated; further, the inclination of the facets would be the same in the two adjacent sides: thus, by a sufficient prolongation of the facets, a new square would result.

These deductions are expressed in the following law, which experiment has completely confirmed :—

The modifications effected by truncations on certain parts of a crystal are reproduced in a like manner on all parts of the same kind, but are not reproduced, or if they are it is in a different manner on unlike parts.

The facets produced by truncations are equally inclined to the adjacent faces if the latter are equal, and unequally inclined if the adjacent faces are unequal.

FIG 28.

FIG. 29.

Thus, if the solid angle of a cube is modified by a facet A (fig. 28) the latter will be an equilateral triangle. If there are three truncations on this angle the three truncations will be equally inclined to the faces or the edges of the cube B (fig. 29.)

FIG. 30.

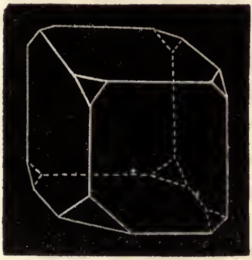
FIG. 31.

It is not possible to have two facets only on the angle of a cube. If four modifying facets were present, C (fig. 30) they would be of two kinds—the one corresponding to the facet of fig. 28, and the three others to the facets of the fig. 29, or of the fig. 31.

Edges or solid angles can be truncated more or less deeply; nothing limits the increment of modifying facets; they may cause even the entire disappearance of the primitive form. It is thus that a right prism, with rectangular base truncated in its four vertical edges, can at first give rise to an eight-sided prism, then to a right prism with a rhombohedral face.

The length of the edges or the dimensions of the faces have no value in crystallography. Thus a substance which crystallizes in the cubical system can have one, two, or three of its angles slightly, whilst all the others are more deeply, truncated (fig. 32). It is the inclination of the faces which determines their equality, and not their measurement taken by compasses. It is even very rare to meet with a *cube* very nearly *cubical,* all the angles are 90°, but nearly always certain faces are longer than others.

FIG. 32.



But then it may be asked, if this inequality exists, how can it be ascertained whether a crystal is a cube, a right prism with a square base, or a right prism with a rectangular base?

The method is easy: it is sufficient to examine the modifications or truncations. If an edge be truncated and the crystal a cube, the other edges will be equally truncated and equally inclined to the adjacent faces. If it be a right prism with rectangular base, four edges only will be truncated. If there be eight truncations, four will be of one kind and four of another. If the twelve edges are truncated, there will be three kinds of truncations, which may be distinguished by the measurement of the angles.

But sometimes crystals are met with which give no marks of modification: in such a case recourse must be had to the lustre of the faces or to cleavage, in order to determine to which system they belong. Suppose there were three perpendicular cleavages,—if the three cleavages are equal, it is the cubical system; if there are two equal, it is the right prismatic with square base; if the three cleavages are unequal, it is the right prismatic with rectangular base. Supposing the crystal to give but two cleavages, it is not a cube; if they are equal, it is a prism with square base—(the cleavages then correspond to the sides of the prism); if they are unequal, it is the rectangular prism. Lastly, in the absence of modifications and cleavages, there are yet other means of determining the system to which a crystal belongs: these will be pointed out hereafter.

It has been stated that a cube whose edge has been truncated ought to have the remaining eleven edges truncated also; yet sometimes crystals of a substance are met with where this symmetry does not exist. Thus, in the examination of alum, which crystallizes as a regular octohedron, whose twelve sides and six angles are equal, small truncations will be perceived on only two or three angles, and on 1, 2, 3, 4.... edges: nevertheless, this kind of abortion of facets must not be regarded as an anomaly in the law of symmetry. The position of the crystal in the vessel in which it was formed, the proximity of the sides or of other crystals, have more or less prevented the development of the crystal, as much in one direction as in the other. Moreover, if the edges or angles which are not truncated be examined by the microscope, small facets, re-establishing the symmetry, will be nearly always perceptible. Other crystals formed by the side of the first may shew truncations on all their angles.

It has been averred that the modifying facets can cause the entire disappearance of the faces of the primitive form, thereby furnishing a new crystal. That, however, as will be shewn, always belongs to the same crystalline system. Thus all crystals derived from the cube (according to the law of symmetry) belong to the cubical system—that is to say, they possess three equal and perpendicular axes. A prism may be at the same time truncated on its angles and on its edges; each angle and each edge can be replaced not only by one facet, but sometimes by 2, 3, 4, 5, 6.... facets. Derived forms are thus obtained, which may have from 50 to 100 or more faces. It appears at first sight very difficult to recognise all these forms, and determine the system to which they belong. Nevertheless, nothing is more easy; but the law of symmetry and the distribution of the axes in the six crystalline types must not be forgotten; neither must it be forgotten that the principal axis, if there be one, or in the contrary case, any other axis, must always occupy a vertical position; lastly, it must always be admitted that if a prism undergoes these modifications, the three axes remain in the same position in relation to the observer.

This being well understood, some examples of modification in the various crystalline systems will be given. In order to become familiar with the study of these transformations, it would be as well to form with clay or chalk the six fundamental forms, and by means of a knife, or, better still, a rasp, gradually truncate the angles and edges strictly in accordance with the law of symmetry: by proceeding in the above manner, it will be easy in a short time to recognise at first sight to which system any described crystal may belong.

It requires some little practice to recognise crystals in which but a part of the faces only is visible, and especially those where certain modifying facets have increased more than others of the same kind.

MODIFICATIONS OF THE CUBICAL SYSTEM.

(The same letters indicate similar faces in the same figure, and all the corresponding faces or facets in the other figures.)

Figures 33 to 37, *Transformation of the cube to the regular octohedron*:—

FIG. 33.

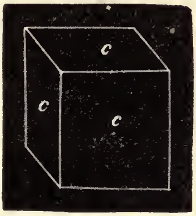


FIG. 34.

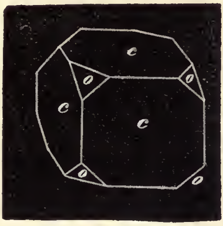


FIG. 35.

33. Cube.

34. Cube truncated on its angles, which are replaced by equilateral triangular facets.

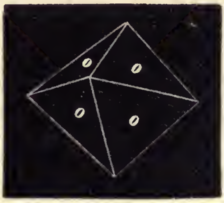
35. Cube more deeply truncated.

36. Ditto ditto.

37. Regular octohedron. The truncations made on the angles of the cube have caused the disappearance of its faces, and of each of these faces there remains nothing but a point, which is one of the summits of the octohedron.

FIG. 36.

FIG. 37.



The eight angles of the cube are replaced by eight equilateral triangles.

The six faces of the cube are replaced by six pyramids with four faces.

The twelve edges of the cube have changed position.

The three axes have not changed place ; they pass through the six summits of the octahedron.

By referring to the figures from 37 to 33 it will be evident that by truncating the six summits of the octahedron a cube will be gradually re-formed.

Passage of the cube to the rhomboidal dodecahedron :—

FIG. 38.

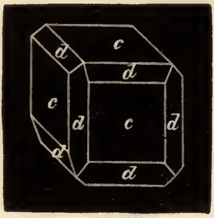


FIG. 39.

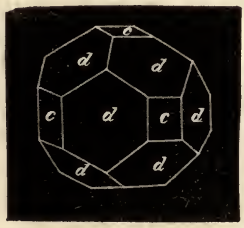
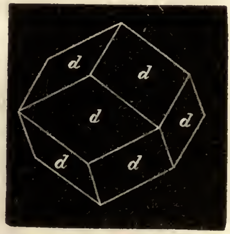


FIG. 40.



38. Cube truncated on its twelve edges.
39. Cube more deeply truncated.
40. Rhomboidal dodecahedron.

The three axes of the cube pass through the six four-faced summits.

The eight angles of the cube are replaced by eight three-faced summits.

The twelve edges of the cube are replaced by twelve equal rhombs.

By truncating the six equal summits a cube will be re-formed.

Passage of the dodecahedron to the octahedron :—

FIG. 41.

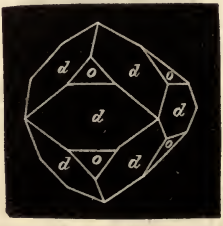


FIG. 42.

It has been shown that the eight solid angles of the cube, during their passage into the dodecahedron, are converted into eight more obtuse angles, which have the same relative position in the dodecahedron. Then, by the truncation of these eight angles of the dodecahedron, at first the figure 41 will be formed, then the figure 42, and lastly the regular octahedron (fig. 37).

Passage of the octahedron to the dodecahedron:—

This conversion is the inverse of that just described. The twelve edges of the octahedron on truncation give at first the figure 42, then 41 and 40.

The twelve small diagonals of the rhombs of the dodecahedron form a cube, and the twelve large diagonals of the same rhombs one octahedron.

Passage of the cube to the trapezohedron:—

Fig. 43.

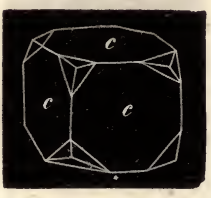


Fig. 44.

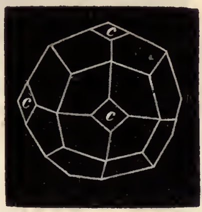


Fig. 45.

43. Cube, each angle being modified by three equal facets.

44. More considerable modification.

45. The complete or trapezohedral modification. This is a solid, with twenty-four equal and trapezoidal faces (8 angles of the cube × by 3).

The three axes pass through the six quadruple and equal square-based summits.

The six faces of the cube are replaced by the six preceding summits.

The eight angles are changes into eight triple obtuse angles.

The twelve angles are replaced by twelve four-faced and rhomboidal-based summits.

Passage of the octahedron to the trapezohedron:—

Fig. 46.

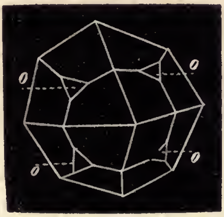


Fig. 47.

Since the eight angles of the cube have furnished the eight triple angles of the trapezohedron, it results that by the truncation of these eight angles there would be first produced the figure 46, then 47, and lastly the regular octahedron; and conversely, by cutting the six summits of the octahedron, with four faces to each summit, the figure 47 would at first result, then 46, lastly 45.

Passage of the dodecahedron to the trapezohedron :—By truncating the 24 edges of the dodecahedron.

Passage of the cube to the hexatetrahedron :—

FIG. 48.

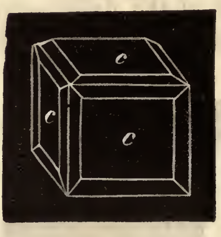


FIG. 49.

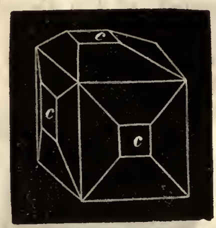
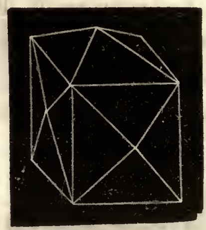


FIG. 50.



By replacing each edge of the cube by two facets the figure 48 will be first produced, then 49, and lastly 50, which is the hexatetrahedron.

If it be considered with a little attention, it will be readily perceived that it is a cube, each face of which is surmounted by a very flattened pyramid. By truncating these four-faced summits a cube will be reproduced.

FIG. 51.

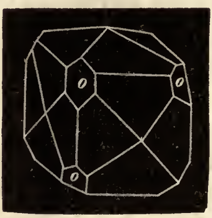
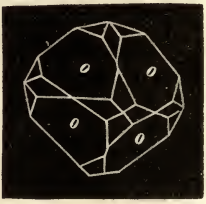


FIG. 52.



The angles of the cube are here replaced by six angles with six faces; then by the truncation of these angles there will be produced first the figure 51, then 52, and lastly the regular octohedron; conversely, by making four truncations on each angle of the octohedron there will be produced the figure 52, then 51, and lastly 50.

Other polyhedra with forty-eight and with twenty-four faces :—

The figure 53 represents the octohedron, in which each edge has been replaced by two facets. In figure 54 the modification is finished. It can be readily seen that it is an octohedron, in which each face is surmounted by a very flattened three-faced pyramid.

Figure 55 shows an octohedron, in which each summit is replaced by eight facets (8 × 6), giving lastly the figure 56, a forty-eight-faced solid.

By truncating the six eight-faced summits of the figure 54 the cube will result.

Fig. 53.

Fig. 54.

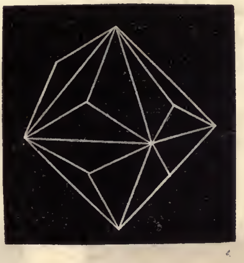


Fig. 55.

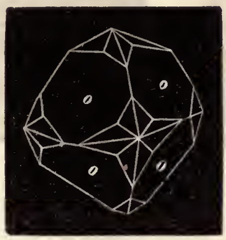
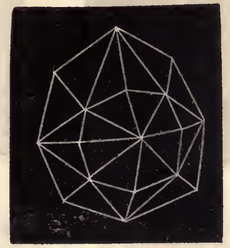


Fig. 56.



By the truncation of the eight three-faced summits the octohedron will be formed.

By truncating the twelve edges which pass from one eight-faced summit to another eight-faced summit, a dodecahedron will be produced.

All the crystals of the cubical system are immediately recognised. They are, so to speak, spherical; that is to say, that all the angles of the same kind are tangents of one sphere.

MODIFICATION OF THE RIGHT PRISM WITH SQUARE BASE (RIGHT SQUARE PRISM).

Fig. 57.

Fig. 58.

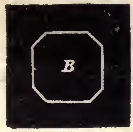
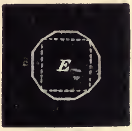


Fig. 59.

Fig. 60.

Fig. 61.



Let A be the base of this prism, it will be seen that by truncating the vertical edges an eight-sided prism (base B) will be first produced, then another prism with a square base (C). There can also be produced a prism with eight sides, whose base is D, and a twelve-sided prism with the base E. They can be easily recognised, because all their prisms have two equal perpendicular axes passing either through the middle of the edges of the square A, or through the opposite angles. It is this equality of four or its multiples which predominates in this system.

Passage of the prism to the octahedron with square base :—

FIG. 62.

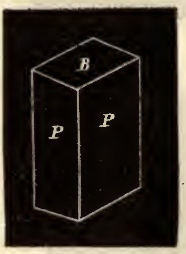


FIG. 63.

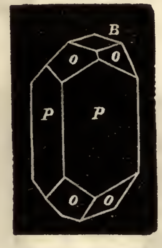
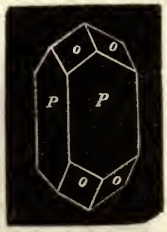


FIG. 64.

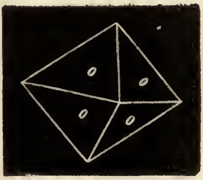


62. Right prism with square base.
63. Right prism modified on its eight angles.
64. Right prism.

FIG. 65.

FIG. 66.

FIG. 67.



65. Right prism. This is a dodecahedron formed like that of the cube by twelve rhombs, but with this difference, they are not all equal. There are four of one kind, the residue of the vertical faces of the prism, and eight of another kind corresponding to the solid angles of the same prism.

66. The same modification passing to an octahedron with a square base (fig. 67) formed by eight *isosceles* and equal triangles, the principal axis passing through the two equal summits. The two

other axes pass either through the four other summits, or through the middle of the four horizontal edges, forming a square.

Fig. 68.

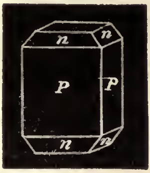


Fig. 69.

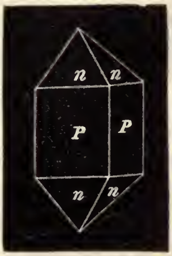
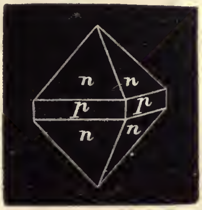


Fig. 70.



68. Prism with its eight similar horizontal sides truncated.

69. Modification passing into fig. 70; lastly, into another octahedron with a square base similar to the preceding.

It can be seen that, by the simple truncation of the four horizontal edges of the octahedron, the figure 70 will result; then 69.

If the four angles traversing the two secondary axes be truncated, another prism will be formed, but always having a square base surmounted by a four-sided pyramid.

Fig. 71.

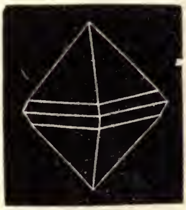


Fig. 72.

Fig. 73.

Fig. 74.

71. An octahedron modified by two facets on its four horizontal edges passing into fig. 72, which may be considered as a combination of two octahedra, the one more acute than the other.

73. A prism in which each angle is replaced by two facets passing into fig. 74, formed by two pyramids with eight faces placed base to base.

FIG.

FIG. 76.

FIG. 77.

75. An octohedron, in which two equal summits are truncated, or a right square prism whose eight horizontal edges have been truncated.

76. The same form, but whose four equal angles with four faces are truncated, and passing into another prism with square base.

77. Octohedron, whose two equal summits are each replaced by four faces passing into another octohedron with a square base.

Modifications of the right prism, with rectangular base; right rectangular prism.—Let A (fig. 78) be the base of such a prism; by truncating the vertical angles a right prism with a rhombic base will be obtained within the first.

FIG. 78.

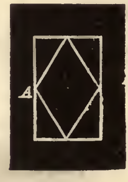


FIG. 79.

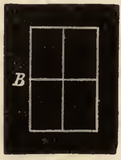


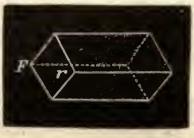
FIG. 80.

Pass two horizontal axes through the middle of the sides (fig. 79) B, or through the opposite angles (fig. 80) C. In the first case there will be two unequal, *but perpendicular* axes; in the second, two equal, *but inclined* axes.

FIG. 81.

FIG. 82.

FIG 83.



In the prism with rhombic base (figs. 81 D, and 82 E) there are also two unequal but perpendicular axes, as well as two equal but inclined axes.

Taking any face of a rectangular prism for a base, there will be three corresponding prisms with rhomboidal bases, since the rectangular prism can be placed in three different positions.

It is the same of the right prism with rhombic base (right rhombic prism); but then if the rhombic base *r* (fig. 83) be placed vertically (F), it must be considered as a right prism with a rectangular base, whose four parallel and similar horizontal edges are truncated.

Fig. 84.

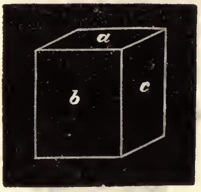


Fig. 85.

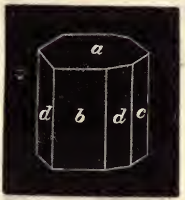
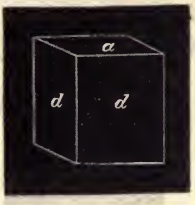


Fig. 86.



84. Right prism with rectangular base; *a* the base, *b* one side, *c* another.

85. A prism, whose four vertical sides are truncated and passing into the figure 86, which is a right rhomboidal prism.

Fig. 87.

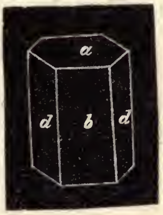


Fig. 88.

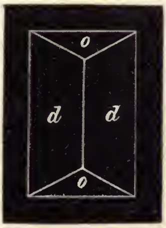
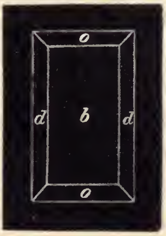


Fig. 89.



87. Is fig. 86, whose two vertical and obtuse edges are truncated. It is then a six-sided prism, having the two faces *b* of fig. 84.

88. Is fig. 86, whose four solid obtuse angles are truncated. The facets *o* correspond to the four horizontal similar edges of the prism 84.

89. Is 88, whose truncated vertical obtuse edge gives the face *b* of the fundamental prism.

90. Rhomboidal prism, whose four acute and equal angles are truncated.

91. The same as 88, but less advanced.

FIG. 90.

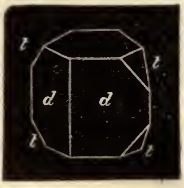


FIG. 91.

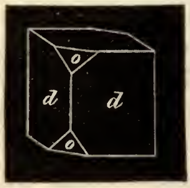
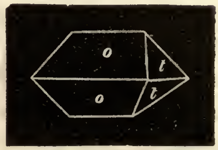


FIG. 92.



92. Cuneiform octahedron (*wedge-like*), whose base is a rectangle. It is obtained either by truncating the four edges of each base of a ctangular prism, or the eight solid angles of a rhomboidal prism.

FIG. 93.

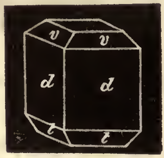


FIG. 94.

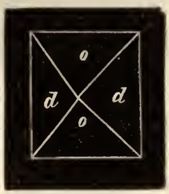
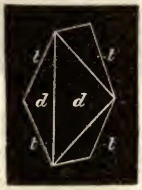


FIG. 95.



93. A Rhomboidal prism, whose eight solid angles are truncated.

94. Is the rhomboidal prism 86, whose obtuse angles are truncated. It may be considered as an octahedron with a rectangular base, but whose axis, which passes through the summit of two pyramids, is horizontal.

95. Another octahedron with rectangular base, produced by the truncation of the acute angles of the rhomboidal prism 86.

FIG 96.

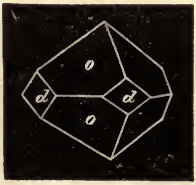


FIG. 97.

96. The rhomboidal prism 86, whose eight angles are truncated, and passing into another octahedron with rectangular base (vertical axis).

97. The octahedron 94, whose eight edges are truncated. The eight facets *o o* corresponding to the eight solid angles of a right prism with rectangular base, or to the eight equal edges of a rhomboidal prism.

FIG. 98.

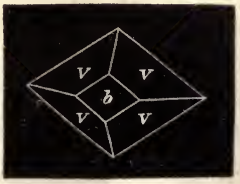


FIG. 99.

98. Is fig. 97, in which the facets *o o* have nearly obliterated all the other faces. This figure represents an octahedron with rhombic base placed so that either axis may be vertical; the pyramids having their summits traversed by the vertical axis, have always rhombic bases.

This octahedron can also be produced by truncating the eight angles of the rectangular prism.

99. The same as 98, having two summits truncated.

FIG. 100.

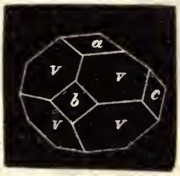


FIG. 101.

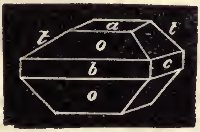


FIG. 102.

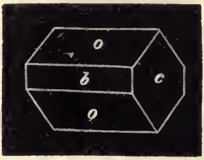
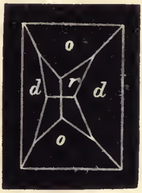


FIG. 103.



100. The same as the preceding, having its six summits truncated. It may be noticed that these six truncations will reproduce the rectangular prism.

By the modification of the edges and angles of all the preceding faces, an infinite variety of crystals will result; but if the facets on these latter be removed, there can always be observed either a rectangular or rhomboidal prism, or a rectangular or rhomboidal octahedron. In a word, the polyhedra are symmetrically traversed by three unequal and perpendicular axes.

Modification of the oblique prism with rectangular base.—

104. Oblique prism with base *a* rectangular. By truncating the

vertical edges there will be first obtained an eight-sided prism, then an oblique prism with a rhombic base (fig. 106). Fig. 105 shews the pointed rhomboidal prism resulting from the rectangular prism which envelopes it. According to the inclination of the truncations to the sides of a rectangular prism, either an oblique rhomboidal prism is obtained, of which the small diagonal of the base is horizontal (fig. 106), or a prism whose great diagonal is horizontal (fig. 107.)

FIG. 104.

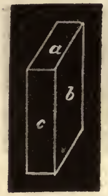


FIG. 105.

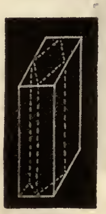


FIG. 106.

FIG. 107.

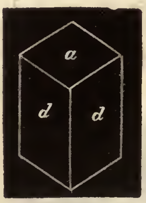
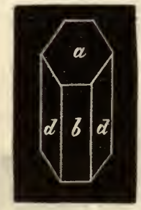


FIG. 108.



108. Prism with six planes.

If the transformations of the three first types have been well understood, the following figures will suffice to show how the oblique prism with either rectangular or rhomboidal base may be metamorphosed:—

FIG. 109.

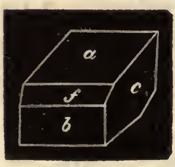


FIG. 110.

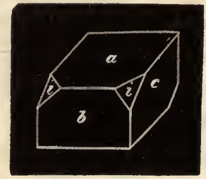


FIG. 111.

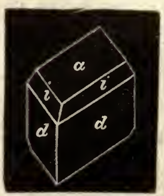


FIG. 112.

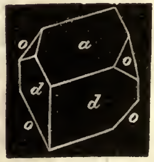


FIG. 113.

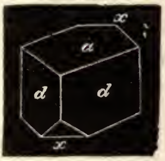


FIG. 114.

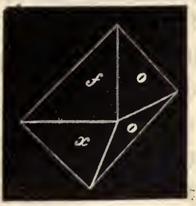


FIG. 115.

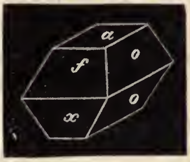


FIG. 116.

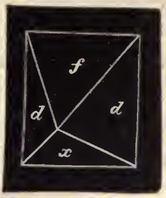


FIG 117.

FIG. 118.

FIG. 119.

Modifications of the oblique prism with oblique-angled parallelogram base.—In this system, which is irregular, the modifications, although susceptible of being varied to infinity, are nevertheless but few.

FIG. 120.

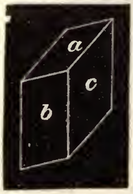


FIG. 121.

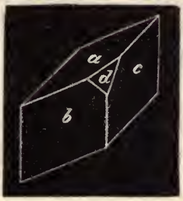


FIG. 122.

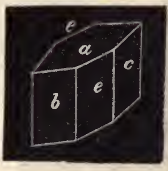


FIG. 123.

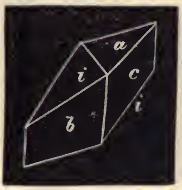


FIG. 124.

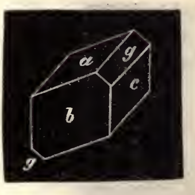
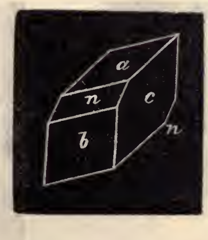


FIG. 125.



An edge or an angle being truncated only, necessarily infers the truncation of the opposite angle or edge, since in this system it is only the opposite angles and edges which are equal. Nevertheless, four, six, or eight edges may be truncated, but the modifications on the different edges will be unlike.

Modifications of the rhombohedron.—The rhombohedron, which is a symmetrical polyhedron around a principal axis, gives rise to a great number of very regular and very elegant forms.

It has been seen that in the right prism with square base and *principal axis,* that the number 4 or its multiples predominate in its modifications. In the rhombohedron (with three horizontal equal axes) it is the number 3 or its multiples which may predominate.

It may be further stated that from each principal summit* spring three equal edges, and that the six other edges pass in a zigzag direction around the rhombohedron.

FIG. 126.

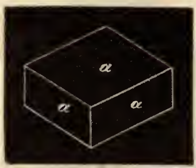


FIG. 127.

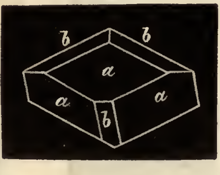
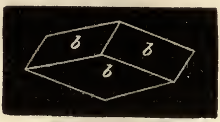


FIG. 128.



126. Rhombohedron.

127. Rhombohedron truncated in six edges of its summits.

128. The truncation completed, giving another rhombohedron more obtuse than the first. By truncating the six edges of the summits of this rhombohedron, a rhombohedron more obtuse than the second will result; and so on.

FIG. 129.

FIG. 130.

129. The rhombohedron 126, whose lateral angles are truncated.

130. Truncation more advanced, forming two hexahedral pyramids placed base to base.

FIG. 131.

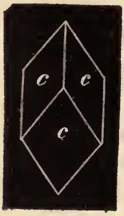


FIG. 132.

FIG. 133.

131. The facets *c* have entirely obliterated the faces *a,* presenting a more acute rhombohedron. This, truncated in the same way as the six lateral angles, furnishes a third still more acute, and so on

---

* The principal summits are the two solid angles traversed by the principal axis.

Sometimes rhombohedra of this kind appear whose summits are like needles.

132. Is figure 130, whose six horizontal edges are truncated.

133. The same modification.

Fig. 134.

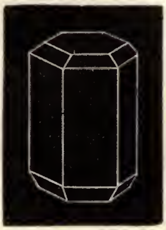


Fig. 135.

134. The preceding, with two summits truncated.

135. The preceding completed. It is a regular prism whose sides are inclined one to the other at 120°.

Fig. 136.

Fig. 137.

Fig. 138.

136. The six-sided prism modified on its twelve solid angles becoming a pyramid like 130, but whose faces would correspond to the edges.

137. Is the figure 130, whose six lateral angles are truncated, and which becomes another hexagonal prism whose planes correspond to the vertical edges of the prism 135.

138. Is 137 more advanced.

Fig. 139.

Fig. 140.

139. The rhombohedron 126, whose six lateral angles are truncated parallel to the principal axis. It is a six-sided prism terminated by rhombohedral summits.

140. The rhombohedron 126, whose six lateral edges are truncated parallel to the axis, passing

into 141 and 142—six-sided prisms terminated by rhombohedric summits. The vertical angles of these prisms correspond to the vertical faces of the prism.

FIG. 141.

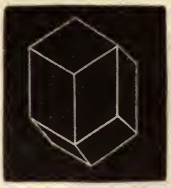


FIG. 142.

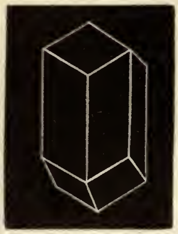
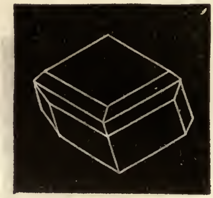


FIG. 143.



143. The rhombohedron 126, each lateral edge being replaced by two facets inclined to the principal axis.

FIG. 144.

FIG. 145.

144. The preceding modification completed; a double six-sided pyramid, but whose base is zigzag.

145. The rhombohedron 126, each lateral angle being replaced by two facets inclined to the principal axis, and forming a double six-sided pyramid analogous to the preceding.

HEMIHEDRIC FORMS.

It has been shown that in truncating the eight angles of a cube a regular octohedron is produced. Suppose, however, instead of truncating the eight angles, four are neglected, replacing the other four, as in fig. 146, it will be seen that the two upper facets *oo*, by increasing in size, obliterate the upper face of the cube, of which there remains but a single line. The diagonal *ab oo′* and *oo″*, by uniting, leave of the two anterior and vertical faces of the cube only the two diagonals *bc* and *ca*. The four truncated angles then give rise to the four equilateral triangular faces,—consequently to a regular tetrahedron,—whilst the six edges represent the five diagonals of the cube.

Fig. 146.

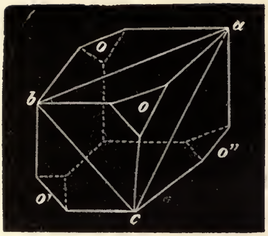


Fig. 147.

Fig. 148.

The three axes pass through the middle of the edges. This solid must not be placed on a base as shown in fig. 148, for then the axes would not keep their primitive positions, and the transformations of the tetrahedra could not be so easily understood. In obtaining this solid the law of symmetry has not been followed; and yet crystals are frequently met with possessing this form. It must be supposed that by a kind of caprice the force of crystallization had neglected to form the other truncations, and the name of hemihedric crystals has been given to these solids, the half of whose faces have not been formed.

Boracite is often met with under the form of a cube truncated on four angles only; and as it has been remarked that each summit was capable of producing a different electricity to the opposite non-truncated summit, the dissymmetrical appearance of the crystal has been attributed to the two electric forces with which it seems endowed.

But as electricity could not act on the crystal before its formation, it must be admitted that the nucleus on which it was formed was already unsymmetrical before electricity was enabled to act on it to continue the hemihedrism; in which case the nucleus was hemihedric without the assistance of electricity, or it must be admitted that the nucleus was cubic; then it cannot be conceived why one of the electricities would seize on one angle more than the other, whilst the contrary electricity seized on the opposite angle.

It is preferable to admit the ingenious ideas of M. Delafosse on this subject, and separate the hemihedric crystals from the systems in which they are placed, and set them apart in new systems.

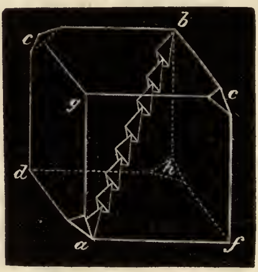
According to M. Delafosse, the regular tetrahedron can give rise by symmetrical transformations to a cube, but this cube, which is so geometrically, is not so in a physical point of view, the eight angles not being physically equal.

An engraving will readily shew this difference.

Suppose that the primitive molecules of a substance were cubical, it is evident that those cubes by symmetrical grouping would give rise to a cubical arrangement whose eight angles would be identical; and it would be impossible that one of these angles should be modified, unless the seven others were equally so.

Fig. 149.

Fig. 150.



Suppose, on the contrary, that the primitive molecules were regular tetrahedra, these tetrahedra would group symmetrically, as shewn in fig. 149.

Admitting that like rows were disposed in a cube (fig. 150), so that the angle *a* of the cube should be formed by the base of a tetrahedral molecule, and consequently the angle *b* of a summit of these tetrahedra. Suppose also the same for the other angles of the cube. Place at *a c e h* the bases of the tetrahedric rows, and at *d f g b* the summits. Although the assemblage of all these tetrahedra would be cubical, it will be seen that the angles are not identical, and that of the eight angles, four, *a c e h*, may be modified without touching the others; at the same time it may be supposed the rows not having their extremities identical, positive electricity may be manifested by one, whilst negative electricity may be exhibited by the other. The crystal would then present 4 + poles and 4 — poles.

Thus tetrahedral molecules may give rise to a crystal which may be cubical, octahedral, dodecahedral, &c.; but a cube, an octahedron, or a dodecahedron, formed by an assemblage of cubical particles, cannot give tetrahedral crystals. It is necessary, then, to divide the cubical system into two others,—the cubical system proper and the tetrahedral system.

The following are some modifications of hemihedric crystals:—
Hemihedrism of the Cubical system: (regular Tetrahedron).

FIG. 151.

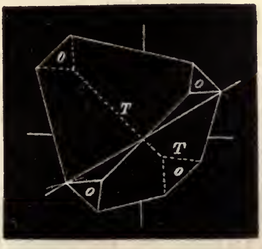
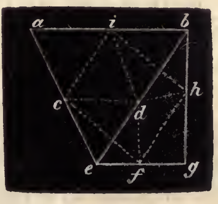


FIG. 152.



151. Tetrahedron, whose four solid angles are truncated. The facets *o* are equilateral triangles, which by increasing meet in the middle of the edges of the tetrahedron; then the faces of the latter only exist as equilateral triangles, *i c d*, *h d f*, and two posterior triangles (fig. 152). The result of which will be a solid composed, firstly, of four equilateral triangles (residue of the faces of the tetrahedron); secondly, of four similar triangles produced by the truncation of the angles; in all, eight equilateral triangles, or a regular octahedron.

Since the six edges of the tetrahedron correspond to the six diagonals of the faces of the cube, it follows that if these six edges be truncated a cube will gradually result.

Hemihedrism of the right prismatic system with square base (square prismatic).—

FIG. 153.

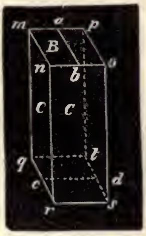


FIG. 154.

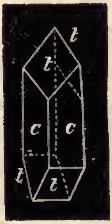


FIG. 155.

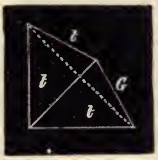
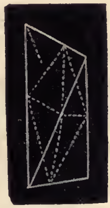


FIG. 156.



Let 153 be a right prism with a square base, and suppose that the angles *m n* and *o p* be truncated until the facets meet at *a b*, that the edges *m p* and *n* be not truncated, and truncating in the same manner on the opposite side the edges *r s* and *g t*, a hemihedric solid (154) will be obtained.

If the four facets be sufficiently prolonged they will obliterate the face *c* of the prism, giving rise to the tetrahedron 155, formed of four equal and isosceles triangles.

The crystals met with under the form 154 may be considered an assemblage of tetrahedra with equal isosceles triangles. A prism with a square base formed of square prismatic molecules could not give a like tetrahedron; whilst a cubical crystal formed of cubes could give only tetrahedra.

Hemihedrism of the rhombohedric system.—Suppose that the primitive molecule of a right prism with a regular hexagonal base be itself an hexagonal prism. According to the law of symmetry, by truncating an edge of the base the remaining eleven ought to be truncated (fig. 157); and the inclination of the facets *a a*.... on the planes P of the prisms ought to be all the same. It can be seen by truncating the six lateral edges or the six lateral angles of a rhombohedron parallel to the axis, a regular hexagonal prism, truncated by rhomboidal summits, may be obtained (figs. 158, 159). By completely truncating the summits of these two prisms, a regular hexagonal prism will result; but this, although geometrically like, is not physically identical with the hexagonal prism (fig. 157). For instance, the prism (fig. 157) cannot, according to the law of symmetry, produce to each base only three truncations leading to a rhombohedroidal summit (fig. 160), for the six edges of each base being identical, three cannot be replaced without replacing the three others; whilst the hexagonal prism obtained from the figures 158 and 159 can generate a rhombohedron by the truncation of three edges of each base. The hexagonal prism 160 could have its six edges on

FIG. 157.

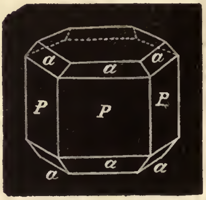


FIG. 158.

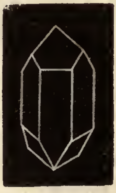
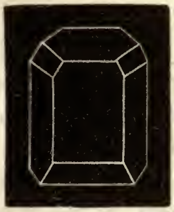


FIG. 159.

FIG. 160.



the same base truncated; but three of these would have one inclination towards the base and three another.

GROUPING OF CRYSTALS.

Crystals are sometimes isolated, but more often they are grouped in various manners—sometimes regularly, sometimes at random.

Regular grouping.—Groupings are regular when crystals unite by their homologous (coinciding) faces. The following figures represent some of these groupings.

Fig. 161.

Fig. 162.

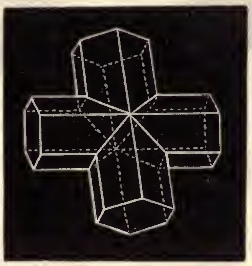


Fig. 163.

Hemitropism.—It has been shown by the law of symmetry that crystals cannot present re-entrant angles. Nevertheless, it is not rare to meet with crystals presenting such angles (gypsum, oxide of tin, &c). These re-entrant angles, however, are owing to the regular grouping of two crystals. It occurs as though a single crystal had been cut in two, and that one half had made a half or a sixth of a revolution on the other.

Let *a b c d* (fig. 164) be a crystal of gypsum divided according to the line *g e*, let the half *g b d b* make half a revolution round the line *i i*, a hemitropic crystal, *a c e f g h*, presenting a re-entrant angle, will be formed; but this crystal would be in reality formed of two crystals grouped in an inverse direction. Figs. 165 and 166 represent this change of gypsum more fully.

Fig. 164.

Fig. 165.

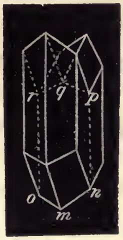
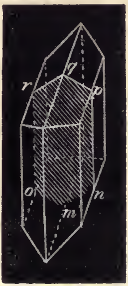


Fig. 166.



Figs. 167 and 168 show a transposition (sixth of a revolution) of a regular octahedron.

FIG. 167.

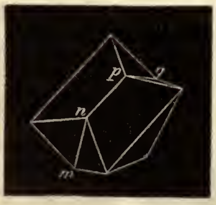


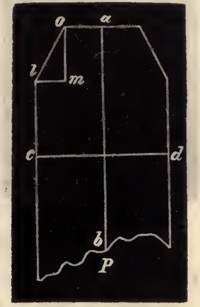
FIG. 168.

Determination of the relative dimensions of primitive molecules.—How can the relation existing between the height, breadth, and depth of a molecule, or the relation existing between its three axes, be determined?

This problem is the same as the following:—Having a compound binary body to determine the weight of the atoms it contains; analysis shows that in water the weight of the oxygen is to the weight of the hydrogen :: 88·9 : 11·1. If it be *supposed* that water contains only *one* atom of oxygen and *one* atom of hydrogen, it is evident that the weight of the oxygen will be to that of the hydrogen :: 88·9 : 11·1, or taking one of these bodies as unity :: 100 : 12·5. But our supposition may be wrong; water may as well contain *one* atom of oxygen and *two* of hydrogen. Then in this case the weight of the atom of oxygen would be to that of two atoms of hydrogen :: 100,0 : 12·5, then $\frac{12 \cdot 5}{2}$ would represent the weight of the atom of hydrogen. Other suppositions could yet be made, but they would all lead to nearly the same result. Knowing that 12·5 represents the weight of 1, 2, 3, $\frac{1}{2}$, $\frac{1}{3}$, $\frac{2}{3}$, of an atom of hydrogen, and whatever may be the numbers chosen, the relation existing between the oxygen and the hydrogen in the different compounds containing those two bodies could always be expressed.

The determination of the three axes of a molecule is made in the same manner, and is subject to the same uncertainty. Suppose we had a right prism with a square base, and wished to know the length of its three axes. Knowing (according to the modifications) that it is a prism with a square base, we already know that the prism has two equal axes: it remains to measure the third. It may be supposed after what has already been stated, that it is not by measuring the height and breadth of a crystal by means of the compasses that the relation of its axes can be ascertained, since the size of the faces has no practical value. The faces or the edges, of the same kind, are only theoretically equal, and it would doubtless be impossible to meet with a cube perfectly cubical.

FIG. 166.



Let p be a fragment of a prism with a square base, $a\,b$ the principal axis, and $c\,d$ one of the two secondary axes. If this prism presented no modification it would be impossible to determine the relation of its two axes. Let $i\,o$ be a modifying facet. It has been shown that this facet was produced by the disappearance of a certain number of ranges of molecules in height and in breadth. Suppose the disappearance to be produced by a molecule in breadth by one in height, we should have the following proportion :

the height of one molecule : its breadth :: om : im :

whence :: SIN $o\,i\,m$: COS $o\,i\,m$;

if the disappearance were produced (and that is not known) by one molecule in height by two in breadth, we should then have :

the height : twice the breadth :: om : im :

whence :: SIN $o\,i\,m$: COS $o\,i\,m$.

Other suppositions might be made, and we should arrive at (as in the weight of the atoms) this conclusion :

the principal axis : the secondary axis

:: om : 1, 2, 2, 4, $\frac{1}{2}$, $\frac{1}{3}$, $\frac{2}{3}$, . . . im.

If om : im :: 100 : 32, we should have by the first supposition,

the principal axis : the secondary axis :: 100 : 32.

in the second,

the principal axis : the secondary axis :: 100 : 16.

in the others,

the principal axis : the secondary axis :: 100 : 64, &c.

To choose between the weight of hydrogen as 12·5 or 6·25 we must be guided by the appearance of the combinations. It is the same with the weight of the atom of sulphur. If we suppose the latter = 200 we have the following series :—

Hyposulphurous acid	SO
Sulphurous acid	SO_2
Hyposulphuric acid	S_2O_5
Sulphuric acid	SO_3

If the number 600 be chosen for sulphur, the preceding series will become—SO_3, SO_6, S_2O_{15}, SO_9.

The simplicity of the relations (in default of other indications) inclines the chemist to choose the first series.

Fig 167

To determine between the numbers 32, 16, 64, for the length of the secondary axis, other modifications, either of the same crystal or of other crystals of the same substance, must, if possible, be examined. Let P (fig. 167) be another crystal of the same substance presenting a facet *rs*, we shall yet have, supposing the decrement effected by one molecule in height by one in breadth—the principal axis : the secondary axis :: *st* : *tr* :: SIN *srt* : COS *srt*.

But there might be withdrawn one molecule in height to two or three in breadth; and this is not known. In every case admit that experiment shows that *st* : *th* :: 100 : 128.

And also admit that in other modifications there is the relation of 100 to 64.

There are then three modifications, having the following relations:—

100 : 32
100 : 64
100 : 128

If in the first case the space had been formed by one molecule in breadth by one in height, the two axes would be :: 100 : 32; in the second the spaces are necessarily made by one molecule in height by two in breadth; and in the third by one and four. We have then the following series (P = principal axis, S = secondary axis) :—PS—PS_2—PS_4

Admitting, then, as in the first case, the space had been formed by three molecules in height by five in breadth, then there would be the following series for the three modifications :—P_3S_5—P_3S_{10}—P_3S_{20}.

The first series, however, is chosen on account of its simplicity; and this gives the relative dimensions of the two axes as the numbers 100 and 32

But besides the series of combinations, chemists have other means of determining in the choice of one number rather than another for the weight of the atom of hydrogen (volume, specific heat, isomorphism, &c).

Crystallographers have also often other means of determining between the choice of many possible relations; in some cases the cleavage, and in others simply the determination of the crystalline system.

If the modifications show that the crystal belongs to the cubical system, then the relative sign of the three axes is known. If the crystal belong to the square prismatic, two axes are known, and the kind alone remains to be determined.

If the crystal cleave in three perpendicular directions, no relative conclusion can be drawn as to the size of its axes; but if the cleavage is in the four directions leading to an octahedron, and if we know, besides, to what system the crystal belongs, it is evident that we should have the relation of the three axes by measuring the angles of this octahedron; for, from the measure of the angles of an octahedron, the three interior diagonals or the three axes can be readily deduced.

It would be useless to enlarge further on this subject, for all those acquainted with trigonometry will easily understand how the length of the axes may be determined: by means of the modifications they can see that the measure of a single angle of an octahedron suffices to determine the axes; but that it requires the measure of a modification on one edge of the base, and a modification on the vertical edge of a right rectangular prism, to determine the three axes; or that it suffices to measure the inclination of a facet produced on one of the solid angles of the prism.

On the relation existing between the crystalline form of bodies, and their chemical composition.—The following hypothesis was set out with, that all the molecules in one body are similar to each other, but different to those of another body, and that the form of these various molecules differs only from each other by the relative dimensions of their edges, or by the value of their angles. It follows, then, that if the molecules of a body, common salt for instance, are cubical, they could only give rise to crystals of the cubical system, and never to crystals derived from the rhomboidal system. It would be the same with rhomboidal molecules,—they could never give rise to any other crystals than those of the rhomboidal system. The same simple or compound body always then exists under the same form, or rather forms, belonging to the same system.

Further, in the same system different bodies will form crystals differing from each other, not by the number of faces, but by their inclination, or by the relative directions of their axes. Thus carbonate of magnesia and carbonate of lime both crystallize in the rhomboidal system; but in the former the faces form angles of 105°·5′, whilst in the second the angles are 107° ·25′. According to the laws of symmetry both these rhombohedra could give derived crystals with 20, 30, or 100 faces; but the influence of the angles of the two rhombohedra would be perceptible in all the secondary crystals.

Crystals belonging to the cubical system are those alone which cannot be distinguished from each other: such are alum, fluoride of calcium, the diamond, and common salt: nevertheless, this distinction can be made with reference to the structure and predominating form of these bodies. The predominating form of a body is that which is most generally met with in crystals of the same substance: thus alum nearly always crystallizes in a regular octahedron truncated at its six angles. According to the truncations, alum might be said to crystallize in the cubical form; but as the faces of the octahedron are much larger than those of the cube, the octahedron is the predominating form of alum.

Fluoride of calcium and diamond cleave into octahedra. The predominating form of fluoride of calcium is cubical, that of the diamond octahedral; common salt cleaves into cubes; alum does not cleave.

There are, however, some exceptions to this law: they will be pointed out.

ISOMORPHISM AND DIMORPHISM.

Carbonate of lime is met with under the form of a rhombohedron, or of crystals derived from the rhombohedron: all these crystals give by cleavage rhombohedra of 107° ·25; yet carbonate of lime is sometimes found under the form of a right rhombic prism, which cannot be cleaved into rhombohedra. Now, the right rhombic prism and the rhombohedron have no relation. Crystals of one could not, by the law of symmetry, give rise to crystals of the other. One body can therefore possess two different forms. This conclusion is not exactly correct; for rhombohedral carbonate of lime and prismatic carbonate of lime are rather two different bodies, which have the same composition, but their properties are different. Thus not only have they not the same form, but they have neither the same hardness nor the same specific gravity; they do not behave in the same manner under the influence of heat; they do not act in the same manner on light, &c.

It is said that carbonate of lime is *dimorphous*; many other bodies are also dimorphous; the following may be mentioned,—sulphur crystallized by fusion, and crystallized from sulphuret of carbon, the diamond and graphite, the two iron pyrites, the two titanic acids, &c.

Bodies of different composition often have the same form: such are the nitrates of lead and baryta, which crystallize in regular octohedra; the carbonates of lime, magnesia, iron, zinc, and manganese, which crystallize in rhombohedra. The similitude of form is due to the analogy of composition these bodies possess. Such bodies are termed *isomorphous*; yet, in order that two bodies should be isomorphous, it is not necessary that they should have exactly the same angles. It is at first necessary that they belong to the same system, and then that there is but little difference between their axes. Thus carbonate of lime and carbonate of magnesia, just mentioned, are isomorphous, because they crystallize in rhombohedra, with a difference of not more than one or two degrees.

OF THE FORM OF MOLECULES.

Nothing is more simple, on seeing a crystal of a simple substance subdivide to infinity into cubical fragments, than to conclude the molecules themselves are cubical; but it is not so when a compound body is thus treated. How can it be conceived, for example, that a molecule of sulphur, which is a rhombic octahedron, and a molecule of lead, which is cubical, can by combining give rise to a sulphuret of lead, which crystallizes in cubes? How can it be supposed that sulphur, a simple body, can sometimes crystallize in the right rectangular prismatic system, and sometimes in the oblique prismatic system? This difficulty can be resolved by supposing, with Wollaston and Ampère, that the atoms of simple bodies are spheres or ellipsoids, and that many of these atoms group in a symmetrical manner to form compound atoms indivisible by cleavage. These groups behave in crystals like the molecules in which the foregone demonstrations have been made; and it is then possible to conceive how atoms of sulphur, by grouping sometimes in one manner, sometimes in another, can form molecules or compound atoms,—sometimes octahedral, sometimes oblique prismatic.

ACTION OF HEAT ON CRYSTALS.

It is known that bodies whose constitution is homogeneous dilate equally in all directions by the action of heat. If we return to the constitution of crystals, and if we bear in mind that the attraction of the molecules varies according to the different axes, it must be concluded that in the cubical system the dilatation ought to be uniformly parallel to the three axes; that in the square prismatic system it ought to be parallel to the two equal horizontal axes, and unequal according to the vertical axes; and the same for the other systems. Hence it follows that the angles of a rhombohedron vary with the temperature, since the principal axis dilates more or less than the others.

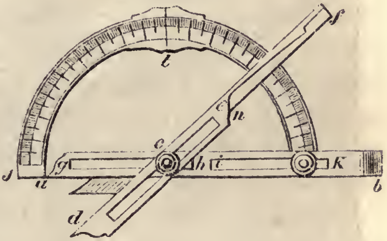
ACTION OF LIGHT ON CRYSTALS.

When a luminous ray passes in an oblique direction from the air through the greater part of non-crystallized substances, as water, glass, &c., it is broken, and departing from the normal law, follows that of Descartes. But it is not so when it passes through a crystalline body; and it might already be ascertained that according as the crystal belonged to the cubic, prismatic, or rhombohedric systems the light would undergo different modifications, not only from one system to another—not only on different bodies belonging to the same system, but also according as it passed through the same crystal in such and such a direction.

It has been noticed that all crystals, excepting those belonging to the cubical system, are capable of causing the division of a luminous ray into two bundles; so that when a small object is seen through such substances, in certain directions it will be constantly seen double. This action is not due to the disposition of the faces of the crystal, but to the intimate arrangement of the molecules composing it; for if the faces of the crystal be cut to other inclinations, double objects will yet be seen through it. It has been observed that light was symmetrically modified in relation to the axes of crystals, as if the cause of these modifications existed in the axes themselves. Crystals having a principal axis (the square and rhomboidal prism), behave differently to those which have three different axes.

Measurement of angles.—Ordinary goniometer.—Various instruments termed Goniometers are employed in the measurement of the angles of crystals. Two kinds are now in use,—the common or contact goniometer, and the reflecting goniometer. The first class only of instrument will be described, as it will sufficiently answer every purpose of the mining mineralogist. The most simple form of instrument (fig. 168) consists of a graduated brass semicircle, on which two metallic cross-blades are fixed. One of these cross-blades, *a b*, is fixed at the zero of the division; the other, *d f*, is moveable, and denotes on the circle the angle of the crystal. In order to measure a dihedral angle, one of its faces is applied to the fixed cross-blade, *a b*, in such a manner that the edge of the angle is perpendicular to the plane of the circle; the moveable cross-blade is then adjusted until its prolongation rests upon the outer face of the angle. It is evident that the angle comprised between the two cross-blades, and which is directly indicated on the circle, is the measure of the angle sought.

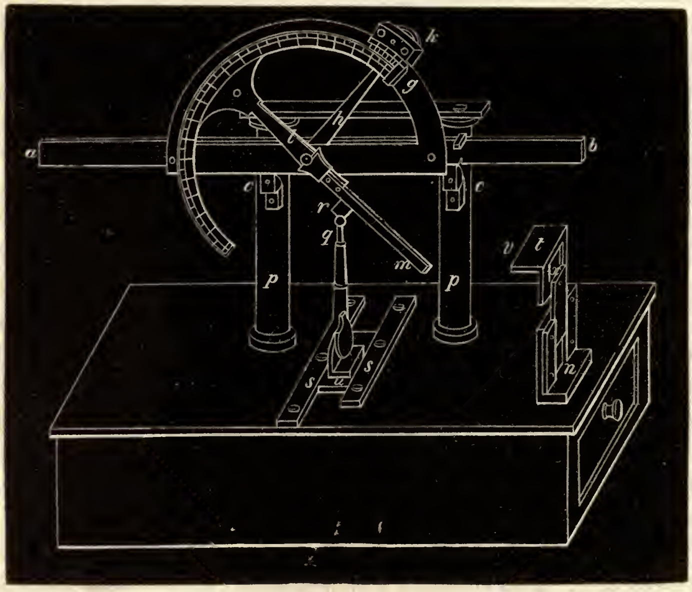
Fig. 168.



The two cross-blades, *a d*, *d f*, slide in the grooves *i k*, *g h*, *d n*, so as to admit of the ends, *c a*, and *c d*, being made as short as is required. This condition is indispensable, as it is often necessary to measure very small crystals, which can only be introduced easily between the two cross-blades when their free ends can be very much shortened.

This form, however, of the common goniometer has many inconveniences. The observations are rendered difficult from the fact that the crystal under examination has to be held with one hand, and the instrument with the other. Moreover, in holding it before the eye, to ascertain if the cross-blade is in perfect contact with the crystal, continual vacillations and disturbances are produced, which render anything like a correct observation very difficult. All these inconveniences are overcome by the use of a fixed instrument contrived by M. Adelmann. The crystal under examination is also fixed on a support, so that both hands are at liberty. This instrument is represented by fig. 169. It consists of a semicircle fixed on a rod, *a b*, supported by columns *p p*. The rod, *a b*, can be moved horizontally, from right to left, in the grooves *c c*, in which are placed small friction rollers, so as to render the movement as easy as possible. The fixed semicircle carries another, *f g*, moveable on the centre *o*, and divided into degrees; *h i k*, is a vernier which also moves on the centre, but behind the moveable semicircle between it and the fixed, to which it can be at any time fastened, and in any

FIG. 169.



required position, by the thumb-screw, *k*. This vernier gives the minutes; *l m* is a blade whose movement carries round the circle, *f g*; *q* is a small stem, the function of which is to support the crystal *r*, which is firmly fastened with wax. It is so arranged that it can be lengthened or shortened, be inclined either from or towards the operator, and capable of turning on itself. It is supported on a small moveable platform, *u*, running between the rods *s s*, which form a groove. The piece, *t v*, seen on the side of the apparatus, is a sight, which, applied against one of the rods, *s*, when the platform is drawn sufficiently forward, enables the operator to judge if the edge formed by the two faces of the crystal is exactly horizontal, and if it be perpendicular to the plane of the circle.

To measure a crystal it must be firmly fixed on *r*, and the moveable platform brought forward: the sight must now be placed against the rod *s*, and the upper part raised or lowered as needed: looking from above, it can be seen whether the edge of the crystal is parallel to the edge *v*, in which case it is perpendicular to the plane of the circle. If the parallelism be not perfect, the rod *q* is turned on its axis, until the proper position is attained. The crystal must then be viewed through the opening *x*, and the same angle adjusted horizontally, which can be effected by inclining the rod either one way or the other as required.

When the crystal is properly adjusted, the moveable platform is pushed under the circle. The blade *l m* is now to be moved, and at the same time the rod *a b* is to be pushed either to the right or left as may be found necessary, so that the edge of the blade may be in perfect juxtaposition with the face of the crystal: when this has been accomplished, the vernier is carried to the end of the moveable semicircle, where a small cleat stops it exactly at zero; it is then fixed by the screw *k*.

This done, the platform is drawn from under the circle, and the blade passed in the contrary direction to that which it before occupied; the platform replaced, and the blade brought into juxtaposition with the other face of the crystal: this accurately done, the stem and crystal are removed.

By this second application of the blade to the crystal the semicircle has turned, and the point where it stops indicates the measure of the angle, which is read on it in degrees: the vernier furnishes the minutes.

Beudent says this apparatus has given him very satisfactory results, — the error being no more than three or four minutes.

If, however, the reader should wish to employ a more accurate and perfect form of goniometer, he had better consult the twenty-third part of the *Proceedings of the Chemical Society*, in which is described a very beautiful instrument invented by the late Dr. Leeson, and termed by him "The Double Refracting Goniometer."

CHAPTER III.

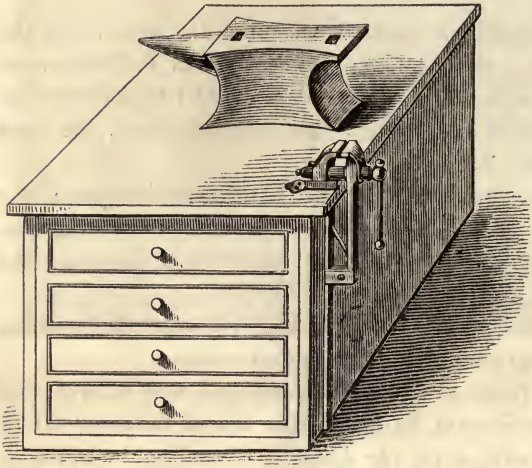
MECHANICAL PREPARATION OF MINERALS FOR ASSAY.

Before the actual assay of an ore commences, it has to go through a series of mechanical operations, the object of which is its reduction into a pulverulent form, more or less fine according to the nature of the chemical operation or assay proper it is to be further subjected to.

This division is effected by means of the anvil, hammer, mortar and pestle, sieve, and decantation, or some of the means generally in use for the preparation of any fine powder.

There is also another operation, which is as strictly mechanical as are the above, viz.: washing, dressing, or vanning a sample of ore, the end and aim of which is to separate, by means of water and difference of specific gravity, in a suitable vessel, the earthy or useless, and, in some cases, objectionable portion, from the heavier metallic and valuable portion. This operation is always employed on the larger scale in dressing ores for the smelter. Weighing samples for assay also comes in this chapter.

FIG. 170.



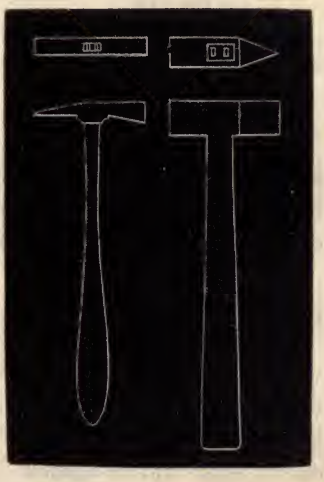
Anvil stand, anvil, vice, and hammers. — The anvil stand is constructed of stout wood about two inches in thickness, and forms a cube of about two feet square. It contains three or four drawers, which serve to hold the hammers, cold chisels, shears, files, &c., which are required in an active assay office. In the centre is firmly fixed the anvil, and in one corner is also firmly secured a vice.

In general the anvil and hammer are employed for the purpose of breaking a small fragment from a mass of ore for examination, or ascertaining whether the button or prill of metal produced in an assay be malleable or otherwise. The anvil is also exceedingly useful as a support for a crucible, while breaking it to extract the metallic or other valuable contents.

The anvil is most useful in size when weighing about 28lbs.; but one of 14lbs. will suffice. By reference to the figure, it will be seen the anvil recommended is of the shape usually employed by the blacksmith. Another anvil is also employed, but will be noticed under the head Blowpipe Manipulation.

The hammer, or rather hammers (figs. 171 and 172), for two are requisite, ought to have a flat square, and a pick or wedge end. The horizontal wedge end of fig. 171 is useful for breaking open crucibles, and detaching small fragments from a specimen of ore; the flat end for ascertaining the malleability of buttons of metal. This hammer should weigh about 1lb. The larger hammer, fig. 172, weighs about 4lbs., and is employed for breaking coke sufficiently fine for the use of the furnace, and detaching fragments from refractory minerals, in both of which cases either end may be employed as may seem most serviceable to the operator. The flat end of this hammer is also used for driving a cold chisel in separating masses of gold, silver, copper, lead, &c., for assay. This hammer has a vertical pick or wedge end.

Fig. 171. Fig. 172.



Very hard and stony minerals which have to be broken on the anvil (and all such ought to be so treated) scatter many fragments, to the certain loss of a portion of the substance, and the probable injury of the operator: this, however, can be prevented by wrapping the mineral in a piece of stout brown paper, or, if necessary, in several folds. The fracture can then be safely attempted.

This latter precaution must be specially taken in fracturing gold quartz, or hard rock containing metallic or native silver, as the loss of a very minute quantity of metal would involve a considerable error in the result afforded by assay.

All minerals, however, unless very friable, must be reduced to a moderate size—say that of a walnut—by means of the anvil and hammer, before pulverisation; otherwise, if the reduction be attempted in a mortar, it is nearly certain to be fractured; and not only should the anvil be used for this reason, but the operator will find his labour much abridged.

The anvil can also be made very serviceable in repointing worn or burnt-out tongs, stirring irons, &c. It need scarcely be added that the anvil must be placed as far as possible away from bottles and other frangible articles; otherwise accidents are liable to occur by the forcible projection of fragments of crucibles, &c.

As just mentioned, the cold chisel (fig. 173) is employed for cutting off metallic masses for assay. It should be five or six inches long, and about half an inch wide, which is the best size for general use. It is, however, handy for some purposes, as cutting copper and other very tough metals, to have a chisel only a quarter of an inch wide, as copper is so much more difficult to cut, and the small chisel meets with the least resistance.

Fig. 173.

Fig. 174.

Small shears (fig. 174) are also exceedingly useful in cutting off pieces of sheet metal, as lead, for cupellation, scorification, &c.

Pulverisation: the pestle and mortar.—Mortars are made of various materials,—as cast iron, bronze, porcelain, agate, &c.; but the assayer merely requires one of cast iron and one of porcelain: if he intend to employ the blowpipe in any of his operations, one of agate will be needed. This will be described in the list of Blowpipe Apparatus.

The iron mortar (fig 175) ought to be of the capacity of from three to four pints; the porcelain (Wedgewood ware) may be about two pints. The ease with which a mortar may be used depends much upon its form; and opinion is greatly divided on this subject. Faraday* says of the pestle and mortar:—

Fig. 175.

Fig. 176.

"The pestle should be strong, and the size of its superior part such as may be sufficient to allow of its being grasped firmly in the hand, and below to permit a considerable grinding surface to come in contact with the mortar. Its diameter in the lower part may be about one-third or one-fourth of the upper diameter of the mortar.

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* Chemical Manipulation, page 149.

The curve at the bottom should be of shorter radius than the curve of the mortar, that it may not touch the mortar in more than one part, whilst at the same time the interval around may gradually increase, though not too rapidly, towards the upper part of the pestle."

The bottoms of all mortars ought to be of considerable thickness, in order to withstand the smart blows they will occasionally have to receive.

Iron mortars can be best cleaned by friction with a little fine sharp sand, if the ordinary process of washing be not sufficient to remove the adhering substance. Great care must be taken to perfectly dry mortars, especially those of iron, otherwise they will become rusted, and the rust so formed will contaminate the substances pulverised in them.

Berzelius recommended (and I have found it extremely serviceable) a mass of pumice-stone for cleansing porcelain mortars. It is used with water as a pestle, and in course of time will be worn to the shape of the mortar; and then its action will be more speedy.

The iron mortar is principally of use in the reduction of the masses of mineral (broken on the anvil as before described) to a state of coarse powder, in order to render the substance more readily capable of pulverisation, strictly so called. In the use of the iron mortar all friction with the pestle ought to be avoided, and the body within it must be struck repeatedly and lightly, in a vertical direction, taking care to strike the larger pieces, so that all may be equally reduced. This process can be carried on until the whole is about the size of fine sand; it can then be transferred to the porcelain mortar, where all blows must be carefully abstained from. The process is now thus carried on: the pestle is to be pressed upon with a moderate force, and a circular motion given to it, taking care every now and then to lessen and enlarge the circles, so as to pass over the whole grinding surface of the mortar, and ensure the pulverisation of the mass of mineral submitted to operation. In general, the finer the state of division to which a mineral is reduced the more accurate and expeditious will be its assay; and in preparing a mineral for assay by the humid method, no labour ought to be spared on this point. Pulverisation is rendered much easier by operating on a small quantity at once, and removing it very often from the sides and bottom of the mortar by means of a spatula. The quantity operated on at one time must be regulated by the hardness or friability of the substance whose pulverisation is to be effected. The harder it is the less must be taken, and *vice versâ.*

In the use of the iron mortar, fragments are occasionally projected. This may be prevented by covering the upper part of the mortar with a cloth. This applies also to the porcelain mortar, for the dust of some minerals has a disagreeable taste and smell; the operator may in some measure protect himself by means of the cloth. Indeed, in some cases, the ambient powder is highly deleterious, as in the pulverisation of arsenical nickel, cobalt, and other ores, and the cloth is not a sufficient protection unless slightly damped with water, when, if tightly tied round the mortar and firmly held round the pestle, nothing can escape.

Some minerals can be pulverised with greater ease if they are ignited and suddenly quenched in cold water. In this list is flint, and many other siliceous matters,—as gold quartz. In the pulverisation of charcoal for assays, it will be found advantageous to ignite it, as hot charcoal is more readily pulverised than cold.

Sifting: the Sieve.—The operation of sifting is had recourse to when a very fine powder is required, or when a powder whose parts must be equal is needed. Sieves of various materials, and different degrees of fineness, are necessary. The larger sieve, for preparing coke for the blast furnace, is made of stout iron wire, and must have its meshes from 1 inch to 1½ inch square. The fine coke which is sifted from that which is the proper size for the blast furnace may be mixed with that of ordinary size, and employed economically in the muffle furnace. For the preparation of minerals, a set of three sieves may be provided, each one finer than the other. The coarsest may contain 40 holes to the linear inch, the finer or medium sieve 60, and the finest from 80 to 100. The coarsest sieve is used in preparing galena for assay; the medium, copper, tin, iron, and other like ores; and the finest, for gold and silver ores, or for preparing any substance for the wet assay; as in the latter case the finer the state of division the substance attains the more rapid will be its solution or decomposition by the liquid agents employed.

The sieve (fig. 177) is made of wood, over which is strained in the ordinary manner wire-gauze (brass), of the necessary degree of fineness. When in use, the part B, fig. 178, is fitted into the lower part, A, same figure. This contrivance prevents all loss of the fine powder. If the matter to be sifted be deleterious or offensive to the operator, a sieve termed the *drum- or box-sieve* may be employed (see fig. 178, where C represents a cover fitting over the sieve). If small, this may be used in the ordinary way; but if large, its method of use is rather peculiar, and requires some practice to fully develope its powers. One side of the under edge must be held by one or both hands, according to its size, whilst the other rests on a table or a bench. A semicircular oscillating motion must now be communicated to it by moving the hands up and down at the same time they are being alternately brought into approximation with the sides of the operator.

FIG. 177.

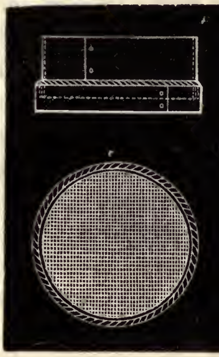
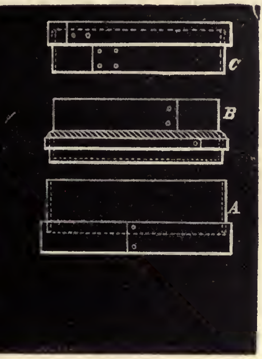


FIG. 178.



In cases of necessity a sieve may be readily extemporised. Place the powder to be sifted in a piece of fine lawn, or muslin, as may be required; tie it up loosely, and shake or tap the powder, with its muslin or other envelope, on a sheet of paper, and the sifting will be rapidly and easily accomplished.

The sieve is also extremely serviceable in the separation of some ores from their gangues or vein-stones, especially if the latter be stony and hard. This point must be particularly noted, as it is the cause of much variance between the results of different assayers: for instance, part of the same sample of ore might be sent to two assayers, and the produce made by one might be 8½ per cent., and that by the other 9 or 9½, or, in some cases, even more. This discrepancy most generally arises as above mentioned. In the one case, the laboratory man has rejected part of the hard gangue, and so rendered the residue richer; and in the other, pulverised the whole, making the produce less, but giving the actual amount of metal in the substance submitted to assay.

A knowledge of this fact is also very useful; but in another point of view, suppose it were wished to separate in a speedy manner any friable mineral, such as gelena or copper pyrites, as perfectly as possible, by mechanical means, it might be accomplished by the use of the sieve. The method of operating is as follows:—Place a small quantity of the mineral in an iron mortar, and strike repeatedly slight vertical blows. When it is tolerably reduced, sift it, and that which passes through is nearly pure mineral, with only a small quantity of matrix; repeat the pounding and sifting operations, until, after a few alternations, that which remains in the sieve is nearly pure gangue. This operation is also effected by means of water, as will be described hereafter.

Native metals, as gold, silver, and copper, are also partially separated after the manner above described. The fine particles of metal, during the process of pounding and trituration, become flattened, and refuse to pass through the sieve, which the more brittle portion passes through, and is separated.

Decantation.—This process can only be employed for those bodies which are not acted on by water; and is thus effected. The substance operated on is reduced to the finest possible state of division by any of the foregone processes; it is then mixed with a quantity of water in a glass or other vessel. After a few moments' repose, the supernatant liquid, retaining in suspension the finer particles of the pulverised substance, is poured off, and the grosser parts, which have fallen to the bottom of the vessel, are repulverised and again treated with water. By alternating these processes the finest possible powder may be obtained in a ready manner.

It is seldom, however, that a substance is required in such a minute state of division as produced by this process for assaying by the dry way. In the humid or wet method it is occasionally very useful. Decantation is not only employed for the above purpose, but as a ready means of separating a liquid from a precipitate in an assay by the humid process, or in washing a precipitate with a large quantity of water, in order to free it from any adhering impurity which is soluble in that fluid. In certain cases, where the precipitate to be washed is light, the least disturbance of the vessel containing it occasions its distribution in the liquid, and the consequent loss of a portion in decantation. This can be avoided by the employment of the syphon. The operation is then thus conducted :—The syphon is filled with water, and the shorter end placed in the liquid whose transversion is to be effected; the forefinger of the right hand, being during this time applied to the longer end of the instrument, is now removed, and the water will flow out until it be level with the immersed end of the syphon. Fresh water can then be added to the precipitate, and the operation of decantation by the syphon carried on as long as requisite.

Washing, dressing, or vanning.—This operation is exceedingly useful for discovering the approximate quantity of pure ore, say galena, copper pyrites, oxide of tin, or native gold or silver, in any sample of earthy matter or gangue in which it may be disseminated.

The theory of the operation about to be described is easily understood. Bodies left to the action of gravity in a liquid in a state of rest, experience a resistance to their descent which is proportionate to their surface, whatever may be their volume and density. Hence, 1stly, that of equal volumes the heaviest fall most rapidly; 2nd, that of equal densities those having the largest sizes move with the greatest speed; for in particles of unequal sizes and like forms the weight is proportional to the cube of the dimensions, and the surfaces are only proportional to the square of these dimensions, from which it follows that in small particles the surface is greater in relation to the weight than in the large particles; 3rd, that of equal densities and volumes, particles offering the largest surface, those which are scaly or laminated, for example, undergo more resistance in their motion than those which, approaching the spherical form, have less surface. The adhesion of the liquid to the particles of bodies held in suspension is also an obstacle to their subsidence. This force is, like the dynamic resistance, proportional to the surfaces and independent of the masses; further, in a fluid in motion the impulse received by different bodies is proportional to their surface and independent of their masses or volumes. Whence it follows that in a fluid in motion, that of bodies having equal volumes, the least dense acquire the greatest rapidity of movement, and which are deposited at the greatest distance from the point of departure, whilst with equal densities the smallest grains are carried furthest; and, lastly, with equal densities and volumes the particles exposing most surface traverse the greatest space.

It is, therefore, evident that the most advantageous condition for separating, by washing, two substances of unequal specific gravity or density is that the heaviest shall be in larger grains than the lightest: this unfortunately, however, is a condition that can be very seldom fulfilled, as the heaviest substances are those metallic minerals whose frangibility is nearly always greater than the earthy matters accompanying them as gangues. This being the case, it is very important so to arrange that the fragments of the various mixed substances shall be nearly of the same size. This may be effected by very frequently sifting the mineral during the process of pulverisation, reducing it also more by blows than by grinding, so as to get as little fine powder as possible, as that is nearly certain to be washed away during the process.

The operation of washing or vanning may be performed by one of two methods. In the first, a small stream of running water is employed; in the second, water is added to the substance to be washed, and poured off as necessary.

In the first process, a vessel somewhat resembling in shape a banker's gold-scoop (but longer in proportion) is employed; the mineral to be washed is placed in the upper part, and a small quantity of water added, with which the mineral is thoroughly and carefully moistened, and mixed with the fingers. The scoop must then be so inclined that a fine stream of water from any convenient source (say a tap) may fall just above the upper part of the mixture of mineral and water; then, firmly holding the larger and consequently upper end of the scoop with the left hand, and sustaining the lower part with the right, it is shaken frequently in the direction of its longitudinal axis. At each shake, all the particles in the scoop are so agitated that they are suspended in the water, and the current of liquid running from the tap into the scoop moves them all in its own direction; but they are deposited at different distances from the point at which the water enters, the heaviest being carried through but a very small space. It is now soon seen that the mineral assumes a heterogeneous surface; at the upper part, the heavy portions are seen nearly pure; the light substances, on the other hand, are nearly without mixture at the lower end, and in the intermediate part the heaviest portion of the mixture is nearest the upper end. If the washed matter were now to be divided into horizontal layers, the heaviest matter would be found at the bottom, and the lightest on the surface. Things being in this state, the scoop must be made to oscillate on its axis, so that the latter shall remain immoveable, and in a slightly inclined position. In this manner, the layer of water running over the surface of the mineral agitates that part only, and carries off all light substances there deposited in the previous operation. When necessary, these matters are removed by the finger, and made to run into a vessel placed below the scoop, in which all the water and matters carried off are received. This operation, however, must not be hurriedly performed, so as to mix the parts already separated; each layer must be removed separately, commencing with the upper one. This being done, the scoop must be alternately kept in motion by shakings, as at first, and then on its axis, and the washing off of the finer particles renewed, and so on until the separation is effected as far as may be judged necessary.

At the commencement of the operation, the water carries out of the scoop the lightest particles, as organic matter, clay, &c.; at a little later period these substances carry with them a small but definite quantity of the heavier portion, the proportion of which increases as the operation proceeds, until at last the greatest possible care is required. It is always better to re-wash the portion which passes off from the scoop: hence the necessity of allowing all the wash water passing from it to collect in a vessel placed for that purpose.

In the second case of washing, a tin-plate or zinc pan is employed. It should be circular, about 12 inches in diameter and 2 inches deep; the sides should descend in a conical manner, so that the bottom is not more than 4 inches in diameter, and the angle between it and the sides as sharp as possible. The bottom should also be perfectly flat.

The substance to be examined is placed in the washing-dish, the latter filled with water, and the mineral well mixed with it, until perfectly moistened, as before. After a moment or so the muddy water is poured off, and the operation repeated until the water passes off clear. When this happens, only so much water must be placed in the pan as will leave a slight layer on the mineral. Now, by holding the pan in one hand and shaking it with the other, the greater part of the heavy mineral, gold, or otherwise, will fall below the sand. If now the pan be inclined towards the hand which is shaking it, the lighter portions, even if tolerably large, will flow off with the water, leaving the heavier matters in the angle, from which, with ordinary care and a little practice, it is difficult to disturb them. If there be a large quantity of earthy matter, it may be (after sufficient shaking) removed by the finger, as in the first described process. By careful repetitions of these processes, the whole, or nearly the whole, of the sandy and earthy matters may be removed, and the gold or other mineral left nearly pure. This is the plan employed in *prospecting* for gold, diamonds, and other gems, and, in some cases, for their commercial extraction.

In Cornwall, and other mining counties, this operation is very cleverly and carefully performed on the miner's common shovel, and the richness of any particular sample of either tin, lead, or copper is very nearly accurately determined.

The Balance: Weighing.—In a properly appointed assay-office, there should be at least three balances; the first to weigh about three or four pounds, and turn with a quarter of a grain. This may be of the form of the bankers' or bullion balance (fig. 179), and is employed in weighing samples of gold quartz or silver ore containing metallic grains capable of being separated by the sieve (see page 64); the second (fig. 180), or rough assay balance, is similar to the apothecary's scales; will weigh 1000 grs., and turn with $\frac{1}{10}$th of a grain. This serves for weighing samples of ore and fluxes for assay, and for determining the weight of buttons or prills of lead, tin, iron, copper, &c. obtained in an assay. The third and most delicate, or true *assay balance* (fig. 181), carries only about 100 grs., and must turn distinctly and accurately with the $\frac{1}{1000}$th of a grain. This is employed in the assay of gold and silver bullion, and in the assay of minerals containing gold and silver; also for general analytical purposes. In

Fig. 179.

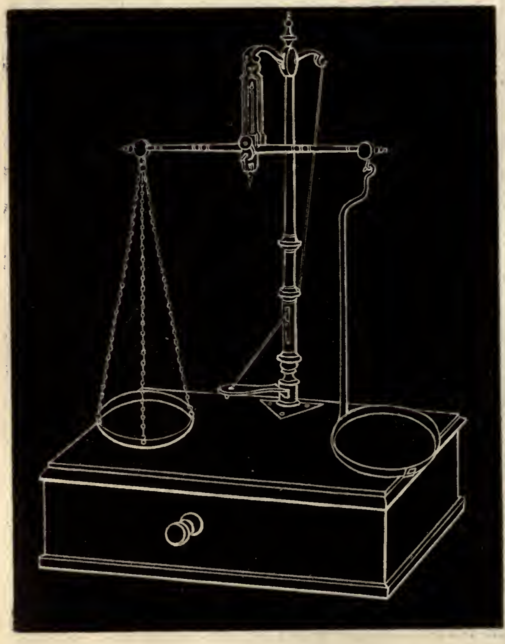
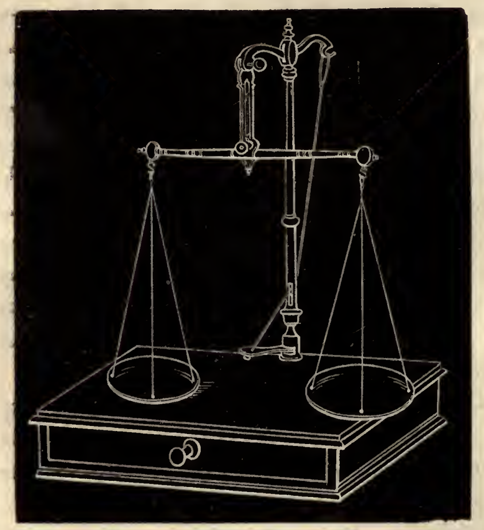
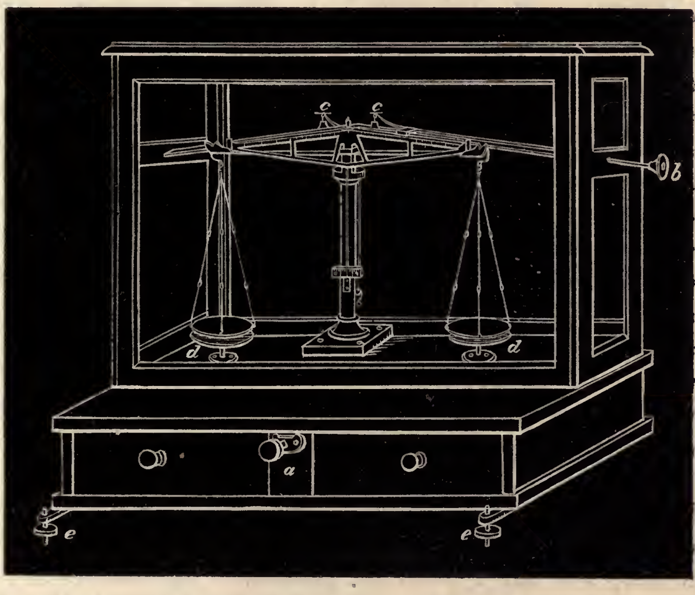


Fig. 180.



case, however, it be intended to conduct analyses of coal or other combustible matters, with a view to ascertain their heating value,

FIG. 181.



&c., this balance must be so constructed as to carry from 800 to 1000 grs, and yet turn with the $\frac{1}{1000}$th of a grain; as the apparatus employed, and which is rather heavy, must necessarily be weighed, as will be described in the chapter devoted to the assay and analysis of fuel.

The two first balances may be used with ordinary care by any one; but the third balance, in its use and adjustment so as to maintain and determine its extreme accuracy, requires some particular instructions, which necessarily involve the principle of the balance, and which have been so admirably given by Mr. Faraday, in his "Chemical Manipulation," that the author can do no better than transcribe them.

"The theory of the balance is so simple that the tests of its accuracy will be easily understood and as easily practised. It may be considered as an uniform inflexible lever, supported horizontally at the centre of gravity, and supporting weights at equal distances from the centre by points in the same horizontal line with the centre of gravity. If the weights be equal, the one will counterpoise the other; if not, the heavier will preponderate. In the balance, as usually constructed, there are certain departures from the theory as above expressed,—some from the impossibility of execution, and others in consequence of their practical utility; and a good balance may be said to consist *essentially* of a beam made as light as is consistent with that inflexibility which it ought to possess, divided into two arms of equal weight and length by a line of support or axis, and also terminated at the end of each arm by a line of support, or axis, intended to sustain the pans. These three lines of support should be exactly parallel to each other in the same horizontal plane, and correctly perpendicular to the length of the beam; and the plane in which they lie should be raised more or less above the centre of gravity of the beam, so that the latter should be exactly under the middle line of suspension. It will be unnecessary in this place to speak of the coarse faults which occur in the ordinary scales—these will easily be understood; and from what has to be stated of the examination of the most delicate instrument, the impossibility of avoiding them without incurring an expense inconsistent with their ordinary use will be as readily comprehended."

It will be easily understood that a beam constructed with knife edges resembles the one above mentioned; and being supported on horizontal planes by the central line of suspension, as is generally the case, will take a horizontal position, in consequence of the situation of the centre of gravity. The addition of the pans causes no change in this ultimate position of the beam, because they are of equal weights.

The delicacy of a balance depends very materially upon the relative situations of the centre of gravity and the lines of support; *i. e.* the middle and extreme lines of suspension. If the centre of gravity be considerably depressed below the fulcrum, then, upon trying the oscillations of the balance by giving it a little motion, they will be found to be quick, and the beam will soon take its ultimate state of rest; and if weights be added to one side, so as to make it vibrate, or *turn*, as the expression is, or else to bring it to a certain permanent state of inclination, the quantity required will be found to be comparatively considerable. As the centre of gravity is raised the oscillations are slower, but producible by a much smaller impulse; the beam is a longer time before it attains a state of rest, and it turns with a smaller quantity. When its situation coincides with the fulcrum or centre of oscillation, that also being in the plane joining the two extreme lines of suspension, then the smallest possible weight will turn the beam (supposing the knife edge and suspending plane perfect): the oscillations no longer exist, but one side or the other preponderates with the slightest force; and the valuable indication which is furnished by the extent and velocity of the vibrations is lost.

The case where the centre of gravity is above the fulcrum rarely if ever occurs. Such a balance, when equally weighted, would set on the one side or the other; that side which was in the slightest degree lowest tending to descend still lower, until obstructed by interposing obstacles: unless, indeed, the fulcrum was placed considerably above the line joining the extreme points of suspension; in which case the weights in the pans might counteract the effect dependent upon the elevation of the centre of gravity.

In balances intended to carry large quantities (as in the balance for weighing gold quartz, &c.), it is necessary to place the centre of gravity lower than in those for minute quantities, that they may vibrate regularly and readily; and hence one cause why they are inferior in delicacy, for, as a consequence of the arrangement, they will not turn except with a larger weight.

The vibrations of a balance vary with the quantity of matter with which it is loaded: the more the weight in the pans, the slower their occurrence. These should be observed, and the appearances retained in the mind, in consequence of the useful indications they afford in operations of weighing. A certain extent and velocity of vibration would indicate to the person used to the instrument nearly the weight required to produce equilibrium; but the same extent and velocity with a weight much larger or smaller would not be occasioned by an equal deficiency or redundancy of weight, as in the former case.

The weight required also to effect a certain inclination of the beam, or to turn it, should be known, both when it is slightly and when it is heavily loaded. Thus, if the instrument turns with $\frac{1}{1000}$th of a grain, with 1000 grs. in each pan, or with $\frac{1}{1,000,000}$th of the weight it carries, it may be considered perfect.

Balances are sometimes liable to *set,* as it is called, when overloaded. The effect consists in a permanent depression of that side which is lowest: thus, if a balance be equally weighted in each pan, but overloaded, it will, if placed exactly horizontal, remain so, but the slightest impulse or depression on one side destroys the equilibrium; the lower side continues to descend with an accelerated force, and ultimately remains down, being to all appearance heavier than the other. Generally speaking, the more delicate a balance the sooner this effect takes place; and hence one limit to the weight it can properly carry.

The setting is considered as dependent upon the position of the fulcrum *below* the line which joins the extreme points of suspension of the beam; the effect which would thus be produced being marked for a time by the centre of gravity in the beam falling below the fulcrum.

When the beam, freed from the pans but supported on its stand, has been found to oscillate with regularity, and gradually to attain a horizontal position of rest, it should be reversed,—that is, taken up and turned half way round, so as to make that arm which before pointed to the right now point to the left. The beam should then again be made to oscillate; and if it perform regularly as before, finally resting in a horizontal position, it has stood a severe test, and promises well.

The faults which are likely to be disclosed in this way depend upon imperfections in the work of the middle knife edge, and the planes upon which it rests.

The edge is made either of agate or steel, and should be formed out of one piece of matter, and finished at once, every part of the edge being ground on the same flat surface at the same time. In this way the existence of the two extreme or bearing parts of the edge in one line is insured; but when the two parts which bear upon the planes are formed separately on the different ends of a piece of agate or steel, or, what is worse, when they are formed on separate pieces, and then fixed, one on each side the beam, it is scarcely possible they should be in the same line; and if not, the beam cannot be correct. These knife edges usually rest in planes, or else in curves. The planes should be perfectly flat and horizontal, and exactly at the same height; the curves should be of equal height, and their axes in the same line. If they are so, and the knife edge is perfect, then the suspension will be accurately on the line of the edge, and reversing the beam will produce no change.

When the pans are hung upon the beam, the balance should of course remain horizontal. The lines of suspension for the pans are not so difficult to obtain correctly as that before spoken of; but they should be tried by changing the pans, then by reversing the beam, and afterwards by changing the pans again. The irregularities which may in this way be discovered are best corrected by a workman; but as in all the best balances now made adjusting screws for all these purposes are provided, and as these delicate balances are now, in consequence of the discovery of gold, gems, &c. in Australia, California, and elsewhere, so often in use where no workman skilled in their management and adjustment resides, it has been thought necessary to introduce here such matter as, after careful perusal, will enable everyone to adjust and examine his balance properly; so that in case it should have become disordered by rough usage or otherwise during its transit, it may be readily put in working order.

The arms should in length and weight be equal to each other. The length of each is accurately the distance from the middle to the distant knife edge, all the edges being considered parallel to each other, and in the same plane. The two arms should accord perfectly in this respect; but the weight is by no means necessarily subject to equality, though it is much better it should be so. One arm with its pan may be considerably heavier than the other; but from the disposition of the weight in the lighter arm towards the extremity, or in the heavier towards the middle of the beam, the equilibrium may be perfect, and therefore no inaccuracy be caused thereby in the use of the balance. Instruments are usually sent home in equilibrium, and require no further examination as to this particular point than to ascertain that they really are in adjustment, and that after vibrating freely they take a horizontal position.

Equality in the length of the arms is much more important, and may be ascertained in two or three ways. Suppose the balance with its pans to vibrate freely, and rest in a horizontal position, and that after changing the pans from one end to the other the balance again takes its horizontal state of rest; in such a case, an almost certain proof is obtained of equality in length of the arms. They may, however, be equal, and yet this change of the pans from end to end may occasion a disturbance of equilibrium, because of the unequal distribution of weight on the beam and pans; but to ensure an accurate test, restore the pans, and consequently the equilibrium, to the first state, put equal, or at least counterpoising, weights into the pans, loading the balance moderately, and then change the weights from one pan to the other, and again observe whether the equilibrium is maintained: if so, the length of the arms is equal.

Tests of this kind are quite sufficient for the purpose of the assayer; who, having ascertained that his balance, whether slightly or fully laden, vibrates freely, turns delicately, has not its indications altered by reversing the beam or changing counterpoising weights, may be perfectly satisfied with it, and leave (excepting under the circumstances above mentioned) the more difficult points and corrections to the instrument-maker.

Weights.—As balances of different kinds are required by the assayer, so will various kinds of weights be necessary. For the larger balance, Troy weights from 4lbs. to $\frac{1}{4}$ grain will be requisite; for the second size, weights from 1000 grains to $\frac{1}{10}$th part of a grain; and for the assay balance, weights from 100 grains to $\frac{1}{1000}$th part of a grain; or, if coal analyses are required, weights from 1000 grains to $\frac{1}{1000}$th of a grain.

Peculiar weights are also necessary for the assay of gold and silver bullion in England (at least with the exception of assays for the Bank of England: see Gold Assay), gold being reported in carats, grains, and eighths, and silver in ozs. and dwts. The most convenient quantity of either of the precious metals for assay is from 6 to 12 grains—the latter quantity is the best. The quantity taken, however, is of no very great consequence; but whatever its real weight it is denominated in England the *assay pound.* This assay pound is then subdivided into aliquot parts, but differing according to the metal. The silver assay pound is subdivided, as the real Troy pound, into 12 ounces, each ounce into 20 pennyweights, and these again into halves (the lowest report for silver); so that there are 480 different reports for silver, and therefore each nominal halfpennyweight weighs $\frac{1}{40}$th part of a Troy grain, when the pound is 12 grains.

Assay Weights for Silver.

Silver.				Assay.
Oz.	*Dwts.*	*Grs.*		*Grains.*
12	0	0	. . . . . . =	12
11	0	0	. . . . . . ,,	11
6	0	0	. . . . . . ,,	6
3	0	0	. . . . . . ,,	3
2	0	0	. . . . . . ,,	2
1	0	0	. . . . . . ,,	1
0	10	0	. . . . . . ,,	0·500
0	5	0	. . . . . . ,,	0·250
0	3	0	. . . . . . ,,	0·150
0	2	0	. . . . . . ,,	0·100
0	1	0	. . . . . . ,,	0·050
0	0	12	. . . . . . ,,	0·025

The *gold assay pound* is subdivided into 24 carats, each carat into 4 assay grains, and each grain into eighths; so that there are 768 reports for gold, and the assay pound, weighing 12 Troy grains, the lowest report, or $\frac{1}{8}$th assay grain, equals $\frac{1}{64}$th Troy grain, thus:

Assay Weights for Gold.

Gold.				Assay.
Carats.	*Grs.*	*Eighths.*		*Grains.*
24	0	0	=	12
22	0	0	,,	11
12	0	0	,,	6
6	0	0	,,	3
3	0	0	,,	1$\frac{32}{64}$ths grain
2	0	0	,,	1
1	0	0	,,	$\frac{32}{64}$ths grain
0	2	0	,,	$\frac{16}{64}$ths ,,
0	1	0	,,	$\frac{8}{64}$ths ,,
0	0	6	,,	$\frac{6}{64}$ths ,,
0	0	3	,,	$\frac{3}{64}$ths ,,
0	0	2	,,	$\frac{2}{64}$ths ,,
0	0	1	,,	$\frac{1}{64}$th ,,

In cases where the very smallest weights have to be employed, great care must be taken in seizing them with the forceps, as they are apt to spring away and be lost. In the assay balance (fig. 181) the use of weights less than $\frac{1}{10}$th of a grain is avoided by a very ingenious contrivance. Each side of the beam is equally divided into ten parts, and over the beam on either side is placed a sliding rod, as represented in the figure. The object of these rods is to carry in the direction of the beam the small bent piece of platinum or gold wire (letter *c*, fig. 181) called a *rider*, which serves in lieu of the smallest weights—the $\frac{1}{100}$th and the $\frac{1}{1000}$th. These riders are thus employed:—One weighing $\frac{1}{10}$th of a grain is placed on the cross piece of the extremity of the sliding rod just mentioned, and the rod thus furnished is brought gradually along the beam from the centre to the end, until the rider can be deposited on the division on the beam marked 10; the balance is then loaded on that side with a weight equal to $\frac{1}{10}$th of a grain. If now the rod be advanced to the centre of the balance and the rider dropped on the mark 5, the half of $\frac{1}{10}$th of a grain will be pressing on that side of the balance, or in other words ·05th of a grain; and when the rider is at the marks 1, 2, 3, 4, ·01, ·02, ·03, ·04 of a grain will be indicated. With a weight weighing $\frac{1}{100}$th of a grain, thousandths of grains may be indicated: thus this last rider placed on the marks 1, 2, 3, 4, would equal ·001, ·002, ·003, ·004 grain, &c.

Use of the assay balance.—The operation of weighing is very simple; and it is only in the hands of the chemist and assayer that it becomes one of extreme difficulty and frequency that the facilities for its performance require to be mentioned. It should in the first place be ascertained before every operation that the balance is in order, as far as relates to its perfect equilibrium and to the freedom of vibration, and also that no currents of air are passing through the case, so as to affect its state of motion or rest, a situation being chosen where such influences may be avoided. If from any accidental cause it be not *in equilibrio,* it should be balanced by a slip of paper, or by a piece of tin- or lead-foil. In most cases, however, there is a small wire on the upper part of the beam, which by being turned either to the right- or left-hand side of the beam, as required, serves to establish perfect equilibrium.

A delicate balance is always furnished with means of supporting the pans independent of the beam; and the beam itself is also supported when required by other bearings than its knife edges, and in such a manner as to admit of the rapid removal of these extra supports, that the instrument may be left free for vibration. This is done that the delicate edges of suspension may not be injured by being constantly subjected to the weight of the beam and the pans, and that they may suffer no sudden injury from undue violence or force impressed upon any part of the balance. When, therefore, a large weight of any kind is put into or removed from the pans, it should never be done without previously supporting them by these contrivances; for the weight, if dropped on, descends with a force highly injurious to the supporting edges; or if a large weight be taken out without first bringing the pans to rest, it cannot be done without producing a similarly bad effect.

When a weight is put in which is assumed to be nearly equal to the substance to be weighed, the balance should be brought to a horizontal state of rest, and should then be liberated gradually by turning the thumb-screw, so as to have the pans wholly supported by the beam. The whole being on its true centres of suspension, it will be observed whether the weight is sufficient or not; and the rapidity of ascent or descent of the pan containing it will enable a judgment to be formed of the quantity still to be added or removed.

It sometimes happens that the balance appears to vibrate with difficulty, or to stick, though no sufficient cause can be discovered: on these occasions a slight tremor given to the instrument by tapping on the case, or by a vibratory motion, will assist the balance, and confer a sufficient delicacy to allow of the operation being completed.

CHAPTER IV.

General Preparatory Chemical Operations.

Calcination.—The terms calcination, calcining, and roasting, are very often confounded. By calcination is here meant either separation of any volatile matter from a mineral substance by the aid of heat alone, the atmosphere being totally or partially excluded, or in effecting rapid changes of temperature to render minerals more fragile; as gold quartz previous to quenching in water, &c.

The hydrates of all minerals, as iron, zinc, &c., whose matrices are argillaceous, are calcined to expel water; the carbonates of lime, iron, copper, and lead, to separate carbonic acid; and the hydrocarbonates of zinc and iron to get rid of both water and carbonic acid; cobalt, nickel, &c., to separate arsenic and sulphur; coal and the iron ore found in the vicinity of collieries, black-lead, &c., to expel bituminous matter.

Vessels termed crucibles are used in calcination, and are made of various materials,—as clay, platinum, silver, and iron. Silver cannot be employed at a heat greater than dull redness. Crucibles of platinum are the most useful; next to them, those of clay. All these crucibles must be furnished with covers.

When the operation is finished, the crucible must be removed from the fire and allowed to cool gradually. When completely cold, the cover may be removed, and the contents taken out by means of a spatula. If any adhere, a small brush will be found very useful for its removal. The difference in weight before and after the calcination equals the volatile matter.

In case the substance to be calcined is fusible, the crucible and contents must be weighed before ignition; and the loss of weight is equal to the quantity of volatile matter expelled: in fact, this latter is the most satisfactory method of conducting the experiment.

If the ignited or calcined substance be soluble in water, it can be removed from the crucible by that menstruum (heat may be employed if required); if not, any suitable acid may be used.

If the substance to be calcined decrepitates on heating, it must be previously pulverised and heated slowly and gradually in a well-covered crucible. There are certain substances which undergo a material alteration by contact with the gases given off during the combustion of the fuel in the heating-furnace, as carbonate of lead; or which, like carbonaceous matters, are consumed by the introduction of atmospheric air. All such substances must be calcined in a closely-covered crucible placed in a second crucible (also covered) for further protection.

There are some rare cases, however, in which these precautions are not sufficient. In such, either a weighed porcelain or German glass retort must be employed.

Sometimes crucibles (earthenware) lined with charcoal are employed in calcining some substances; for even if the substance be fusible it may generally be collected and weighed without loss, as very few bodies either penetrate into or adhere to a charcoal lining. In this way grey cobalt and other arsenio-sulphurets are calcined at a high temperature to expel the greatest possible amount of arsenic and sulphur.

It may be as well to state in this part, as the use of platinum crucibles has been mentioned, that certain bodies cannot be ignited in them; and the best and most complete instructions for their use are those of the celebrated Berzelius.

"It is improper to ignite in platinum vessels the caustic alkalies or the nitrates of any alkaline base, such as lime, baryta, or strontia, because the affinity of the alkali for oxide of platinum causes a very considerable oxidation of the metal; and after the saline matter is removed the surface of the metal is found to be honeycombed."

The alkaline sulphurets or the alkaline sulphates mixed with charcoal are inadmissible, because the sulphurets so formed attack platinum even more energetically than the caustic alkalies: again, metals whose fusing point is lower than that of platinum, because an alloy would be formed. Gold, silver, and copper may be heated to dull redness in platinum vessels without danger; but fused lead cannot come in contact with platinum without destroying it.

A drop of fused lead, tin, zinc, or bismuth placed on red-hot platinum always produces a hole. Neither can phosphorus or phosphoric acid mixed with charcoal be ignited in vessels of platinum, because a phosphuret of platinum is produced, which is an exceedingly brittle compound.

In analyses by the humid method, nitro-hydrochloric acid (*aqua regia*), even when very dilute, must not be allowed to come in contact with platinum. It is a general rule that liquids containing either free chlorine, bromine, or iodine, must not be boiled in platinum capsules.

The best method of cleaning a platinum capsule or crucible, when it has become stained or scoriaceous, is to smear it with a paste made of borax and carbonate of soda, and then heat it to redness. After it has cooled, place it in boiling water until all the saline matter is dissolved, when the vessel will generally be found bright and clean: if not, the operation must be repeated.

Roasting.—In this operation, arsenic, sulphur, selenium, carbon, and antimony are separated from certain metals with which they were combined. Roasting differs from calcination in this particular: the latter is carried on in close vessels, independent of the atmosphere; the former in open vessels by the aid of the atmosphere. It is thus we are enabled to separate the bodies just mentioned by this process; for the oxygen of the air, by combining with them, forms a volatile substance which the heat expels. Thus, in roasting sulphuret of copper and iron (copper pyrites), the sulphur, copper, and iron mutually combine with oxygen to form sulphurous acid (volatile) and the protoxide of copper and peroxide of iron, thus:

$$2(FeS + CuS) + 13O = Fe_2O_3 + 2(CuO) + 4(SO_2)$$

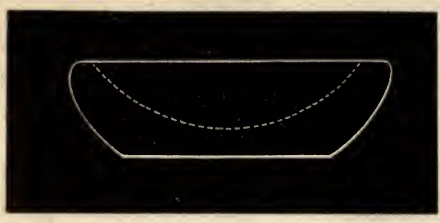
This is the final change in this case. During the process, however, some sulphate and sub-sulphate of copper and iron are formed. This change will be given under the head Copper Assay.

When carbonaceous matters are roasted, the operation also takes the name *combustion*, or incineration; because the object of roasting a fuel, for instance, is generally to ascertain the amount of ash left.

In roasting, in the ordinary acceptation of the term, the body must *not be fused*, but kept in a pulverulent state; but there are roastings in which the substance *is fused*,—as in cupellation and scorification.

The process of roasting is performed in different ways; in one, a small flat vessel (roasting test, fig. 182), made of the same material as the earthen crucibles, and similar to a saucer, is employed. It is placed in a muffle or a roasting-furnace; the former is the best; the latter is more suitable for carrying on the operation in crucibles. The substance to be roasted must be finely pulverised, placed in the roasting vessel, and constantly stirred with an iron rod until no fumes are given off, or until it ceases to evolve the odour of sulphurous acid, when sulphur is one of the constituents to be eliminated.

Fig. 182.



If the operation be performed in a crucible, the latter must be inclined to the operator, so that the draught of air passing to the furnace flue may impinge as much as possible on the substance under manipulation.

The heat in this operation must be very nicely regulated for some time. At first it ought only to be the dullest red; and the substance must be assiduously stirred in order to present the largest possible surface to the action of the atmosphere, and prevent fusion; for some assays, when roasting, will fuse readily at a low temperature unless the surface be continually renewed. Even by paying the utmost attention to this point it cannot be always prevented. In such cases the assay must be mixed with its own weight of fine white sand (silver sand): the operation will then proceed steadily.

If the assay at all agglutinates it must be taken from the fire, and rejected if the substance be plentiful; if not, the fused mass must be carefully removed from the crucible or test, pulverised, and the roasting recommenced. In this case, however, the operation is always rendered very tedious, and the final result less exact, so that much care ought to be taken at the commencement of the roasting. After the assay has continued at a dull red heat for some time, and shows no inclination to agglutinate, the heat may be slightly increased; at the same time the stirring must be diligently pursued. After the heat has arrived at full redness there is little fear of fusion; and as the operation at this point proceeds more rapidly than at any other,—at a high temperature than a low one,—it is well to increase the heat to a yellowish red, and lastly, in certain cases, to nearly a white heat. If the stirring of the assay has been constant during the various gradations of heat, the roasting at this point will be accomplished; and the remaining operations of the assay may be proceeded with.

There are certain other precautions to be taken in roasting some minerals; but they will be pointed out under the head of their respective metals.

It may be as well to mention here, that platinum capsules are useful in certain roasting operations. The sulphurets of copper, iron, and molybdenum, are most conveniently oxidised in this kind of vessel, without fear of injury to it, providing that fusion of the roasting substance be carefully avoided. Platinum vessels must also be used in ascertaining the amount of ash in coal where the experiment is conducted so as to afford exact results.

Reduction.—The process of reduction consists in removing oxygen from any body containing it, by means of either carbonaceous matter or hydrogen, or a body containing both of these elements. The *rationale* of the operation is as follows, when oxide of lead is employed with carbon:—

$$2(PbO)+C=2Pb+CO_2.$$

The reaction between oxide of nickel and hydrogen is thus expressed:—

$$NiO+H_2=Ni+H_2O.$$

In the first case we have, on one side, oxide of lead and carbon; on the other, metallic lead and carbonic acid. In the latter, on one side, oxide of nickel and hydrogen; and on the other, metallic nickel and water. If the reducing substance contain both carbon and hydrogen the action will be thus, when a metal (lead) is reduced from its oxide, with the formation of carbonic acid and water:—

$$3(PbO)+CH=3Pb+CO_2+HO.$$

In the operation of reduction by the aid of carbonaceous matters two methods are employed: in the one, charcoal, coal, or any carbonaceous or hydro-carbonaceous body, as argol, is mixed with the substance to be reduced; in the other, the process of cementation is employed, as in the manufacture of steel. This process is conducted by placing the oxide to be reduced in a crucible lined with charcoal, and covering it closely during the time it is in the furnace; the reduction proceeds gradually from the outside of the oxide to the centre of the mass. The time requisite for this operation depends on three circumstances,—viz. the nature of the oxide, the degree of temperature, and the mass acted on.

Some oxides treated this way are reduced very readily; others, again, take a considerable time; while certain of them do not appear to be acted on beyond the outermost layer. Of the first class is oxide of nickel; of the second, oxide of manganese; and of the third and last, oxide of chromium.

Each of these classes of reduction has its advantages. The former, or reduction by *mixture* with carbonaceous matter, takes place very quickly and completely, but the metallic residue is mixed with charcoal; in the latter process, the residue is comparatively pure, but it is not generally preferred, on account of the time and high temperature necessary.

Reduction by hydrogen gas is very seldom employed; it is, however, absolutely necessary in the determination of per-centage of cobalt or nickel in a sample where perfect accuracy is desirable. The operation is carried on in a tube of hard German glass, having a bulb blown in its centre, which is heated either by a spirit-lamp or gas. Attached to it is a tube full of dried chloride of calcium, through which the hydrogen gas effecting the reduction passes to perfectly dry it.

The bulb tube is weighed and the oxide introduced into it; it is then again weighed, and the apparatus united by caoutchouc tubes; hydrogen gas (see Reducing Agents) is then passed through it until the whole of the atmospheric air is expelled. Heat is then applied till the bulb is bright red, and the current of gas continued until no more water (from the decomposition of the oxide, as explained at p. 81) is formed; the source of heat is then removed, and the current of gas continued until the apparatus is cold. The bulb-tube, with the reduced metal, is then weighed, and the excess of weight over the first weighing gives the amount of metal in the amount of oxide operated on.

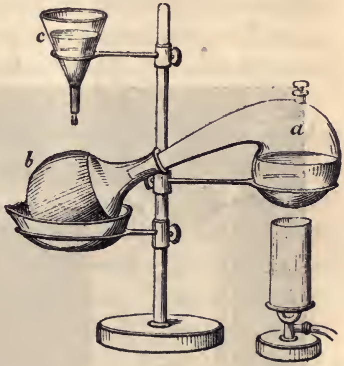
Fusion.—This operation is sufficiently simple, and is employed in all assays by the dry way, in order to obtain, in conjunction with the last process, a button or prill, as it is termed, of the metal whose assay is in progress. It is also a necessary step in the granulation of metals, preparation of certain fluxes and alloys, also chips of bar-lead for assay for silver, in order that a homogeneous ingot may be obtained.

Sublimation.—This operation is a kind of distillation in which the product is obtained under the solid form. The apparatus generally employed for this purpose are tubes, flasks, capsules, and crucibles. Flasks (those in which Florence oil is imported) are exceedingly useful: they must be sunk in a sand-bath, and the sublimed substance received directly into another flask, or by passing through an intermediate tube. Sometimes, however, it is difficult to entirely remove the sublimed substance; and in order to avoid this inconvenience, Dr. Ure has proposed the following very excellent subliming apparatus:—It consists of two metallic or other vessels, one of which is flatter and larger than the other. The substance to be sublimed is placed in the smaller vessel, and its opening is covered by the larger filled with cold water, which may be replaced from time to time as it becomes hot. The sublimed substance is formed on the lower part of the upper vessel. A large platinum crucible filled with cold water, and placed on the top of a smaller one, answers the purpose of the before-mentioned apparatus very well.

Distillation.—There exist two distinct classes of this operation: in the one, liquids are submitted to experiment; in the other, solid bodies, as wood, coal, &c., in order generally to ascertain the amount of gas or other volatile matter given off, in the course of an experiment, from a certain quantity of the coal or other substance operated on.

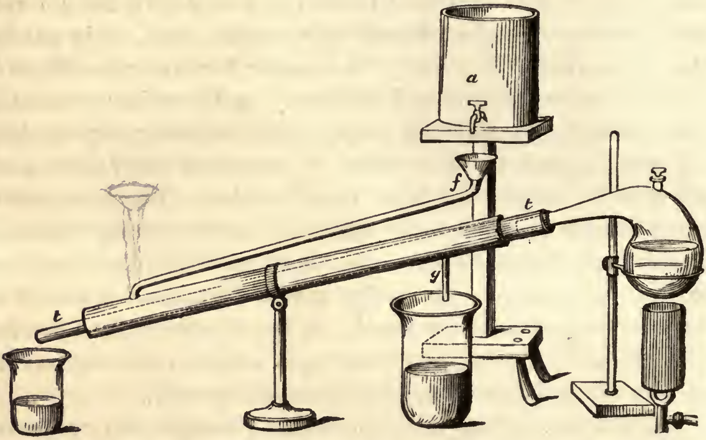
In liquid distillations (as in the purification of nitric acid, &c.) glass vessels termed retorts are used. The best form for general use is furnished with a stopper at the upper part of the body, *a*, through which the liquid is introduced; the neck of the retort is then placed in that of a receiver, *b* (fig. 183), over which a piece of wet cotton or woollen cloth is placed, and which must be kept cold by means of a stream of water from a funnel, *c*. Heat is then applied to the retort, and as much of the liquid as is desired is distilled over into the receiver. It is advisable to fill the retort no more than two-thirds full, and to apply the heat at first very gently, otherwise there is a fear of breaking the vessel.

FIG. 183.



A more convenient form of apparatus for distillation and condensation is shown at fig. 184, in which a Liebig's condenser is attached

FIG. 184.



to the retort. The fig. 185 will show the construction of the condensing apparatus. The cold water passes into the funnel above, is conveyed at once to the lowest end of the condenser, whilst the heated water passes off by the upper tube.

FIG. 185.

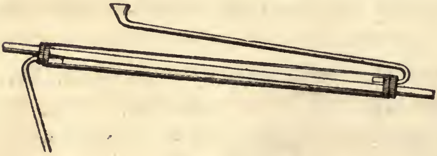
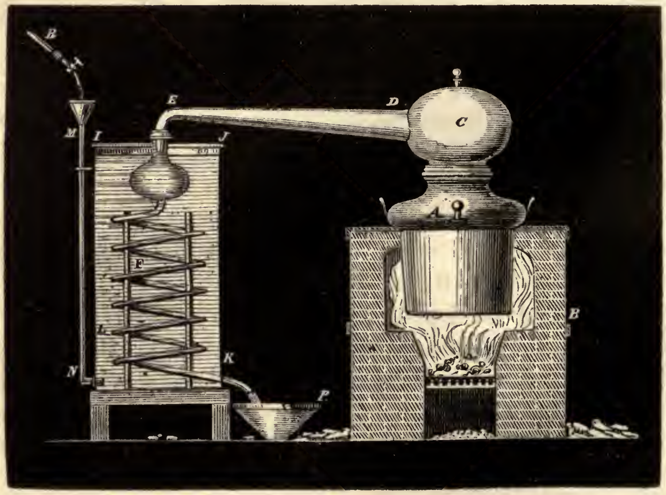


FIG. 186.



Distilled water is a most important agent in the laboratory; and, as much is needed, it is better to have a still specially adapted for its production. Such an one is depicted at fig. 186: where A is the body of the still; B the furnace in which it is set (the still may also be placed in the portable furnace, fig. 191, p. 95); C the still-head; D E the neck; F the worm; I J K L worm-tub containing cold water to condense steam generated in still; M N pipe to lead fresh cold water to bottom of worm-tub, while the warm water runs off at the top, as in Liebig's condenser; and P the vessel in which the distilled water is received.

In the distillation of dry bodies, earthenware, glass, or iron retorts are employed; but in general I find a tube of wrought-iron, about one inch internal diameter, and plugged at one end, to be the most convenient form of apparatus. It is placed with the substance contained in it in a furnace, and a small tube, either of glass or pewter, is fixed by means of a perforated cork to the open end of the large tube. The gas given off during the operation is to be collected by aid of the pneumatic trough. It will be necessary here to describe the pneumatic trough and jars, together with all the requisite calculations for temperature, pressure, and moisture, to be made in experimenting with gaseous bodies.

The pneumatic trough is a vessel of either a circular or square form (the latter is most convenient) made of tin-plate or zinc, furnished with a shelf at the distance of about three inches from its upper part. This shelf, according to its size, is perforated with one, two, or more holes, each of which is furnished with a small funnel-shaped opening on the inferior part. This opening is for the purpose of receiving the mouth of a tube delivering gas. The lower part of the trough ought to be furnished with a tap, for the purpose of drawing off the water when it is soiled. The gas jars are made of glass (the most convenient form is cylindrical), and graduated to cubic inches and parts. Each of the jars may hold from 50 to 100 cubic inches, or more, according to the quantity of gas expected to be furnished during each experiment.

To use the trough, proceed as follows:—Fill it with water to about two inches above the shelf, then fill one of the jars with water; place a ground-glass valve over its orifice, and then set it in an inverted position on the shelf over one of the holes with the funnel-shaped opening, into which introduce the gas-delivering tube. When the mouth of the gas jar is under water, the glass plate is removed. As soon as the gas passes off, by the aid of heat, from the coal or other body in the iron tube, or retort, whichever may have been employed, it will pass into the jar and displace the water. As soon as the jar is full it must be replaced by another, and so on until no more gas passes over. The quantity produced in the experiment is then ascertained by reading off the graduations on the jars. It is, however, not the true quantity, as most likely it has been expanded to a larger volume by the heat employed in its production, or has combined with a quantity of aqueous vapour from the water with which it was in contact; or, lastly, the barometer might not have been at the height of 30 inches, from some change in the state of the atmosphere. If it were less than 30 inches the gas would appear greater in quantity; if more than 30 inches it would appear less in quantity than it really was. The following is the method of making the calculations necessary in reducing the gas to its true volume;—

Correction for Temperature.—It has been ascertained by the recent researches of Magnus and Regnault that 100 parts of air or any other gas at 32° of Fahrenheit, when heated to 212°, expand to 136·65 parts, the increase being $\frac{36\cdot65}{100}$ths, or ·3665 of the original bulk. If this be divided by 180, the number of degrees between 32° and 212°, it will be found that air expands $\frac{1}{491\cdot2}$, or in round numbers $\frac{1}{491}$th for each degree of Fahrenheit; and we can from this datum determine the expansion or contraction any gas would undergo for any given number of degrees of temperature.

But supposing it be required to know what volume 100 cubic inches of gas at 80° would occupy at 60°, the standard temperature, it must be kept in view that it is not $\frac{1}{491}$th part per degree of the volume at 80°, but of the volume at 32°, which is to be deducted. 491 parts of air at 32° become 492 at 33°, and 493 at 34°, and so on; so that at 60° they have increased to 519 parts, and at 80° to 539; so that we have a proportion between the bulks at 60° and at 80°, from whence the question may be determined, for—

Volume at 80°.		Volume at 60°.		Cubic inches.		Cubic inches.
491 + 48	:	491 + 28	::	100	:	96·288

or the reverse, supposing it were wished to ascertain the real volume at 60° of 100 cubic inches of gas at 40°—

Volume at 40°.		Volume at 60°.		Cubic inches.		Cubic inches.
491 + 8	:	491 + 28	::	100	:	104·008

Correction for Pressure.—As before stated, the standard pressure is 30 inches of mercury; and the law must be kept in mind that the bulk of a body of gas is inversely proportionate to the weight, and directly proportionate to the pressure; so that if we had 100 cubic inches of air when the barometer was 29 inches it would be as—

30 : 29 :: 100 : 96·6

or if the barometer stood at 31 inches when the 100 cubic inches were measured, it would be as—

30 : 31 :: 100 : 103·33

so that the rule is: as the mean pressure is to the observed pressure, so is the observed volume to the true volume. The correction for temperature or pressure may be made indiscriminately; the result being the same in either case.

Correction for Moisture.—This correction must be made after the two previous. As before mentioned, the elastic force of the aqueous vapour causes the gas with which it may be mixed to expand; and by reference to tables founded on calculations upon the force of steam at different temperatures, the amount of correction may be easily ascertained. Thus, for 100 cubic inches of a gas saturated with vapour properly corrected to the temperature of 60° and 30 inches pressure, we wish to know the equivalent bulk of the dry gas. The observed volume is partly due to the expansion occasioned by the vapour; and this proportion will be, in proportion to the whole, as the elasticity of the vapour is to the total elasticity; therefore—

Elasticity of air.		Elasticity of vapour.		Cubic inches.		Cubic inches.
30·000	:	0·560	::	100	:	1·86

The volume of the dry gas is therefore—

100 − 1·86 = 98·14 cubic inches.

Scorification: Cupellation.—These operations will be described under the head Silver Assay.

CHAPTER V.

FURNACES, FUEL, CRUCIBLES, &c.

Furnaces are of two distinct kinds,—viz. *blast* and *wind*. In the former, the fire is urged by means of bellows; and in the latter, by a chimney, or common draught. We shall commence with the latter, as they are in most common use. They are of various kinds, according to the purpose for which they are required. The three principal kinds are those of fusion, calcination, and cupellation. Coal, coke, or charcoal, are the fuels employed, and the merits of each will be particularly discussed. Blast furnaces are only employed for the purpose of fusion, although their forms are various: charcoal and coke are the fuels in use.

All furnaces consist of certain essential parts,—viz. 1st, the ash-pit, or part destined to contain the refuse of the combustible employed. 2nd, the bars on which the fuel rests: these are sometimes made moveable, or fixed to a frame; the former arrangement is more convenient, as it allows clinkers and other refuse matters to be readily removed. 3rd, the crucible, or body of the furnace in which the heat is produced. And lastly, in wind furnaces, the chimney by which the heated air and gaseous products of combustion are carried off.

Wind Furnaces: Calcining Furnace.—Calcining furnaces are small and shallow, because a high temperature is not required. They may be made square or circular: the former are most readily constructed, and the fuel they contain can be easily stirred without fear of overturning the contained crucibles. Where many crucibles are to be heated at once, they are preferable to the circular; but the latter give the greatest degree of heat with the least possible consumption of fuel, and are to be preferred on that account where one crucible only is to be ignited.

The *crucible*, or *body* of the furnace, is best made with good bricks, lined with Welsh lump, fire-bricks, or a mixture of Stourbridge clay and sand. It is also desirable that a plate of iron with a ledge be placed over the upper part of the furnace to protect the brickwork from blows with crucible tongs, &c., and to keep it in its place when disturbed by sudden alternations of temperature. The bars of the furnace may be either one single piece, or made up of several bars of iron fastened to a frame. They ought to be as far as may be from each other, and not too large. They must be large enough, however, not to bend under the weight of the fuel and crucibles when they become hot, and they must not be so far removed from each other as to allow the coke or charcoal to fall through easily. Lastly, the more readily the air can find access to the centre of the fuel, the higher will be the temperature produced in the furnace; and very simple assays occasionally fail, only because the bars are either too large, or too close together.

The *ash-pit,* as before stated, is an open space under the bars, and serves as a receptacle for ashes, clinkers, &c., produced during the time the furnace is in use. It ought to have the same area as the crucible, and be completely open, so that the air may have free access: it is well, however, for the sake of economy, to furnish this opening with a hinged door, having a register plate fixed in it, so that the draught may be reduced, or entirely shut off, in order that the fire may be extinguished and fuel saved, which otherwise would be burnt in sheer waste.

Chimney.—Calcining furnaces generally have no fixed chimney, but are covered with a moveable one when a greater degree of heat is required. This chimney is made of strong plate iron, furnished with a wooden handle. The lower part is provided with a door, by means of which the interior of the furnace may be examined without disturbing the whole arrangement of the chimney, and consequent cooling of the contents of the furnace.

If, during the course of any experiment, noxious or inconvenient vapours are expected to be given off, the furnace must be so arranged that they are introduced into a flue by fastening a piece of iron plate pipe, furnished with an elbow-joint, on to the moveable chimney before spoken of.

Evaporating Furnaces.—The furnaces just described answer exceedingly well for heating small flasks, evaporating basins, &c., when furnished with a tripod stand or sand-bath. The latter is necessary, as many assays by the dry way are preceded or followed by certain operations by the humid method.

The Hood.—In order to prevent certain vapours from fires, evaporating basins, &c., from entering into the laboratory, a large metal covering, termed a hood, is employed, which hood terminates in a chimney having a good draught. They are best made of sheet zinc, plate iron, or, better still, of galvanized iron, as that is cheaper than zinc, and quite as serviceable; it has also the advantage of not being combustible.

Fusion Furnace: Wind Furnace.—The wind furnace, properly so called, is a furnace provided with a chimney, and which is capable of producing a very high temperature.

Wind furnaces are generally square, but if more than four crucibles are to be heated at one time, they may be made rectangular, the chimney being placed at one of the long sides. However, when the furnace is required to hold but one pot, it may be made circular.

The body of the furnace ought to be made of good bricks, solidly cemented with clay, and bound by strong iron bands. The bricks must be very refractory, and capable of sustaining changes of temperature without cracking. They are ordinarily made with the clay used in the manufacture of crucibles. In some cases bricks are not used for the lining of this kind of furnace; for instance, a mould of wood is placed in the centre, and the open space between the surface of that and the outer brickwork is filled with a paste of very refractory clay, each layer being well beaten down. When the space is filled, the case is withdrawn, and the crust of clay dried with much precaution, every crack that may be caused by unequal desiccation being filled up as fast as formed. This method of manufacture is very applicable to circular furnaces. In every case, however, it is necessary to border the edge with a band of iron, to prevent injuries from tongs or pots.

The Ash-pit.—On the one hand, it is well to have the power of cutting off access of air into the body of the furnace by the lower part, either to put out the fire entirely, or to deaden it whilst putting in a pot; and, on the other, to attain the maximum of temperature, we must have the means of allowing the air to pass with the greatest possible facility into the furnace. In order to do this, it is necessary to furnish the ash-pit with doors, or valves, whereby the quantity admitted may be regulated as desired.

The *bars* are made in one piece, or are made up of moveable pieces of metal, which latter arrangement is the most convenient. Wherever a wind furnace is in use, the superior opening is closed by a cover made of a fire-tile encircled with iron.

The *chimney* is a very essential part of a wind furnace; it is on its height and size that the draught depends, and, in consequence, the degree of heat produced within the furnace. In general, the higher and larger the chimney the stronger is the draught; so that, by giving it a great elevation, exceedingly high temperatures may be obtained. But there is a limit which it is useless to pass in a furnace destined for operations by the dry way; and besides this, the building a very high chimney presents many difficulties and much expense, so that in laboratory operations, where a very strong current of air is required, recourse is had to a pair of double bellows. A temperature can be produced in a wind furnace sufficiently strong to soften the most refractory crucibles by means of a chimney from thirty-six to forty feet high. They are generally made square or rectangular, and have interiorly the same dimensions as the crucible of the furnace. About two feet above the upper part of the furnace these chimneys are furnished with a register, or damper, by means of which the current of air may be regulated, or entirely stopped at will. The damper is a plate of iron sliding into a small opening across the chimney.

A wind furnace of the kind above described is represented by figs. 187 and 188.

FIG. 187.

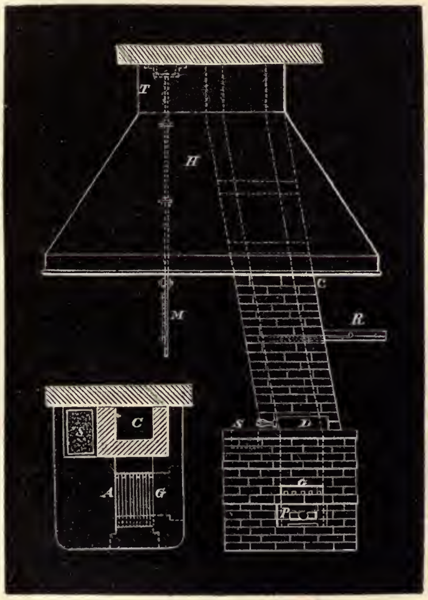
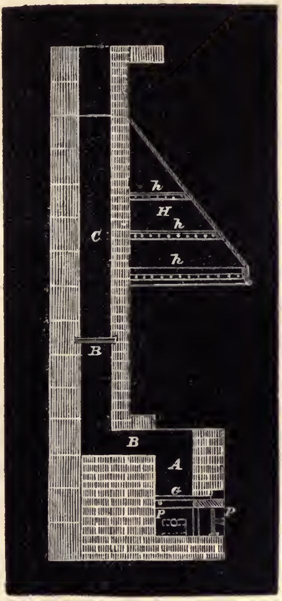


FIG. 188.



The left-hand figure in 187 is the plan, the right an elevation; and in fig. 188 is shown a sectional view. A the body of the furnace in which the crucibles to be heated are placed; G the bars, and P the ash-pit; the cover formed of a thick fire-tile of the requisite size, firmly encircled by a stout iron band, and furnished with a handle for convenience in moving it; B the flue; C the chimney; R the damper; H a hood over the furnace, supported by iron bands *h h h*; M the handle of a ventilator T, which serves to carry off hot air and fumes from furnace when open; and finally S, a small sand-bath, in which to set the red-hot crucibles when taken from the fire: one foot square inside the fire-place of the furnace is a very good and convenient size: the remainder will then be in proportion.

Blast Furnaces.—In this species of furnace, the air necessary to keep up the combustion is forced through the fuel by means of a blowing apparatus, instead of being introduced by the draught of a chimney, as in the wind furnace.

The most convenient apparatus for forcing air into a furnace is a double bellows; a fan may be used, but, in the small way, is not so powerful.

The quantity of air passing into a furnace varies with the length of the assay, and ought to increase gradually, the stream at first being small; and as the temperature becomes higher, the bellows ought to be worked with more force.

The following is the description of a most excellent blast furnace which has been in use for some years in the laboratory of the Royal Institution. I have in my own laboratory one of these furnaces, and the temperature produced by it is extraordinary, considering the small amount of time and fuel employed. It is sufficiently powerful to melt pure iron in a crucible in ten to fifteen minutes, the fire having been previously lighted. It will effect the fusion of rhodium, and even pieces of pure platinum have sunk together into one button in a crucible subjected to its heat.* All kinds of crucibles, including the Cornish and Hessian, soften, fuse, and become frothy in it; and it is the want of vessels which has hitherto put a limit to its application. The exterior consists of a blue pot (black-lead pot), eighteen inches in height, and thirteen inches in external diameter at the top; a small blue pot of seven and a half inches external diameter at the top had the lower part cut off, so as to leave an aperture of five inches. This, when put into the larger pot, rested upon its lower external edge, the tops of the two being level. The interval between them, which gradually increased from the lower to the upper part, was filled with pulverized glass-blowers' pots, to which enough water had been added to moisten the powder, which was pressed down by sticks, so as to make the whole a compact mass. A round grate

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* Faraday.

was then dropped into the furnace, of such a size that it rested about an inch above the lower edge of the inner pot: the space beneath it, therefore, constituted the air-chamber, and the part above the body of the furnace. The former was 7½ inches from the grate to the bottom, and the latter 7½ inches from the grate to the top. Finally, a longitudinal hole, conical in form, and 1½ inches in diameter in the exterior, was cut through the outer pot, forming an opening into the air-chamber at the lower part, its use being to receive the nozzle of the bellows by which the draught was thrown in. Sefstrom's Blast Furnace, obtainable at most chemical instrument makers, is also very powerful and convenient.

The *Muffle*, or *Cupel Furnace*, is a species of reverberatory furnace, in the centre of which is placed a small semi-cylindrical oven, which is termed the muffle.

This muffle, being completely surrounded by ignited fuel, acquires a very high temperature, and in its interior all operations requiring the presence of air, and which cannot be carried on in contact with carbonaceous matters, may be performed,—such as roastings, scorifications, and cupellations.

When from ten to twenty cupellations have to be effected at one time, large brick furnaces are employed; and, in consequence, much fuel is consumed to waste where only a few cupellations are required. This has occasioned many persons to endeavour to form small furnaces, where one or two cupellations may be carried on with the smallest possible quantity of fuel. MM. Aufryé and d'Arcet have contrived a furnace which is capable of fulfilling all these conditions.

The furnace is elliptical, and about 7 inches wide and 18 high; its ash-pit has but one circular opening, and its height is such, that when the furnace is placed upon it, and the whole upon a table, the assayer can, when seated, readily observe the course of the assay within the muffle. The hearth has five openings, in one of which the muffle is placed; in another, a brick to support it; a third for the purpose of introducing a poker to stir the ashes, and make them fall through the grate-holes: this can be closed with a small earthen plug; and lastly, two round holes, placed in its largest diameter, to facilitate the introduction of air, either by draught or a pair of bellows, as the case may require. The support for the fuel is generally a plate of earthenware, pierced with holes, and bound round with iron wire to keep it together in case it cracks by changes of temperature; but it is better to use an iron grating.

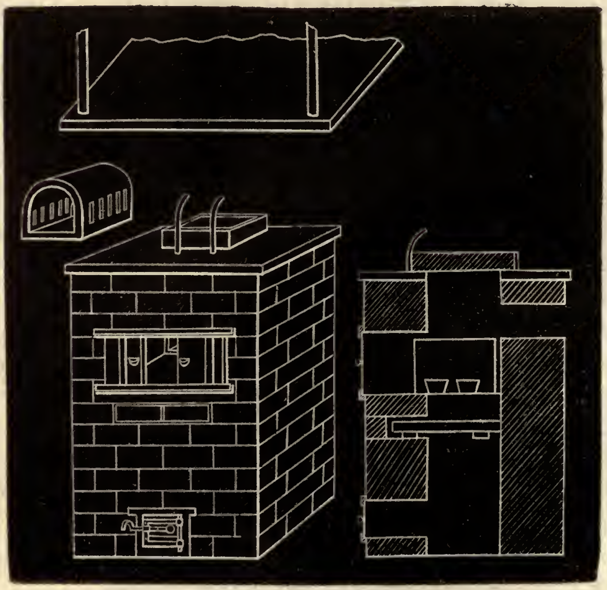
The dome of the furnace has a circular opening, which can be closed by a plug of earthenware: this opening serves for the introduction of the fuel. A chimney is necessary to increase the draught; it is made of sheet-iron, and may be from 1½ to 2 feet in height, and ought to fit the upper part of the dome very exactly. At its base there is a small gallery, also of sheet-iron, in which it is intended to place the new cupels, so that they may be strongly heated before introduction to the muffle. This saves many of them from fracture.

MM. Aufryé and d'Arcet have estimated the quantity of charcoal necessary to heat this furnace. The following are comparative experiments:—

No.	Silver employed. grains.	Lead employed. grains.	Time of assay. minutes.	Standard. thousandths.	Charcoal used. grains.
1	1	4	12	947	173
2	1	4	11	950	86
3	1	4	13	949	93
4	1	4	10	949	60

Coke or charcoal may be used in this furnace, but the fire must

FIG. 189. FIG. 190.



be lighted by means of charcoal alone, as coke is very difficult to inflame in a cold furnace. When it is red-hot, it may be fed with coke alone, or, better still, a mixture of coke and charcoal.

Where great numbers of cupellations have to be made at once, the following form of brick furnace is requisite. Such a furnace is represented by the preceding figures :—

Fig. 189 shows an elevation of the furnace. Fig. 190, section. The interior of the furnace is of fire-brick; the exterior, common brick. The upper part is protected by a plate of iron, and the superior opening, through which the fuel is introduced, is covered when necessary by a large fire-tile strongly encircled with an iron band, to which are attached two handles, by which the whole can be moved.

The muffle opening, as seen partially open in the diagram, can be entirely closed by means of two sliding doors, made of sheet iron, running in a stout wrought-iron frame, built into the brick-work. Immediately below the muffle entrance are two moveable bricks; these close the openings through which the fire bars are introduced; and still lower down is the ash-pit door, furnished with a register for the better regulation of the current of air required by the furnace. In fig. 190 is shown a brick built into the back of the furnace, on which the closed end of the muffle is supported. This brick may, however, be replaced by a crucible or fire brick, standing on the bars of the furnace.*

I will now describe what I have been in the habit of using as a portable furnace. It may very aptly be termed the "universal furnace," as it is capable of performing all that is required of any furnace in an assay (see figs. 191 and 192, elevation and section). It is to be much recommended for its durability and cheapness, and lastly, for its small size compared with the heat it can produce. It was made, I believe, only by Mr. New-

Fig. 191.

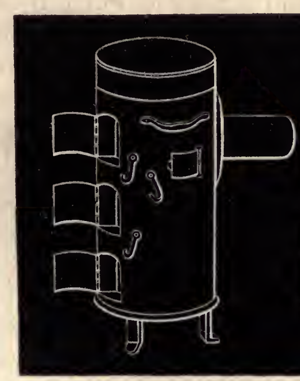
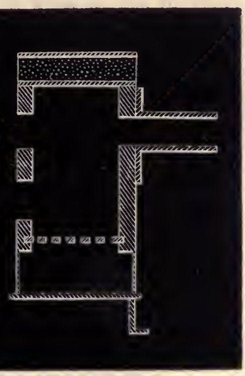


Fig. 192.



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* For other forms of cupel furnaces, see this page, and under the head Silver Assay.

man of Regent Street, but now similar furnaces may be obtained at Messrs. Simpson and Maule's, Kennington Road, and is constructed externally of sheet-iron, very stout, and is lined with fire brick, not cemented together, but ground and keyed, as an arch, so that it can never fall out until it is completely useless. It is furnished with five doors, one in the ash-pit, and four in the body of the furnace; two in the front, one above the other, and two opposite each other, at the sides. The cover serves as a sand-bath, and when that is taken off there is a series of cast-iron rings, fitting the top of the furnace, for the purpose of placing basins either for the purpose of evaporation, calcination, or roasting. The two opposite holes serve for the introduction of a tube in operations where it is requisite to pass a gas over any body, at a red heat. In the lower hole, in front, I place a muffle for roastings and cupellations, and introduce fuel and crucibles by the upper one; it also serves as an opening through which the state of the furnace can be seen, or the progress of any assay observed.

Iron, manganese, nickel, and cobalt, can be fused in this furnace, when it has a flue of about thirty feet in height attached to it; and by closing the ash-pit door, the dullest red heat, for gentle roastings, can be obtained. Its height is about 2¼ feet, and diameter 1 foot; internal diameter, 8 inches, and depth of fire-place 1¼ foot.

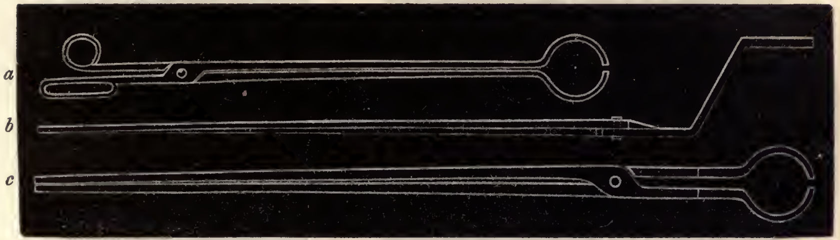
The Use of Furnaces.—Care must be taken in placing the crucibles in the fire. They must stand solidly, and be at equal distances from the sides and bottom of the furnace, so as to receive a like share of heat, and they must be completely surrounded with the fuel. The fire must be got up gradually, so as to prevent the sides of the furnace and the crucibles within from cracking from the sudden increase of heat. After the furnace has arrived at a full red heat, give more air, and in from about twenty minutes to one hour the assay will be finished. During the time the furnace is in full action, the cover must be frequently removed to add more fuel, if any open spaces occur round the crucibles,—also to press the fuel close to the pots. When the pots are taken out, they may be placed in a sand-bath, and allowed to cool gradually, before they are broken, to examine the contents.

In commencing a second assay immediately in the same furnace, certain precautions must be taken to ensure success. In the first place, all ash and clinker must be removed from the grate, by means of a crooked poker; secondly, the fuel must be pressed down firmly; and lastly, a layer of fresh combustible must be placed on the fire, and before that is ignited the crucibles must be arranged upon it, and the spaces about them be filled with coke or charcoal, as the case may be, and the assay proceeded with as before.

In executing many assays, one after the other, a great saving of fuel is made, for the furnace is not allowed time to cool.

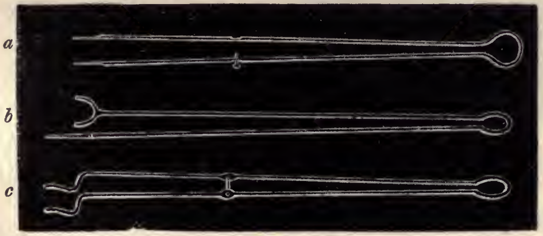
Auxiliary Apparatus.—Ordinary assay furnaces require very few instruments; they are, firstly, pokers or stirring rods, made of stout bar-iron: these may be straight, as for stirring the fuel from the top of the furnace, so as to fill up cavities formed by uneven combustion; or curved, for clearing the bars from below from clinkers and ashes. Straight and curved tongs are also required; for small crucibles the blacksmith's common forge tongs are the most suitable: tongs with semicircular ends (see fig. 193) are very serviceable for larger crucibles. The tongs *a* are particularly adapted for removing large cupels or calcining tests from the muffle; the tongs *b* and *c* for heavy crucibles from the wind or blast furnace. In case the eyes of the operator are weak, it is advisable to make use of a pair of deep neutral-tint spectacles. Some assayers recommend the use of masks for the face, and gloves for the hands: but these are not needed.

FIG. 193.



In cupel furnaces pokers or stirring rods are required both curved and straight; also a curved rod made of lighter iron, to be used in closing the sliding doors, slightly moving cupels, &c. The tongs used are varied in form (see fig. 194): *a* represents a very light elastic tong or pincer employed in the introduction of lead and other

FIG. 194.



matters to the cupel; *b* tongs for holding scorifier: the curved part fits the lower part of scorifier, (see fig. 201), and the upper or single part passes over the upper part of the scorifier so that its contents may be emptied into the proper mould without fear of its slipping from the operator's grasp; *c* represents the tongs used in moving cupels; they are slightly curved, so that cupels from the back part of the muffle may be removed without disturbing those in front.

Fig. 195 shews the plan and section of ingot mould, into which contents of scorifiers are poured: it is made of thin sheet iron, and the depression for the reception of the fused lead, slag, and ore hammered out. Fig. 196 is a wrought-iron ladle, in which lead clippings, &c. are melted, in order to obtain a fair average of a large cargo; and fig. 197 represents the ingot mould into which the fused lead, or other metal, is poured. Other special apparatus will be described under the assay in which they are required, as will also blowpipe apparatus in a chapter devoted to that subject.

FIG. 195.

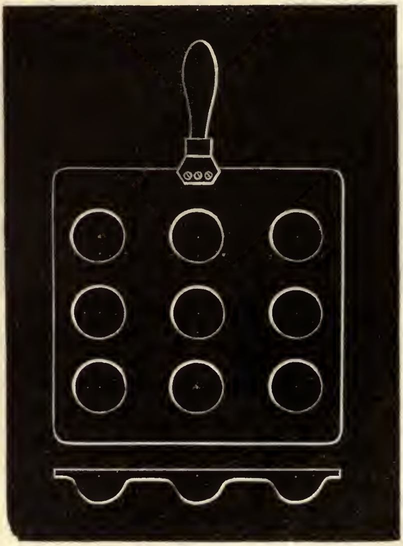


FIG. 196.

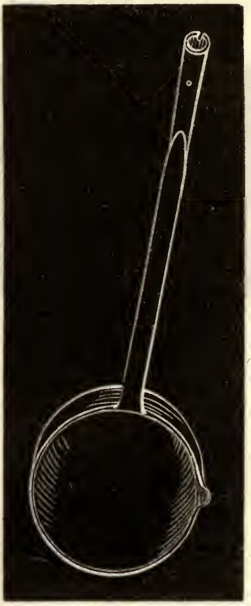
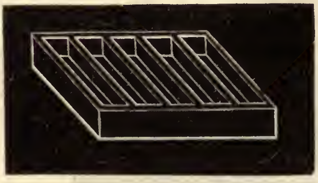


FIG. 197.



Fuel.—Assay furnaces are heated with coal, anthracite, coke, and charcoal, and sometimes with a mixture of the two latter; coal is very seldom employed, and therefore will not be much spoken of;

coke is the principal combustible used in assaying. Calcining furnaces ought to be heated with charcoal alone, because coke employed in small quantities lights and burns with too much difficulty. All fuels contain certain fixed matters, which remain after combustion, and which constitute the ash. These ashes fuse or agglutinate together, and when a certain quantity is formed, if it be not removed, the fire will decrease in intensity, and finally die out. As all combustibles do not contain the same amount of ash, we must choose amongst them, and those containing the least are to be preferred; in the first place, because, weight for weight, they contain more available matter; and secondly, because they can be used in a furnace a longer time without the formation of so much clinker. The composition of the ash merits much attention.

Charcoal contains from 3 to 4 per cent. of ash in general, the components of which are lime and potash, as carbonates. It is true, certain other matters are present, as phosphoric acid, oxide of iron, manganese, &c., but in very minute proportions. It is not fusible *per se*, and if it do not meet with any substance capable of combining with it, it passes through the bars as a white powder, but when the potash predominates, it exercises a very corrosive action on the bricks with which the furnace is lined, as also on crucibles, lutes, &c., by the formation of a fusible silicate of potash, which in course of time runs down the sides of the furnace, and chokes the bars. Whenever the ash is in very small proportion to the charcoal, its fusion is rather useful than otherwise, because a species of varnish is formed, which penetrating into the substance of the bricks and lutes, gives them solidity by binding them together with a cement, forming part of their substance.

The proportion of ash which coke contains is very variable; that of commerce contains from 8 to 10 per cent., while some samples of coke, made from very pure coal, give but 2 to 3 per cent.; so that this fuel ought to be carefully chosen. The nature of this ash is different to that of charcoal; it consists principally of oxide of iron and clay. The former is produced from the pyrites which coal generally contains. The clay is similar to the carbonaceous schists, not very fusible by itself, but nevertheless capable of softening. When pure, it forms a slag, which attacks neither the bricks nor crucibles. This happens very rarely; it is more often that oxide of iron predominates, which by contact with the carbonaceous matter becomes reduced to the state of protoxide, and then not only becomes very fusible, but exercises on all argillaceous matters a very corrosive action, so that crucibles are very seriously injured, and the sides of the furnace require frequent repairs.

Weight for weight, coke and charcoal give out nearly the same quantity of heat; but in equal bulks, the former developes much more heat, because its density is greater: so, from this difference in the calorific power of coke and charcoal, it results that in the same furnace the former produces a greater degree of heat than the latter; and it has been proved that at high temperatures the difference is nearly 10 per cent. In order to account for this, we must consider, firstly, that in a given space the quantity of heat produced in a certain time, and, in consequence, the temperature, depends on the weight of fuel burnt, and increases with its weight; secondly, that combustion taking place but at the surface of the masses, (which has been proved by a great number of observations), whatever may be the nature of the fuel; from whence may be deduced, that the weight of fuel burned in an unit of time ought to be exactly proportionate to its density; and in consequence, the densest fuel furnishing the most food for combustion, ought to give out the greatest heat. But, as for the same reason they consume a larger proportion of oxygen, they require, in order to produce all their effect, a more rapid and strong current of air.

It is clear, from that which has been stated concerning the relative properties of coke and charcoal, that when the former can be procured of good quality, and especially when the ash contains but little oxide of iron, it ought to be preferred to charcoal, for assays requiring a high temperature.

A very essential condition in obtaining the maximum effect of a furnace, and the importance of which can be alone appreciated by experience, is the choice of pieces of fuel of a suitable size. If, on the one hand, a shovelful of coke or charcoal be taken at random, it generally contains the dust and dirt found in most fuel, and which, by filling all the interstices, prevents the air from passing as required, and the consequent combustion is slow. On the other, if a furnace be filled with large pieces, considerable spaces are left between them, so that but a comparatively small surface is exposed to the action of the atmospheric oxygen, and a correspondingly small quantity of fuel consumed in a given time; so that the maximum heat can never be obtained. In order to produce this desirable result, it is necesssary that the pieces have a certain mean size, and experience has proved that pieces about 1 inch to 1¼ inches square produce the best effect.

The Effects produced by Wind and Blast Furnaces.—Assays by the dry can be made either in wind or blast furnaces. In either of them, the degree of heat depends upon the volume of air which passes through the fuel in the same time; but, *cæteris paribus,* large furnaces produce more heat than small, because comparatively less heat is lost by the first than the last.

In a wind furnace, the maximum of heat is limited by the size of the chimney, and in a blast furnace, by the dimensions of the bellows; but by weighting the latter, more or less, the force of the blast can be increased, and, in consequence, the temperature, to an almost indefinite extent. In this respect, blast have the advantage over wind furnaces.

In the latter, the draught increases in proportion as the heat becomes more intense in the furnace, so that the temperature producible increases progressively. In a blast furnace, the bellows can be weighted and worked as heavily as possible at once, and by opening all the apertures for receiving air, the maximum temperature can be produced nearly immediately, and a very high temperature obtained more rapidly than in a wind furnace; but this is of little use, because, as heat passes very slowly into the substance of a crucible, when the object is to fuse its contents it must be heated gradually, so as to avoid running the risk of softening the crucible before its contents were acted upon, or even scarcely made warm.

Wind furnaces are, however, infinitely more serviceable and economical than blast, because they work themselves, and do not require the service of a man to attend to the bellows. A blast furnace is useful in a laboratory, in certain cases,—for instance, when a single crucible has to be submitted to an intense heat, and when the furnace is small and the bellows large, in which case the operation resembles a blow-pipe assay.

In whatever manner the air is introduced into any kind of furnace, either wind or blast, it is evident that the quantity of heat developed in equal-sized furnaces depends upon the quantity of air introduced in the same time: but the degree of temperature is not the same in different parts of the furnace, and the distribution of heat varies according to the manner in which the air is introduced into the midst of the fuel. The side over which the air passes is kept cold by the current, on which account fire-bars last a long time without becoming oxidated, when the draught is stopped only when the fuel is totally consumed; but the heat rapidly augments up to a certain distance from the bars, at which place it has arrived at its maximum; above that it diminishes rapidly, because the air is nearly deprived of its oxygen. Experiment has proved that this maximum is about 2½ to 3 inches above the bars or tuyères.

In common wind furnaces the air enters by horizontal bars, which form the bottom of the furnace, and the crucibles are placed on a stand which rests on these bars. By this means, the lower and centre part of the crucibles, and in which parts the matter to be fused is placed, are exactly situated in the maximum of heat, but the stand being constantly kept cold by the contact of a current of air, establishes a continual draining or carrying away of heat from the interior of the crucible outwards, so that the substance submitted to assay can never arrive at the maximum temperature but after a length of time, and then *that* maximum is always inferior to that in the mass of fuel. It is on this account that assays in a blast or wind furnace generally occupy from one hour to two hours. I have found that the time may be reduced to half that just stated, if a good solid foundation of fuel be made, and the crucible placed on that, and well surrounded by coke constantly kept close to the pot and the sides of the furnace: in this manner the cooling effect of the stand is removed, and the consequent maximum effect of the furnace produced.

Lutes.—The best fire lute is that employed by Mr. Parker, and is composed of good clay 2 parts, sharp washed sand 8 parts, horse-dung 1 part. These materials are to be intimately mixed; and afterwards, the whole is to be thoroughly tempered, like mortar. Mr. Watt's fire lute is an excellent one, but is more expensive. It is made of finely powdered Cornish (porcelain) clay, mixed to the consistence of thick paint, with a solution of borax, in the proportion of two ounces of borax to a pint of hot water.

It may be as well to mention in this part of the work the various lutes which may be employed, either in fire operations, or in making good joints in experiments with gases or liquids. The following are the principal kinds:—

1. *Fat lute* is prepared by mixing dry clay, in a fine powder, with drying oil, so that the mixture may form a ductile paste. When this paste is used, the part to which it is applied ought to be very clean and dry, otherwise it will not adhere.

2. *Roman cement,* which must be kept in well-closed vessels, and not moistened until the instant it is required for use.

3. *Plaster of Paris,* mixed with water, milk, or weak glue, or

starch water. These three lutes stand a dull red heat. The two latter may be rendered perfectly impermeable to gaseous bodies by being smeared over with oil, or a mixture of oil and wax.

4. *Linseed or almond meal,* mixed to the consistence of a paste with water, milk, lime-water, or starch paste. This lute is very manageable and impermeable, but does not withstand a heat greater than about 500°.

5. If just the sufficient quantity of water be added to quick-lime to reduce it to a dry powder, and that is mixed well and rapidly with white of egg diluted with its own volume of water, and the mixture spread immediately in strips of linen and applied to the part, then powdered with quick-lime, it forms a good cement. Instead of white of egg, lime and cheese may be used, or lime with weak glue water or blood. This lute dries very rapidly, becoming very hard, and adhering strongly to the glass; but its great inconvenience is the want of flexibility.

6. *White lead mixed with oil.*—If the mixture be spread upon strips of linen, or bundles of tow, it acts much in the same manner as the lime lutes.

7. *Yellow wax* is often used as a lute, but it becomes very brittle at a low temperature. It may be rendered less brittle, and at the same time more fusible, by an admixture of one-eighth of crude turpentine.

8. *Soft cement* is prepared by fusing yellow wax with half its weight of crude turpentine and a little Venetian red, in order to colour it. It is very flexible, and takes any desired form under the pressure of the fingers.

9. *Resinous, or hard cement,* is made by fusing together at the lowest possible temperature 1 part of yellow wax and 5 or 6 of resin, and then adding gradually 1 part of red ochre, or finely powdered brick-dust, (plaster of Paris succeeds very well), and then raising the temperature to 212° at least, until no more froth arises, or agitation takes place, and stirring it continually until cold. This cement is employed in a hot state. This lute is much used for fixing brass caps, &c., to air jars.

10. *Paper,* covered with common glue, is occasionally employed.

11. *Bladders* cut in small strips are occasionally used in covering other lutes when the pressure of gas is considerable, or when the lute is subject to strain from any other cause. They are digested in water until they become soft and flaccid; they are then applied to the part like a piece of pasted paper, by the pressure of the hand. These strips adhere very strongly to glass or earthenware, and their adhesive

power may be much augmented by smearing them with white of egg. Lastly, the joints made in this manner may be made firmer by binding them with string or fine wire.

12. *Caoutchouc.*—Tubes of this material form a very ready means of attaching one piece of apparatus to another, and they possess the peculiar advantage of flexibility, which allows the various parts of the apparatus which they connect to move in different directions to a slight extent, so that the whole is not so likely to be fractured as when connected in an inflexible manner. Caoutchouc is also less acted upon by gases and vapours than almost any other substance we know; even chlorine attacks it but slowly, and it possesses the valuable property of forming a perfect joint when freshly cut joints are brought and pressed together: hence the facility with which it is manufactured into tubes. The mode of manufacture is as follows: Take a piece of the sheet caoutchouc of the required size, and warm it either in the hand, or before a fire until it is perfectly soft; then place it around a glass rod of the requisite size, pressing the edges close together with the fingers; when close together, cut off the superabundance with a sharp pair of scissors, and the newly cut edges will unite by simple pressure of the nail. When well executed the join is scarcely apparent. In order to prevent the caoutchouc from adhering to the rods on which the tube is formed, a little moisture or starch powder may be employed: vulcanised india-rubber tubing of different sizes is also very useful.

When caoutchouc is not at hand, oiled paper may be substituted, the joint being made with wax.

Faraday gives the following directions for luting iron, glass, or earthenware retorts, tubes, &c., for furnace operations. When the lute has to withstand a very high temperature, it should be made of the best Stourbridge clay, which is to be made into a paste varying in thickness according to the opinion of the operator. The paste should be beaten until it is perfectly ductile and uniform, and a portion should then be flattened out into a cake of the required thickness, and of such a size as shall be most manageable with th vessel to be coated. If the vessel be a retort or flask, it should be placed in the middle of the cake, and the edges of the latter raised on all sides, and gradually moulded and applied to the glass; if it be a tube, it should be laid on one edge of the plate, and then applied by rolling the tube forward. In all cases, the surface to be coated should be rubbed over with a piece of the lute dipped in water, for the purpose of slightly moistening and leaving a little of the earth upon it: if any part of the surface becames dry before the lute is applied, it should be re-moistened. The lute should be pressed and rubbed down upon the glass successively from the part where the contact was first made to the edges, until all air bubbles are excluded, and an intimate adhesion effected. When one cake of lute has been applied, and is not large enough to cover the whole required surface, another must be adapted in a similar manner. Great care must be taken in joining the edges, for which purpose it is better to make them thin by pressure, and also somewhat irregular in form, and if at all dry they should be moistened with a little soft lute. The general thickness may be about one-quarter to one third of an inch.

Being thus luted, the vessels are afterwards to be placed in a warm situation, over the sand-bath or near the ash-pit, or in the sun's rays. They should not be allowed to dry rapidly or irregularly, and should be moved now and then to change their positions.

To prevent cracking during desiccation, and the consequent separation of the coat from the vessel, some chemists recommend the introduction of fibrous substances into the lute, so as mechanically to increase the tenacity of its parts. Horse-dung, chopped hay and straw, horse- and cow-hair, and tow cut short, are amongst the number. When they are used, they should be added in small quantity, and it is generally necessary to add more water than with simple lute, and employ more labour to ensure a uniform mixture. It is best to mix the chopped material with the clay before the water is put to it, and by adding the latter to effect the mixture, at first by stirring up the mass lightly with a pointed stick or fork; it will then be found easy, by a little management, to obtain a good mixture without making it very moist.

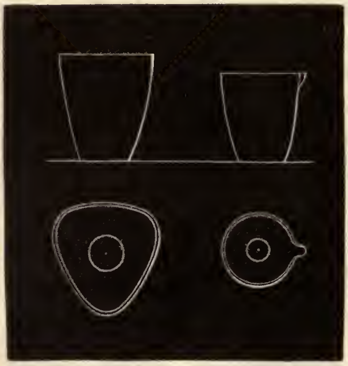
The luting ought to be made as dry as possible, consistent with facility in working it. The wetter it is, the more liable to crack in drying, and *vice versâ*.

Mr. Willis recommends, when earthenware retorts, &c., are to be rendered impervious to air, the following coating. One ounce of borax is to be dissolved in half a pint of boiling water, and as much slaked lime added as will make a thin paste. This composition is to be spread over the vessel with a brush, and when dry, a coating of slaked lime and linseed oil is to be applied. This will dry sufficiently in a day or two, and is then fit for use.

Iron cement.—This mixture is used for making permanent joints generally between surfaces of iron. Clean iron borings or turnings are to be slightly pounded so as to be broken but not pulverized; the result is to be sifted coarsely, mixed with powdered sal ammoniac and sulphur, and enough water to moisten the whole slightly. The proportions are, 1 sulphur, 2 sal ammoniac, and 80 iron. No more should be mixed than can be used at one time.

Crucibles, Cupels, &c.—The crucibles best known in commerce are the Hessian, the Cornish, and the London; the latter of which are much to be preferred, on account of their general refractory nature; they are also much better made than the two other kinds, being much smoother and more regularly formed. They have the form of a triangular pyramid, (see fig. 198, crucibles and cover), and are made in such sizes that they fit one into the other, forming nests. The triangular form is very convenient, because there are three spouts, from either of which can be poured the fused contents of the pot. The Cornish crucibles are circular, and do not stand changes of temperature so well as the London pots, neither can they endure such an extreme of heat, for they agglutinate and run together at a temperature which does not touch the others. The Hessian pots are worst of all; they do not stand the least change of temperature without a certain fracture, so that they require to be very carefully used. There is also another kind of pot in use, made of the same material as the London crucibles, termed a "skittle pot," from its resemblance, no doubt, to the ordinary wooden skittle or nine-pin. They are exceedingly useful for the fusion of large masses of matter, or such substances as boil or bubble much when heated.

Fig. 198.



Crucibles in order to be perfect and capable of being used indifferently for any operation, ought to possess the four following qualities: Firstly, not to break or split when exposed to sudden changes of temperature; secondly, to be infusible; thirdly, to be only slightly attacked by the fused substances they may contain; fourthly and lastly, to be impermeable, or nearly so, to liquids and gases. But as it is very difficult to unite all these qualifications, various kinds of pots are made to fulfil one or more of them.

In order to render crucibles capable of withstanding changes of temperature without breaking, a certain proportion of substances, infusible by themselves, is mixed with the pasty clay; sand, flint, fragments of old crucibles, black-lead and coke, are used for this purpose. They are reduced to a state of division more or less fine, according to the grain of the clay paste. For ordinary pots, the powder ought not to be very fine; but for porcelain crucibles it ought to be as fine as flour. The choice of these various bodies depends upon the use for which the crucible is intended.

The most refractory crucibles are those made with the pure clays, or such as contain little or no oxide of iron, and especially free from calcareous matters. Amongst those clays, the best are those which contain most silica; nevertheless, crucibles of pure clay are not absolutely infusible, and in the high temperature of a wind furnace they sometimes soften so much as actually to fall into a shapeless mass. This defect, as before stated, can be in some measure diminished by mixing with the clay a quantity of graphite or coke; either of these substances forms a kind of solid skeleton, which retains the softened clay, and prevents its falling out of shape.

Coke and black-lead are more efficacious than sand, because they have no action on clay, and because quartz forms a fusible compound with it. If too large a quantity of black-lead or coke be employed, it gradually consumes in the fire, and the pots become porous, and break at the least movement. Wood charcoal can be used instead of black-lead or coke, but is not so good, because it burns more readily.

Black-lead crucibles are generally composed of 1 part of refractory clay, and from 2 to 3 of black-lead. These pots withstand all possible changes of temperature without cracking, and their form is rarely changed by the heat, not because they are absolutely infusible, but because they are supported by the skeleton of graphite.

Black-lead being a very rare and expensive material, certain artificial mixtures have been contrived; coke seems to be the best substitute. Those made by Marshall and Anstey are said to approach, in many of their properties, to the ordinary blue pots. They are made of Stourbridge clay and pulverized coke; about 2 parts of the former and 1 of the latter.

Crucibles into whose composition carbonaceous matters enter, reduce any oxides that may be heated in them, and hence are inconvenient in certain cases. They can, nevertheless, be employed in all cases, by giving them a lining of clay, which must be tolerably thick, and well dried before use.

Earthen crucibles, which have not been baked at a white heat, are more or less permeable to liquids and gases, according to the grain. In order to render them impermeable to liquids, they must be heated to such a temperature as will suffice to fuse the outside. When treated in this way, however, they are very liable to crack with sudden changes of temperature; the best method, therefore, of rendering them capable of containing water, &c., is to coat them with the mixture of borax and lime, described as Willis's lute.

Resistance to Corrosion.—In order that crucibles may resist the corrosive action of the fused substances contained within them, they must be as compact as possible, and the substance of which they are made must have little or no tendency to combine with the fused contents. The metals and their non-oxidated compounds neither attack clay nor black-lead; but there are, nevertheless, some metallic substances,—galena, for instance, which without exercising any chemical action on earthy matters, have the property of filtering through their pores.

The readily reducible oxides gradually corrode black-lead crucibles, and those pots in the composition of which coke enters, by burning the carbonaceous matter. The greater portion of these same oxides, the alkalies, earths, and glasses, which are the fusible silicates, borates, &c., act more or less powerfully on the earthy base of all crucibles; so that these substances are the most difficult to keep in fusion for any length of time. They attack the crucible layer by layer, dissolving the substance of which it is composed, and after a lapse of time rendering it so thin that it cannot withstand the pressure of the molten mass within it; and the fracture of the pot, and consequent loss of contents, is inevitable.

Impermeability.—Under the same circumstances, all those crucibles whose texture is loose are more readily corroded than those with a firm compact body; because the corrosive substance filters to a certain depth in the former crucibles, and, in consequence, has a larger surface to act upon than when it is contained in a compact pot.

Examination of Crucibles.—Earthen crucibles may be assayed by the time they will contain fused litharge, which exercises a very corrosive action, honeycombing them in all directions, and those pots which contain it longest without undergoing much damage may be considered the best. However, this method of assay is not exact, even by taking into account the thickness of the pot, for litharge runs through crucibles; firstly, because it is very fusible, and easily filters through their pores; and secondly, it has the property of forming fusible compounds with all the silicates by combining with them. From these remarks, it will be evident that a crucible whose grain is loose will readily allow litharge to pass through it, however slightly its substance may be fusible or acted on; or on the contrary, it may be very easily acted on (even when absolutely infusible) with an extremely fine grain; so that the promptitude with which a crucible is traversed by litharge bears no relation to its fusibility. A crucible of pure quartz will be very readily attacked by litharge, because it has much affinity for silica, and the simple silicates of lead are all very fusible; whilst a crucible composed of silica, alumina, and lime, which by itself is very fusible, would be corroded less rapidly, because the oxide of lead has much less affinity for the earths than it has for the silica; moreover, it forms less fusible compounds with the earths than with silica alone. The assays of crucibles made with litharge, if not of use in ascertaining their degree of fusibility, fulfils perfectly its object when it is wished to prove the resistance a crucible has to the corrosive action of various bodies in a state of fusion; for of all fusible substances none exercise such a powerful action on earthy matters as litharge.

Crucibles ought not only to resist the corrosive action of those bodies they may contain, but also that of the ash produced by the combustion of the fuel in which they may be placed. These ashes being often calcareous, alkaline, or ferruginous, act on the clayey part of the crucibles exactly as the fluxes. From whence it follows, that those crucibles which contain litharge longest will also resist the action of the fluxes best.

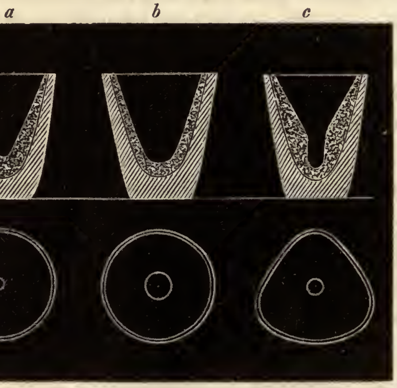
In order to ascertain the fusibility of a crucible, a direct experiment must be made, either by heating a piece in a crucible lined with charcoal, and ascertaining if its angles be rounded, if its substance has become translucid, &c.; or better still, by heating the crucible to be assayed with another whose properties are well known.

As to permeability, it may approximately be ascertained by filling two crucibles with water, and noting what length of time is required to empty them completely: the crucible which contains it longest by exudation is, of course, the least permeable.

To prove if a crucible be able to sustain great changes of temperature without breaking, introduce it, perfectly cold, into a furnace full of lighted coal; take it out when reddish white, and expose it to a current of cold air produced by a bellows or otherwise: if it stand these trials, it may be heated afresh and plunged red hot into water, and if it be not broken, placed immediately in the fire. The best pots support all these operations without breaking; but it often happens that they are filled with innumerable small fissures, through which fused matters can pass. This can be ascertained by fusing rapidly in the assay pot a quantity of litharge; if these be present, the fused oxide will readily filter through them.

Charcoal Crucibles.—As all oxidated matters act very readily on clay pots, and a great number of the metals and their compounds adhere to them, they have long since been replaced, under certain circumstances, by charcoal crucibles, which do not possess these disadvantages. The older assayers used merely a piece of charcoal, with a hole made in it, and then bound round with iron or other wire. The use of these has, however, been abandoned for some length of time, and earthenware crucibles lined with charcoal have been substituted (see fig. 199, *a*, *b*, and *c*). These may be considered as charcoal pots enveloped with refractory clay; they are solid, always free from cracks, and easy of preparation, and they have the same properties as the solid charcoal crucibles, without their inconveniences.

FIG. 199.



In order to prepare these crucibles, the charcoal must be chosen carefully, so as to contain no foreign substances; it must be pulverized and passed through a sieve; the powder moistened with water, mixed with a spatula, and then kneaded with the fingers until it just adheres, and forms cohesive lumps without being sufficiently wet to adhere to the hand. Some advise the addition of gum to the water with which the charcoal is moistened; which addition is, however, useless, water alone being sufficient to give a suitable consistence to the charcoal lining. Crucibles are lined with charcoal by the following method:—

The crucible is moistened slightly by being plunged into water and withdrawn as speedily as possible, and about ½ an inch in depth of the charcoal paste, prepared as above, placed in it: the paste is then pressed firmly down by means of a wooden pestle: the blows are to be slight at first, and then increasing in force until it is as firm as possible: another layer is then applied and pressed as before, and the process repeated until the crucible is quite full, taking great care to render all as firm as possible, especially at the sides. In order to make each layer adhere firmly to the other, they must be scratched rather deeply with the point of a knife before a new layer is applied. When the crucible is completely filled, a hole is to be scooped in the charcoal, of about the form of the pot. The sides are then rendered smooth by friction with a glass rod. This is absolutely necessary, so that the metallic globules produced in an assay may not be retained by the asperities of the lining, but may be readily enabled to unite into one button. When a lined charcoal pot is well made, its sides are very smooth and shining. For ordinary use, the lining may be $\frac{3}{8}$ths of an inch thick at the bottom, and $\frac{1}{8}$th or so at the sides; but in some cases, for instance when the substance to be fused is capable of filtering through the lining and attacking the pot as a flux, it must be at least twice the above thickness in every part.

As before stated, in the article on Reduction, lined crucibles have many advantages over plain crucibles. The lining gives them greater solidity, and prevents a loss of shape when softened; for plain crucibles are always three-fourths empty when their contents are fused: on account of contraction in volume, the pots then have nothing to sustain their sides when they soften towards the end of the assay, at which period the highest temperature is employed. Besides, vitreous matters do not penetrate the lining, and, exercising no action on it, can be obtained in a state of purity, and the exact weight determined: if fused in a plain pot, the weight could not be ascertained, because a portion would adhere to the sides, and the resulting mass would not be pure, having taken up a portion of the crucible in which the fusion was effected.

The lining, too, effects the reduction of certain metallic oxides by cementation, and does away with the necessity of adding powdered charcoal to the body to be reduced. This property is very valuable, because, when an oxide is reduced by mixing it with charcoal, an excess must always be employed, and which excess remains with the metal, and prevents us from obtaining its exact weight.

In certain particular experiments crucibles are lined with other bodies besides charcoal, such as silica, alumina, magnesia, or chalk, by merely moistening their respective powders with water, and applying the paste as above described for the charcoal. A slight layer of chalk lessens the liability of attack from fused litharge.

Malleable iron crucibles are often very serviceable in assays of fusibility, and of certain seleniurets and sulphurets, as in assays of galena or ordinary lead ore. They are either made of hammered sheet-iron, or by plugging up small iron tubes, as gun-barrels, &c. The latter are preferable, because thick solid crucibles can be used a number of times, whilst the others are necessarily very thin, and can be used only once. Whenever iron crucibles are employed at a very high temperature they must be placed in those of earthenware, which protect them from the oxidating action of the air; but when they are not heated above the temperature of a copper assay, they may be used naked, if they are tolerably thick.

For assays at the above temperature, cast iron crucibles may be employed with advantage, instead of wrought iron, because they are very nearly as good, and much less expensive.

Cupels and Scorifiers.—Cupels are vessels in which the operation termed cupellation is carried on. They are made of such substances as are not acted upon by certain fused oxides, as those of lead or bismuth, and their texture is sufficiently loose to allow those oxides to penetrate their substance readily, and yet be sufficiently strong to bear handling without breaking.

There are a great number of substances of which cupels can be made, which will fulfil all these conditions, but only one is in general use, viz.: the ash of burnt bones. The powdered and sifted ash is washed repeatedly with water, to remove all saline and extraneous soluble matter; and, lastly, dried. It now consists principally of pure phosphate of lime, with a little carbonate partially decomposed. It is sometimes made into a paste with water, but I have found beer to answer much better. The following are the proportions I employ: 4 lbs. of bone-ash, and ½ lb. of beer. The above mixture is just sufficiently moist to adhere strongly when well pressed, but not so moist as to adhere to the finger or the mould employed to fashion the cupels. The mould (fig. 200), consists of three pieces, one a ring, *b*, having a conical opening; another, a pestle, *a*, having a hemispherical end fitting the larger opening of the ring, and the third, *c*, a piece of turned metal, into which *b* fits; *c* serves to form an even bottom to the cupel. In order to mould the cupels, proceed as follows: Place the ring on the lower piece *c*, and fill it with the composition; then place the pestle upon it, and force it down as much as possible: by this means

Fig. 200.

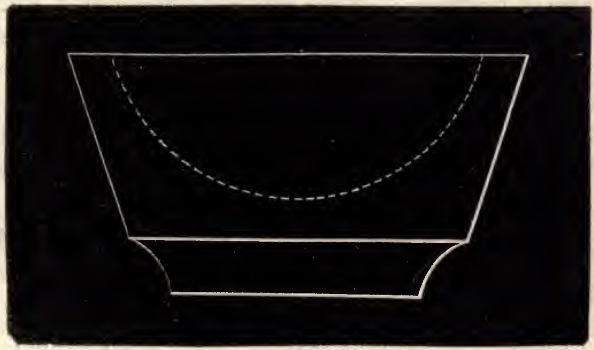
the moistened bone-ash will become hardened, and take the form of the pestle; the latter must then be driven as much as possible, by repeated blows from a hammer, until quite home. It is then to be turned lightly round, so as to smooth the inner surface of the cupel, and withdrawn; the cupel is removed from the mould by a gentle pressure on the narrowest end. When in this state the cupel must be dried gently by a stove; and lastly, ignited in a muffle, to expel all moisture. It is then ready for use.

There are two or three points to attend to in manufacturing the best cupels. Firstly, the powdered bone-ash must be of a certain degree of fineness; secondly, the paste must be neither too soft nor too dry; and thirdly, the pressure must be made with a certain degree of force. A coarse powder, only slightly moistened and compressed, furnishes cupels which are very porous, break on the least pressure, and allow small globules of metal to enter into their pores; this last is the most serious inconvenience of all.

When, on the contrary, the powder is very fine, the paste moist and compressed strongly, the cupels have much solidity, and are porous, the fine metal cannot penetrate them, and the operation proceeds very slowly: besides, the assay is likely to become dulled, and incapable of proceeding, without a much higher degree of temperature being employed.

Scorifier.—A scorifier (fig. 201), is a vessel made much in the shape of a cupel, but of crucible earth. Its use will be explained under the head Silver Assay.

FIG. 201.



Methods of Measuring the Heat of Furnaces.—As much of the accuracy of an assay depends on the temperature at which it is made, and the temperature required varies with the metal, it is very desirable to possess some means of ascertaining the heat of the furnace more accurately than by the eye. Many have devised instruments for this purpose. The chief inventors are Mr. Wedgwood and the late Professor Daniell, of King's College. The instruments are termed pyrometers, and both of those just mentioned will be described, and their peculiarities and use pointed out; commencing with Wedgwood's.

This pyrometer is constructed on the principle that the purest clay is contracted in proportion to the heat applied to it. This contraction is occasioned by its giving up water, which it holds with great tenacity, by exposure to a high temperature. It is composed of two parts; of a gauge which serves to measure the degrees of heat, and of small pieces of clay which are employed to ascertain the same degrees by their contraction. The gauge is formed of a plate of brass, with two rulers of the same substance firmly fixed to it. The two rulers are 24 inches long, and fixed in the plate $\frac{5}{10}$ths of an inch asunder at one end, and $\frac{3}{10}$ths of an inch at the other; so that the distance between the two rods gradually diminishes, and the whole diminution amounts to $\frac{2}{10}$ths of an inch. The ruler is divided into 240 equal parts, each of which measures $\frac{1}{10}$th of an inch.

To form the pieces by whose contraction the heat is measured, the finely powdered and sifted clay is mixed with water, and the paste made to pass through an iron tube; it is then cut into cylinders of a suitable length. When these pieces are dry they must be adapted to the zero of the gauge. When this pyrometer is used, one of the pieces of clay is placed in the furnace whose temperature is to be ascertained, and when it has experienced the utmost extremity of the heat, it is withdrawn and allowed to cool. Then it is placed in the gauge, and passed between the two rulers until it will go no further: the degree of heat is then calculated from the contraction which it has undergone.

The following is a table drawn up by Mr. Wedgwood of some of the corresponding degrees of his pyrometer with those of the Fahrenheit thermometer.

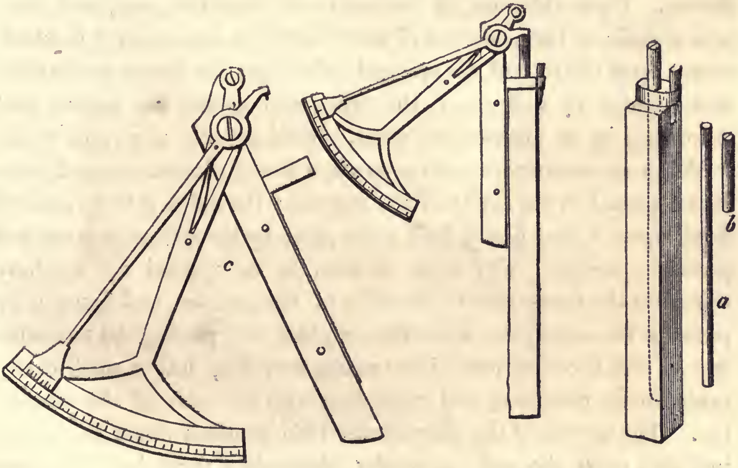
	Wedgwood.	Fahrenheit.
Red heat, visible by daylight . .	0°	1077°
Copper melts	57	4587
Silver melts	28	4717
Gold melts	32	5237
Cast iron melts	130	17977
Greatest heat of wind furnace . .	160	21877

The indications of this pyrometer are, however, very inaccurate, from the fact that clay will contract as much by the long continuance of a low heat, as by the short continuance of a high one. Hence the degrees of heat measured by Wedgwood's pyrometer have been enormously exaggerated. It was long since noticed that it does not produce comparable effects; and this was supposed to proceed wholly from the impossibility of obtaining clay perfectly alike for each experiment.

This led M. Guyton* to propose another form of pyrometer, which is essentially the same as Professor Daniell's. The only difference in the latter is its more perfect construction. It is composed of a rod of platinum simply laid in a groove made of refractory clay, and baked in the highest degree of heat. This rod rests at one end on the edge which terminates the groove, and at the other on a lever with two arms, the larger of which forms a needle on a graduated arc of a circle; so that the removal of this needle from its position marks the additional length which this metal acquires by the heat. I will now give Professor Daniell's description of his own pyrometer; and the resemblance between the two will be at once seen.

"It consists of two parts, (see fig. 202), which may be distinguished as the register and the scale. The register is a solid bar of black-lead earthenware highly baked. In this a hole is drilled, into which a bar of any metal, *a*, six inches long, may be dropped, and which will then rest upon its solid end. A cylindrical piece of

FIG. 202.



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* Annales de Chimie, vol. xlvi. p. 276.

porcelain, *b*, called the index, is then placed upon the top of the bar, and confined in its place by a ring or strap of platinum passing round the top of the register, which is partly cut away at the top, and tightened by a wedge of porcelain. When such an arrangement is exposed to a high temperature, it is obvious that the expansion of the metallic bar will force the index forward to the amount of the excess of its expansion over that of the black-lead, and that when again cooled it will be left at the point of greatest elongation. What is now required is the measurement of the distance which the index has been thrust forward from its first position, and this, though in any case but small, may be effected with great precision by means of the scale, *c*."*

This is independent of the register, and consists of two rules of brass accurately joined together at a right angle by their edges, and fitting square upon the two sides of the black-lead bar. At one end of this double rule, a small plate of brass projects at a right angle, which may be brought down upon the shoulder of the register formed by the notch cut away for the reception of the index. A moveable arm is attached to this frame, turning at its fixed extremity on a centre, and at its other carrying the arc of a circle, whose radius is exactly five inches, accurately divided into degrees and thirds of a degree. Upon this arm, at the centre of the circle, another lighter arm is made to turn, one end of which carries a nonius with it, which moves upon the face of the arc, and subdivides the former graduation into minutes of a degree; the other end crosses the centre, and terminates in an obtuse steel point, turned inwards at a right angle.

When an observation is to be made, a bar of platinum or malleable iron is placed in the cavity of the register; the index is to be pressed down upon it, and firmly fixed in its place by the platinum strap and porcelain wedge. The scale is then to be applied by carefully adjusting the brass rule to the sides of the register, and fixing it by pressing the cross piece upon the shoulder, and placing the moveable arm so that the steel part of the radius may drop into a small cavity made for its reception, and coinciding with the axis of the metallic bar. The minute of the degree must then be noted which the nonius indicates upon the arc. A similar observation must be made after the register has been exposed to the increased temperature which it is designed to measure, and again cooled, and it will be found that the nonius has been moved forward a certain number of degrees or

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* Daniell's Chemical Philosophy, p. 111.

minutes. The scale of this pyrometer is readily connected with that of the thermometer by immersing the register in boiling mercury whose temperature is as constant as that of boiling water, and has been accurately determined by the thermometer. The amount of expansion for a known number of degrees is thus determined, and the value of all other expansions may be considered as proportionate.

We shall now see, by comparing the indications as determined by this pyrometer with those of Wedgwood, to what an enormous extent those of the latter were wrong.

By Daniell's, the melting point of cast iron has been ascertained to be 2786°, and the highest temperature of a good wind furnace, 3300° Fahrenheit,—points which, as the table before mentioned shows, were estimated by Mr. Wedgwood at 17977° and 21877° respectively.

The following is a list of the melting points of some of the metals; and it is obvious that in an assay of each particular metal the temperature employed must exceed by a considerable number of degrees its melting point. The table is, therefore, very useful.

	Fahrenheit.
Tin melts at	422°*
Bismuth	497
Lead	612
Zinc	773
Cadmium	442
Silver	1860
Copper	1996
Gold	2016
Cast iron	2786

Cobalt and Nickel rather less fusible than iron.

CHAPTER VI.

THE FLUXES, THEIR COMPOSITION, MODE OF PREPARATION, AND USE.

In some of the operations in the dry way, bodies are heated in suitable vessels *per se*; but more often it is necessary to add to the bodies submitted to assay other substances, which are varied

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* Daniell.

according to the nature of the change to be effected. As these substances generally determine the fusion of the body to which they are added, they are termed fluxes, or fusing agents; but this name cannot be applied to all of them with exactitude.

They are generally divided into five classes:—1. reducing agents; 2. oxidising agents; 3. desulphurising agents; 4. sulphurising agents; and lastly, fluxes properly so called.

REDUCING AGENTS.

All the substances belonging to this class have the power of removing oxygen from those bodies with which it may be combined. They are as follows:

1. Hydrogen gas.
2. Charcoal.
3. The fat oils, tallow, and resins.
4. Sugar, starch, and gum.
5. Tartaric acid.
6. Oxalic acid.
7. Metallic iron, and lead.

Hydrogen Gas (H).—This body is so termed because in combining with oxygen it forms water. The most common method of preparing this gas consists in dissolving zinc in dilute sulphuric acid. It is invisible and colourless when absolutely pure, and is the lightest body in nature. It is a most powerful reducing agent, and reduces a great number of metallic oxides at a red or white heat; viz. the oxides of lead, bismuth, copper, antimony, iron, cobalt, nickel, tungsten, molybdenum, and uranium. When any metal is required in a state of absolute purity this is the only reducing agent admissible, as all others give the metal combined with a certain proportion of carbon.

Carbon (C).—Perfectly pure carbon is exceedingly rare in nature. It is found in large quantities in the mineral kingdom combined with other bodies. In a perfect state of purity it constitutes the diamond. The diamond, like all other species of carbon, is unacted on by the highest possible temperature when in close vessels. It burns in atmospheric air and oxygen gas, but requires a higher temperature than ordinary charcoal. After the diamond the most remarkable and purest species of carbon are:—

Firstly. *Black-lead* or *Graphite*. This is a mineral found in beds in the primitive formations, principally in granite and mica-schist.

The purest at present known is found at Borrowdale in Cumberland.

Secondly. *Anthracite* is another species of fossil carbon much resembling ordinary coal, but differing from it by burning with neither smell, smoke, nor flame.

Thirdly. *Coke* is the residue of the coal employed in the gas works after all the volatile matter is expelled. It is generally iron black, and has nearly a metallic lustre: it is difficult to inflame, and burns well only in small pieces, but gives a very intense heat: oven or furnace coke is preferable, as it is much harder, lasts longer, and is more economical in use.

Fourthly. *Wood Charcoal* is obtained by burning the woody part of plants with a limited supply of air, so as to drive off all their volatile matters, and leave merely their carbon. It is this kind that is generally employed in assays. It ought to be chosen with care, well pulverized, passed through a sieve and preserved in well-stopped vessels. Wood charcoal is never perfectly pure, it generally contains a proportion of hydrogen and watery vapour: these bodies are not exactly prejudicial, but in some experiments they ought not to be present: in that case pure charcoal may be readily procured by heating sugar to redness in a close crucible.

Charcoal by itself possesses two inconveniences: firstly, it has the property of combining with many metals; and in the second place it is infusible, and cannot combine with vitreous substances. The property it possesses of combining with iron, nickel, cobalt, &c., is of no consequence to the assayer, for the increase of weight it gives is not material, excepting under the circumstances to be hereafter pointed out: but its infusibility and inability to combine with fluxes is a very serious inconvenience; for after the reduction, that portion which has not been consumed remains disseminated with the grains of metal in the fused slag, and prevents the separation of all the metal, and the consequent formation of a good button: a large quantity of charcoal can thus irreparably injure an assay. This inconvenience does not happen, however, when an oxide is reduced by cementation in a lined crucible; but there are some cases in which its employment is inadmissible.

In default of charcoal, coke may be employed, but it must be chosen with much care, for it often contains a very large proportion of earthy and other extraneous matters, (more particularly sulphur, which in most cases is very injurious); so that before use it is necessary to burn a quantity, in order to ascertain their amount and composition, and that coke ought only to be used which gives nearly white ashes, and which contains no more than a few per cents. Coke is never so good as wood charcoal as a reducing agent, because it burns more slowly by combining less rapidly with oxygen. When it is used the temperature employed for an assay must be much increased.

Coal is nearly always inconvenient, because it swells by heat; nevertheless as it is not required in very large quantity it is sometimes employed, being previous to use finely powdered and sifted.

THE FAT OILS, TALLOW, AND RESINS.

The Fat Oils.—The name oil is generally given to those bodies that are fat and unctuous to the touch, more or less fluid, insoluble in water, combustible, and forming soaps with alkalies. They all congeal and become solid at various degrees of temperature. There are even some which, in the temperature of our climate, have constantly a solid form; as butter, palm oil, cocoa nut oil, &c.

Fixed oils have a very marked unctuosity; they neither dissolve in water nor alcohol, and take fire at a heat capable of reducing them to a state of vapour. Their density is from ·915 to ·940, and the boiling temperature about 600°. When distilled, they are decomposed, disengaging margaric and oleic acids, &c., then an empyreumatic oil, and lastly a yellowish red substance, and leaving about 2 per cent. of charcoal. When heated to a higher temperature than their poiling point, they are very nearly wholly resolved into an inflammable gas.

According to MM. Gay-Lussac and Thénard, these oils consist of:

Carbon	·77213
Oxygen	·09451
Hydrogen	·13336
	1·00000

Tallow is an animal product analogous to the fat oils both in chemical composition and properties; it is soft but solid, white, translucid, and granular. According to Chevreul, mutton fat is composed of:

Carbon	·78876
Oxygen	·11790
Hydrogen . . .	·09334
	1·00000

The Resins.—The greater part of the resins are solid; but some are soft. They are brittle, with a vitreous and shining fracture, and often transparent. They are very fusible, but cannot be raised to their boiling point without partial decomposition. They give an acid water, an empyreumatic oil, and combustible gas by distillation, leaving a variable proportion of charcoal.

Colophony has the following composition:

Carbon	·75944
Oxygen	·13338
Hydrogen	·10718
	1·00000

Although all the bodies just mentioned consume in their combustion a large quantity of oxygen, they cannot generally effect the total reduction of on oxide, on account of their volatility; so that before the temperature at which the reduction takes place can be attained, the greater part of the reducing agent has been expelled. They generally act only by virtue of the small carbonaceous residue produced by the action of heat; so that their use is very limited and uncertain. Whenever they are employed as reducing agents, without covering the substance, a loss is experienced, on account of the bubbling and boiling caused by their decomposition: this will always take place, unless the contents of the crucible be covered with charcoal powder. Oils are very serviceable in the reduction of a large mass of oxide by cementation: in this case, after the oxide has been placed in the crucible, as much oil is added as the oxide and the lining of the crucible will soak up. Fat or resin is also used to prevent the oxidation of the surface of a metallic bath, (as in the fusion of bar-lead samples), by reducing the film of oxide formed by the action of the atmospheric oxygen.

SUGAR, STARCH, AND GUM.

These three bodies are so well known that a description is useless; so their use will merely be mentioned.

All three have the same chemical composition, viz.

Carbon	44·91
Hydrogen	6·11
Oxygen	48·98
	100·00

Sugar in its decomposition by heat leaves a much larger proportion of carbon than the oils, fats, or resins; so that it would appear serviceable as a reducing agent. There are some cases in which it may be used with advantage, but unfortunately it undergoes a great increase in volume when heated, and is much agitated at the same time, so that losses in an assay may occur by the use of this agent. The charcoal of sugar is pure carbon, because it leaves no residue when burnt; it is, therefore, preferable to wood charcoal, in cases where no foreign matter should be introduced into the assay.

Starch.—Common starch, well dried, and better still torrefied, is employed with advantage as a reducing agent, and is much preferable to sugar as it neither fuses, swells up, nor spirts, and in many cases is even preferable to charcoal, because it is in such a fine state of division that it can be more readily and intimately mixed with the substance to be reduced.

Gum.—Decrepitates slightly by heat, softens, agglomerates and boils, without spirting. The gums can be employed as reducing agents under the same circumstances as sugar and starch, but the two latter are preferable, because they contain no earthy substances.

Tartaric Acid ($C_4H_2O_5,HO=\overline{T},HO$).—When heated in close vessels it fuses and bubbles very strongly, and decomposes, giving off combustible gases, leaving a little charcoal. It burns when heated in contact with air, giving rise to a peculiar and not unpleasant odour. This acid is the reducing agent in the cream of tartar, or argol, ($KO,\overline{T},HO,\overline{T},$) of which so frequent use is made; but the acid is never employed by itself.

Oxalic acid (C_2O_3,HO).—Fuses at a temperature of 208° without decomposing, but when heated to 230° it is decomposed, giving rise to 6 parts of carbonic acid, 5 parts of carbonic oxide, and a little formic acid vapour; and when heated strongly, some portions are volatilized without decomposition: it never leaves a carbonaceous residue.

The anhydrous acid consists of:

Carbon	·3376
Oxygen	·6624
	1·0000

The crystallized acid consists of:

Carbon	·1904
Oxygen	·3811
Water	·4285
	1·0000

The property which oxalic acid possesses of not leaving a residue would render it remarkably valuable for the reduction of the metallic oxides in cases where the slightest trace of carbon is to be avoided, if its reducing power were greater; but it decomposes at a low temperature, and in burning absorbs but a small quantity of oxygen, especially when it has not been dried, so that even for the most easily reducible oxides a large proportion must be employed. When it is combined with a base, as potash in the salt of sorrel, ($KO,\bar{O}HO,\bar{O}$), (binoxalate of potash) its reducing power is much augmented, and it is rendered much less volatile.

Oxalate of Ammonia ($NH_4O,\bar{O}$).—When heated in close vessels, it is decomposed and furnishes oxamide. The reducing power is nearly double that of oxalic acid.

Comparative Reducing Power of the above Fluxes.—In order to give an idea of the comparative reducing power of the fluxes just described, I will give the result of some assays made on them by Berthier, by means of litharge.

By heating the same weight of each reducing agent with an excess of litharge, buttons of lead were obtained, whose weights were proportional to the quantity of oxygen absorbed, and by comparing them with each other the reducing power of each flux is given; by taking for unity the weight of the re-agent, calculation has proved that 1 part of pure carbon reduces from litharge 34·31 of lead. The following are the results of some experiments:

Pure carbon	34·31
Hydrogen	104·00
Calcined wood charcoal	31·81
Ordinary wood charcoal	28·00

Animal oil	17·40
Resin	14·50
Amber resin	30·00
Tallow	15·20
Sugar	14·50
Common starch	11·50
Torrefied starch	13·00
Gum arabic	11·00
Tartaric acid	6·00
Oxalic acid	·90
Oxalate of ammonia	1 70

It must be borne in mind that these numbers do not represent the quantities of oxygen each re-agent would absorb in complete combustion; but that it only indicates the quantity of metal produced from those oxides reduced about the same temperature as oxide of lead.

In assaying, however, it is rarely that these agents are used by themselves: they are generally mixed with a flux properly so called, and under the head of Reducing Fluxes they will be more particularly described.

Metallic Iron (Fe).—This metal removes oxygen from the oxides of lead, bismuth, copper, &c., but is rarely added for that especial purpose; and when it does produce this effect, it is generally secondary, because it previously existed in the matter subjected to assay, or was added for some other purpose.

Metallic Lead (Pb).—Reduces but a very small number of oxides, but it reduces many to the minimum of oxidation; it also decomposes some sulphates and arseniates.

OXIDISING AGENTS.

The oxidising agents in general use are as follows:

1. The oxygen of the air.
2. Litharge and ceruse.
3. Silicates and borates of lead.
4. Nitrate of potash.
5. Nitrate of lead.
6. Peroxide of manganese.

7. Oxide of copper.
8. Peroxide of iron.
9. The caustic alkalies.
10. The alkaline carbonates.
11. The sulphates of lead, copper, and iron.
12. Sulphate of soda.

Oxygen (O) has never yet been obtained as a liquid or solid, although some of the recent experiments of Faraday tend to prove that it may yet be liquefied, if not solidified. Its general form, however, is gaseous; and it is under this form it is contained in the atmosphere, of which it constitutes one-fifth. In order to obtain the gas, we cannot act directly on the atmosphere, but must make use of certain metallic oxides which are reducible by heat,—as the oxide of mercury or peroxide of manganese. Oxygen gas has neither smell nor taste, and is about one-tenth heavier than atmospheric air. It has the property of forming compounds with nearly every body, and its affinities are very energetic.

Atmospheric air consists of four-fifths nitrogen and one-fifth oxygen. It acts on bodies in the same manner as oxygen, but much less energetically.

LITHARGE AND CERUSE.

Litharge (PbO) is a fused protoxide of lead, and is generally obtained from the silver lead works. It oxidises nearly all the metals, excepting mercury, silver, palladium, platinum, &c., and generally forms very fusible compounds with the oxides. These two properties cause it to be a very valuable agent in separating silver and gold from all the substances with which they may be mixed.

Litharge is essentially protoxide of lead, but is occasionally mixed with a little of the red oxide; its presence is often not inconvenient, excepting it is in large quantity; it then becomes injurious, as it has the property of oxidising silver. Ordinary litharge can be easily freed from this oxide by fusing it and pouring it into a cold ingot mould, then pulverizing and carefully keeping it from contact with air, as it readily absorbs oxygen; and if it be allowed to cool in the atmosphere, it will nearly all be converted into the red oxide.

Ceruse (PbO,CO_2) is a carbonate of the protoxide of lead. As it does not contain the slightest traces of red oxide, it may be used where the presence of that substance may be inconvenient; but it is troublesome to use, as it is much lighter than litharge; large vessels must be employed in consequence: besides, it generally contains a small quantity of acetate or sub-acetate of lead, and about 5 per cent. of metallic lead separates from it when it fuses, which is, in some cases, disastrous to the result of an experiment. When ceruse is employed, a certain quantity must be fused to ascertain if any metallic lead be produced;* and on the other hand, it must be examined to ascertain if it be adulterated with sulphate of baryta. When it is pure, it dissolves completely in acetic or nitric acid.†

ACTION OF OXIDE OF LEAD ON THE METALS.

The following are the results of the experiments of Berthier on the action exercised by oxide of lead on sulphur, selenium, tellurium, arsenic, and the most common of the metals. The following experiments were made in a furnace capable of producing heat enough for a copper assay.

Sulphur.—Oxide of lead is completely reduced by sulphur, with the formation of sulphurous acid, but not a trace of sulphuric acid: thus $S + 2PbO = 2Pb + SO_2$.

Selenium is dissolved by oxide of lead in all proportions; but these bodies exercise no action on each other.

Tellurium is strongly attacked and converted into telluric acid, and combines with the oxide of lead when the latter is in excess ($Te + 4PbO = 3Pb + PbO,TeO_3$). If the contrary be the case, the excess of acid is volatilized and telluret of lead produced (thus $2Te + 3PbO = Te3Pb + TeO_3$).

Arsenic.—When metallic arsenic is heated with litharge, if the latter be employed in great excess, all the arsenic is oxidated ($As + 3PbO = As_2O_3 + 3Pb$); if not, a part only is oxidized, and lead reduced: the remainder volatilizes or forms an arseniuret of lead. (For nature of reaction refer to the preceding metal, Tellurium). Mixtures of:

	1.	2.	3.
Arsenic . .	75·24	37·60	9·40
Litharge .	111·60	111·60	111·60

gave: No. 1, a lamellar metallic button, and a compact vitreous

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* Berthier.

† I have never yet met with a sample which produced metallic lead on fusion.

slag of a fine orange-colour. The fusion was accompanied by a considerable arsenical smoke.

No. 3, a semi-ductile metallic button, with a lamellar fracture, like galena, but not so blue, and a transparent vitreous orange-coloured slag.

The third, a button of lead and a deep olive-green slag, very crystalline, and in large plates. This fusion was not accompanied by smoke. It is probable that arsenious acid is formed in these reactions: the last slag contained about a fifth of its weight.

Lead reduces, in part, arsenious acid; in the same manner, arsenic partly reduces oxide of lead.

Arsenious acid	12·40
Lead	38·80

produced in fusing a very arsenical vapour, and produced 32 parts of arseniuret of lead, which was deep grey, semi-ductile, and had a granular fracture: a fine orange-yellow vitreous arsenite of lead was also produced.

Antimony.—The two following mixtures of antimony and litharge:

	1.	2.
Antimony	10	10
Litharge	40	80

gave (No. 1), 23 parts of lead, and a compact, well-fused slag, of a topaz yellow colour, which contained rather more than one-third of its weight of protoxide of antimony ($\mathrm{Sb} + 3\mathrm{PbO} = \mathrm{SbO3} + 3\mathrm{Pb}$). The second gave 26 parts of lead, and a very fluid glass, which cooled rapidly, was opaque, and like yellow wax; it contained:

Oxide of lead	52
Protoxide of antimony	11·86

Tin.—This metal, cut into small fragments, was heated with the following quantities of litharge:

Tin	10	10	10
Litharge	37·5	80	120

The first mixture gave a slaggy substance, of dull grey colour, not well fused, with globules of lead at the lower part.

The second mixture gave 26 of lead, and a semi-fused slag, compact and opaque, the colour yellowish-grey. It contained:

Oxide of lead	52
Protoxide of tin	11·4

The third mixture produced 26.3 of lead, and a very fluid slag, which was compact, opaque, and greyish yellow, with a granular fracture ($Sn + PbO = SnO + Pb$). It contained:

Oxide of lead	97·0
Oxide of tin	11·4

Zinc.—10 parts of zinc filings and 100 of litharge were heated together; as soon as the latter softened, action commenced. A slight bubbling and flaming occasioned by the combustion of a portion of the zinc took place, and on increasing the heat the mixture fused completely. The result was a button of lead equal to 13 parts: it was pure and ductile, and a crystalline slag, like litharge, opaque and yellowish, but in small plates. This experiment proves that about one-fifth of the zinc employed is volatilized, whilst the remainder reduces the litharge ($Zn + PbO = ZnO + Pb$). The slag contains:

Oxide of lead	877
Oxide of zinc	123

Bismuth.—20 of bismuth heated with 40 of litharge, gave a ductile metallic button, tin-white, and weighing 24·3, and a crystalline slag, like litharge.

Iron.—M. Berthier heated metallic iron with litharge in the following proportions:

Iron wire	10	10
Litharge	100	160

The first mixture gave 40 of lead, and a pasty, compact, opaque slag, of a deep metallic black-colour, and very magnetic, $Fe + PbO = FeO + Pb$. There was no metallic iron, but some globules of lead were present. The slag contained about:

Oxide of lead	55·9
Oxide of iron	13·4

The second mixture gave a button of lead, weighing 46·6, and a very fluid, compact, opaque slag, with an unequal shining lustre, deep-brown, and very magnetic. The slag contained nearly:

Oxide of lead	110
Oxide of iron	13·4

Copper.—The following are the results obtained with different mixtures:

Copper	15·8	15·8	15·8	15·8	15·8
Litharge	13·9	27·9	55·8	167·4	334·8

With the first mixture a button was produced; copper-red on the exterior, grey in the interior, weighing 17 parts, and a compact, opaque, deep-red slag. It contained:

Oxide of lead	10·3
Suboxide of copper	2·4

and the button:

Copper	13·6
Lead	3·4

The button produced by the second mixture was exteriorly copper-red, and interiorly grey, spotted with red; it weighed 17·8, and the slag was compact, reddish-brown, and opaque. The slag contained:

Oxide of lead	22·3
Suboxide of copper	3·6

and the button:

Copper	12·4
Lead	5·2

The third mixture gave a button similar to the last, weighing 18, and a compact, opaque, reddish-brown slag. It contained:

Oxide of lead	49·8
Suboxide of copper	3·8

The button was composed of:

Copper	12·4
Lead	5·6

With the fourth mixture, a button weighing 25·6 was produced, and a slightly crystalline, reddish-brown slag, which contained:

Oxide of lead	151·28
Suboxide of copper	10·32

and with the fifth, a grey metallic button, weighing 23·6, and a crystalline slag in large plates, like litharge, yellowish-green and reflecting red. The analysis of the button gave:

Copper	3·6
Lead	20·0

and the slag contained:

Oxide of lead	313·28
Suboxide of copper	13·72

While on this subject, it may be as well to point out the action of the oxides of copper upon lead.

The oxide is speedily reduced to the state of suboxide by excess of lead. If the lead be not in excess, it is totally oxidised, reducing a corresponding quantity of the oxide to the minimum of oxidation.

The oxide is reduced to the metallic state by lead, but not completely, because a certain quantity is taken up by litharge. The following mixtures have been made the subject of experiment:

Metallic lead	25·9	25·9	25·9	38·8	51·8
Suboxide of copper	19·8	14·9	9·9	9·9	9·9

All of these gave an imperfect alloy of copper and lead, and a very fusible slag composed of oxide of lead and suboxide of copper. The first produced a very small globule of copper and a very fluid slag, having a much greater tendency to run through the body of a crucible than litharge. Cooled slowly, it was reddish-brown, opaque, and had a lamellar texture. It was composed of:

Oxide of lead	27·9
Suboxide of copper	17·8

The second mixture produced a button of copper weighing 4·4, and a deep reddish-brown slag composed of:

Oxide of lead	27·7
Suboxide of copper	8·7

The button gave:

Copper	4·1
Lead	0·3

The third gave a metallic button weighing 8·8, and a deep-red, opaque slag, which contained:

Oxide of lead	24·89
Suboxide of copper	2·11

The button contained:

Copper	5·9
Lead	2·9

In the fourth and fifth mixtures, buttons weighing 21·2 and 34·8 were produced, together with slags similar to the preceding, and containing about 8 per cent. of suboxide of copper.

Silicates ($Pb,OSiO_3$) *and Borates* (PbO,BO_3) *of Lead* behave as litharge, but they oxidise less rapidly. They may be prepared by fusing together 1 part of silica, or boracic acid, with 1 part of litharge. The borates are more fusible than the silicates, but their use is attended with an inconvenience; they swell very much in fusing.

Nitrates of Potash (KO,NO_5) *and Soda* (NaO,NO_5) fuse at a temperature below redness without alteration, but when heated more strongly, they lose oxygen and become nitrites. If silica be present, they are still further decomposed. The action of these salts is very energetic, because they have a great tendency to decompose, and because they contain a large quantity of oxygen. They are used as oxidising agents in the purification of the noble metals, and for preparing black, and some other fluxes. They ought always to be employed in a state of purity.

Nitrate of Lead (PbO,NO_5), acts much in the same way as the two last mentioned salts. It is prepared by dissolving litharge in nitric acid, and crystallizing the solution.

Peroxide of Manganese (MnO_2), is easily reduced to the state of protoxide by many metals, and is a very powerful oxidising agent: thus with lead, ($Pb + MnO_2 = PbO + MnO$); but is rarely employed, because all its compounds are very infusible. It is employed occasionally in the purification of gold and silver. It is found in great quantity in Devonshire.

Oxide of Copper (CuO), is not employed as a flux, but is often contained in substances submitted to assay; it then acts as an oxidising agent. A great number of metals, even silver, reduce it to the minimum of oxidation (thus $Ag + 2CuO = AgO + Cu_2O$): and other metals, as iron, for instance, totally reduce it, (thus $Fe + CuO = FeO + Cu$).

Peroxide of Iron (Fe_2O_3).—This, like oxide of copper, sometimes acts accidentally as an oxidising agent.

The Caustic Alkalies are Potash (KO,HO) and Soda (NaO,HO). They fuse below a red heat, and then volatilize sensibly at a higher temperature; the vapours produced are abundant. Charcoal decomposes the water combined with potash and soda, converting the hydrate into carbonate; but an excess decomposes the carbonate, and potassium or sodium is the product. Sulphur, phosphorus, &c., separate the water from their hydrates by decomposing it.

Carbonates of Potash (KO,CO_2) *and Soda* (NaO,CO_2) are very much employed as agents in the assay by the dry way. They have the power of oxidising many metals, as iron, zinc, and tin, by the action of the carbonic acid they contain. A part of it is decomposed, with the formation of carbonic oxide, and a compound is produced made up of alkali, carbonic acid, and the metallic oxide. When fused with iron, a compact, granular, opaque body is produced, which is deep-grey and very magnetic. With zinc, a white matter is formed during the operation; a portion of the zinc volatilizes and burns off. With tin, a very fluid, compact, crystalline, wax-yellow substance is the result.

The alkaline carbonates attack neither lead, antimony, nor copper.

The Sulphates of Lead (PbO,SO_3), *Copper* (CuO,SO_3), *and Iron* (FeO,SO_3).—These three salts oxidise the greater part of the metals, even silver, (thus $PbO,SO_3 + Pb = 2PbO + SO_2$). It is the sulphuric acid which oxidises, giving off sulphurous acid. They are used in certain processes in the assay of gold.

Sulphate of Soda (NaO,SO_3) is not used by itself as a re-agent, but is often a product in many operations; it is either formed in the course of an assay, or because some of the bodies employed contain it. On account of the great affinity of soda for sulphuric acid it only oxidises those metals which combine with that element readily; as iron and zinc, for example.

DESULPHURISING RE-AGENTS.

1. The oxygen of the atmosphere.
2. Charcoal.
3. Metallic iron.
4. Litharge.
5. The caustic alkalies.

6. The alkaline carbonates.
7. Nitre.
8. Carbonate of lead.
9. Sulphate of lead.

The Oxygen of the Atmosphere (O) acts as a desulphurising agent in roasting, combining with the sulphur present, forming sulphurous ($2FeS_2+11O=Fe_2O_3+4SO_2$) or sulphuric ($CuS+4O=CuO,SO_3$) acids, sometimes both.

Charcoal decomposes many sulphurets by taking their sulphur to form sulphuret of carbon. It acts in this manner with the sulphurets of mercury, antimony, and zinc ($2ZnS+C=2Zn+CS_2$). Nevertheless, it is only employed as an auxiliary to the desulphurising power of the alkalies and their carbonates.

Iron separates sulphur from lead ($PbS+Fe=Pb+FeS$), silver, mercury, bismuth, zinc, antimony and tin, but only partially decomposes the sulphuret of copper. It is generally used in the state of filings, or nails; the latter are preferable, and ought to be kept free from rust. Oxide of iron may be used if it be mixed with the requisite quantity of charcoal to reduce it. Cast iron must not be employed, as it has very little affinity for sulphur.

Litharge (PbO) exercises a very energetic action on the sulphurets, even at a low temperature. If it be employed in sufficient proportion, the sulphuret acted on is wholly decomposed. The sulphur is often disengaged as sulphurous acid, and the metal remains alloyed with the lead proceeding from the reduction of a portion of the litharge, or combines as oxide with that portion of the litharge which is not reduced. The quantity of litharge requisite for the decomposition of a sulphuret is considerable, and varies according to its nature; some sulphurets require 34 times their weight. When less than the requisite quantity is used, only a portion of the sulphuret is decomposed, and a corresponding quantity only of lead reduced, whilst the remainder of the sulphuret forms, with the litharge and the metallic oxide which can be produced, a compound belonging to the class of oxi-sulphurets, which is generally very fusible. Oxide of lead and the sulphurets are so strongly united in this class of compounds, that galena, which is so readily attacked by pure litharge, cannot separate the least portion of lead from an oxi-sulphuret when the latter is saturated with sulphur; and it may even be introduced into such compounds without undergoing any alteration.

Many oxides, by combining with the oxide of lead, much diminish its decomposing action on the sulphurets. When litharge is heated with sulphur, its decomposing action is limited by the chemical affinity of that portion of sulphur which combines with it, and by the affinity of the metallic oxide resulting from the partial decomposition of the sulphuret. But by the addition of a suitable quantity of litharge, the sulphuret which it contains will be wholly decomposed.

When the sulphurets have a very strong base, as an alkali or alkaline earth, no sulphurous acid is given off by the action of litharge, but all the sulphur is converted into sulphuric acid.

Litharge is a very valuable re-agent, and its use is nearly exclusively confined to the assay of sulphurets containing the noble metals: as in the estimation of such metals they are obtained as alloys of lead, which are afterwards assayed by cupellation.

The following is an account of the behaviour of this re-agent with the ordinary sulphurets.

Sulphuret of Manganese requires at least six times its weight of litharge to produce a fusible compound, and thirty times its weight to desulphurise it completely The sulphur and metal oxidize simultaneously ($MnS + 3PbO = MnO + SO_2 + 3Pb$), and a protoxide of manganese is formed, which partly peroxidizes, taking a brownish tint in contact with the atmosphere. Berthier assayed the four following mixtures:

Sulphuret of manganese . .	5	5	5	5
Litharge	20	30	100	150

The first produced an infusible, greyish-black, scoriform mass, in which small plates, having the look of galena, could be discovered. It is composed of the sulphurets and oxides of manganese and lead. Much sulphurous acid is given off during the operation.

The second fused to a soft paste, and gave 17·5 of lead, and a compact, vitreous, opaque slag, of a very deep brown colour. The slag contained about half its weight of sulphuret of manganese.

The third fused readily, and produced 31·5 of ductile lead, and a transparent, vitreous slag, of a deep hyacinth red.

The fourth produced 33·7 of lead, exceedingly ductile, and the desulphurisation was complete.

Sulphuret of Iron.—Thirty parts of litharge are sufficient to scorify protosulphuret of iron; the metal is converted merely into the protoxide ($FeS + 3PbO = FeO + SO_2 + 3Pb$).

The four following mixtures:

Protosulphuret of iron	10	10	10	10
Litharge	60	125	250	300

gave, from the first a pasty, scoriform mass, colour metallic grey, and very magnetic. It was composed of the sulphurets and protoxides of iron and lead.

The second, a very fluid metallic black slag, very magnetic, opaque and possessing great lustre, and 36 of lead.

The third, a compact, vitreous, transparent slag, of a fine resin-red, and 67 of lead.

And the last, a similar slag to the former, but containing no sulphur, and 70 of lead.

When native iron pyrites was treated with the following proportions of litharge ($FeS_2 + 5PbO = FeO + 2SO_2 + 5Pb$), the results were as below indicated:

Iron pyrites	10	10	10	10	10	10
Litharge	60	125	200	300	400	500

The mixtures fused very readily, with an abundant disengagement of sulphurous acid.

The first produced only a metallic button, divisible into two parts: the lower was the largest, and was a sub-sulphuret of lead; the other looked like compact galena, but was magnetic; it was composed essentially of the sulphurets of iron and lead, but probably contained a small quantity of their oxides.

The second and third gave black, vitreous, opaque slags, which stained the crucibles brown, together with lead, having a granular fracture, and a deep-grey colour: the first button weighed 35, and the second 40. Both samples of lead were contaminated with a small quantity of slag, and contained from $\frac{8}{1000}$ths to $\frac{1}{100}$th of sulphur, and a small quantity of iron.

The slags from the three last mixtures were vitreous, transparent, and of a fine resin-red colour: the buttons of lead weighed 45·4, 54·8, and 86 parts. A much larger proportion of litharge does not produce more than 86 of lead; proving that 50 parts of litharge completely effect the desulphurisation of iron pyrites.

Sulphuret of Copper.—The following mixtures of sulphuret of copper and litharge:

Sulphuret of copper	10	10	10	10	10
Litharge	20	30	50	100	250

fuse very readily, giving off an abundance of sulphurous acid. The slags formed were compact, vitreous, opaque, or translucid, and more or less bright red. The copper which they contain is at the minimum of oxidation.

The three first mixtures gave metallic buttons, composed of uncombined lead and sulphuret of copper.

The fourth gave 28 of lead, with a little adhering sulphuret of copper.

And the fifth gave 38·5 of pure ductile lead, the exact quantity that ought to be produced from litharge by the transformation of the above quantity of sulphuret of copper into suboxide and sulphurous acid ($2CuS + 5PbO = Cu_2O + 2SO_2 + 5Pb$).

The sulphuret of copper does not combine with litharge; which is an exception to the general rule. It requires about twenty-five times its weight of litharge to decompose it completely. When litharge is combined with a certain quantity of protoxide of copper, it has no action on the sulphuret of that metal.

The desulphurisation of copper pyrites requires about 30 parts of litharge.

Copper pyrites	10	10	10	10
Litharge	50	100	200	300

In the first assay the fusion was accompanied with much ebullition, and the mass remained pasty: 6 parts of ductile lead were produced, and a matte similar to galena, but deep grey, with small facets, and a brownish-black vitreous slag.

In the second, much ebullition and swelling up took place: 35 of lead, 45 of matte, and a deep brown vitreous slag, were produced.

In the third assay, 49 of lead was the result. It was covered by a thin layer of matte, and a very shining, deep brown, vitreous, translucid slag.

The last mixture fused readily, almost without ebullition, and gave 72 of lead, and a compact shining slag, of a bright grey, and without the least trace of matte; the desulphurisation was complete ($CuS,FeS + 6PbO = CuO + FeO + 2SO_2$).

Sulphuret of Antimony has a great tendency to combine with litharge, and it must be heated with at least 25 parts to effect its desulphurisation. By mixing these two substances in the following proportion:

Sulphuret of antimony . .	10	10	10	10	10
Litharge	38	60	100	140	250

the three first mixtures afforded very fluid slags, compact, deep black, and slightly metallic, and buttons of ductile lead, weighing 2, 9, and 26 parts. These slags resembled the black litharge produced at the commencement of a cupellation.

The fourth mixture gave a transparent compact slag, vitreous and shining, having a splendid hyacinth-red colour, and 50 of lead.

The last produced 57 of lead, proving the desulphurisation to be complete ($SbS_3 + 9PbO = SbO_3 + 3SO_2 + 9Pb$). The antimony, in this case, exists as protoxide in the slag.

M. Fournet has observed that the sulphuret of antimony has the property of carrying sulphuret of copper, and even sulphuret of silver, into the compounds formed with litharge. In one of the experiments made, a double sulphuret, composed of sulphuret of silver and sulphuret of antimony in equal parts, was fused with three times its weight of litharge, and gave, firstly, a button of lead, mixed with silver; secondly, a matte-like galena; and thirdly, a black slag. This slag was analysed, and found to contain from 8 to 9 per cent. of silver.

It is probable that all the sulphurets, having a strong tendency to combine with oxide of lead, have, like sulphuret of antimony, the property of determining the scorification of a certain quantity of sulphuret of silver, like all the sulphurets, which in a state of purity are completely decomposed by oxide of lead.

Sulphuret of Zinc must be fused with twenty-five times its weight of litharge to be decomposed. Thus:

Blende . . .	24·08	12·08	10	10
Litharge . . .	55·78	83·68	100	250

However strongly the first mixture was heated, it always remained pasty; 29·2 of a greyish-black lead were produced, which contained ·018 of sulphur and ·008 of zinc. The button was covered by a metallic-looking black substance, intermediate between a matte and a slag: it was composed of the sulphurets and oxides of zinc and lead.

The second mixture gave 35·5 of lead and a fluid slag, which was compact, opaque, and black.

The third gave 43 of lead, and a deep grey slag.

The last produced 65 of pure lead ($ZnS + 3PbO = ZnO + SO_2 + 3Pb$), and a vitreous slag, of an olive-colour, and translucid on the edges.

Sulphuret of Lead.—Galena and litharge, at a heat just sufficient to fuse them, combine and form an oxi-sulphuret; but if the temperature be increased, the two bodies re-act on each other, and are mutually decomposed ($PbS+2PbO=3Pb+SO_2$). If 2789 parts of litharge be employed to 1496 of lead, or 1865 of litharge to 1000 of galena, nothing but pure lead is obtained. If more litharge be employed, a portion is not decomposed, and covers the lead. If less be employed, the galena is not completely decomposed, and the lead is covered by a matte of sub-sulphuret.

But when litharge is combined with a certain proportion of sulphurets or metallic oxides, it completely loses its oxidising power on galena, even at a white heat; so that it can be combined with this substance as with the other sulphurets, without effecting its total decomposition.

The Caustic Alkalies and their Carbonates.—All the sulphurets are decomposed by caustic alkalies, and by their carbonates also; but in the latter case carbonaceous matter must be present. In the absence of charcoal, there are some sulphurets, as of copper, on which they have no action. In these decomposition salkaline sulphurets are formed, and combine with and retain a certain quantity of the sulphuret submitted to experiment. The proportion of the sulphuret which remains in combination with the alkaline sulphurets depends on many circumstances. It is always less when a large proportion of alkali or carbonate has been employed, as it is also when a high degree of temperature has been employed; and the presence of charcoal always much diminishes the proportion. When the radical of a sulphuret is a very volatile metal, as mercury or zinc, the decomposition may be perfect.

The reduction of that portion of alkali to the metallic state which combines with the sulphur, is brought about either by the action of a portion of the sulphur of the metallic sulphuret, when the metal is but slightly oxidizable, and then sulphuric acid is formed, which remains as a sulphate in the slag, or by the action of the metal itself when very oxidizable: the addition of charcoal always prevents the acidification of the sulphur and the oxidation of the metal; it is, then, the charcoal which reduces the alkali. When the metal of the sulphuret is readily oxidised, that portion which separates from the sulphur is completely oxidised, because it combines with the oxygen of the alkali and the carbonic acid: this occurs with the sulphuret of iron; but when the metal cannot decompose carbonic acid, a part is always obtained in the metallic state, even when no sulphuric acid is formed during the operation: this takes place with the sulphuret of antimony.

Pearlash and native soda act more powerfully on sulphurets than the carbonate of potash obtained with nitre and charcoal, or the artificial carbonate of soda, because they always contain a part of the alkali in the caustic state.

Nitre, Saltpetre, Nitrate of Potash (KO,NO_5), has a very powerful action on the sulphurets: in fact, if not modified by the addition of some inert substance, as an alkaline carbonate or sulphate, explosion may take place, and a portion of the contents of the crucible be thrown out. Where an excess of nitre is used, all the sulphur is converted into sulphuric acid, and every metal but gold and silver oxidised ($PbS + KO,NO_5 = PbO + KO,SO_3 + N + O$). When only the exact quantity of nitre is employed, that is to say, just as much as is sufficient to burn all the sulphur in the sulphurets of those metals which are not very oxidisable, as those of copper, silver, and lead ($5PbS + 3KO,NO_5 = 5Pb + 5SO_3 + 3KO + 3N$), the metal is obtained in a state of purity, and the whole of the sulphur converted into sulphuric acid; but with the sulphurets of the very oxidizable metals, the oxygen of the nitre is divided between the sulphur and the metal.

Nitrate of Lead (PbO,NO_5) possesses the combined properties of nitre and litharge. It is not much used.

Sulphate of Lead (PbO,SO_3) is not used as a re-agent, but is often formed in the assay of lead ores. It decomposes the sulphuret of lead by burning the sulphur ($PbO,SO_3 + 2PbS = 3Pb + 2SO_2$). It acts on many other sulphurets in a similar manner.

SULPHURISING AGENTS.

1. Sulphur.
2. Cinnabar, or sulphuret of mercury.
3. Galena.
4. Sulphuret of antimony.
5. Iron pyrites.
6. The alkaline persulphurets.

Sulphur (S) fuses at 226°, and at 284° is very liquid. It has very powerful affinities, combines with all the gases excepting nitrogen, and with the greater part of the metals. That kind generally known as flour of sulphur ought to be employed; and, before use, the presence or absence of earthy matters ought to be ascertained, by burning a portion.

It is principally used in the preparation of the alkaline sulphurets, and in the assay of some of the noble metals.

Cinnabar (HgS) is decomposed by many of the metals, and it is better for use as a sulphurising agent than sulphur itself, as it is less volatile.

Galena (PbS).—Many of the metals, as iron, copper, &c., separate sulphur from lead, while some others, as silver, gold, &c., do not; so that if galena be heated with an alloy of various metals, some of which decompose it, and some do not, the former are transformed into sulphurets, and the latter combine with the metallic lead which is produced. It is often employed for this purpose. It is a common ore, and readily procured. The samples employed must contain no sulphuret of antimony, and all the matrix must be carefully separated by sifting and washing.

Sulphuret of Antimony (SbS_3) yields its sulphur to many of the metals, but it is only used in the separation of gold from silver, &c. In this operation the sulphur combines with the alloyed metals, and the antimony with the gold, for which it has much affinity.

Iron Pyrites (FeS_2) is a persulphuret which loses half its sulphur at a white heat. It is much employed in metallurgical operations, but not in assaying.

The Alkaline Sulphurets can support a tolerably elevated temperature without losing sulphur, but they have a great tendency to do so, to which their sulphurising power is due. By their means every metal can be made to combine with sulphur. When an alkaline persulphuret is heated with a metal, or an oxide of a metal mixed with charcoal, a fused compound, a mixture of the sulphuret of the metal and an alkaline sulphuret, is obtained.

When they are in combination, they are held together by very feeble affinities, and their decomposition is generally effected by the mere action of water, which dissolves the alkaline sulphuret and leaves the other perfectly pure. But with gold, molybdenum, tungstenum, antimony, &c., the compound is stable and soluble in water; and it is from this fact that the alkaline sulphurets are sometimes employed in the assay of auriferous substances.

In order to effect a sulphurisation by means of the alkaline sulphurets, it is much better to use equivalent mixtures of sulphur and alkaline carbonates than to prepare them beforehand. To obtain persulphuret of potassium, 46 parts of carbonate of potash, and 54 of flour of sulphur, must be employed; and for persulphuret of sodium, 40 parts of fused carbonate of soda and 60 parts of sulphur.

When the mixture is fused in a plain crucible, sulphate of potash, or sulphate of soda, is formed, because part of the alkali is reduced to the metallic state by its affinity for the sulphur, giving up its oxygen to a portion of the sulphur, which becomes sulphuric acid; but when lined crucibles are used, the carbon combines with the oxygen of the alkali, and not a trace of sulphate is produced.

FLUXES.

Fluxes are used for the purpose of causing fusion, as their name indicates, and are employed for the following reasons:—

1stly. To cause the fusion of a body, either difficultly fusible, or infusible by itself.

2dly. To fuse foreign substances mixed with a metal, in order to separate the latter by its difference of specific gravity.

3dly. To destroy a compound into which an oxide enters, and which prevents the oxide being reduced by charcoal. Silicate of zinc, for instance, yields no metallic zinc with charcoal, unless it be mixed with a flux capable of combining with the silica.

4thly. To prevent the formation of certain alloys, and consequently the combination of some metals with others, as in the case of a mixture of the oxides of manganese and iron with a suitable flux, the iron is obtained in a state of purity, whereas if no flux had been added an alloy would have been obtained. Gold and silver can be separated from many other metals by means of a flux.

5thly. To scorify some of the metals contained in the substance to be assayed, and obtain the others alloyed with a metal contained in the flux, as gold or silver with lead.

6thly. And lastly, a flux may be employed to obtain a single button of metal, which otherwise would be obtained in globules.

Fluxes are divided into non-metallic and metallic; and the non-metallic fluxes are—

1. Silica.
2. Lime.
3. Magnesia.
4. Alumina.
5. Silicates of lime and alumina.

6. Glass.
7. Boracic acid.
8. Borax (biborate of soda).
9. Fluor-spar (fluoride of calcium).
10. Carbonate of potash.
11. Carbonate of soda.
12. Nitre (nitrate of potash).
13. Common salt (chloride of sodium).
14. Black flux and its equivalents.
15. Argol (bitartrate of potash).
16. Salt of sorrel (binoxalate of potash).
17. Soap.

The metallic fluxes are—

18. Litharge (oxide of lead) and ceruse (carbonate of lead).
19. Glass of lead (silicate of lead).
20. Sulphate of lead.
21. Oxide of copper.
22. Oxides of iron.

Silica (SiO_3) is employed frequently to cause the fusion of some gangues in assays made at an elevated temperature. Silica combines with all the bases, and forms with them bodies termed silicates, which are more or less fusible.

Lime (CaO), *Magnesia* (MgO), *and Alumina* (Al_2O_3).—It is known that no simple silicate is readily fusible, so that lime, magnesia, or alumina are employed, according to circumstances, to reduce a simple silicate to such a condition that it will readily fuse in an assay furnace. Sometimes, to attain this end, it is requisite to use all the above-mentioned earths.

Glass is a very useful flux in certain iron assays. The kind employed must contain no lead.

Boracic Acid (BO_3).—The native boracic acid, after fusion and pulverisation, is to be employed whenever the use of this acid is indicated. It ought to be kept in well-stopped bottles.

Boracic acid has the property of forming with silica, and all the bases, very fusible compounds, and is, from this cause, a very universal flux. Nevertheless, there is an inconvenience attached to its use: it is very volatile, so that sometimes the greater part employed in an assay sublimes before it has had time to perform its office.

Borax (*Biborate of Soda*, $NaO,2BO_3+10HO$) is an excellent and nearly universal flux, because it has the property of forming, like boracic acid, fusible compounds with silica and nearly all the bases, and is preferable to that acid because it is much less volatile.

It may be used at a high or a low temperature. In the first case it is employed in the assay of gold and silver, because it fuses and combines with most metallic oxides, or in obtaining a *regulus*,—that is to say, to separate the metals, their arseniurets, and sulphurets, from any stony matter with which they may be mixed; because this salt is neither oxidising nor desulphurising. In the second case, it is employed in the assay of iron and tin ores, as in the presence of charcoal it retains but traces of their oxides, and, indeed, much less than generally remains with the silicates.

When borax is heated, it fuses in its water of crystallisation, and undergoes an enormous increase of volume; at a higher temperature, it fuses, and forms a transparent glass, which becomes dull on the surface by exposure to air. Only the fused vitrified borax ought to be used in assays. It must be reduced to powder, and kept in well-closed vessels.

Fluor-spar (*Fluoride of Calcium*, CaF), is rarely employed in assays, but in certain cases is an excellent flux; as will be hereafter shewn.

Carbonate of Potash (KO,CO_2) *and Carbonate of Soda* (NaO,CO_2).—It has been already proved that they possess oxidising and desulphurising power: they will now be considered as fluxes.

They are decomposed in the dry way by silica and the silicates, with the separation of carbonic acid ($KO,CO_2 + SiO_3 = KO,SiO_3 + CO_2$). The presence of charcoal much facilitates this decomposition.

They form fusible compounds with the greater part of the metallic oxides. In these combinations the oxide replaces a certain quantity of carbonic acid; but these compounds are not stable,—they are decomposed by carbon, which reduces the oxide, or by water, which dissolves the alkali.

On account of their great fusibility, the alkaline carbonates can retain in suspension, without losing their fluidity, a large proportion of pulverised infusible substances; as an earth, charcoal, &c.

The alkaline carbonates ought to be deprived of their water of crystallisation, for assaying purposes: in fact, it would be better to fuse them before use. They must in all cases be kept in well-stopped vessels.

They may be used indifferently, but carbonate of soda is to be preferred, as it does not deliquesce.

The alkaline carbonates of commerce always contain sulphates and chlorides. In ordinary cases this causes no inconvenience, but there are circumstances under which the presence of sulphuric acid would be injurious.

Carbonate of potash can readily be procured free from sulphate and chloride by means of nitre and charcoal, as follows:—Pulverise, roughly, 6 parts of pure nitre, and mix them with 1 part of charcoal; then project the mixture, spoonful by spoonful, into a red-hot iron crucible. The projection of each spoonful is accompanied by a vivid deflagration, and carbonate of potash is found in a fused state at the bottom of the crucible. It must be pulverised, separated from excess of charcoal, and kept in a dry state for use.

Carbonate of soda may be obtained in much the same way, substituting nitrate of soda for nitrate of potash, or by repeatedly crystallising the carbonate of commerce.

Nitrate of Potash (KO,NO_5).—Its properties have already been pointed out. The presence of silica or silicates much assists its decomposition.

Common Salt (*Chloride of Sodium*, $NaCl$), was much recommended by the older assayers, either mixed with flux, or a certain quantity placed above it, for the purpose of preserving the substance beneath from the action of the atmosphere, or to ameliorate the action of such bodies as cause much ebullition. It is very useful in lead assays. When it is used, it must be previously pounded, and heated to dull redness in a crucible, to prevent its decrepitation.

Black Flux and its Equivalents ($KO,CO_2 + C^n$).—Black flux is both a reducing and fusing agent. It is a mixture of carbonate of potash and charcoal in a minute state of division. It is much employed, and very serviceable. It is prepared by mixing 2 parts of argol with 1 part of nitre, placing the mixture in an iron vessel, and setting it on fire by a burning coal, or red-hot rod. When the combustion is finished, the substance is pulverised, sifted whilst yet hot, and kept in well-stopped jars, as it rapidly absorbs moisture from the atmosphere.

Black flux is much used in lead and copper assays; but as it boils up greatly at the commencement of the operation, the crucible must not be more than two-thirds full.

It can be readily imagined that, as it fuses and reduces at the same time, the relative proportions of alkaline carbonate and charcoal, ought to vary according to the nature of the substance acted upon; and it is often expedient to employ the greatest possible proportion of alkali to obtain the largest yield of metal. Black flux may be obtained richer in carbon by mixing 1 part of nitre with $2\frac{1}{2}$ or 3 parts of argol.

Common black flux contains 5 per cent. of charcoal. The flux prepared with $2\frac{1}{2}$ of tartar or argol to 1 of nitre contains 8 per cent., and that with 3 contains 12 per cent. of charcoal.

Black flux can be replaced by anhydrous or dry carbonate of soda, mixed with some reducing agent. When charcoal is employed it must be reduced to a very fine powder: in fact, it ought to be levigated. Lamp black is, however, the best form of carbon.

The three following fluxes are very useful:—

Carbonate of soda	94	88	816
Charcoal	6	12	184

The second is very nearly equivalent to sodium and carbonic acid, and the third to sodium and carbonic oxide; but it must be observed, that whatever precautions be taken, these mixtures never become so liquid as black flux, because the charcoal tends very much to separate and rise to the surface.

Instead of charcoal, it is preferable to use sugar or starch to make a flux equivalent to black flux with carbonate of soda: the mixture must be made most intimately.

Cream of tartar, carbonised by a semi-combustion until it is reduced to half its weight, is a very good substitute for black flux: it contains about 10 per cent. of charcoal.

Argol, Cream of Tartar, Bitartrate of Potash $(KO\,\bar{T}, HO\,\bar{T})$. —When bitartrate of potash is heated in a covered crucible, a rapid decomposition takes place, accompanied by a disengagement of inflammable gases: the substance agglomerates, but without fusing or boiling up. The residue is black, blebby, and friable, and contains 15 per cent. of carbon when produced from rough tartar or argol, and 7 per cent. from cream of tartar.

These re-agents produce the same effects as black flux, and possess more reducing power, because they contain more combustible matter: but this is an inconvenience, for the excess prevents their entering into full fusion when the substance to be assayed requires but a small proportion of a reducing agent. They can be used with success in assays requiring much carbonaceous matter.

Salt of Sorrel, Binoxalate of Potash $(KO\,\bar{O}, HO\,\bar{O})$, when heated, is decomposed. It decrepitates feebly, and during its decomposition is covered with a blue flame; it at first softens, and when fully fused is wholly converted into carbonate. When the oxalate is very pure, the resulting carbonate is perfectly white, and free from charcoal; but very often it is spotted with blackish marks. It has no very great reducing power.

White, or Mottled Soap, is a compound of soda with a fat acid. When heated in closed vessels it fuses, boiling up considerably, and during its decomposition gives off smoke and combustible gases, and leaves a residue composed of carbonate of soda with about 5 per cent. of charcoal. Of all reducing agents, soap absorbs the greatest quantity of oxygen; and, as the residue of its decomposition by heat affords but little charcoal, it has the property of forming very fluid slags. Nevertheless, it is rarely employed, because certain inconveniences outweigh its advantages. These inconveniences are, its bubbling up, and its extreme lightness. It also requires to be rasped, in order to mix it perfectly with the substances it is to decompose, and it then occupies a very large volume, and requires correspondingly large crucibles. There are, nevertheless, cases where it may be used with advantage by mixing it with other fluxes.

Reducing Power of the various Fluxes.—By fusing each of the above-mentioned reducing fluxes with an excess of litharge, the same weight of each yielded the following quantities of lead :—

Common black flux, made with 2 parts of tartar		1·40
Ditto, with 2½ of tartar		1·90
Ditto, with 3 of tartar		3·80
Carbonate of soda	94	1·80
Charcoal	6	
Carbonate of soda	88	3 60
Charcoal	12	
Carbonate of soda	90	1·40
Sugar	10	
Carbonate of soda	80	2·80
Sugar	20	
Carbonate of soda	90	1·15
Starch	10	
Carbonate of soda	80	2·30
Starch	20	
Crude tartar, Argol		5·60
Cream of tartar		4·50
Ditto, ditto, carbonised		3·10
Ditto, ditto, calcined		2·20
Binoxalate of potash		·90
White soda soap		16·00

By mixing rasped soap with binoxalate of potash or carbonate of soda, excellent reducing fluxes may be made:—

Salt of sorrel	85	3·25
Soap	15	
Carbonate of soda	85	2·40
Soap	15	

All the fluxes containing alkaline and carbonaceous substances are reducing and desulphurising; besides acting as fluxes, properly so called. They also produce another effect which it is useful to know, viz. they have the property of introducing a certain quantity of potassium or sodium into the reduced metal. This was first pointed out by M. Vauquelin.[*] He found that when oxide of antimony, bismuth, or lead, was fused with an excess of tartar, the metals obtained possessed some peculiar characters, which they owed to the presence of several per cents of potassium.

METALLIC FLUXES. *Litharge* (PbO) *and Ceruse* (PbO,CO_2).—These bodies always act as fluxes, but at the same time often produce an alloy with the metal contained in the ore to be assayed. Ceruse produces the same fluxing effect as litharge. The former is the better flux, and is very useful in a great number of assays.

Glass of Lead (*Silicate of Lead*, PbO,SiO_3).—The silicates of lead are preferable to litharge in the treatment of substances containing no silica, or which contain earths or oxides not capable of forming a compound with oxide of lead, excepting by the aid of silica. It may be made by fusing 1 part of sand with 4 parts of litharge: if required more fusible, a larger proportion of litharge must be added.

Borate of Lead (PbO,BO_3).—The borates of lead are better fluxes than the silicates when the substance to be assayed contains free earths; but in order to prevent them swelling up much when fused, they must contain an excess of oxide of lead. The borate of lead containing 90·56 of oxide of lead and 9·44 of boracic acid, is very good. Instead of borate of lead, a mixture of fused borax and litharge may be employed; it is equally serviceable.

Sulphate of Lead (PbO,SO_3) is decomposed by all siliceous matters, and by lime, so that when these substances are present litharge is produced, which fluxes them.

Oxide of Copper (CuO) is rarely used as a flux for oxidised

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[*] Annales des Mines.

matters, but is sometimes employed in the assays of gold and zinc, to form an alloy with those metals. In this case a reducing flux must be mixed with the oxide. Metallic copper may be used, but is not so useful, as it cannot be so intimately mixed with the assay.

Oxides of Iron (FeO and Fe_2O_3) are good fluxes for silica and the silicates. They are, however, rarely employed for that purpose; they are more often used to introduce metallic iron into an alloy to collect an infusible, or nearly infusible metal, by alloying it with iron; such as manganese, tungstenum, or molybdenum.

CHAPTER VII.

ON THE BLOW-PIPE AND ITS USE—DISCRIMINATION OF MINERALS, &C.

Notwithstanding the able works already written on this portion of my subject, I should think the present deficient were I not to give a short account of the blow-pipe, its method of use, &c. I am the more inclined to do this, from the fact that the instrument to be presently considered is of much importance to the mineral analyst (saving him, in some cases, days of needless labour); that these pages would not be that which they were intended, viz. a complete Guide to Practical Assaying, without giving short rules for its use. Having premised thus much, I hope my readers will excuse me carrying them over matter so well and ably treated by many others.

The blow-pipe formerly was only used by jewellers and workers of metal for producing sufficient heat for soldering certain small portions of their work; and it was only about the year 1738, that Anton Swab applied it to the analysis of mineral substances. Cronstedt used the blow-pipe to ascertain the difference between various mineral substances as to fusibility, &c. In 1765, Von Engestrom published Cronstedt's System of Mineralogy, and added to it a Treatise on the Blow-pipe, in which he pointed out the processes of Cronstedt.

This work attracted the attention of philosophers to this valuable instrument, and its use became more general. Bergman, after Cronstedt, extended the use of the blow-pipe beyond the bounds of mineralogy to the inorganic kingdom, and in his hands this instrument became an invaluable agent for the detection of minute portions of many metallic substances. Bergman treated the greater number of the minerals known in his time with the re-agents employed by Cronstedt, described their action, and improved many of the instruments necessary for their performance. In these experiments, Bergman, whose health did not permit him to carry out such a laborious work, was assisted in his mineralogical studies by Gahn, who became particularly expert in the use of the blow-pipe. The following is a very good example of the utility of this instrument in practised hands: "Ekeberg asked Gahn his opinion of the then newly discovered mineral, the oxide of tantalum, and Gahn immediately discovered that it contained tin, although it did not amount to more than 1 per cent."

Berzelius, after Gahn, was particularly famed for his skill with the blow-pipe, and for his improvements in the form of apparatus; and it is from his excellent work on this subject that the principal portion of the descriptive part of Blow-pipes, Lamps, Tongs, &c., is derived.

The common blow-pipe of gas-fitters, jewellers, &c., is a tube of brass, tapering towards one end, and curved at that extremity, which has an opening as fine as that made by the finest needle; it is this opening which is held against the flame of the lamp, and air is blown through it to increase the amount of heat. In all ordinary operations, the blast is required to be kept up not more than a minute, so that the quantity of moisture exhaled from the lungs produces no inconvenience by stopping up the tube. But in certain chemical operations this is exceedingly troublesome, as a continuous blast is required, and a large quantity of water collects in consequence; generally sufficient to mar the success of an experiment. In order to obviate this, Cronstedt placed in the centre of his blow-pipe a bulb, in which the greater part of the water collected. This form was, however, inconvenient, because if the jet of the blow-pipe were at all inclined, even for an instant, the water ran from the bulb, and filled it. There have been several methods contrived to avoid this.

Bergman overcame this defect in the following manner: he fitted to the extremity of his blow-pipe a semicircular chamber, and placed the jet in the upper part of it. The best and cheapest blow-pipe, however, I have found to be that contrived by Black (see fig. 202). The one I am in the habit of using is made of tin-plate, japanned, and is accompanied by several platinum jets, to be hereafter spoken of. Silver is the best material for the construction of a blow-pipe;

FIG. 202.

next to that, tin-plate, and lastly, brass; blow-pipes made of the latter substance soon acquire a very disagreeable odour, which they also communicate to the hands. On an emergency, a blow-pipe may be constructed with a glass tube, but owing to its frangibility and fusibility it is not to be recommended.

Many persons have conceived that the process of using the blow-pipe by blowing in the ordinary manner is a very difficult matter; and some have gone even so far as to say it is injurious. Hence, various contrivances have been made to use this instrument by other means; some have employed double bellows, others bladders, and others, again, the pressure of water; but none of these methods have afforded satisfactory results, except in the hands of the contrivers, and even in some cases the results have been very problematical; and as there is in reality nothing very difficult in acquiring the art of using the blow-pipe, and as it is in my opinion not at all injurious, and moreover, as by the ordinary method more accurate results are arrived at, the matter of the various blowing machines will not be further discussed, but the necessary description of fuel now spoken of.

Any kind of flame may be used for the blow-pipe, provided it be not too small; a candle, a lamp, or gas, may be employed: Engestrom and Bergman used common candles in preference. Berzelius employs a lamp, which is certainly much preferable to a candle. I have occasionally employed the flame of coal gas, which answers very well, but is not so good as that of a lamp. Berzelius says on this subject, "Lamps have doubtless many advantages over candles, but are not so convenient in travelling, on account of the escape of oil. The oil employed ought to be the best olive or salad oil.

"The lamp which I use has the advantage of being portable, and closes in such a manner that no oil can escape. It is made of japanned tin-plate, and is about 4 inches long, and 1 inch wide, furnished at one end with a wick-holder, capable of being completely closed by a screw, and at the other with a ring of tin-plate, which passes over the upright end of a support. It may be mentioned, that the screw-cap is furnished with a leather washer, by the aid of which it can be rendered much tighter, and the escape of oil entirely prevented."

Sometimes a spirit-lamp is employed in assays by the blow-pipe, particularly when glass tubes are employed, as in the detection of volatile substances. In these cases they are much more convenient; as an oil lamp, in the first place, blackens the tube; and secondly; does not yield a sufficiency of heat, excepting when the blow-pipe blast is employed; then the flame has more intensity than that produced by a spirit-lamp urged by the same means.

It is very difficult to give in writing a method whereby a student may acquire the practice of using the blow-pipe: that given by Faraday,* is perhaps the clearest and most concise. It is as follows: "The practice necessary, in the first place, is that of making the mouth replace the lungs for a short time, by using no other air for the blow-pipe than that contained in it." This practice is simple in itself, and easy to acquire, but as before stated, difficult to describe. Let the student first observe, that it is easy after having closed the lips to fill the mouth with air, and to retain it so, at the same time that respiration may be carried on; and if, while the mouth is in this state, a blow-pipe be introduced between the lips, it will be found that the small quantity of air which its jet allows to pass through it, will be amply supplied for ten or fifteen seconds by the quantity contained in the mouth; and this being repeated a few times, a ready facility for using the blow-pipe, independent of the lungs, will be acquired.

This step being taken, the next is to combine this process with the ordinary one of propelling air directly from the lungs through the mouth, in such a way that when the action of the lungs is suspended during inspiration, the blast may be continued by the action of the mouth itself, from the air contained within it. The time of fourteen or fifteen seconds, during which the mouth can supply air independently of the lungs, is far more than that required for one or even many more inspirations; and all that is required to acquire the necessary habit is the power of opening and closing the communication between the mouth and the lungs, and between the air and the lungs, at pleasure.

The capability of closing the passages to the nostrils is very readily proved: every one possesses and uses it when he blows from the mouth, and that of closing or opening the mouth to the lungs

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* Chemical Manipulation.

may be acquired with equal readiness. Applying the blow-pipe to the lips as before, use the air in the mouth to produce a current, and when it is about half expended, open the lungs to the mouth, so as to replace the air which has passed through the blow-pipe; again cut off the supply, as at first, but continue to send a current through the instrument, and when the second mouthful of air is gone, renew it as before from the lungs.

To some this may be difficult; but if the preceding instructions be followed and persevered in for a short time, a continuous blast may be kept up from ten minutes to a quarter of an hour, without any other inconvenience than the mere lassitude of the lips, caused by compressing the mouthpiece of the instrument.

After having conquered the difficulty of keeping up a continuous blast, the student must learn how to attain the maximum of heat with the least exertion to himself. The chief points to be observed are, neither to blow too fiercely nor too gently; in the first case, the force of the blast would carry away heat by the quantity of cold air thrown into the flame, and in the second, a sufficient amount of heat would not be obtained; because a less amount of air would pass into the flame than that required for perfect combustion.

The highest degree of temperature is required in testing the fusibility of many bodies, as also in the reduction of certain oxides; as those of iron, tin, &c. We have yet another class of phenomena to describe, which do not essentially depend on a high temperature; these are the processes of *reduction* and *oxidation*. In order to explain and point out the best methods of effecting these two objects, it will be necessary to enter somewhat into the nature of flame; this will be done as briefly as is consistent with perspicuity. The species of flame examined will be that of a candle, as it is with a similar one to that with which the blow-pipe operator will have to experiment.

On careful examination, it will be found that the flame of a candle or lamp may be divided into four distinct portions: firstly, a deep blue ring at the base; this consists of the vapour of the combustible, which can hardly burn because it has not acquired a sufficient temperature; secondly, a dark cone in the centre; this is also the vapour, but heated intensely, not, however, in a state of combustion, on account of the absence of air; thirdly, of a very brilliant envelope, which surrounds the dark part just mentioned,—this is the partially consumed vapour at a very high temperature; the luminous property it possesses is due to the precipitation and subsequent ignition of particles of solid carbon; and fourthly, of an almost invisible envelope which surrounds the luminous portion; this is the substance of the combustible in full ignition,—it here mingles with the atmospheric oxygen, and is consumed. The highest degree of temperature in the whole flame is to be found at the point of contact between the luminous and this part. It must be particularly borne in mind that the inner portions of the flame have an excess of carbonaceous matters, and the outer an excess of oxygenated matters.

Having premised thus much, we will examine the nature of the flame of a candle when acted on by the blow-pipe blast, and ascertain how far it is altered, and what are the properties of its separate parts in relation to their oxidising and reducing powers. Supposing the lighted lamp or candle be ready and neatly snuffed, place the nozzle of the blow-pipe just in the edge of the flame, and about the sixteenth of an inch above the level of the wick: when things are in this state, blow gently and evenly through the blow-pipe, and a conical jet or dart of flame will be produced, which, when formed in a steady atmosphere, free from accidental draughts and currents, will be found to consist of two essential parts,—the inner cone, blue, small, and well defined; the outer, brownish and vague. The greatest intensity of heat is found a little beyond the apex of the blue flame; it is there, also, *reduction* takes place. It is formed of the combustible matter mixed with air, which, however, does not burn, because it is not sufficiently heated. The outer flame is formed by the complete combustion of the combustible matter of the inner; and it is there, and just beyond it, that *oxidation* takes place.

Oxidation, as before stated, takes place at the extremity of the outer flame; hence it is termed the *oxidising* flame; in it all the combustible portions are super-saturated with oxygen. In general the further the substance to be oxidised can be placed from the extremity of the flame, the better the operation proceeds, provided always that the necessary temperature be maintained. Dull redness is the best suited to oxidation.

Reduction.—In this operation the jet of the blow-pipe must be introduced into the body of the flame, so as only to produce a small dart; and a jet having a smaller hole than that used for oxidation ought to be employed. By operating thus, a more brilliant flame than the last is produced; it is the result of a less perfect combustion, and therefore contains a large amount of carbonaceous matter, fitting it more especially for the purpose of separating oxygen from all metallic bodies.

Berzelius says, "the most important point in blow-pipe assays is the power of producing *oxidation* and *reduction* at will." Oxidation is so easy, that to do it requires only to read a description of it; but reduction requires some practice, and a certain knowledge of producing various kinds of blasts. One of the best methods of exercise in this operation is to take a small grain of tin, and place it on charcoal; then direct the blow-pipe dart upon it,—it will soon fuse; and if the operator has not produced a good reducing flame, it will become covered with a crust of oxide; so that it becomes a witness against him each time this happens. The nature of the flame must be altered until, by observation, the proper kind is produced at will. The longer the button of tin is kept bright, the better and more expert the operator.

AUXILIARY APPARATUS, &c.

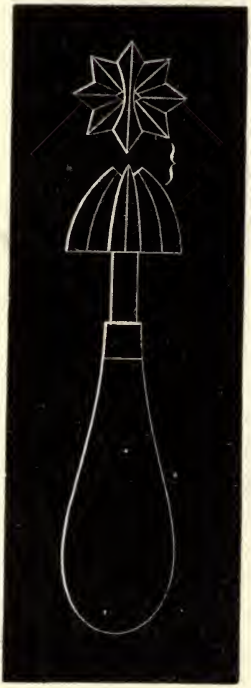
Supports.—The support is the substance destined to hold the material to be assayed whilst under the influence of heat. From this it will be seen that a solid body must necessarily be employed; it ought also to be exceedingly refractory, so as not to give way under the excessive heat; and lastly (with the exception of charcoal), ought to have no chemical action on the substances placed in contact with it. Supports may be divided into combustible and incombustible; the former is charcoal, and the latter, metal, glass, and earthenware, and in some cases certain minerals have been employed.

Well-burnt wood charcoal is the best support in most cases. Berzelius remarks that light woods make the best charcoal for blow-pipe purposes, and recommends that made from the willow. Alder forms an excellent charcoal for blow-pipe experiments.

Hard woods generally give so much ash as to render them unfit, on account of the chemical action of its contents. It is generally very ferruginous. Gahn supposed that box-wood charcoal would be best; but on trial it was found to crack very much.

It is almost needless to observe that the charcoal must be well made, because that which scintillates, smokes, or burns with flame, is worse than useless. It ought to be cut with a saw into conveniently sized pieces, and a small hole bored in them, so as to receive the sub-

FIG. 203.



stance to be assayed. Fig. 203 represents the most convenient form of apparatus for boring holes in charcoal: the upper or boring part is made of steel.

I have used a very convenient charcoal support, contrived by Mr. John J. Griffin. The following is his description* of its manufacture and properties, the latter of which I most gladly corroborate: "Several of the most important experiments performed with the blow-pipe require the assistance of charcoal, upon which the object submitted to examination is supported in the flame. The charcoal employed for this purpose should be of soft wood, well burnt, compact, and free from crevices. Such charcoal is difficult to obtain. I have several times examined a sackful of charcoal without finding above half-a-dozen sticks adapted for these experiments. This circumstance induced me to seek for a substitute, and having found one which seems likely to prove serviceable, I think it possible that other persons accustomed to operate with a blow-pipe, and accustomed also to feel the want of appropriate charcoal, may be willing to learn in what manner they can efficiently replace it. For this reason I have drawn up the following notice:

"The blow-pipe experiments that require the assistance of charcoal may be divided into two classes. In the first class may be named the formation of beads with microcosmic salt, the trial of fusibility *per se*, and the roasting of the metallic compounds that contain such volatile elements as sulphur and arsenic. The second class of experiments is restricted to the fusion of minerals or metallic compounds with carbonate of soda, or with soda and borax, for the purpose of effecting particular combinations, or of procuring their metals in a state of regulus. For these two classes of experiments I make use of two different composition supports; the first of which I call *Supports for Fusions*, and the second, *Supports for Reductions.* They are alike in appearance. Each consists of two parts, an upper

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* Proceedings of the Philosophical Society of Glasgow, April 26, 1843.

or combustible portion, and a base, or incombustible portion. The former is the proper substitute for the ordinary charcoal, the under portion acting only as a crucible in which the combustible portion is contained. I shall first describe the composition and formation of the supports, and afterwards show the way to use them.

"The incombustible portion of both supports is made of fine pipe clay and charcoal powder, mixed in equal parts by weight with as much water, slightly thickened with rice paste, as is sufficient to form a stiff plastic mass.

"The combustible portion of the *Support for Fusions* consists of:

Charcoal in fine powder . .	12 parts.
Rice flour	½ „
Water, about . . .	8 „

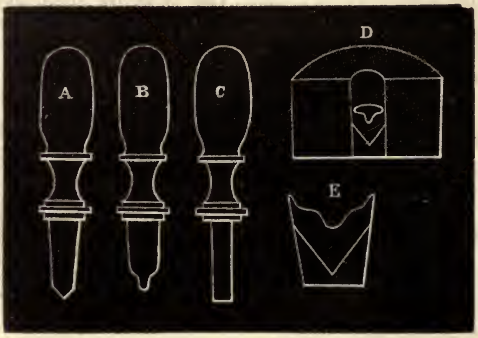
The rice is boiled in the water to form a paste, with which the charcoal is afterwards mixed into a mass of the consistency of dough.

"The upper part of the *Support for Reductions* consists of the following mixture:

Charcoal in fine powder . .	9 parts.
Carbonate of soda, crystallized .	2 „
Borax, crystallized . .	1 „
Rice flour	½ „
Water, about . . .	8 „

The water is boiled, the soda and borax are dissolved in it, and the rice is then added to form a paste, with which the charcoal is finally incorporated, and the whole well kneaded into a stiff mass. The mould (see fig. 204, D) in which these compositions are pressed to form the supports is made of boxwood.

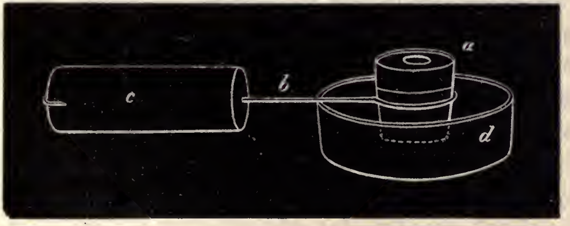
Fig. 204.



"The principal points which require attention to ensure success in this process are to have the materials in the state of a very fine powder, and the moist compositions of a proper degree of consistency. If they are too soft, the support will not quit the mould without losing its form. If too dry, the particles of the support will not cohere. The proper state is found after a few trials. It is most convenient to begin by making the mixture too soft, and then drying it slowly, till it is found to be hard enough to work easily. The composition is rolled into balls with the fingers. The moulds should be kept clean, and the forming parts of the pestle (B, fig. 204) for the charcoal composition and the ring should be oiled. The point of the pestle (A, fig. 204) for the clay composition must not be oiled, because grease prevents the adhesion of the combustible portion of clay base. The pestle C is used to remove the finished support from the mould by pressure on the clay foundation (E, fig. 204, is the finished support).

"When the support is taken from the mould it is placed in a hot plate or sand-bath to dry, after which the rough edges are taken off by a rasp. It is then ready for use. The bottoms of *Supports for Reductions* are painted with red ochre, mixed with rice paste, to distinguish them from the other kind. The size I have fixed upon is as follows: height, half an inch; diameter at top, half an inch; at bottom, two-fifths of an inch. The weight is about 16 grains, consisting of 10 grains of clay crucible, and 6 grains of combustible matter. I have tried several other sizes, but this I find to be the most generally convenient. Nevertheless, a higher temperature can be produced upon a smaller support, and I find that large masses of charcoal are not essential, since many blow-pipe experiments can be finished during the combustion of only two grains of charcoal. When in use, they are supported by a handle made of wire, turned into the form of a ring" (see fig. 205: *b* a wire passing through a cork, *c*, which serves as a handle, *d* is a small capsule. Mr. Griffin recommmends a piece of tobacco pipe for the handle of the wire support.)

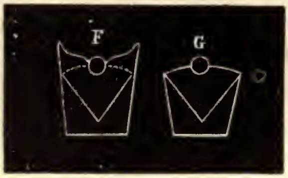
FIG. 205.



"The following is the method of using these supports:

"Firstly, the surface of one of the supports for fusion is heated before the blow-pipe till it is red hot. If then removed from the blow-pipe flame, the support continues to burn like an ordinary pastile till it is consumed down to the clay: in this respect the support has a superiority over common charcoal, which soon ceases to burn when removed from the fire. The ignited support is then to be rested on a porcelain capsule, (*d*, Fig. 205), and a quantity of microcosmic salt, sufficient to form a bead, is placed on its red hot surface. The salt instantly melts, and sinks into the central cavity, so as to form a bead (F, Fig. 206), the heat, the form, and the smoothness of the surface of the support facilitating this part of the process. The salt is then heated before the blow-pipe, till it is converted into a transparent colourless bead. The support is again placed on the porcelain capsule, and the metallic substance intended to be incorporated with the bead is added to it. The support continuing to be red hot, and the bead consequently continuing soft, the substance so added is immediately absorbed, and its loss by dispersion prevented: whereas, upon common charcoal, the fused salt solidifies soon after it is removed from the flame, and the substance added for examination, not adhering to it, is often blown away by the first blast from the blow-pipe jet. The bead is now again fused, till the substance added to it is decomposed, and the resulting glass is observed to fuse quietly. It is then ready for examination, but it is sunk in the bottom of the hollow of the support (see F, Fig. 206), and cannot be seen by transmitted light, unless the projecting sides of the support be removed. This is effected as follows: The support is placed as before on the porcelain capsule, and the operator blows with his mouth, without the blow-pipe, strongly down upon its surface. The pastile then burns away rapidly, and the force of the blast disperses the ashes, until the whole rim of the support is consumed. The bead then appears situated on the summit of a cone (see G, Fig. 206), and can be examined either by reflected or transmitted light. It is also in a position adapted for exposure to the different action of the oxidating and reducing flames, so as to have the character of the included metal fully developed. If, finally, the charcoal is allowed to burn wholly away, the coloured bead can be lifted from the ashes and preserved in a closed glass tube for subsequent examination and comparison.

FIG. 206.



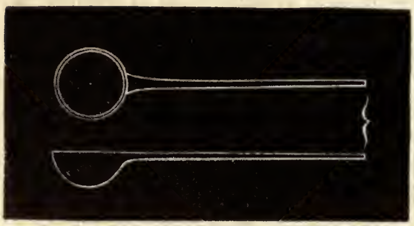
"Secondly, if the surface of one of the *Supports for Reductions* be heated before the blow-pipe, it burns at first like the simple charcoal support; but in proportion as the charcoal is consumed, the fluxes which were mixed with it, and which are not volatile, concentrate and fuse upon the surface of the residue. If, therefore, a reducible metallic compound is heated upon such a support, it becomes at once exposed to the reducing action of the high temperature, of the nascent oxide of carbon, and of the carbonate of soda, whilst any earthy matter that it may contain is vitrified by the attendant borax. For example, a crystal of sulphate of copper, as large as the surface of the support, can be decomposed upon it, and all its elements can be driven off, except the copper, which is finally obtained in a metallic bead. A globule of metallic tin, an eighth of an inch in diameter, can be kept boiling upon a support without being converted into oxide. A crystal of quartz can be fused into soda-glass. Flint-glass can be melted with metallic oxides in such quantities as to form metallic beads of enamel or coloured glass, the sixth of an inch in diameter. And these effects are producible upon a support of the weight of only 16 grains, and, during the combustion, of not more than 2 or 3 grains of charcoal."

The power of restricting the consumption of charcoal is a merit which will render these composition supports acceptable to travelling mineralogists.

Platinum.—This metal is much employed as a support in cases where charcoal would be injurious by its reducing power. It is used in three forms, viz. wire foil, and as a spoon, or small capsule.

Wire forms a support which in many cases renders the use of a foil or a spoon superfluous. It ought to be about 2½ inches long, and curved at one of its extremities, so as to form there a small circle, which is employed as a support in the following manner. After having moistened the necessary flux, place it on the curved part and fuse it in the blow-pipe dart: it will be converted into a bead, which will adhere to the curvature. The substance to be examined is then placed on the fused bead, and the whole heated together. This method of procedure is exceedingly convenient, but must not be employed where any metal is expected to be produced. This caution must be heeded in the use of all platinum vessels. To clean the wire for use after an operation, all that is necessary is to soak it in dilute hydrochloric acid, which will generally dissolve the metallic glass formed, and the wire will then be fit for a new operation. When the end of the wire has become too thin by repeated use, it must be cut off, and a new curve made. It will by this management be enabled to be used a very great number of times.

Fig. 207.



The platinum spoon (see fig. 207) and foil are used in much the same way; but as charcoal and the platinum wire answer every purpose, it will be unnecessary to describe their use further: small iron spoons of the above form are also made, and are very useful in cases where the presence of iron is not objectionable.

Cyanite and *Mica* have been employed as supports, but since platinum has been in use, they have been discarded.

Glass tubes.—In cases where it is necessary to roast a substance, in order to ascertain whether any volatile body is given off during that process, glass tubes, about 3 inches long, and the eighth of an inch in diameter, are to be recommended. They ought to be made of hard German glass, or at all events a hard glass containing no lead. In order to use them, the substance must be introduced, and placed at about an inch from one end: the tube is then to be so inclined that this end is the lowest: heat is then applied either by a spirit lamp or the blow-pipe flame, as circumstances require: if only a gentle heat be needed, the lamp is sufficient; if a stronger, the blow-pipe must be employed. Air may be made to pass over the ignited body with any degree of velocity, according to the inclination given to the tube; if it be horizontal, air is nearly excluded, and the more it is inclined to the perpendicular, the greater will be the current admitted. The nature of the volatile substances may be ascertained at the upper end of the tube by the smell, if gaseous, by the appearance if merely sublimed. This is a most useful apparatus, and, moreover, has great simplicity in construction and use to recommend it.

Closed glass tube, or matrass.—This apparatus is to be employed where the presence of air is prejudicial or not necessary; as, for instance, in experimenting on minerals, to ascertain whether they contain water or other volatile substance, or to heat such minerals as decrepitate. In cases where sulphur, for instance, is required to be sublimed, the top of the tube must be closed by the finger, so as to prevent access of air; otherwise the sulphur would burn, and become converted into a gaseous compound, viz. sulphurous acid.

Forceps are of several kinds, according to the use for which they are destined. There are forceps for holding fragments of mineral in the blow-pipe flame, for the purpose of ascertaining the comparative fusibility, &c.; this kind of forceps is furnished with platinum tips on one extremity, and steel nippers at the other, (see fig. 208); these latter are intended for breaking a fragment from a mineral or harder substance; other forceps made of steel are also very useful, (see figs. 209 and 210). These are employed for more refractory minerals, alloys, &c.

FIG. 208

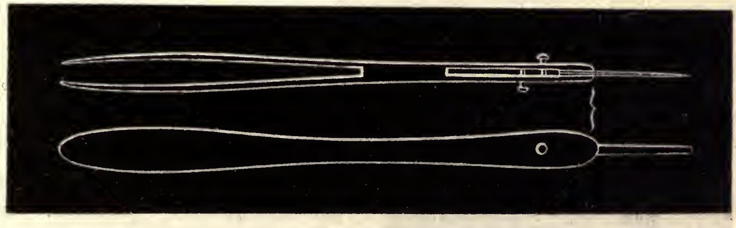


FIG. 209.

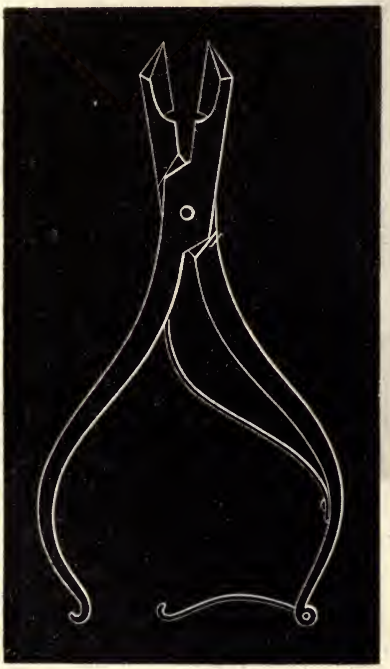
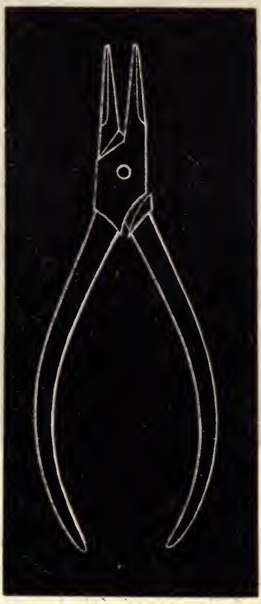


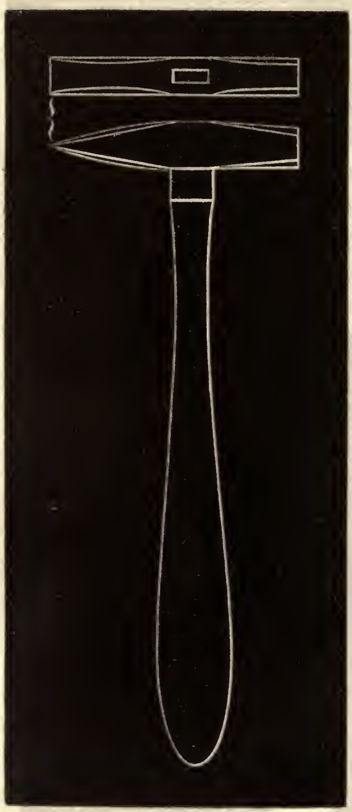
FIG. 210.



There are also forceps for trimming the lamp or candle. These are conveniently furnished with a small spoon or shovel at the opposite end: this is used for taking up small portions of fluxes or substance to be assayed.

Hammer.—This useful instrument is in constant requisition by the blow-pipe operator. Two sizes are needed; they may be of the form recommended for those employed in the ordinary course of assay, as described in the first chapter, but must be very much lighter, (see fig. 211).

FIG. 211.



Anvil.—An anvil is also requisite to flatten grains of metal, crush ore, &c. It is best made of a block of steel, about 2 inches square and ½ an inch thick, polished well on both sides. It must be kept very clean.

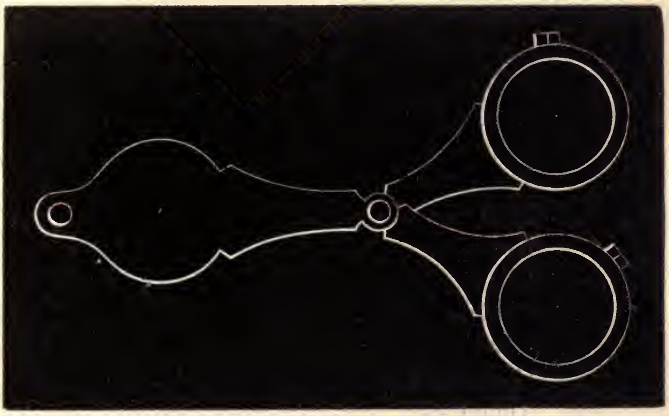
Knife.—A knife is absolutely indispensable. It is used for ascertaining the relative degree of hardness of minerals, for taking up portions of fluxes and pulverized ore in order to mix them together, cutting charcoal, and a multitude of other important operations. It ought to be made of the best steel, and have a stout sharp point, and a rather large handle, which enables it to be held firmly in the hand.

A few *files* are necessary. They ought to be of the best description; some may be triangular, others half round, and others round, of various degrees of fineness. They are useful for trying the hardness of minerals, cutting glass tubes, wires, &c.

Pestle and Mortar.—This piece of apparatus must be made of agate; it ought to be about ½ an inch deep, and 2 inches in diameter. When they are bought, the pestles are generally without handles, and they are in that state inconvenient in use; it is therefore advisable to furnish them with handles, turned from some hard wood. The mortar is used for pulverizing samples of minerals and fluxes, also for detecting traces of metal in any substance submitted to assay. They may be cleaned either by strong nitric acid, or friction with a piece of pumice stone; the latter method of procedure is generally the best in practice.

A series of stoppered, wide-mouthed bottles, or turned wood boxes, is required to keep the re-agents in. The bottles are preferable. A dropping tube, a few porcelain capsules, and a pocket magnifying glass, (see fig. 212), will complete the list of apparatus, if we except a tin-plate or other box, fitted with compartments, to receive the various re-agents, and apparatus.

Fig. 212.



Fluxes and Re-agents.—These most important bodies may be classified under two heads—the liquid and solid. They are as follows:

LIQUID.

Nitrate of cobalt.
,, baryta.
,, silver.
Nitric acid (aqua fortis).
Sulphuric acid (oil of vitriol).
Hydrochloric acid (spirits of salts).
Ammonia.
,, hydrosulphuret (sulphuret of ammonium).
,, carbonate.
,, oxalate.
Soda, phosphate.
,, carbonate.
,, sulphate.

Potash, caustic.
Platinum, sodio-chloride.
Alcohol.
Ferrocyanide of potassium.
Ferridcyanide of potassium.

SOLID.

Carbonate of soda.
Ammonio-phosphate of soda (microcosmic salt).
Biborate of soda (borax).
Fluor-spar.
Boracic acid.
Sulphate of lime.
Pure lead.
Bisulphate of potash.
Iron wire.
Litmus paper.
Oxide of copper.
Brazil wood paper.
Copper wire.
Tinfoil.
Nitre.
Cyanide of potassium.
Bone ashes.
Silica.

LIQUIDS.

Nitrate of Cobalt (CoO,NO_5) is best formed by dissolving the carbonate or oxide of cobalt in nitric acid. It ought to be free from arsenic and nickel, and the solution must be moderately strong. It is used as a test for alumina, magnesia, and zinc, by the blow-pipe.

Nitrate of Baryta (BaO,NO_5) may be prepared by acting on the native carbonate of baryta by dilute nitric acid, until no more is taken up. The solution is then to be filtered, and evaporated to the point of crystallization. When all the crystals are formed, drain them from the mother liquor, and dry them on filtering paper. When used as a test, this salt must be dissolved in distilled water. It is employed as a test for sulphuric acid.

Nitrate of Silver (AgO,NO_5).—This compound is always employed in a state of solution, and may be prepared by acting on metallic silver by means of hot dilute nitric acid. When no more red fumes are given off, and all the silver dissolved, evaporate by a gentle heat to dryness to expel excess of acid, redissolve in distilled water, and crystallize. When required for use, the crystals must be dissolved in distilled water. It is a most delicate test for chlorine.

Nitric Acid (HO,NO_5), (aqua fortis), is best bought ready-made. It is employed in the solution of various metals, alloys, and ores, and for the discrimination of certain precipitates.

Sulphuric Acid (HO,SO_3), (oil of vitriol), is employed for the detection of lead, lime, baryta, and many other substances. It is in constant use.

Hydrochloric Acid (HCl), (spirit of salts), is used in the solution of many minerals, precipitates, &c. It is an excellent test for silver.

Ammonia (NH_4O) is much employed in the precipitation of metallic oxides, neutralization of acids, &c.

Ammonia, Hydrosulphuret, Sulphuret of Ammonium (NH_4S) forms sulphurets of most of the metals when added to their solutions. Some of these sulphurets are soluble in excess of acid, some are not, and some are soluble in an excess of the re-agent itself, so that a complete separation of all the metals into three classes can be effected by means of this re-agent.

Ammonia, Carbonate (NH_4O,CO_2), is employed as a test for many of the earths; it is also employed in in the removal of an excess of acid from a solution.

Oxalate of Ammonia ($NH_4O,\bar{O}$) is used as a test for lime, with which its oxalic acid forms a salt perfectly insoluble in water.

Soda, Phosphate ($2NaO,HO,PO_5$), is employed as a test for magnesia.

Soda, Carbonate (NaO,CO_2).—For its uses, see *Carbonate of Ammonia.*

Soda, Sulphate (NaO,SO_3), is used as a test for lead, baryta, &c.

Potash, Caustic (KO,HO), is used in the separation of iron from alumina, as also nickel from cobalt.

Platinum, Sodio-chloride ($NaCl,PtCl_2$), is an excellent test for potash in any substance.

Alcohol (C_4H_5O,HO) is used in the detection of boracic acid, soda, &c.

Ferrocyanide ($Cy_3FeK_2=CfyK_2$) and *Ferridcyanide* ($Cy_6Fe_2K_3=$

CfdyK$_3$) *of Potassium* are tests for the peroxide and the protoxide of iron; the former salts giving a blue precipitate with salts of the peroxide, and the latter with salts of the protoxide.

SOLIDS.

Carbonate of Soda (NaO,CO_2).—The plain carbonate or the bicarbonate may be indifferently employed; but in either case it is absolutely necessary that they be free from sulphates.

There are two objects in view in the employment of soda as an auxiliary to the blow-pipe; firstly, to ascertain if the substances combining with this body be fusible or infusible; and secondly, to facilitate the reduction of certain metallic oxides.

The Fusion of Substances with Soda.—Berzelius says, that, "relatively to the employment of soda, there are many things to observe. The necessary quantity must be taken from its receptacle on the moistened point of a knife, and kneaded in the palm of the hand, so that it may form a coherent mass. If the body under examination be pulverulent, it must be incorporated with it, but if in lump it must be placed upon it, forcing it slightly into the moistened soda; then carefully heated on the charcoal with a gentle flame, until thoroughly dry; and lastly, it may be fused. It generally happens that the soda, at the instant of fusion, is absorbed by the charcoal; but this does not hinder its action on the assay; for if it be fusible with soda, the latter comes to the surface and attacks it, finally forming a liquid globule. If the substance be infusible in soda, but decomposable by it, it alters its appearance without entering into fusion. But, however, before pronouncing any substance to be infusible by soda, the flux ought to be mixed with the pulverized substance. If in these trials too little soda be taken, a portion of the substance remains solid, and the rest forms a covering of transparent glass; if too much, the bead of glass becomes opaque on cooling. It sometimes happens that the assay contains a substance which being insoluble in the glass of soda, prevents it becoming transparent. Then, in order that we may fall into no error respecting the nature of the glass, it becomes necessary in the two last-mentioned cases to add a new quantity of the body under examination, and then ascertain if a limpid globule cannot be obtained. In general, it is the best method to add the soda by successive small doses, and note the changes produced by each addition. It sometimes happens, in this kind of assay, that the glass becomes coloured at the moment of cooling, and finally takes a yellow or deep hyacinth red; it even becomes occasionally opaque and yellowish-brown. These phenomena indicate the presence of sulphur, either in the assay or the soda employed. If the same colour be constantly produced by the same soda, it is a proof that it contains sulphate of soda; it must then be discarded; but if it give generally a colourless glass, it is the substance under assay that contains sulphur or sulphuric acid."

Reduction of Metallic Oxides.—This species of assay, by which quantities of reducible metals, so small as to escape the best humid analyses, can be detected, is the most important discovery Gahn made in the application of the blow-pipe.

If a small quantity of native or artificial oxide of tin be placed on charcoal, it requires a long blast and a skilful operator to produce a grain of metallic tin; but if a small quantity of soda be added, the reduction takes place readily, and so completely with pure oxide, that the whole is transformed into a button of tin. From this it is certain, that the presence of soda favours the decomposition; but in what manner? Berzelius says that the reason is not known.

The action, however, can be explained thus, as Berzelius himself hints: "The red-hot charcoal reacts upon the carbonate of soda, producing by its reduction a certain amount of sodium, which by its strong attraction for oxygen seizes on that contained by the metallic oxide which is required to be reduced." If the metallic oxide contain an irreducible substance, the reduction of the former becomes difficult; but if a little borax be added, the reduction takes place as usual.

This assay is very easy of execution, and the metal is moreover readily recognized, as by previous assays the nature of it is somewhat ascertained, and the reduction but confirms the previous idea.

Supposing, however, that the metallic oxide be mixed with such a quantity of non-reducible substances that its nature cannot be ascertained by previous experiment, how can it be proved that a reducible metal is present?

Gahn has solved this question in a very simple manner. "After having pulverized the substance to be assayed, it is kneaded in the palm of the hand with moistened soda, and the mixture placed on charcoal and exposed to a good reducing flame; a little more soda is then added, and the blast recommenced. As long as any portion of the substance remains on the charcoal, soda is added in small portions, and the blast continued until the charcoal has absorbed the whole of the mass. The first quantities of soda serve to collect the metallic particles scattered in the substance to be assayed, and the final absorption of the latter completes the reduction of any that may remain in the state of oxide.

"This done, the burning charcoal is extinguished with a few drops of water; then having cut out the part which absorbed the soda and assay, grind it to a very fine powder in an agate mortar. This powder is then washed with water to carry away the finest portion of the charcoal. The grinding and washing are repeated until all the charcoal is washed away. If the substance contained no metallic body, nothing will remain in the mortar after this last washing. But if it contained the smallest quantity of reducible matter, it is found at the bottom of the mortar, as small brilliant plates if it be malleable, or as a fine powder if it be brittle or not fusible. In either case, the bottom of the mortar is covered by metallic traces, resulting from the friction of the particles of metal against its sides, (provided that the quantity of metal contained in the sample be not too small). The flattening of almost imperceptible globules of any malleable metal converts them into shining discs of a perceptible diameter. In this manner may be discovered by the blow-pipe, in an assay of ordinary size, less than a half per cent. of tin, and even less than that of copper."

The following points in this class of assay ought to be particularly attended to. Firstly, to produce the strongest possible flame, taking care that it covers every part of the assay. Secondly, to leave none of the metal in the charcoal, or lose the smallest quantity in the collection. Thirdly, to well grind the carbonaceous mass. Fourthly, to decant very slowly, so that only the lighter parts may be carried away by the water. Fifthly, not to judge of the result until the whole of the charcoal has been removed, for a small quantity remaining suffices to hide the metallic particles; and, moreover, the particles of charcoal, viewed in a certain light, have themselves a metallic lustre, which will deceive an inexperienced eye. Sixthly and lastly, not to trust to the naked eye, however plain the sample may be, but always examine by the aid of a good microscope.

The metals reducible by this process are (besides the noble metals), molybdenum, tungstenum, antimony, tellurium, bismuth, tin, lead, copper, nickel, cobalt, and iron. Amongst these, antimony, bismuth, and tellurium, volatilise easily when they are exposed to a strong heat. Selenium, arsenic, cadmium, zinc, and mercury, volatilise so completely that they cannot be collected except by means of a small subliming apparatus.

The reduction can always be effected the first time when the assay contains from 8 to 10 per cent. of metal; but in proportion as the standard decreases, more attention and care must be paid to the washing and recognition of the reduced metal in the mortar. A good system of practice in this experiment is to employ any cupreous substance, and make on it a great number of experiments, taking care to mix it each time with a substance containing no copper; thus the metallic value will diminish at each new assay, until at last no copper can be found.

If the substance to be assayed contains several metals, the reduction of their oxides must be made *in globo*, and a metallic alloy obtained. Some, small in number, are reduced separately. For instance, copper and iron give a regulus of each metal; copper and zinc, the first gives a regulus of copper, whilst the latter volatilises. But when the result of the operation is an alloy, recourse must be had to the re-actions produced by other fluxes to ascertain its constituents.

Ammonio-phosphate of Soda, Microcosmic Salt ($2NaO,NH_4O,PO_5$) is obtained by dissolving 16 parts of sal ammoniac in a very small quantity of boiling water, and mixing with it 100 parts of crystallized phosphate of soda, dissolving the whole on the fire, filtering the boiling liquid, and during cooling the double salt crystallizes. When microcosmic salt is not pure, it forms a glass, which becomes opaque by cooling. It is then necessary to dissolve it in a small quantity of water and recrystallize it.

It may be collected in large crystals, or in a pulverulent state. The crystals are in general of a suitable size for ordinary assays. Placed on charcoal, and submitted to the blow-pipe flame, it bubbles and swells up, giving off ammonia; that which remains after this treatment is an acid phosphate of soda, which fuses readily, and forms on cooling a transparent and colourless glass. As a re-agent, it acts principally by its free phosphoric acid; and if the salt be employed in preference to the acid, it is because it is less deliquescent, costs less, and passes readily into the charcoal. By means of microcosmic salt we then ascertain the action of free acids on any substance we may wish to assay. The excess of acid it contains combines with all bases, and forms a class of double salts, more or less fusible, which are examined as to their transparency and colour. In consequence, this flux is used more particularly in the detection of the metallic oxides, most of which impart to it very characteristic colours. This flux exercises on acids a repulsive action. Those which are volatile, sublime; and those which are fixed remain in the mass, dividing the base with the phosphoric acid, or yielding it up entirely; in which case they are suspended in the glass without being dissolved. In this respect, microcosmic salt is a good test for silicates; for by its aid silica is liberated, and appears in the glass as a gelatinous mass.

Borax, Biborate of Soda ($NaO,2BO_3+10HO$).—The borax of commerce must be dissolved in hot water, and re-crystallized before it can be used in blow-pipe analysis. Gahn made many experiments on the fusion of borax on charcoal with soda, until both salts were absorbed; a whitish metal was produced, which appeared to proceed from the vessels in which the borax was manufactured. This never happened with borax which had been re-crystallized.

Borax may be employed either in crystals, the requisite size for an assay, or in a pulverulent form, in which case it must be taken up on the moistened point of a knife. Some operators prefer fusing the borax before use, in order to drive off its water of crystallization, and thus avoid the tumefaction ensuing after the heating of a crystal on charcoal. This, as Berzelius observes, would be an excellent precaution, provided the borax did not regain its water of crystallization; but it recovers it to a small depth, and boils up when exposed to the blow-pipe flame, although not so much as before. As for myself, I always employ plain borax, because the tumefaction is no great inconvenience, and it is not difficult to fuse a mass so tumefied into a globule.

Borax is employed in the solution or fusion of a variety of substances. It is best to commence by acting upon a scale of the substance to be examined, because if a powder be employed the resulting action cannot be so well ascertained. The following phenomena are to be carefully watched, for in treating any substance with borax it must be particularly noted whether the fusion takes place rapidly or otherwise; without motion or with effervescence; if the glass resulting from the fusion is coloured; and if that colour changes in the oxidising or reducing flame; and lastly, if the colour diminishes or increases on cooling, and if, under the same circumstances, it loses or retains its transparency.

Some substances possess the property of forming a limpid glass with borax, which preserves its transparency on cooling, but which, if slightly heated in the exterior (oxidising) flame, becomes opaque and milk white, or coloured when the flame strikes it in an unequal or intermittent manner. The alkaline earths, as yttria, glucina, zirconia; the oxides of cerium, tantalum, titanium, &c., belong to this class. In order to be certain of this result we must assure ourselves that the glass is saturated to a certain point with either of the above class of bodies. The same thing, however, does not happen with silica, alumina, the oxides of iron, manganese, &c., and the presence of silica prevents the production of this phenomenon with the earths; so that alone they present this peculiar appearance with borax; but when combined wieh silica, (as natural silicates, for instance), no such effect is produced. This operation has received the name of *flaming*, and any substance thus acted upon is said to become *opaque by flaming*.

Fluor-spar, Fluoride of Calcium (CaFl), and *Gypsum, Sulphate of Lime* (CaO,SO_3).—These two bodies (deprived of water) are used to indicate the presence of each other. If a small piece of gypsum be placed in contact with a similar piece of fluor-spar, they soon liquefy at their points of contact; they then combine, and form, by fusing, a colourless and transparent bead of glass, which becomes enamel-white on cooling. Fluoride of calcium is thus employed as a test for gypsum, and *vice versâ*.

Boracic Acid (BO_3) (*fused*) is used to ascertain the presence of phosphoric acid.

Lead (Pb) is made use of in cupelling argentiferous or auriferous substances; it must be free from silver. Dumas states that the best method of obtaining lead in this desirable state is to decompose the best white-lead by means of charcoal, as it is then impossible for it to contain any other metal.

Bisulphate of Potash ($KO,SO_3,HOSO_3$) is employed in the detection of nitric acid, bromine, iodine, and fluorine.

Litmus Paper is made by brushing over the finest writing-paper with a strong watery infusion of litmus, and allowing it to dry out of contact of acid fumes. In this state, it is of a fine blue colour, which is changed to red on contact with an acid base; it is used to detect that class of bodies. When reddened by a slight excess of an acid, it becomes blued by an alkali, and hence can be used as a test for all those substances.

Brazil Wood Paper is prepared in the same manner as the last, substituting rasped Brazil wood for litmus in making the infusion.

It is used as a test for sulphurous acid, which bleaches it, and fluorine, which renders it yellow.

Tinfoil (Sn) is employed to reduce certain peroxides to the state of protoxide. When it is used, a small roll of it, about ¼ of an inch long, is plunged into the fused button, and heated strongly in the reducing flame: the desired effect is then produced.

Bone-ash is employed with lead in the cupellation of those substances containing gold or silver. The following method may be employed in preparing this substance for the purpose it is required. A small portion of very finely powdered bone-ash is taken up on the point of a knife, adding to it a small portion of soda, and making the whole into a consistent paste with a little water. A hole of the size of the intended cupel is then scraped in a piece of charcoal, and filled with the bone-ash paste, which is then formed into a smooth hollow by means of the small agate pestle. It may then be heated gradually by the blow-pipe until perfectly dry. The substance to be assayed, previously fused with lead, is then placed in the centre of the cupel, and heated in the exterior flame. The lead thus becomes oxidised, and the noble metal, or metals, remain on the cupel. This test is so delicate, that from a very small bead of lead (commercial) a globule of silver, visible to the naked eye, may be obtained; and, in fact, it may be demonstrated that the globule is silver, by dissolving it in nitric acid on a slip of glass, and precipitating it as chloride by hydrochloric acid.

Silica (SiO_3) has the property of forming with soda a perfectly transparent glass, which is employed in the detection of sulphuric acid.

Oxide of Copper (CuO) is employed to detect the presence of hydrochloric acid and chlorine.

Copper Wire (Cu) is sometimes employed in ascertaining the presence of iodine and chlorine.

Nitre, Nitrate of Potash (KO,NO_5), in long and thin crystals, is employed in hastening the oxidation of those substances which do not readily combine with oxygen in the exterior flame. It is used as follows: the point of a crystal is thrust into the fused bead; but in order to prevent the cooling of the latter, the crystal is held by a pair of pliers, so that when the bead begins to cool it may be withdrawn, the bead re-heated, and the crystal employed as before, until the desired effect is produced.

Iron Wire (Fe) is employed to precipitate many metals, and in the separation of sulphur and the fixed acids from any substance with which they may be combined. The metals which can thus be precipitated, or deprived of sulphur, are copper, lead, nickel, and antimony. For instance, if a small piece of iron (harpsichord) wire be placed in a substance in fusion, and acted upon by the blow-pipe, it becomes covered with the reduced metal; the latter sometimes appears as small globules.

Iron has the property of reducing phosphorus from phosphoric acid or the phosphates, giving rise to a phosphuret of iron, which forms on fusion a white, brittle, metallic globule.

Cyanide of Potassium (KCy).—This is a most useful flux, and has only lately been introduced. MM. Haidlen and Fresenius say: "We have examined its action on many oxides, sulphurets, salts, &c., in reference to its use as a re-agent combined with the blow-pipe. We prefer, in general, a mixture of equal parts of anhydrous soda and cyanide of potassium. This mixture was employed on account of the great facility with which the pure cyanide fuses. It acts, in general, so very similarly to pure soda, that it would be superfluous to describe singly the changes which each individual body appeared to undergo when exposed to its action. We cannot, however, pass over the following especial advantages which it possesses as compared with soda. Firstly, reductions are obtained with such great facility that the least practised operator may execute reductions which would otherwise be very difficult; for instance, the reduction of tin from either its oxide or sulphuret: and, secondly, that the fused mixture of cyanide of potassium with soda is so easily absorbed by the charcoal, that the grains of reduced metal can always be most distinctly perceived, and may be most easily separated therefrom for further examination."

Pure cyanide of potassium may be made by heating dry ferrocyanide of potassium to whiteness in close iron vessels, and dissolving the cyanide in alcohol of 60 per cent.; but the salt in its pure state is not used as a blow-pipe re-agent; it is the mixture of cyanide of potassium with cyanate of potash, formed in the readiest manner by Liebig's process, which may be thus conducted. Eight parts of ferrocyanide of potassium are rendered anhydrous by a gentle heat, and intimately mixed with three parts of dry carbonate of potash; this mixture is thrown into a red-hot earthen crucible, and kept in fusion, with occasional stirring, until gas ceases to be evolved, and the resulting mass becomes colourless. The crucible is left at rest for a moment, and the clear salt decanted from the heavy black sediment at the bottom. The ferrocyanide and the carbonate employed ought to be perfectly free from sulphuric acid.

GENERAL ROUTINE OF BLOW-PIPE OPERATIONS.

Size of the Assay.—The morsel operated on is sufficiently large when the effect of the heat and the fluxes added can be distinctly discerned. The size of the assay-piece generally recommended is much too large; its size ought to be about that of a mustard-seed; that of the flux added, about the size of a hemp-seed. Besides, when a large piece is employed, the experiment consumes so much more time, and requires so much more labour than a smaller piece. It is only in reductions that a larger piece may be successfully employed, because in that case, the more metal produced, the more readily can its nature be ascertained. Having thus endeavoured to fix the size of the assay, we will now lead our readers to the operations necessary in blow-pipe analysis, and in the order in which they are to be performed.

Firstly.—The substance is heated in the closed tube, or matrass, over a spirit-lamp. It may, by this treatment, decrepitate, or give off water, or some other volatile substance.

Secondly.—It is heated gently on charcoal, by aid of the blow-pipe; and, as soon as warm, withdrawn from the heat, and the odour given off ascertained: volatile acids, arsenic, selenium, or sulphur, may be present. The odour thus produced by the oxidising flame must be compared with that produced by the reducing flame; if any difference, it must be carefully noted. Sulphur, selenium, &c., are best detected in the oxidising flame, and arsenic in the reducing flame.

Thirdly.—The substance is examined as regards its fusibility. If it be in grains, it is better acted upon on charcoal, notwithstanding its liability to escape on the first insufflation, when they are not very fusible. But if we can choose the form, it is better to knock off a small splinter, by means of the hammer, and hold it in the flame by the platinum-pointed pincers. A fragment with the most pointed and the thinnest edges ought to be selected. By thus acting, we can always ascertain at a glance if the substance be fusible or not. Infusible substances retain their sharp points and angles, which can be ascertained immediately by means of a microscope. The same points are merely rounded in bodies of difficult fusibility, and in substances of easy fusion are rendered globular.

Certain substances, and particularly some minerals, change both aspect and form when exposed to the blow-pipe flame without entering into fusion; some swell up like borax; some of them fuse after tumefaction; others keep in that state without fusion. Some minerals give off a sort of foam on fusing, giving rise to a kind of blebby glass, which, although transparent itself, does not appear so, on account of the multitude of air-bubbles it contains.

This bubbling and tumefaction take place in the greater part of the minerals only at that temperature at which all the water is disengaged; and these ramifications appear to proceed from a new molecular arrangement, produced by the increment of heat on the constituent parts of the substance. It cannot be said that the expansion of a particular part of the substance, and its formation into gas, gives rise to this, because it most often happens in those substances which contain no such substance. The minerals which generally give these indications are the double silicates of lime, or alkali and alumina. It sometimes disappears after a few instants, and occasionally lasts as long as the substance is kept in fusion. In the latter case, it seems that the assay takes carbonic acid from the flame, which carbonic acid is transformed by the charcoal into carbonic oxide, and it is that gas which causes the bubbles.

In the employment of fluxes, it is necessary to continue the blast for a sufficiently long time, because some substances appear infusible at the commencement of the operation, and gradually yield to the influence of the flux, and in about two minutes enter into full fusion. The substance is best added in small quantities, and no new dose must be introduced until the former one is perfectly acted upon; so that at last the glass arrives at that degree of saturation that it can dissolve no more: it is at this particular point the re-actions are most vivid and plain. Beads of glass, not so saturated, do not give such decided indications.

Occasionally, in operating with a flux on the reducing flame, it happens that the assay-bead re-oxidises during the cooling of the charcoal, and thus the labour of a preceding operation is lost. In order to obviate this inconvenience, the charcoal is turned over, so that the bead may fall in a yet liquid state on some cold body, as a porcelain plate.

When the colour of the bead is so intense that it appears opaque, its transparency can be proved by holding it opposite to the flame of a lamp; the reversed image of the flame can then be seen in the bead, tinged with the colour imparted to the flux by the body under experiment. The globule may also be flattened by a pair of pliers before it cools, or it may be drawn into a thin thread. In either of the last-mentioned cases its colour can readily be ascertained.

Minerals exposed to the exterior and interior flame, either with or without fluxes, present a variety of phenomena, which ought to be carefully noted, and which, collectively, form the result of the assay. The smallest circumstance must not be overlooked, because it may lead us to ascertain the presence of a substance not suspected. It is always necessary, in all cases, to make two assays, and compare the separate results; because it sometimes happens that an apparently trivial fact had been overlooked in the first series of operations, which materially conduces to the good result of the experiment. We shall now proceed to indicate the re-actions produced on the various oxides of the commoner metals, in a state of purity, by the blow-pipe, with and without fluxes. Their hydrates and carbonates present much the same appearances.

Potash (KO), *Soda* (NaO), and *Lithia* (LiO), cannot be distinguished with any degree of certainty by the blow-pipe; their presence is best ascertained by the wet assay; that is to say, however, with the exception of soda. Potash colours the blow-pipe flame bluish; soda, yellow; and lithia, red. These indications, however, will be more fully discussed under the head of *Coloured Flames.*

Baryta (BaO), alone, is infusible. The hydrate is fusible, but soon becomes a solid crust, on account of its losing water.

Carbonate of Baryta (BaO,CO_2) fuses very readily into a limpid glass; and, on cooling, takes the appearance of a white enamel. On charcoal it effervesces, and becomes caustic baryta; it then behaves as above stated.

With borax, baryta fuses easily into a limpid glass, with a lively effervescence. It becomes opaque by *flaming.*

With microcosmic salt it fuses easily, with a brisk effervescence, during which the globule foams and swells; after which, it is transformed into a limpid glass.

With soda it fuses and sinks into the charcoal.

With nitrate of cobalt it produces a bead, which, when hot, is brick-red. It loses this colour by cooling.

Strontia (SrO).—*Alone,* it presents the same phenomena as baryta; as it does also with microcosmic salt and borax.

Soda does not dissolve caustic strontia. Carbonate of strontia, mixed with its own volume of soda, fuses into a limpid glass, which becomes enamel-white on cooling.

With nitrate of cobalt strontia becomes black, or greyish-black, and does not fuse like baryta.

Lime (CaO), alone, undergoes no alteration. Carbonate of lime becomes caustic, giving off a very strong light.

With borax it readily fuses, giving a limpid glass, which becomes opaque by flaming.

With microcosmic salt it fuses in large quantity, giving rise to a limpid glass, which preserves its transparency on cooling.

Soda scarcely acts either upon lime or its carbonate, passing into the charcoal, and leaving them unaltered upon its surface.

Acted on by *nitrate of cobalt, lime* gives a blackish mass, which is infusible.

Magnesia (MgO), *alone*, undergoes no alteration.

With borax, behaves as with lime.

With microcosmic salt, fuses readily.

With soda, no action.

With nitrate of cobalt, after a strong heat, becomes flesh-red; which tint, however, is not well seen until after perfect cooling.

Alumina (Al_2O_3), *alone*, does not change.

With borax, fuses slowly, and forms a diaphanous glass, which becomes opaque either by cooling or flaming.

With microcosmic salt it forms a transparent glass.

With soda it swells a little, forming an infusible compound. The excess of soda is absorbed by the charcoal.

With nitrate of cobalt it gives a fine blue colour by a strong blast. This colour is best observed by daylight, and is very characteristic of alumina.

Molybdic Acid (MO_3).—*Alone*, in the open inclined tube, it fuses, giving off a white smoke, which condenses in the form of a white powder on the sides of the tube. Heated on platinum foil, it fuses and smokes. The fused portion is brown, but becomes yellowish and crystalline on cooling. In the reducing flame it becomes blue.

With borax it fuses on the platinum wire, forming in the exterior flame a colourless and transparent glass. On charcoal, in the reducing flame, the glass becomes brown, and loses its transparency.

With microcosmic salt it fuses on the platinum wire in the exterior flame, producing a transparent glass, which, while hot, is greenish, but which colour it loses on cooling. In the reducing flame, the green becomes opaque, appears black or deep blue, but by cooling becomes nearly as beautiful a green as that produced by oxide of chromium.

With soda, molybdic acid fuses on the platinum wire with effervescence, forming a limpid glass, which becomes milk-white by cooling.

Acted on by soda on charcoal, molybdic acid is absorbed as soon as fused; and by removing the charcoal which has absorbed it, and treating it by washing and grinding, a large quantity of metallic molybdenum may be obtained.

Tungstic Acid (WO_3).—*Alone,* it blackens, but does not fuse in the reducing flame.

With borax it fuses readily on the platinum wire, forming a colourless glass in the outer flame, which does not become opaque by flaming. In the reducing flame the glass is yellowish when it contains only a small proportion of acid, and the colour augments in intensity by cooling, becoming perfectly yellow.

With microcosmic salt, tungstic acid dissolves, forming in the exterior flame a colourless or slightly yellowish glass. In the reducing flame it becomes a fine blue, more beautiful than that of cobalt. If the acid contains iron, the glass assumes a perfectly different appearance, becoming blood-red.

Soda dissolves tungstic acid on the platinum wire, converting it into a transparent and deep yellow glass, which crystallizes on cooling, becoming an opaque white or yellow. If tungstic acid be treated on charcoal with a small quantity of soda in the reducing flame, a steel-grey slag is obtained, which, by washing and levigating, furnishes metallic tungsten.

Oxide of Chromium (Cr_2O_3).—*Alone,* undergoes no change.

With borax, fuses difficultly, even in small quantity. The glass has a splendid emerald-green colour, which is principally developed during cooling.

With microcosmic salt it fuses in the exterior as well as in the interior flame, furnishing a deep green glass; and a very small quantity of oxide suffices to produce this effect.

Soda dissolves oxide of chromium on the platinum wire in the exterior flame, producing a deep orange glass, which becomes yellow on cooling. In the reducing flame it becomes opaque. It is green after cooling.

Antimony (Sb) *and its Oxides.—Metallic antimony* fuses readily on charcoal, and, when heated to redness, remains a considerable time in a state of ignition without the aid of the blow-pipe, disengaging a thick white smoke. This smoke is gradually deposited on the charcoal around the metallic globule in small crystals, having a pearly lustre, and which, in course of time, cover it entirely. These crystals are oxide of antimony. Metallic antimony alone in the matrass does not sublime but at the fusing point of glass. Heated to redness in the open tube, it burns slowly, giving a white smoke, which deposits on the glass, and presenting here and there traces of crystallisation.

Oxide of Antimony (SbO_3).—*Alone,* readily fuses, and passes off as a thick white vapour. It is reduced to the metallic state on charcoal. In this operation it colours the flame greenish.

Antimonious Acid (SbO_4) does not fuse, but gives off a vivid light, diminishing at the same time in bulk, and covering the charcoal with a white powder, but is not reduced.

Antimonic Acid (SbO_5) whitens at the first impingement of the flame, and is converted into antimonious acid.

The oxides and acids of antimony behave alike with fluxes.

Borax dissolves a large quantity of antimonious acid without becoming opaque. The glass continues yellow while hot, but loses nearly all its colour on cooling. When saturated, a portion of the antimony sublimes in the metallic state.

Microcosmic salt forms with the same acid a transparent and colourless glass. On the platinum wire, in the oxidating flame, it becomes yellow, which tint vanishes on cooling.

With soda, on the platinum wire, it fuses into a transparent and colourless glass, which becomes white on cooling. It is reduced on charcoal.

Oxide of Tellurium (TeO_2).—*Alone,* on the platinum wire, it fuses, giving off a smoke. It fuses and is reduced on charcoal. The reduced metal is easily confounded with antimony and bismuth.

With borax and microcosmic salt it gives on the platinum wire a limpid and colourless glass, which on charcoal becomes grey and opaque, on account of the presence of particles of reduced metal.

With soda, on the platinum wire, it produces a colourless glass, which becomes white by cooling. It is reduced on charcoal.

Oxide of Tantalum (TaO_2).—*Alone,* undergoes no change.

With borax it forms a colourless and transparent glass, which becomes opaque by flaming.

With microcosmic salt it fuses readily and in large quantity, giving rise to a colourless glass, which preserves its transparency on cooling.

Soda takes it up, and the combination is made with effervescence, but without the solution or reduction of the oxide.

As oxide of tantalum much resembles some of the earths in its reactions with the fluxes, it may be confounded with some of them in an assay by the blow-pipe. It can be recognised from glucina, yttria and zirconia, by combining with the microcosmic salt, and remaining transparent on cooling, even when the oxide of tantalum is in excess. It is distinguished from alumina by its action with borax and nitrate of cobalt; the last-mentioned re-agent having no action on oxide of tantalum, but producing a pure blue colour with alumina.

Oxide of Titanium (TiO).—*Alone,* undergoes no change.

With borax it fuses readily on the platinum wire, forming a transparent glass, which becomes opaque by flaming. If the proportion of oxide be increased, the glass becomes opaque on cooling. Exposed to the reducing flame, the glass is yellow, if the proportion of oxide is small, becoming deep amethystine red after complete reduction, which tint becomes deeper by cooling. The glass is transparent, and very like that furnished by oxide of manganese in the oxidating flame, but is rather more blue. With a larger proportion of oxide, on charcoal, in the reducing flame, the glass becomes deep yellow, and acquires, by cooling, so deep a blue colour, that it appears black and opaque. If, however, it be *flamed,* it becomes light blue, but opaque and similar to an enamel. The tint varies in several experiments, being sometimes finer one time than another.

Microcosmic salt dissolves oxide of titanium in the outer flame, forming a colourless and limpid glass. In the reducing flame it gives a yellowish glass while hot, but when cold it first takes a red tint, and finally becomes a very fine bluish violet. A large quantity renders the colour so opaque that it appears black, but does not assume the appearance of an enamel. This colour may be made to disappear in the exterior flame. Its reduction is effected better on charcoal than on the platinum wire; but requires even on charcoal a sustained fire. The addition of tin much facilitates the reduction of oxide of titanium. If the oxide of titanium contain iron, or if iron be added to the glass coloured by oxide of titanium, the violet colour disappears, and the glass becomes red in the reducing flame.

Soda dissolves oxide of titanium with effervescence, forming a transparent and deep yellow glass, which does not sink into the charcoal, and becomes white by cooling. This glass possesses the property of crystallising the instant its ignition ceases. The oxide of titanium is not reducible on charcoal, even with soda.

With solution of cobalt, oxide of titanium takes a black or greyish-black colour.

Oxides of Uranium (UO and U_2O_3).—*Alone,* blacken, but do not fuse.

With borax fuse into a deep yellow glass, which becomes dull green in the reducing flame. The colour can be restored by exposing it to the oxidating flame on the platinum wire. On charcoal, the same operation is very difficult.

With microcosmic salt give a transparent yellow glass on the platinum wire, the colour of which is lessened on cooling, and finally becomes straw-yellow with a tint of green. In the reducing flame they give a fine green glass, which becomes yet more beautiful on cooling.

Soda does not dissolve them. With an extremely small quantity of the flux, some signs of fusion may be perceived. The mass, with a larger quantity, becomes a deep brown.

Oxides of Cerium (CeO and Ce_2O_3).—*Alone,* the peroxide becomes protoxide, which latter does not change.

Borax dissolves the oxide in the oxidating flame, giving rise to a fine red or deep orange glass, which becomes lighter, and finally takes a yellow tint, which becomes enamel-white on flaming. In the reducing flame it loses its colour.

With microcosmic salt the oxide gives by fusion a fine red glass, which, on cooling, loses its colour, taking the limpidity of water. In the reducing flame the glass becomes colourless.

With soda it does not fuse; the flux, however, passes into the charcoal.

The reactions of oxide of cerium much resemble those of iron, especially when the cerium is combined with silica. The oxides of iron and cerium do not behave in the same manner with the fluxes, excepting when they are combined with silica, as before stated, in which case it is impossible to detect cerium by means of the blow-pipe.

Oxides of Manganese (MnO, MnO_2, Mn_3O_4).—*Alone,* the protoxide is not fusible, but becomes brown in a strong flame.

With borax it forms a transparent glass, having the colour of amethyst, which becomes colourless in the reducing flame. If much oxide be present, the glass must be poured on a cold body, at the instant the blast ceases. The colour returns by a slow cooling.

With microcosmic salt it fuses readily, forming a transparent glass, which is colourless in the reducing flame, and amethystine in the oxidising flame. If the glass produced hy the union of oxide of manganese with phosphoric acid contain so little of the former as to give no sensible reaction, it can be rendered evident by plunging into the bead a crystal of nitre. The bead swells and foams, and the froth becomes on cooling an amethystine or pale rose tint, according to the quantity present.

With soda, the oxide fuses on platinum foil or wire, forming a transparent green glass, which becomes on cooling a bluish green. This assay is best made on platinum foil. One-thousandth of oxide of manganese gives a very perceptible colour with soda.

Oxide of Zinc (ZnO).—*Alone,* becomes deep yellow when heated. This assay must be made by day-light. It re-assumes its white colour on cooling. It does not fuse, but gives off a vivid light during incandescence. It is gradually evaporated in the reducing flame, during the continuance of which a yellow ring is deposited on the charcoal, which becomes white on cooling.

With borax it fuses readily, and gives a transparent glass, which, with a large proportion of oxide, becomes milky by flaming. It assumes an enamel-white appearance on cooling. In the reducing flame the metal sublimes, and covers the charcoal with a white film.

With microcosmic salt it behaves as with borax, except that the metal sublimes less readily with the first than the second.

Soda does not dissolve it; but acted on by this re-agent on charcoal, it is reduced, and covers the charcoal with a coating of oxide.

With solution of cobalt it assumes a fine green colour.

Oxide of Cadmium (CdO).—*Alone,* in the oxidising flame, on platinum foil, undergoes no change. On charcoal it is very soon dissipated, at the same time covering the charcoal with a red or orange-yellow powder. This phenomenon is so decided in oxide of cadmium, that minerals—as carbonate of zinc, for instance—containing only 2 per cent. of carbonate of cadmium, on being exposed for a moment to the reducing flame, deposit, at a slight distance from the assay, a yellow or orange-yellow ring of oxide of cadmium. The cooler the charcoal is, the better it is observed. This ring forms before that of zinc, and the insufflation must not be long continued, otherwise the coloured ring will be covered by the deposit of oxide of zinc, and the operator be inclined to believe that the mineral contained no cadmium.

Borax dissolves a very large quantity on the platinum wire, forming a transparent glass, whose yellowish colour disappears on cooling. If the glass be nearly saturated, it becomes opaque by flaming; and if quite saturated, it is enamel-white on cooling. On charcoal, the cadmium is reduced, covering the former with its characteristic yellow film.

Microcosmic salt also dissolves a very large quantity, forming a transparent glass, which, when saturated, forms a milk-white enamel on cooling.

Soda does not fuse it on the platinum wire. It is reduced on charcoal, with the production of the orange-yellow coating.

Oxides of iron (FeO, Fe_2O_3 and Fe_3O_4).—*Alone,* undergo no change in the oxidising flame; but in the reducing flame the first two blacken and become magnetic.

With borax they give a dull red glass in the oxidising flame, which brightens on cooling, and finally takes a yellowish tint, or even becomes colourless on cooling. If the bead contain a very large proportion of oxide, it is opaque in the liquid state, and, on cooling, becomes a dull impure yellow. In the reducing flame, it becomes bottle-green, and, if the reduction be forced to the highest possible extent, assumes a lively bluish-green tint, exactly like protosulphate of iron. Tin very much accelerates the reduction of the higher oxides to the state of protoxide.

With Microcosmic salt they behave as with borax, but the green colour disappears more completely, and may be entirely got rid of by the application of tin.

Soda does not dissolve the oxides of iron, but causes them to be absorbed by the charcoal, in which they are easily reduced, and may be obtained as a grey, magnetic, metallic powder.

Oxide of Cobalt (CoO).—*Alone,* suffers no change.

With borax it readily fuses, forming a fine transparent blue glass, which does not become opaque by flaming. A very small quantity colours the glass completely blue, and a large quantity imparts so deep a colour as to make it appear black.

With microcosmic salt the appearances are the same as with borax.

Soda dissolves but a very small quantity on the platinum wire: the fused mass is pale red by transmitted light, and becomes grey on cooling.

Carbonate of potash dissolves a larger quantity of this oxide, forming a black mass, without the slightest mixture of red. This reaction presents a method of distinguishing potash from soda.

The oxide of cobalt is very readily reduced on charcoal in the interior flame, either by an alkali or an alkaline salt. After the soda and charcoal are washed away, a grey metallic powder is obtained, which takes the metallic lustre under the burnisher.

Oxide of Nickel (NiO).—*Alone,* is not acted upon.

With borax it fuses very readily, producing an orange-yellow or red glass, which, by cooling, becomes yellowish or nearly colourless. A larger quantity of the oxide gives a glass which, when liquid, is deep brown, but which, on cooling, becomes dull red and transparent. This colour is destroyed in the reducing flame, and the glass becomes grey, on account of particles of metallic nickel being disseminated through it.

With microcosmic salt it fuses, giving rise to the same phenomena as with borax; but the colour nearly, if not quite, disappears on cooling. It behaves alike in the oxidising and reducing flames, by which reaction it is distinguished from iron. Tin produces, at first, no change; but after a short time the nickel precipitates and the colour disappears. If cobalt be present, it can then be perceived; but the blue glass is opaque, and cannot be so well distinguished with this flux as when treated in the same manner with borax.

Soda does not dissolve oxide of nickel. A large quantity of this flux, however, causes the charcoal to absorb it; it is then reduced, and furnishes, by washing, small, white, brilliant, metallic particles, which are as strongly attracted by the magnet as wrought iron.

Bismuth (Bi), *Oxide of Bismuth* (BiO).—*Alone,* oxide of bismuth fuses readily on the platinum wire, forming a deep brown mass, which becomes yellow on cooling. If acted upon by a very intense flame, it is reduced, and perforates the platinum. It is reduced instantaneously on charcoal.

With borax it fuses into a colourless glass in the oxidising flame. In the reducing flame it becomes greyish, owing to the dissemination of particles of bismuth.

Microcosmic salt forms with it a brownish-yellow glass. In the reducing flame, particularly with tin, a glass is formed, which is clear and colourless while hot, but becomes greyish-black on cooling. Oxide of copper presents nearly the same phenomena under the same circumstances, but with this difference, that tin produces a red colour.

Owing to the facility with which bismuth may be reduced, it is nearly always on the metal that the assay is made; hence it becomes very important to distinguish it from the antimony and tellurium, with which it may be readily confounded.

Firstly, in the matrass neither antimony nor bismuth sublime at a temperature the glass can bear. Tellurium, on the contrary, gives at once a little smoke (by means of the oxygen of the atmosphere), and finally, a grey sublimate of metallic tellurium is obtained.

Secondly, in the open tube antimony gives a white vapour, which lines the interior of the tube, and which can be driven by heat from one part to another without leaving the least trace. The metallic bead is always covered by a notable quantity of fused oxide.

Tellurium gives much vapour, which attaches itself to the sides of the tube as a white powder, which is capable of fusion into colourless drops by the application of heat.

Bismuth gives no smoke if it be not combined with sulphur; and the fused metal is surrounded by the brown fused oxide, which strongly attacks the glass.

Thirdly, on charcoal these three metals give off vapour by the action of heat, and leave a ring around the spot on which they are placed. That from antimony is quite white; those from bismuth and tellurium, red or orange. If the reducing flame be made to play upon them they disappear, at the same time colouring the flame a deep green if tellurium be present, and pale bluish-green if antimony. It is not coloured at all by bismuth.

Oxides of Tin (SnO and S_2).—*Alone*, the protoxide, in the state of hydrate, lights and burns like tinder, becoming peroxidised. The peroxide does not fuse or undergo any change except in the reducing flame, which, if strong and long continued, entirely reduces it without the aid of any re-agent. Nevertheless, this operation requires much practice and experience.

With borax it fuses with great difficulty and in small quantity, giving rise to a transparent and colourless glass, which remains so during cooling. The colour of the glass is not changed in the reducing flame.

With microcosmic salt it behaves as with borax.

Soda and oxide of tin combine with effervescence on the platinum wire. The result of this combination is a blebby infusible mass, which cannot be dissolved by a large quantity of borax. On charcoal it is easily reduced, and gives a grain of tin.

Oxide of Lead (PbO).—*Alone*, minium blackens when heated, and is transformed into the yellow oxide. It forms by fusion a fine orange glass, which is reduced by effervescence on charcoal.

With borax it fuses readily on the platinum wire, and gives a transparent glass, which, when saturated and hot, is yellowish, but which becomes colourless on cooling. It is reduced on charcoal.

With microcosmic salt it readily fuses into a transparent and colourless glass.

With soda, oxide of lead readily fuses on the platinum wire, forming a transparent glass, which becomes yellowish and opaque by cooling. Its reduction takes place instantaneously on charcoal.

Oxide of Copper (CuO).—*Alone,* in the oxidising flame, it is fused into a black bead, which is reduced on charcoal. In the reducing flame, at a temperature which does not suffice to fuse copper, the oxide is reduced, and shines with the lustre characteristic of metallic copper; but as soon as the blast ceases the metal re-oxidises, and becomes black or brown. Exposed to a stronger heat, it gives a bead of metallic copper on fusion.

With borax, oxide of copper readily fuses in the oxidising flame, forming a beautiful green glass, which loses its colour in the reducing flame, but which on cooling becomes cinnabar-red and opaque. If the oxide of copper be impure, the glass is generally deep brown, and does not become opaque but in an intermittent flame.

With microcosmic salt it fuses, attended with the same phenomena as with borax. If the quantity of copper be small, the glass occasionally becomes transparent and ruby-coloured in the reducing flame: this change takes place at the instant of solidification. Commonly the glass becomes red and opaque, similar in appearance to an enamel.

When the quantity of copper is so small that the character of the red oxide cannot be made evident in the reducing flame, a small quantity of tin must be added, and the flame kept up only for an instant. The glass, previously colourless, becomes red and opaque by cooling. If the blast be kept up too long, the colour is destroyed, owing to the reduction of the copper.

With soda, on the platinum wire, a beautiful green glass is formed, which becomes opaque and colourless on cooling. On charcoal it is absorbed, and the oxide reduced. There are no means of detecting so small a quantity of copper as by the aid of the blowpipe; that is, when it is not in combination with other metals, which by their reduction would disguise its presence. In the latter case we must use borax and tin. When copper and iron are associated together, a single assay separates them into distinct particles; the one may be told by colour, and the other by being attracted by the magnet.

Mercury (Hg).—The compounds of mercury are all volatile, and cannot, in consequence, be distinguished by their reaction with any of the fluxes. Substances containing mercury are assayed by being mixed with a little tin, iron filings, or oxide of lead, and heating the mixture to redness in the closed tube or matrass. In this operation the mercury is reduced, and collects in the coldest part of the tube as a greyish powder, which being brought together by the end of a feather, collects as metallic globules. When the quantity is very small, the globules may be distinguished by aid of the microscope.

Oxide of Silver (AgO).—*Alone,* is reduced instantaneously.

With borax a part is dissolved and a part reduced. In the oxidising flame the glass becomes, on cooling, milk-white, taking the colours of the opal according to the quantity of the silver dissolved. In the reducing flame it becomes greyish, owing to the dissemination of particles of metallic silver.

With microcosmic salt the oxide and the metal give in the oxidising flame a yellowish opaline glass; seen by refraction, in the day, it appears yellow; seen in the same manner by the light of the lamp, it appears reddish.

The other noble metals, as gold, platinum, iridium, rhodium, and palladium, give no reactions with the fluxes, as they are not oxidisable. They are best examined by cupellation.

Osmium is a metal found associated in the ores of platinum. It possesses the following characteristic: it is converted into an oxide which immediately volatilises, giving a peculiar pungent odour, somewhat similar to chlorine.

Silica (SiO_3).—*Alone,* undergoes no change.

With borax it fuses slowly and gives a clear glass, of difficult fusion, which is not rendered opaque by flaming.

Microcosmic salt dissolves but a very small quantity. The fused glass preserves its transparency after cooling; that which is half fused has but a semi-transparency.

With soda it fuses, giving rise to a brisk effervescence, with the production of a limpid glass.

With solution of cobalt, in certain proportions, it takes a faint bluish tint, which becomes black, or deep grey, according to the quantity of cobalt. It is by means of this colour that silica is distinguished from some aluminous substances.

Sulphur (S) gives, on burning, the well-known odour which is due to the formation of sulphurous acid. It leaves no residue, when pure, on being heated on the platinum foil.

COMPOUNDS OF SULPHUR WITH THE METALS: SULPHURETS.

These bodies may be recognised by the odour of sulphurous acid they exhale when heated on charcoal or in the open tube. When the quantity of sulphur contained in any compound is too small to be detected by the smell, its presence may be ascertained by fusing it with a bead composed of carbonate of soda and silica. The glass, on cooling, takes a brown or reddish-yellow colour, according to the quantity of contained sulphur. This method cannot always be employed, because the associated metals mask the colour, in which case the mineral must be roasted in the open tube, in the upper part of which is placed a piece of Brazil-wood paper. If sulphur be present, the red colour of the paper will disappear. A quantity of sulphur, so small as to be imperceptible to the smell, will bleach this test paper. This method must always be followed in the detection of sulphur in the sulphurets of antimony, because it is difficult to ascertain its presence by the smell.

The principal object, however, in view in the examination of the metallic sulphurets, is to ascertain the presence of some particular metal, in which case they must be roasted, taking care to observe the precautions pointed out for the roasting of ores for assay by the furnace. The roasting must always be executed in the oxidising flame, and great care taken to apply only a very gentle heat at first, otherwise the assay will fuse, and it will then be impossible to continue the roasting with the sample. Great care must be taken to expel the whole of the sulphur, otherwise no reduced metal can be obtained by the action of soda, as sulphuret of sodium forms fusible compounds with most of the metallic sulphurets.

Selenium (Se) can be sublimed under the same circumstances as sulphur. The sublimate, if small, is reddish; but if large, so deep a colour as to appear black. It gives, when heated in the open air, according to some writers, a strong smell of decayed horse-radish; but to me the smell most resembles that of the bisulphuret of carbon. Owing to this peculiar smell, it is very readily distinguished by the blow-pipe from all other bodies.

Seleniurets.—With the glass of silica and soda, the seleniurets behave as the sulphurets; but the colour disappears sooner by a long blast than that produced by the sulphurets. When a seleniuret is combined with a sulphuret, the selenium sublimes as selenium, while the sulphur is disengaged as sulphurous acid. If selenium be found with tellurium, the oxide of tellurium first sublimes, and, finally, the selenium is deposited nearest the point heated. Sometimes the sulphuret of arsenic sublimes with the same appearances as selenium, but never with the same odour.

Phosphorus entirely burns away, giving off a white fume, which is phosphoric acid.

SALINE SUBSTANCES: SULPHATES, PHOSPHATES, IODIDES, BROMIDES, &C.

Sulphates.—The presence of this class of bodies is ascertained in the same manner as sulphur, by means of the glass of soda and silica. The sulphates of the metals proper, when heated with charcoal in the close tube, give off sulphurous acid, which may be detected either by the smell or by its action on Brazil-wood paper. The metals of the alkalies and alkaline earths give no sulphurous acid when treated in this manner.

Nitrates.—All the salts of nitric acid deflagrate with carbonaceous matters. This, however, is not characteristic, for the chlorates also possess this property. If any nitrate be heated in the close tube with bisulphate of potash, red fumes of nitrous acid are evolved.

Bromides, heated with bisulphate of potash in the closed tube, give off vapours of bromine, which are similar in appearance to those of nitrous acid, but which recall the smell of chlorine. Under the head of *Coloured Flames,* another method of distinguishing bromine will be pointed out.

Iodides, acted on by bisulphate of potash, give rise to splendid violet-coloured vapours, which are characteristic. — (Also, see *Coloured Flames.*)

Chlorides, treated with bisulphate of potash and peroxide of manganese, evolve chlorine, which may be recognised by its peculiar odour and yellowish-green colour. — (For further information, see *Coloured Flames.*)

Fluorides, heated with bisulphate of potash, give rise to fluoric acid, which may be distinguished by its power of corroding glass.

As fluorine occurs in very small quantities in certain minerals, and as it is rather difficult of detection, full instructions will be given.

In case the mineral is very rich in fluoric acid, it may be mixed with microcosmic salt (previously fused), and heated at the extremity of an open tube, so that part of the current of air feeding the flame can pass into the tube. Aqueous fluoric acid is then formed, which can be recognised by its odour and by the corrosive action it exercises on the tube. If a slip of Brazil-wood paper be held at the opening of the tube, it becomes immediately yellow. On the contrary, when the acid exists but in minute quantity, as in fossils, or where it is combined with weak bases, or with a certain proportion of water, the substance can be heated in the close tube, after the introduction of a piece of moistened Brazil-wood paper. Hydro-fluosilicic acid is liberated by the heat, and a dull ring of silica deposited on the glass, a little above the assay; and lastly, the end of the Brazil-wood paper is turned yellow. Three or four per cent. of fluoric acid can be detected in this manner.

Phosphates.—The following is the method recommended by Berzelius for the detection of phosphoric acid. "The substance to be assayed is dissolved in boracic acid, and, when a good fusion is effected, a piece of fine steel wire, a little larger than the diameter of the bead, is forced into it, and the whole then exposed to a good reducing flame. The iron is oxidised at the expense of the phosphoric acid, causing the formation of a borate of the oxide of iron and phosphuret of iron, which fuses at a sufficiently high temperature. The bead is then taken from the charcoal, enveloped in a piece of paper, and struck lightly with a hammer, by which means the phosphuret of iron is separated from the surrounding flux. It exists as a metallic-looking button, attractable by the magnet, frangible on the anvil, the fracture having the colour of iron. If the substance under assay contained no phosphoric acid, the iron wire will keep its form and metallic lustre, excepting at the ends, where it will be oxidated and burnt. The substance to be assayed ought not to contain sulphuric acid, arsenic acid, or any metallic oxides reducible by iron."

Hydrates.—The presence of water in these substances can be ascertained by heating them in the close tube. If any water be present, it will vaporise and condense on the coolest portions of the tube.

Silicates. — These compounds of silica with bases are decomposed by fusion with microcosmic salt, the silica being set at liberty, and the base combining with the phosphoric acid. When but a small quantity of microcosmic salt is employed, it often happens that the silica swells at the moment of decomposition, absorbing the liquefied mass. By adding a large quantity of the flux, the whole can be converted into a globule, which retains in suspension the semi-transparent tumefied silica. This can best be perceived when the glass is in a state of ignition.

COLOURED FLAMES.

There are a great number of substances best detected by the colours they impart to the flame of the blow-pipe. Indeed, so important is this point, that it has been thought advisable to collect all the facts known on this subject into one place, rather than scatter them over the work. These experiments are best made in a dark room, and with a very small flame.*

BLUE FLAMES.

Large intense blue	Chloride of copper.
Pale clear blue	Lead.
Light blue	Arsenic.
Blue	Selenium.
Greenish blue	Antimony.
Blue mixed with green	Bromide of copper.

GREEN FLAMES.

Very dark green, feeble	Ammonia.
Dark green	Boracic acid.
Dark green	Iron wire.
Full green	Tellurium.
Full green	Copper.
Intense emerald green	Iodide of copper.
Emerald green, mixed with blue	Bromide of copper.
Pale green	Phosphoric acid.
Very pale apple green	Barytes.
Intense whitish green	Zinc.

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* Griffin's Blow-pipe Analysis, page 148.

YELLOW FLAMES.

Intense greenish yellow	Soda.
Feeble brownish yellow	Water.

RED FLAMES.

Intense crimson	Strontian.
Reddish purple	Lithia.
Reddish purple	Lime.
Violet	Potash.

Chlorine, combined with copper, gives an intense blue flame. This phenomenon may be produced as follows:—Take a piece of thin brass wire, and bend one end of it several times upon itself; place upon this some microcosmic salt, and fuse it until it has acquired a green colour. Then add to it the substance suspected to contain chlorine, and place it in the oxidising flame just at the point of the blue flame, when, if any chloride be present, a splendid blue colour will be produced.

Lead.—The blue colour produced by this metal is readily obtained. Fragments of a mineral must be held in the tongs, and powder may be assayed on charcoal.

Arsenic, in the metallic state, gives rise to a light blue flame.

Selenium and *Antimony,* when treated in the same manner, afford characteristic flames.

Bromine.—If any substance containing bromine be placed in a bead of fused microcosmic salt on the brass wire, and then in the oxidising flame, a bright blue flame, with emerald green edges, will be produced.

Boracic Acid.—The following is Dr. Turner's process for the detection of boracic acid. "The substance is to be mixed with a flux composed of 1 part of fluor-spar, and 4½ parts of bisulphate of potash. This mixture is to be made to adhere to the moistened end of a platinum wire, and held at the point of the blue flame; at the instant of fusion, a dark green flame will be produced. It may also be produced by merely dipping the mineral in sulphuric acid, and exposing it to the blow-pipe blast. In case a very small quantity of boracic acid is contained in a mineral, the following process may be employed:—The substance must be fused with carbonate of potash on charcoal, moistened with a drop or two of sulphuric acid, and then a few drops of alcohol; the latter will burn with a green flame when exposed to the flame of the blow-pipe.

Tellurium.—The peculiar flame given by this metal is produced by heating a portion of its oxide on charcoal in the reducing flame.

Copper.—All the compounds of copper, except those in which bromine and chlorine enter, give a beautiful green flame. The soluble salts give it *per se*, but the insoluble require moistening with sulphuric acid.

Iodine and Copper.—To the bead of microcosmic salt on the brass wire, add any compound containing iodine, and a bright green flame will be produced when the mass is heated in the oxidising flame.

Phosphoric Acid.—The phosphates, when moistened with sulphuric acid, give a light green tint to the outer flame.

Baryta.—The soluble salts of baryta give a light green colour to the outer flame when moistened with water.

Zinc, when exposed to the blow-pipe flame, burns with an intense whitish-green light.

Soda.—Any salt of soda, or substance containing soda, being exposed to the outer flame, gives a brush of intensely coloured flame, of a fine amber or greenish-yellow.

Water.—Certain minerals containing water give a feeble yellowish tint to the flame.

Strontia.—All the salts of this substance which are soluble in water give a crimson tint to the flame, which does not endure after the substance is fused. Carbonate of strontia must be moistened with hydrochloric acid, and sulphate of strontia must be reduced to the state of sulphuret by ignition with charcoal; it must then be moistened with hydrochloric acid; after which treatment it will exhibit the characteristic flame.

Lithia.—All that has been said of strontia applies to lithia, with the remarkable exception, that the coloured flame given by lithia is permanent, whilst that afforded by strontia is evanescent.

Lime acts as strontia.

Potash, treated as soda, gives a purplish light; but the re-actions of potash and soda with oxide of cobalt are the best tests of their presence, combined with the peculiar light afforded by soda.

ON THE INDICATIONS GIVEN BY THE MOST COMMON OF THE MINERALS ON BEING TREATED BY THE BLOW-PIPE, AIDED BY FLUXES.

MINERALS OF COPPER.

Sulphuret of Copper.—Alone, on charcoal, gives off sulphurous acid, fusing readily in the outer flame. In the inner flame it is covered with a crust, and does not fuse.

In the *open tube* sulphurous acid is disengaged, but no sublimate is produced. The residue, treated with soda and borax, gives a button of copper.

Argentiferous Sulphuret of Copper.—Alone, fuses easily, giving off sulphurous acid. Cupelled with lead, on bone-ash, it leaves a large bead of silver, and the cupel appears a blackish green.

Sulphuret of Antimony and Copper, Bournonite.—Alone, in the open tube, gives off the antimonial smoke, with an odour of sulphurous acid. A slip of Brazil-wood paper, on being placed within the tube, is bleached.

On charcoal, a deposit of antimony, but no trace of lead. The bead diminishes in size, becoming grey, and semi-malleable. Fused with soda, it gives a grain of copper.

Copper Pyrites, Sulphuret of Iron and Copper.—Alone, on being heated, blackens, becomes red by cooling, and fuses more easily than the sulphuret of copper, finally giving a bead attractable by the magnet. This bead is brittle, and reddish-grey in the fracture. If after a long exposure to the oxidising flame it be treated with a small quantity of borax, a regulus of copper is obtained.

In the *open tube,* much sulphurous acid is given off.

With Soda, globules of iron and globules of copper are obtained, provided the ore has been sufficiently roasted.

Sulphuret of Tin and Copper, Tin Pyrites.—Before the blow-pipe it becomes, by roasting, covered with a snow-white powder, which is oxide of tin. The white powder also encircles the globule to the extent of about two lines.

In the *open tube,* sulphurous acid is given off.

*Needle-ore, Aikenite.**—*Alone,* it fuses, giving off vapour, which coats the charcoal snow-white, slightly yellowish on the interior edge, finally giving a metallic bead resembling bismuth.

In the *open tube* it gives off a white smoke, one part of which is fusible, and the other volatile. The first part is converted by fusion into limpid drops, which become white by cooling; there is also an odour of sulphurous acid. Treated by fluxes, the resulting bead of bismuth gives the re-action of copper. After a long blast, a grain of copper may be obtained, which by cupellation with lead

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* So named by Chapman.

gives traces of silver. The fusible white smoke, at the commencement of the operation, indicates the presence of tellurium.

The Oxides of Copper.—The action of the fluxes, &c., on these bodies has already been pointed out.

Chloride of Copper.—Alone, colours the flame blue, with greenish edges. A red pulverulent deposit forms on the charcoal around the assay; the fused matter reduces, giving a grain of copper, surrounded by slag.

With the fluxes, the chloride behaves as the oxides.

Carbonate of Copper.—Alone, in the matrass, gives water, and blackens.

On charcoal it fuses, and behaves like oxide of copper.

Arseniate of Copper behaves with the fluxes in the same manner as the oxide of copper, but exhales a strong odour of arsenic, and gives, when reduced with soda, a white and brittle bead.

ORES OF LEAD.

Sulphuret of Lead, Galena.—Alone, on charcoal, does not fuse until after disengagement of sulphur; globules of lead then form on the surface, and finally a bead of lead is obtained. By cupelling this, the presence of silver may be ascertained. After cupellation, the bone-ash indicates by its colour whether the lead were pure or not; if it were, when cold the cupel would be pure yellow; copper renders it green, and iron brown or blackish.

In the tube, galena gives off sulphur, and a white sublimate of sulphate of lead.

Oxide of Lead.—Its action with fluxes has been already shown.

Sulphate of Lead decrepitates, fuses on charcoal in the outer flame into a transparent bead, which becomes milky by cooling. In the reducing flame it effervesces, giving a button of lead.

Carbonate of Lead behaves like oxide of lead.

Phosphate of Lead.—Alone, on charcoal, it fuses, the bead crystallizing as it cools. The crystals have large facets, and a pearly whiteness.

With the fluxes it behaves like oxide of lead.

ORES OF ZINC.

Zinc Blende, Black Jack, Sulphuret of Zinc.—Alone, decrepitates violently. Suffers no remarkable change on ignition; does not fuse, and gives off but a very slight odour of sulphurous acid, being very difficult to roast.

On charcoal, an annular deposit of oxide of zinc is formed when heated violently in the outer flame.

Soda attacks it feebly; but the zinc is reduced in a good fire, with the deposition of oxide of zinc on the charcoal.

Carbonate of Zinc, Calamine.—Alone, gives off no water, but becomes a white enamel, which behaves like oxide of zinc.

ORES OF TIN.

Oxide of Tin.—Its behaviour with fluxes has already been noticed.

ORES OF IRON.

Sulphuret of Iron (Magnetic Pyrites).—Alone, undergoes no change.

In the *open tube,* gives sulphurous acid.

On charcoal, becomes red in the outer flame, and is changed, by roasting, into an oxide of iron.

Common Pyrites.—Alone, in the matrass, exhales an odour of sulphuretted hydrogen, whilst sulphur is eliminated.

On charcoal it behaves like magnetic pyrites.

Mispickel, Arsenical Pyrites.—Alone, gives first a red sublimate, which is sulphuret of arsenic, then a black; and lastly, in a strong fire, metallic arsenic sublimes. Treated on charcoal, the residue gives no arsenical odour, and behaves like magnetic pyrites.

On charcoal, mispickel gives a thick smoke of arsenic, then fuses, exhaling the odour of that metal. If the mispickel contain cobalt, it can be detected after well roasting the ore, and fusing the residue with borax or microcosmic salt; after cooling, the glass takes the characteristic colour of cobalt.

Magnetic Oxide of Iron, and Oxide of Iron, behave as already described.

Carbonate of Oxide of Iron, heated in the matrass, gives no water. Some species decrepitate strongly. Exposed to a gentle heat, it blackens, and gives oxide of iron, very attractable by the magnet.

Chromate of Iron.—Alone, undergoes no alteration. With borax and microcosmic salt, the solution is slow but complete. The characteristic colours are alone apparent when the bead is hot; but as soon as it cools, the fine green of chromium makes its appearance.

This re-action is most intense when the substance is treated in the reducing flame, and appears in all its lustre by the addition of tin.

Hydrate of Iron gives water in the matrass, and leaves red oxide after fusion with microcosmic salt; it gives with tin some traces of copper.

COBALT ORES.

Sulphuret of Cobalt.—In the matrass, gives no volatile substance, and does not decrepitate. In the open tube gives sulphurous acid, and a white sublimate, which consists of drops perceptible by the microscope; they are concentrated sulphuric acid. There are no traces of arsenic.

With the fluxes, the re-actions of cobalt so predominate that it is impossible to discover those of iron and copper; but if it be fused many times with borax, in the exterior flame, (that is, the grey bead produced by fusion on charcoal of the mineral itself), the borax removes the cobalt, and the copper concentrates; so that when the mass is fused with microcosmic salt, and exposed to the reducing flame, the red colour of the oxide of copper is produced, shaded, however, by the cobalt blue.

Arsenical Cobalt.—Alone, in the open tube, gives an abundance of arsenious acid with great facility. In the *matrass*, some species give a little metallic arsenic; others give none.

On charcoal all disengage an arsenical smoke and odour, and give by fusion a white metallic bead.

Cobalt Glance (Tunaberg).—*Alone*, in the matrass, suffers no change.

In the *open tube*, roasts with difficulty, giving no arsenious acid but by a very strong fire, but disengaging sulphurous acid.

On charcoal, gives an abundance of fumes, and enters into fusion after some considerable roasting; it then behaves as arsenical cobalt.

Black Oxide of Cobalt.—Alone, gives a little empyreumatic water.

On charcoal, gives traces of arsenic, but does not fuse.

Dissolves in borax and microcosmic salt, giving so deep a blue as to disguise all other action.

It is infusible with soda, and gives on the platinum wire a mass strongly tinted green by manganese.

Arseniate of Cobalt.—Alone, in the matrass, gives off water and becomes brown, but furnishes no sublimate.

On charcoal, gives off much vapour, and a smell of arsenic. Fuses in a good reducing flame, and is converted into arsenical cobalt.

ORES OF MANGANESE.

Sulphuret of Manganese.—Alone, in the matrass, undergoes no change.

In the *open tube* roasts slowly, but gives no sublimate. The roasted surface takes a bright green tinge.

On charcoal, after complete roasting, behaves with the fluxes like pure oxide of manganese.

Peroxide of Manganese.—Alone, in the matrass, when pure, undergoes no sensible alteration, but in general it contains more or less hydrate of manganese, the water of which may be driven off by means of heat. The more water the heated matter gives off, the less available oxide of manganese it contains. On charcoal it becomes reddish brown in a good reducing flame.

With borax and microcosmic salt it dissolves with a brisk effervescence, produced by disengagement of oxygen; it then behaves as oxide of manganese.

ORES OF CHROMIUM.

Chrome Ochre.—Alone, decolorises, and becomes nearly white, but does not fuse.

Borax separates oxide of chromium, and takes a fine green colour.

It dissolves with great difficulty in microcosmic salt, and the green colour is not so beautiful as with borax.

ORES OF ANTIMONY.

Red and Black Sulphurets of Antimony.—Alone, they fuse readily on charcoal, which absorbs them and becomes covered with a black vitreous crust. After the blast has been continued for a few moments, metallic globules appear on the charcoal, which seem to be a sub-sulphuret, as they do not behave like the pure metal; for they do not burn, but blacken, and become dull on the surface after cooling.

Roasted in the glass tube, much antimonious acid forms at the commencement; that which sublimes afterwards is a mixture of antimonious acid with much oxide.

GOLD.

Graphic Gold.—On charcoal, fuses into a dull grey metallic bead, covering the charcoal with a white smoke, which disappears with a green or bluish light, when the reducing flame is thrown upon it. After a continued blast, a bright yellow metallic grain is obtained. It is, after cooling, brilliant and malleable.

In the *open tube* it deposits a smoke, which is white, excepting in the neighbourhood of the assay, where it is greyish. This is sublimed tellurium. This deposit forms limpid drops when the flame is directed upon it.

Telluriferous and Plumbiferous Gold.—Alone, on charcoal, it fuses like the preceding, and forms a pulverulent deposit on the support; but this deposit is yellow; it disappears in the reducing flame with a blue colour, which is not at all green. It gives, after a strong blast, a grain of gold, which ignites at the instant of congelation. This grain is malleable.

In the *tube* it fumes, giving a very sensible fume of sulphurous acid. It then gives a sublimate, which is grey close to the assay, but white elsewhere.

ORES OF MERCURY.

Cinnabar, Sulphuret of Mercury.—Alone, on charcoal, it volatilizes without residue, giving off an odour of sulphurous acid. In the matrass, it sublimes, giving a blackish sublimate. In the open tube, it gives, by roasting, mercury and sublimed cinnabar. In the matrass, with soda, globules of mercury are obtained.

Muriate of Mercury, Horn Mercury.—On charcoal, volatilizes without residue. In the matrass, gives a white sublimate. With soda, in the matrass, gives much mercury in globules.

With microcosmic salt, fused on the brass wire, it communicates a fine azure blue colour to the flame, indicative of chlorine.

ORES OF SILVER.

Sulphuret of Silver.—Alone, on charcoal, fuses and swells considerably, forming large bubbles; but after a continued blast, it forms a grain. It gives off an odour of sulphurous acid, and finally furnishes a grain of silver, surrounded by slag. Fused with borax and microcosmic salt, the slag gives traces of copper.

Red Silver.—Alone, on charcoal, decrepitates a little, fuses, burns, and smokes, like antimony, but gives no arsenical odour. The production of vapour lasts but for a few minutes.

In the *open tube,* it gives much vapour, and a smell of sulphurous acid, which is very strong at the commencement. The deposit on the sides of the tube is sometimes crystalline; it is oxide of antimony. The bead which remains after a long exposure to the exterior flame is a button of pure silver.

Antimonial Silver, and Argentiferous Antimony.—Alone, on charcoal, fuse readily, forming a metallic bead, which is not malleable, giving off a vapour like that of pure antimony, but less abundant. The bead becomes, after the disengagement of a certain quantity of antimony, dull white, and very crystalline, entering into ignition at the instant of congelation. When it has lost yet more antimony, its surface becomes smooth, like glass; and the heat which it then disengages is more intense than at any other time. Lastly, after a long-continued blast, nothing but pure silver remains.

In the tube, much oxide of antimony is given off, and the bead which remains is surrounded by a bead of deep yellow glass.

Electrum gives by fusion a grain of gold, which varies in whiteness, and which gives with borax and microcosmic salt the same re-actions as pure silver.

Amalgam, in the matrass, swells up, and gives much mercury, leaving silver, which may be fused to a bead on charcoal.

Muriate of Silver, Horn Silver.—On charcoal becomes a bead, which, according to the purity of the salt, is grey, brownish, or black. In the reducing flame it is gradually converted into metallic silver. It gives with microcosmic salt, fused on the platinum wire, a blue flame, like the muriate of mercury.

BISMUTH.

Native Bismuth.—Alone, fuses, giving a weak arsenical odour. Otherwise, it presents the same phenomena as pure bismuth.

In the open tube it gives a little arsenious acid. Cupelled, it tinges the bone-ash pure orange-yellow.

Sulphuret of Bismuth.—Alone, in the tube, gives sulphurous acid, and a white sublimate; heated to redness, it deposits oxide of bismuth round the assay, like pure bismuth.

On charcoal, it fuses with bubbling, throwing out small incandescent globules. This agitation lasts but a short time.

ORES OF NICKEL.

Sulphuret of Nickel.—In the open tube gives sulphurous acid, becomes black, but does not change form. On charcoal, gives, by aid of a good flame, a mass conglomerated by semi-fusion. It is metallic, malleable, and is pure nickel.

After roasting in the open air, it behaves with fluxes like oxide of nickel.

Arsenical Nickel, in the matrass, gives nothing volatile; semi-fuses at the temperature which softens glass, and a deposit of arsenious acid is formed on the sides of the matrass: this is owing to the included air.

It fuses on charcoal, with a vapour and arsenical odour, and a white metallic globule.

In the open tube it roasts easily, with the formation of a large quantity of arsenious acid; the residue is a yellowish-green substance, which, on roasting afresh on charcoal, and fusion with soda and borax, gives a tolerably malleable metallic grain, and is very magnetic.

After roasting, it behaves with the fluxes like oxide of nickel, and generally gives a glass, which is slightly blue, owing to the presence of a small quantity of cobalt.

ON THE DISCRIMINATION OF MINERALS BY MEANS OF THE BLOWPIPE, AIDED BY HUMID ANALYSIS.

We now come to that part of our subject which treats of the discrimination of minerals by a few simple tests; and for the greater part of the remarks which follow the author is indebted to Campbell's translation of Kobell's work on this subject, and to Chapman's "Practical Mineralogy;" and for a more extended account of these processes, the reader is referred to the above-mentioned works.

In both the works just quoted, the first thing to be done with a mineral in its examination is to ascertain whether its lustre be *metallic* or *non-metallic;* this point is most important. There are, however, a few minerals in which the determination of this is doubtful; in which case a single experiment will point out to which class the mineral really belongs.

The *degree of fusibility* is next to be attended to; and in case a beginner should be mistaken on this point, Von Kobell has arranged a certain set of minerals to be employed as checks against the opinion any one may form of the fusibility of any substance submitted to his examination.

They are six in number, and are as follows:—

1. Sulphuret of antimony.
2. Natrolite.
3. Almandine.
4. Strahlstein (actinolite).
5. Adularia (felspar).
6. Diallage (bronzite).

The great advantage of this scale is, that it facilitates the very useful practice of comparative experiment. If a mineral be more fusible than No. 2, and less so than No. 3, it is said to be 2·5 in the scale of fusibility, and so on.

Another great requisite is to ascertain the *hardness* of any specimen we may have to examine; and here, again, a comparative scale is necessary. The following has been arranged by Mohr:—

1. Talc.
2. Gypsum (crystallized).
3. Calc spar (carbonate of lime).
4. Fluor spar.
5. Apatite.
6. Adularia (felspar).
7. Rock crystal.
8. Topaz.
9. Corundum.
10. Diamond.

As the above set of minerals may not always be at hand, and as it is very necessary to determine the degree of hardness, Mr. Chapman has, with much ingenuity, arranged a very useful set of materials which are always present. This scale is of great value to the experimenter:—

1. Yields easily to the nail.

2. Yields with difficulty to the nail, or merely receives an impression from it. Does not scratch a copper coin.

3. Scratches a copper coin; but is also scratched by it, being of about the same degree of hardness.

4. Not scratched by a copper coin; does not scratch glass.

5. Scratches glass, though rather with difficulty, leaving its powder on it. Yields readily to the knife.

6. Scratches glass easily. Yields with difficulty to the knife.

7. Does not yield to the knife. Yields to the edge of a file, though with difficulty.

8, 9, 10. Harder than flint.

In ascertaining the degrees of hardness by the first scale, a file ought to be employed, and it is by the comparative ease or difficulty that the mineral and sample yield to it that the degree of hardness is determined. This is a part, however, to which much attention must be paid.

The *specific gravity* of a mineral is also of great importance in its discrimination. It may be determined as follows, if the sample be of sufficient size to suspend from the pan of a balance by means of a fibre of silk; if not, another mode must be adopted, which will be pointed out as we proceed.

If the mineral can be suspended, attach it by a short fibre of silk to one of the pans of a delicate balance, and ascertain its weight; then immerse it (still suspended to the pan) in distilled water of the temperature of 60° Fah., and then note its weight; it will be found to have lost a certain amount, which will correspond to the weight of the bulk of water it has displaced. Divide its weight in air by the loss of weight in water, and the quotient will be the required specific gravity. This will be more readily understood by an example. Suppose we find the mineral to weigh 80 grains in the air, and only 66 in water; the loss$=80-66=14$. We must now divide 80 by 14, thus $\frac{80}{14}=5{\cdot}7$, which is about the specific gravity of a sample of bournonite.

We have now the second case to consider; the mineral may be in very small fragments, or it may even be in powder, in which case its specific gravity must be determined thus:

A bottle must be obtained capable of containing a known quantity of water, as 500 grs. The ordinary specific gravity bottle is well suited for this purpose. A known weight of the body whose specific gravity is to be ascertained,—say 100 grs.,—is to be introduced into the bottle, which is then to be filled with water, and the weight of the whole to be determined: it will be less than the united weight of the contents of the bottle full of water and the weight of the mineral in air. The loss of weight is to be ascertained, and the weight in air divided by it; the quotient is the specific gravity required. The following example may suffice to render this clearer:—

Suppose the bottle contains of water . .	500 grs.
And the mineral introduced into it weighs	100 grs.
	600
Weight of mineral and water in bottle . .	560
	40 loss.

Then $\frac{100}{40}=2\cdot5$, required specific gravity.

Besides ascertaining hardness, fusibility, and specific gravity, it is required to determine the re-actions of the mineral with the various fluxes. The method of doing this has been already described. Finally, it is necessary to ascertain the behaviour of the mineral in solution, or otherwise, with certain liquid re-agents. The method of conducting this class of examination will be presently pointed out.

Having thus given a rough sketch of the processes to be employed, we will now describe the whole method to be followed in ascertaining the nature of certain minerals, principally confining ourselves to those generally met with, and worked by the miner. The following is a list of them:—

Amalgam.
Anhydrite.
Anhydrous silicate of zinc.
Grey antimony.
Native antimony.
Native mercury.
Red antimony.
Oxide of antimony.
Antimonial nickel.
Antimonial silver.
Antimonial grey copper.
Dark red silver,
Muriate of silver (horn silver).
Native silver.
Sulphuret of silver.
Argentiferous gold.
Argentiferous grey copper.
Arseniate of cobalt.
Arseniate of copper.
Arseniate of iron.
Arseniate of lead.
Native arsenic.
Arsenic glance.
Oxide of arsenic.
Red sulphuret of arsenic.
Yellow ditto.
Arsenical iron.
Arsenical cobalt.

Arsenical nickel.
Arsenical pyrites.
Arsenical grey copper.
Arsenical bismuth.
Arsenious acid.
Arsenic acid.
Light red silver.
Muriate of copper (Atakamite).
Azure copper ore.
Azurite.
Azure stone.
Carbonate of baryta.
Sulphate of baryta.
Bismuth blende.
Native bismuth.
Black manganese.
Black oxide of copper.
Black silicate of manganese.
Black tellurium.
Graphic tellurium.
Galena.
Sulphate of lead.
Carbonate of lead.
Horn lead (chloride of lead).
Blende.
Bog iron ore.
Bournonite.
Bright white cobalt.
Calamine.
Calomel.
Baryta, carbonate.
Copper, carbonate, green.
Copper, carbonate, blue.
Iron, carbonate.
Lime, carbonate.
Silver, carbonate.
Strontia, carbonate.
Phosphate of lime.
Chromate of iron.
Chromate of lead.
Cinnabar.
Copper.
Copper pyrites.
Copper, red oxide.
Copper, vitreous.
Earthy cobalt.
Oxide of tin.
Sulphuret of tin.
Oligistic iron.
Iron, hydrated oxide.
Iron, spathose.
Iron, specular.
Iron, sulphuret.
Iron, sulphuret, white.
Iron, sulphuret, magnetic.
Fluor spar.
Galena.
Graphic tellurium.
Gypsum.
Gypsum, anhydrous.
Hydrated deutoxoide of manganese.
Hydrous silicate of iron.
Nickel, arsenical.
Nickel ochre.
Tin stone.
Palladium.
Platinum.
Purple copper.
Quartz.
Sulphuret of molybdenum.
Sulphuret of nickel.
Sulphuret of nickel and bismuth.

CLASS I.—MINERALS POSSESSING A METALLIC LUSTRE.

CLASS II.—MINERALS POSSESSING NO METALLIC LUSTRE.

These classes are further divided thus :

CLASS I.

Division 1. *Metals proper.*
Division 2. *Fusible* 1-5, *or readily volatile.*
Division 3. *Infusible, or fusibility above* 5, *and not volatile.*

CLASS II.

Division 1. *Easily volatile or combustible.*
Division 2. *Fusible* 1-5 ; *not, or only partially, volatile.*
Division 3. *Infusible, or fusible above* 5.

Division 1.

CLASS I.

Metals proper, readily distinguished.

Division 2.

CLASS I.

Section 1. Give an arsenical odour on charcoal.
Section 2. Give the horse-radish odour of selenium.
Section 3. Give a white sublimate in open glass tube, which is fusible into colourless drops, indicative of tellurium.
Section 4. On charcoal give antimonial vapour.
Section 5. With soda give a sulphuret, but do not give indications as above.
Section 6. Behave differently to five preceding.

Division 3.

CLASS I.

Section 1. Give the re-action of manganese with borax.
Section 2. On charcoal in reducing flame become magnetic.
Section 3. Partly agreeing with section 2.

CLASS II.

Division 1. Easily volatile or combustible.
Division 2. *Part* 1. *Give on charcoal, either alone or with soda, a metallic bead or magnetic metallic mass.*
Section 1. Give silver.
Section 2. Give lead.

Section 3. Give copper, and when moistened with hydrochloric acid, colour the flame transiently blue.
  1. Give a strong odour of arsenic.
  2. Give no odour of arsenic.

Section 4. Give a bright blue with borax.

Section 5. Give a black or grey metallic magnetic mass, but not behaving as any of the minerals of the preceding sections.
  1. Indicate arsenic during fusion.

Section 6. Not belonging to either of the foregone sections.

Part 2. Give no metallic bead, or magnetic metallic mass.

Section 7. After fusion, alone or with charcoal, have an alkaline re-action.

Division 3.

CLASS II.

Section 1. Ignited with nitrate of cobalt, give zinc re-action.

Section 2. Soluble in hydrochloric or nitric acids, giving no jelly or residue.

Section 3. Not included in the five preceding sections, but divided thus:
  1. Hardness under 7.
  2. Hardness 7, or above 7.

CLASS I.

Division 1. *Metals proper.*

Native Mercury.—Liquid at ordinary temperatures. Tin-white and opaque. Lustre metallic. Sp. gr. 12. Entirely volatilizable before the blow-pipe.

Native Silver.—Hardness = 2·5 – 3. Silver-white, perfectly malleable, easily fusible, soluble in nitric acid. The solution, mixed with hydrochloric acid, gives a white curdy precipitate of chloride of silver, which is soluble in ammonia. Metallic silver is also precipitated from the nitric acid solution by a plate of copper. Sp. gr. about 10.

Native Gold.—Hardness, 2·5 – 3. Colour, yellowish or greyish yellow, easible fusible and very ductile, soluble in nitro-hydrochloric acid (aqua regia) without residue: the solution gives a purple precipitate on the addition of protochloride of tin, and a brown precipitate with protosulphate of iron. Sp. gr. about 19.

Electrum, Auriferous Silver.—Colour, inclining to silver-white. Hardness, 2·5 to 3. Sp. gr. about 12·5. Partially soluble in aqua regia, giving a residue of chloride of silver. The solution is acted on by proto-sulphate of iron, as the above.

Native Iron.—Hardness, 4·5. Light steel-grey, ductile and malleable, attractable by the magnet, soluble in dilute sulphuric acid, giving a blue precipitate with ferrocyanide of potassium. Sp. gr. 7·4 to 7·8.

Native Copper.—Colour, brownish-red, ductile and malleable. Hardness, 2·5 to 3. Sp. gr. 8·4 to 8·9, easily soluble in nitric acid, with evolution of red fumes. The solution is blue, which becomes intense on the addition of excess of ammonia. Metallic copper can be obtained from it by precipitation on a plate of iron or zinc.

Native Lead.—Hardness, 1·5. Sp. gr. 11 to 12. Colour, lead-grey, ductile and malleable, easily fusible, giving a yellow sublimate of oxide of lead on the charcoal support. Soluble in nitric acid, the solution giving a white precipitate with sulphuric acid, or yellow with chromate of potash, and a deeper yellow with iodide of potassium. Metallic lead is also obtainable from it by deposition on a bar of zinc.

Native Platinum.—Hardness, 4 to 4·5. Sp. gr. 16 to 20. Colour, silver-whitish or grey, ductile and malleable. Not fusible, nor acted on by any fluxes. Soluble in aqua regia. The solution gives a yellow granular precipitate with carbonate of potash, which is insoluble in excess.

Native Palladium.—Hardness, 4·5 to 5. Sp. gr. 11·5 to 12·5. Colour, steel-grey or silvery white. Soluble in nitric acid. The solution gives a brownish precipitate with carbonate of potash, which is soluble in excess. The metal also becomes blue when heated gently in the oxidising flame, but which colour disappears when the heat is more intense. It is infusible by itself, but fusible with sulphur, which on being burnt off leaves a globule of palladium.

Division 2. CLASS I.

Section 1. *Give a strong odour of arsenic.*

Native Arsenic.—Hardness, 3·5. Sp. gr. 5·7 to 5·9. Colour, tin-white on fresh fracture, but soon tarnishes. Fusible, entirely volatilizable if pure.

Arsenical Grey Copper.—Hardness, 3 to 4. Sp. gr. 4·4 to 5. Moistened with hydrochloric acid and ignited on charcoal, gives an intense blue colour to the flame. It gives a grey globule, generally attractable by the magnet, and a bead of copper, with borax. Acted on by caustic potash, the sulphurets of antimony and arsenic are dissolved out, and may be precipitated from the solution by hydrochloric acid. Some varieties contain silver, the presence of which may be ascertained by acting on the ore with nitric acid, and precipitating with common salt, or hydrochloric acid. The precipitate ought to be soluble in ammonia.

Tin-white Cobalt.—Hardness, 5·5. Sp. gr. 5·4 to 6·7. Colour, tin-white; gives blue colour to borax, and pink solution to nitric acid. Silicate of potash in solution gives a sky-blue precipitate. It fuses into brittle magnetic globules.

Bright-white Cobalt.—Hardness, 5·5. Sp. gr. 6·2 to 6·3. Colour, silver-white, sometimes reddish. Roasted in the open tube it gives off sulphurous acid, which may be ascertained by smell, and test paper. It fuses into a magnetic globule, giving cobalt blue to borax. Its solution in nitric acid behaves with silicate of potash as before, but gives a copious precipitate with nitrate of baryta, indicative of the presence of sulphuric acid.

Arsenical Nickel, Nickeline.—Hardness, 5 to 5·5. Sp. gr. 6·6 to 7·7. Colour, reddish or whitish. Fuses readily into a white or yellowish globule. Partially soluble in nitric acid. The solution is green, and with silicate of potash gives an apple-green precipitate. The solution becomes violet blue on the addition of an excess of ammonia. In the varieties of this mineral containing sulphur, the nitric acid solution gives a white precipitate, with nitrate of baryta, or chloride of barium.

Arsenical Iron.—Sp. gr. 6·2. Hardness, 5 to 5·5. Colour, steel-grey. Fuses into a brittle magnetic globule, which gives the re-actions of iron with the fluxes. It is soluble in nitric acid, the solution giving a blue colour to ferrocyanide of potassium, and a yellowish brown precipitate of arseniate of iron to ammonia.

Section 2. *Give evidence of the presence of selenium.*

Section 3. *Give evidence of the presence of tellurium.*

Graphic Tellurium.—Hardness, 1·5 to 2. Sp. gr. 5·7. Steel-grey, like galena. Easily fusible, giving a yellowish white button, which, on lamination, is partially soluble in nitric acid; the solution containing silver, which can be ascertained by chloride of sodium. The residue is soluble in aqua regia, and has all the characteristics of a solution of gold. It gives no precipitate with sulphuric acid.

Black Tellurium.—Hardness, 1 to 1·5, Sp. gr. 7 to 7·2. Blackish lead-grey. Very fusible, producing a bead of malleable metal. The charcoal gives evidence of the presence of lead by the coating of yellow oxide. It dissolves in nitric acid, and the solution gives a dense white precipitate with sulphuric acid.

Section 4. *Give evidence of antimony.*

Native Antimony.—Sp. gr. 6·5 to 6·8. Hardness, 3 to 3·5. Colour, tin-white, but becomes yellowish by exposure before the blow-pipe. It fuses readily, and continues to burn for some time after it has been removed from the flame; the globule being covered with crystals.

Grey Antimony, Sulphuret of Antimony.—Sp. gr. 4·3 to 4·6. Hardness, 2. Colour, light grey. It melts even in the flame of a candle. It is absorbed by charcoal before the blow-pipe. If heated with solution of caustic potash, its powder becomes ochry red, and almost entirely dissolves. It can be reprecipitated by hydrochloric acid.

Bournonite.—Sp. gr. 5·7 to 5·8. Hardness, 2·5 to 3. Colour, approaching to steel-grey, with a shining lustre. Before the blow-pipe it decrepitates. A crust of sulphuret of lead remains after fusion, enclosing a globule of copper. It partially dissolves in nitric acid. The solution is blue, and gives with sulphuric acid a white precipitate of sulphate of lead, and an azure blue with ammonia.

Antimonial Silver.—Sp. gr. 9·4 to 9·8. Hardness, 3·5. Colour, between silver-white and tin-white. Before the blow-pipe on charcoal, it melts into a grey metallic globule, which is not malleable. It gives no sulphuret with soda, and is not acted on by caustic potash; with borax and soda it gives a button of silver.

Antimonial Grey Copper.—Its colour is dark reddish grey. Sulphuret of antimony can be obtained from it by the action of caustic potash. It gives evidence of sulphur with soda, and its solution in nitric acid gives a deep blue with ammonia. It gives with borax and soda a button of silver.

Antimonial Nickel.—Sp. gr. 6·4 to 6·5. Hardness, 5 to 5·5. Colour, steel-grey or silver-white. Before the blow-pipe, is partly volatilized, and finally gives a metallic globule, which is magnetic. It is readily dissolved in nitric acid, giving the usual indication of nickel. It is scarcely acted upon by hydrochloric acid.

Section 5.—*Give a sulphuret with soda, but do not possess the general properties of the foregone sections.*

Sulphuret of Silver.—Sp. gr. 6·9 to 7·2. Hardness, 2 to 2·5. Dark lead-grey colour. In the flame of a candle it intumesces. It is sectile. Before the blow-pipe the sulphur volatilizes, and a bead of pure silver remains. It is soluble in dilute nitric acid, and gives the characteristic curdy precipitate (which is soluble in ammonia) by the re-action of hydrochloric acid.

Sulphuret of Manganese.—Sp. gr. 3·9 to 4. Hardness, 3·5 to 4. Colour, brownish black, streak dark green; this is almost characteristic. It gives the usual indications of manganese by the blow-pipe with the fluxes. It dissolves, when in powder, in hydrochloric acid with the evolution of sulphuretted hydrogen.

Vitreous Copper.—Sp. gr. 5·6 to 5·8. Hardness, 2·5 to 3. Colour, lead or iron-grey. Before the blow-pipe on charcoal, it gives off sulphurous acid, and when the sulphur is wholly volatilized gives a bead of copper. With nitric acid it gives a green solution, which becomes azure-blue on addition of ammonia. Moistened with hydrochloric acid, the flame is coloured blue.

Sulphuret of Tin (*Tin Pyrites*).—Sp. gr. 4·3 to 4·7. Hardness, 4. Steel-grey colour. Before the blow-pipe sulphur is driven off; it then fuses to a black slag. Soluble in nitric acid, with separation of sulphur and oxide of tin. The solution gives a deep blue with ammonia. This mineral gives, by itself, no bead of malleable metal.

Sulphuret of Copper (*Copper Pyrites*).—Sp. gr. 4·1 to 4·3. Hardness 3·5 to 4. Colour, brass-yellow. It fuses on charcoal before the blow-pipe, and melts into a black brittle globule, attractable by the magnet. With borax, in small proportion, it yields a copper bead, and when the blast is long continued gives *per se* a button of copper on charcoal. It is soluble in nitric acid under separation of sulphur.

Purple Copper.—Sp. gr. 5. Hardness, 3. Colour, between copper-red and brown. Soft, and easily frangible. Before the blow-pipe it blackens, and becomes red on cooling; at a higher temperature it fuses; the globule is magnetic. Fused with soda, it is reduced with the formation of a bead of copper. It is soluble in nitric acid. The solution acted on by ammonia gives a precipitate of peroxide of iron and an azure-blue solution. The original solution gives a white precipitate with chloride of barium.

Sulphuret of Nickel.—Sp. gr. 6·4. Hardness, 4. It is steel-grey. It gives, with a strong, continued heat, a globule, which is magnetic, malleable, and metallic. In the open tube it gives sulphurous acid. It is not much acted on by nitric acid, but dissolves in aqua regia, giving a greenish solution, in which potash and silicate of potash give an apple-green precipitate, and chloride of barium a white precipitate.

Sulphuret of Iron.—Sp. gr. 4·7 to 5. Hardness, 6 to 6·5. General colour, brass-yellow: does not yield to the knife; hence it may be distinguished from copper pyrites. It does not attract the magnet before roasting, but does after; it is only acted on very slightly by muriatic acid, but is decomposable by aqua regia. The solution gives indications of sulphur and iron, by chloride of barium and ferrocyanide of potassium.

Magnetic Iron Pyrites.—Sp. gr. 4·4 to 4·7. Hardness, 3·5 to 4·5. General colour, bronze-yellow. Acts on the magnet before being heated. Dissolves very readily in hydrochloric and dilute sulphuric acids, under evolution of sulphuretted hydrogen.

Sulphuret of Bismuth.—Sp. gr. 6·5. Hardness, 2 to 2·5. Colour, tin-white, or lead-grey. It melts in the flame of a candle: before the blow-pipe the greater part of it is volatilized. It gives a bead of bismuth, and coats the charcoal with the oxide of that metal. It is soluble in nitric acid with a separation of sulphur; the solution lets fall a white precipitate on dilution with water.

Suphuret of Lead (*Galena*).—Sp. gr. 7·4 to 7·6. Hardness, 2·7. Colour, lead-grey. Before the blow-pipe, it decrepitates; after long heating, it is reduced to metallic lead, which, on cupellation, generally yields a little silver. It is soluble in dilute nitric acid; the solution gives metallic lead on a slip of zinc, a white precipitate with sulphate of soda, and a yellow one with iodide of potassium.

Section 6. *The following minerals belong to this division, but cannot be readily classed.*

Amalgam.—Sp. gr. 10 to 14. Hardness, 1 to 3·5. Colour, silver-white, or greyish. It is sometimes fluid, sometimes solid. Before the blow-pipe it volatilizes, and a globule of silver remains. It is easily soluble in nitric acid, and whitens the surface of copper when rubbed upon it; in the matrass, sublimed mercury is obtainable.

Native Bismuth.—Sp. gr. 9·6 to 9·8. Hardness, 2 to 2·5. Colour, silver-white, tinged with red. When cold, it is not malleable; but, when hot, may be laminated. It readily fuses and vaporizes, coating the charcoal with an orange-yellow sublimate. It dissolves easily in nitric acid.

Black Silicate of Manganese fuses with intumescence, and gives a deep amethyst-red with borax; it gives a large quantity of water in the matrass. Its general colour is lead-grey to iron-black. It gives a green colour to soda on the platinum foil. It is soluble in muriatic acid, with disengagement of silica.

Division 3. CLASS I.

Section 1. *Give the re-actions of manganese with borax.*

All the oxides of manganese belong to this class; they may be distinguished by their action, as above stated, with borax, in conjunction with the fact that they evolve chlorine when treated with hydrochloric acid, and the solution gives a flesh-red precipitate with hydrosulphuret of ammonia, and a dirty-white with caustic potash, which speedily becomes brown. They also give the characteristic green when acted on by soda on the platinum foil. There are several varieties; but it does not come within our province to particularize them.

Section 2. *On charcoal, in reducing flame, becoming magnetic.*

Red Hæmatite.—There are several varieties of this ore; some crystalline, others not; those which are not, have a very low degree of hardness, which is not determinate; those which are, have a hardness of from 5·5 to 6. They may be distinguished by becoming magnetic after roasting, and giving the usual indication of iron with the fluxes. They are slightly soluble in hydrochloric acid; but if fused with carbonate of soda, they are perfectly soluble in that acid. The solution, after boiling with a few drops of nitric acid, gives a deep blue with ferrocyanide of potassium, and a brown bulky precipitate with an excess of ammonia or caustic potash.

Section 3. *Partially agreeing with the above minerals.*

Magnetic Iron Ore.—This ore, before roasting, is strongly attracted by the magnet, as its name implies. It slowly dissolves in strong hydrochloric acid. Its colour is iron-black, with a shining metallic or glimmering lustre. It colours glass of borax, in the oxidating flame, deep red, which becomes dingy yellow on cooling. In the reducing flame, it is bottle-green.

Chrome Iron Ore.—Sp. gr. 4·3 to 4·6. Hardness, 5·4. It is iron-black, or brownish-black, with a shining and somewhat metallic lustre. Some varieties are strongly magnetic. With borax and microcosmic salt, it melts slowly, and the beads possess the fine green colour imparted by chromium, which increases in intensity on the addition of tin. It is scarcely acted on by acids. It gives a yellow solution to water after fusion with nitre; the solution becomes green with alcohol and sulphuric acid, or with sulphuretted hydrogen.

Sulphuret of Molybdenum.—Sp. gr. 4·4 to 4·7. Hardness, 1 to 1·5. Its colour is similar to that of freshly cut metallic lead. It is opaque, highly sectile and flexible. It is unctuous to the touch. Held in the forceps, it colours the blow-pipe flame light green. It is acted on by nitric acid, with effervescence, and leaves a grey substance, which is molybdic acid; if this be treated with alcohol and sulphuric acid, heated and allowed to cool, it becomes a splendid intense blue, which entirely disappears on the addition of water.

CLASS II.

Minerals possessing no metallic lustre.

Division 1. *Easily volatile or combustible.*

Sulphur.—Sp. gr. about 2. Hardness, 1·5 to 2·5. Its colour, when pure, is the well-known sulphur-yellow, that is, in a state of powder, but when in the crystalline form is more of a deep topaz yellow. It is, however, from extraneous circumstances and mixtures, sometimes grey, brown, or even greenish It burns, giving off the well-known smell of burning sulphur.

Realgar, Red Sulphuret of Arsenic.—Sp. gr. 3·3 to 3·6. Hardness, 1·5 to 2. It is of a bright red colour, approximating to scarlet, sometimes having an orange tint. Before the blow-pipe, on charcoal, it burns with a pale yellow flame, giving an odour of garlic. It is soluble in caustic potash, from which hydrochloric acid precipitates lemon-yellow flocks.

Orpiment, Yellow Sulphuret of Arsenic.—Sp. gr. 3·45. Hardness, 1·5 to 2. It behaves like realgar, but is distinguished by its fine yellow colour.

Arsenious Acid.—Sp. gr. 3·6 to 3·7. Hardness, 1·5. Colour, snow-white, though occasionally tinged with red or brown: this is accidental. It is soluble in hot water; the solution giving a yellow precipitate with sulphuretted hydrogen. It sublimes in the matrass; the deposit is crystalline. On charcoal, it exhales the odour of garlic in the reducing flame.

Oxide of Antimony.—Sp. gr. 5·5 to 5·6. Hardness, 2·5 to 3. Its colour is generally snow-white, although sometimes yellow or grey. It melts very readily before the blow-pipe, and is volatilized as a white vapour, very characteristic of antimony. It is entirely soluble in hydrochloric acid without the evolution of any gas, and does not change its colour in caustic potash. With borax it forms a bead, which is yellowish while hot, but colourless when cold.

Red Antimony.—Sp. gr. 4·5 to 4·6. Hardness, 1 to 1·5. It is cherry-red, fuses easily on charcoal, which absorbs it; it is, however, finally volatilized. If immersed in nitric acid, it becomes covered with a white coating. It is soluble in hydrochloric acid, with the evolution of sulphuretted hydrogen. Its colour is changed to ochre-yellow by immersion in caustic potash.

Sulphuret of Mercury, Cinnabar.—Sp. gr. 6·7 to 8·2. Hardness, 2 to 2·5. Its colour varies from carmine to vermilion red, or lead-grey. It always gives a bright scarlet streak. It fuses before the blow-pipe, and volatilizes with a bluish flame and sulphurous odour. Mixed with soda, in the matrass, it gives metallic mercury. Its colour is not changed by the ordinary acids or by caustic potash.

Subchloride of Mercury, Horn Mercury, Calomel.—Sp. gr. 6·4 to 6·5. Hardness, 1·5 to 2. Colour, greyish-white, grey, or yellowish. It is completely volatilized before the blow-pipe, and gives metallic mercury when heated in the matrass with soda. If treated with caustic potash it becomes black instantaneously.

Division 2. *All minerals having no metallic lustre and exhaling the odour of arsenic before the blow-pipe, belong to this division, with the exception of arseniate of lime.*

Part 1. *Give on charcoal, either alone or with soda, a metallic bead or magnetic metallic mass.*

Section 1. *Give silver.*

Light Red Silver.—Sp. gr. 5·4 to 5·6. On charcoal, gives the garlic odour characteristic of arsenic. If the pulverized mineral be treated with caustic potash, the solution gives lemon-yellow flocks of sulphuret of arsenic on the addition of hydrochloric acid.

Dark Red Silver.—Sp. gr. 5·8 to 5·9. On charcoal it gives the antimonial fume; and with caustic potash its solution gives orange-red flocks of sulphuret of antimony on the addition of hydrochloric acid.

Chloride of Silver, Horn Silver.—Sp. gr. 4·7 to 5·5. Colour, pearl-grey, greenish or reddish blue. It is fusible in the flame of a candle. When rubbed with a piece of moistened zinc, its surface becomes covered with a thin film of silver. It is insoluble in nitric acid.

If treated before the blow-pipe, with a bead of microcosmic salt, in which oxide of copper has been dissolved, it colours the flame a splendid purple.

Section 2. *Give Lead.*

Arseniate of Lead.—Sp. gr. 6·9 to 7·3. Hardness, 3·5 to 4. Its colour varies from many shades of yellow to aurora or hyacinth red. Before the blow-pipe it fuses with difficulty, giving off arsenical fumes. It is soluble in nitric acid; its solution gives metallic lead to a plate of zinc, and a white precipitate with sulphuric acid or a soluble sulphate. When pure, it dissolves without residue in caustic potash.

Sulphate of Lead.—Sp. gr. 6·2 to 6·3. Hardness, 3. General colour, white-grey, or yellowish.

It decrepitates before the blow-pipe; fuses in the oxidising flame to a transparent bead, which becomes white on cooling. It gives a sulphuret with soda. It dissolves in caustic potash, and with difficulty in nitric acid.

Carbonate of Lead.—Sp. gr. 6·3 to 6·6. Hardness, 3 to 3·5. Either colourless or white, passing into a greyish black. Its powder, thrown on coal, emits a phosphorescent light. Before the blow-pipe it decrepitates, becomes yellow, and then red, and finally gives a bead of metallic lead. It is soluble, with effervescence, in nitric acid, and is also soluble in caustic potash. Its acid solution gives a fine yellow with chromate of potash or iodide of potassium.

Chloride of Lead, Horn Lead.—Sp. gr. 7 to 7·1 Hardness, 2·5 to 3. Before the blow-pipe it is reduced, giving off hydrochloric acid. With microcosmic salt and oxide of copper it gives a beautiful blue flame before the blow-pipe. It dissolves in nitric acid and caustic potash.

Chromate of Lead.—Sp. gr. 5·9 to 6·6. Hardness, 2·5. Colour, deep red, or hyacinth red. Its lustre is adamantine, and streak yellow; before the blow-pipe it becomes black, and decrepitates. It gives an emerald-green colour to borax, and dissolves in hydrochloric acid, with separation of chloride of lead. It is soluble, without effervescence, in nitric acid, giving a yellowish solution. When fused with nitre, it gives a yellow solution in water, which is chromate of potash.

Section 3. *Give copper, and, when moistened with hydrochloric acid, colour the flame transiently blue.*

1. *Give a strong odour of arsenic.*
2. *Give no odour of arsenic.*

Arseniate of Copper.—There are several varieties of arseniate of copper belonging to this section, which need not be particularized. Arseniate of copper may be detected by boiling it with caustic potash; there is a separation of oxide of copper, and the arsenic acid unites with the potash, forming arseniate of potash, which gives, with sulphuretted hydrogen, a yellow precipitate, and with nitrate of silver a brick-red precipitate.

2. *Give no odour of arsenic.*

Chloride of Copper.—Sp. gr. 4 to 4·3. Hardness, 3 to 3·5. Colour, various shades of green. It tinges the flame of the blow-pipe or a candle bright blue. It is soluble, without effervescence, in nitric acid, and gives to ammonia a bright azure blue.

Blue Carbonate of Copper.—Sp. gr. 3·5 to 3·7. Hardness, 3 to 4. Colour, from azure to Berlin blue, with an occasional tinge of black. It yields easily to the knife. Before the blow-pipe it decrepitates, blackens, and ultimately fuses. It is soluble, with effervescence, in nitric acid, and the solution, on the addition of ammonia in excess, becomes azure blue. All solutions of copper deposit that metal on a plate of clean iron.

Green Carbonate of Copper, Malachite.—Sp. gr. 3·5 to 4. Hardness, 3·5 to 4. Colour, various shades of green. Before the blow-pipe it decrepitates, and fuses into a black slag, and behaves as the blue carbonate.

Black Oxide of Copper dissolves readily in acids. This mineral rarely occurs massive.

Red Oxide of Copper, Ruby Copper.—Sp. gr. 5·6 to 6·1. Hardness, 3·5 to 4. The colour of this mineral is red, of various shades. Before the blow-pipe, it is reducible, like the last species, on charcoal, to the metallic state. It acts as under with the fluxes. Soluble in nitric acid. Its solution in hydrochloric acid gives a white precipitate with water, and an ochre-yellow precipitate with caustic potash. Under similar circumstances, the solution of black oxide gives no precipitate with water, and a bluish precipitate with caustic potash.

Section 4. *Give a bright blue with borax.*

Arseniate of Cobalt.—Sp. gr. 2·9 to 3. Hardness, 2·5 to 3. Colour, reddish violet, or red; gives water by calcination. Fusible in the blow-pipe flame, with disengagement of arsenical vapour; soluble in nitric acid. The rose-coloured solution gives with the alkalies a violet-coloured precipitate; and with ferrocyanide of potassium, a green precipitate.

Nickel Ochre.—This substance is found adhering to or coating arsenical nickel, and is doubtless derived from its decomposition. General colour, apple-green. In the matrass, it loses about one-fourth of its weight of water. It is soluble in acids, without effervescence. Caustic ammonia in excess gives a blue solution. It gives a strong arsenical odour before the blow-pipe on charcoal.

Section 5. *Give a black or grey metallic mass, but not behaving as any of the minerals of the preceding sections.*

1. *Indicate arsenic during fusion.*

Arseniate of Iron.—Sp. gr. 2·9 to 3. Hardness, 2·5. Various shades between light and dark green, or yellowish and brownish green. Before the blow-pipe, on charcoal, it gives off arsenical vapours, and fuses into a grey slag, which exhibits the metallic lustre, and is attracted by the magnet. It gives, after roasting, bottle-green globules with the fluxes.

Section 6. *Not belonging to either of the foregone sections.*

Bismuth Blende.—Sp. gr. 5·9 to 6. Hardness, 3·5 to 4. Colour, dark brown to wax yellow. Decrepitates before the blow-pipe, giving off an arsenical odour, and is ultimately converted into a glass, which effervesces with borax. It is reduced with soda, on charcoal, to a button of bismuth. It forms a perfect jelly with hydrochloric acid, and its solution gives a white precipitate on the admixture of water.

Part 2. *Give no metallic bead or magnetic metallic mass.*

Section 7. *After fusion, alone or with charcoal, have an alkaline re-action.*

Anhydrite.—Sp. gr. 2·5 to 2·9. Hardness, 3 to 3·5. The colour varies from white to bluish violet or reddish; it is translucent, and sometimes transparent. In the matrass, it gives no water. Before the blow-pipe, it becomes glazed over with a whitish enamel. Anhydrite is sparingly soluble in water; the solution gives with oxalate of ammonia a white precipitate, and the same with a soluble salt of baryta. It dissolves quietly in a tolerable large quantity of hydrochloric acid.

Gypsum behaves as above, with the exception that it gives water; and instead of becoming glazed with a white enamel before the blow-pipe, it exfoliates.

Carbonate of Baryta.—Sp. gr. 4·3. Hardness, 3 to 3·5. Exposed to the blow-pipe flame, in the platinum forceps, it melts readily into a white enamel, with a brilliant light. It dissolves in diluted hydrochloric or nitric acid; the solution gives a precipitate with solution of sulphate of lime, or any other soluble sulphate.

Sulphate of Baryta.—Sp. gr. 4·4 to 4·6. Hardness, 3 to 3·5. Its colour varies much, being shades of grey, red, green, or yellow; its general colour is, however, white; it is either transparent or opaque. When fused in the platinum tongs, it imparts a greenish yellow colour to the blow-pipe flame. It decrepitates, and is difficultly fusible, but finally melts into a white enamel. If fused with carbonate of soda, the watery solution acidulated with hydrochloric acid gives a precipitate with a salt of baryta, as do all the earthy insoluble sulphates.

Sulphate of Strontia, Celestine.—Sp. gr. 3·6 to 4. Hardness, 3 to 3·5. It is white, grey, yellow, or reddish; it also occurs of a beautiful delicate blue: hence the term celestine has been applied to it. It decrepitates before the blow-pipe, and behaves like the preceding mineral, sulphate of baryta, with this exception, that it colours the blow-pipe flame, faintly, reddish purple. This test, however, can be rendered more delicate by moistening the specimen with hydrochloric acid, before submitting it to the blow-pipe; the colour of the flame is then intensely purple.

Fluor Spar, Fluoride of Calcium.—Sp. gr. 3 to 3·3. Hardness, 4. This mineral appears of many colours; as white, yellow, purple, and green. If it be pulverized and placed on a red hot plate of iron or glowing coals, it phosphoresces. It is acted on very powerfully by hot sulphuric acid, and evolves vapours of hydrofluoric acid, which corrode glass. The best method of ascertaining the presence of this mineral is to heat it in a glass tube with bisulphate of potash; the vapours given off corrode glass, as above stated, and turn Brazil paper yellow.

Division 3.

CLASS II.

Section 1. *Ignited with nitrate of cobalt, give zinc re-action.*

Calamine.—Sp. gr. 4·2 to 4·5. Hardness, 5. Its general colour is greyish or yellowish; but it sometimes occurs of various shades of green or brown. It dissolves with effervescence in nitric or hydrochloric acid. It is infusible before the blow-pipe; but after ignition, it behaves like oxide of zinc. On charcoal, it is reduced, coating the charcoal with a white sublimate, which when hot is yellow.

Section 2.

Carbonate of Iron, Spathose Iron.—Sp. gr. 3·6 to 3·8. Hardness, 3·5 to 4·5. Colour, various shades of yellow; when exposed to the action of the atmosphere it becomes brownish. It dissolves in hydrochloric acid, with effervescence, arising from the escape of carbonic acid. The solution gives a blue with ferrocyanide of potassium, and a whitish green with caustic potash, which speedily becomes brown, more especially on the surface. It affects the magnetic needle. It communicates to borax a bottle-green colour. The *hydrous oxide of iron, bog iron ore, clay iron stone*, &c., behave in much the same way, excepting that the two first do not effervesce with hydrochloric acid.

Earthy Cobalt.—Sp. gr. 2·1 to 2·4. Very soft. Its colour varies from brown to black. It exhales a slight arsenical odour before the blow-pipe, and forms a deep-coloured blue glass with borax.

Zinc Blende, Sulphuret of Zinc.—Sp. gr. 4 to 4·2. Hardness, 3·5 to 4. Colour, black, brown, yellow, or red. It is soluble in hydrochloric acid, under separation of sulphuretted hydrogen, and when roasted and heated in the reducing flame coats the charcoal with oxide of zinc. Its solution in acid gives a white precipitate with caustic ammonia, or potash, which is soluble in excess of either of the precipitants.

Section 3. *Hardness under* 7.

Tin Stone.—Sp. gr. 6·4 to 6·9. Hardness, 6·6 to 7. It sometimes occurs almost transparent and colourless, but is generally brownish-black or black. It decrepitates strongly on charcoal, and after a long exposure to the reducing flame is reduced to metallic tin. It is soluble in acids, only after fusion with an alkali.

Hardness, 7 or above 7.

Quartz.—Sp. gr. 2·6. Hardness, 7. This abundant substance occurs most variously coloured. It forms with soda on charcoal a clear glass, the solution taking place with effervescence. *Per se*, it is absolutely infusible. It is soluble in no acid but the hydrofluoric.

CHAPTER VIII.

THE ASSAY OF IRON.

Berthier divides all substances containing iron, which are ordinarily assayed, into five classes, as follows:—

Class 1.—Pure ferruginous substances,—as the Hæmatites, &c.

Class 2.—Iron ores mixed with quartz, but containing no other substance.

Class 3.—Ferruginous matters containing quartz and various bases,—as lime, magnesia, &c.

Class 4.—Ferruginous substances containing one or many bases,—as lime, magnesia, manganese, &c., and little or no quartz.

Class 5.—Iron ores containing silica, lime, and another base, which ores are fusible *per se.*

Class 1.—The minerals belonging to this class are the following:—

Magnetic Iron Ore.
Specular Iron, Elba Ore.
Red and Brown Hæmatites.

Magnetic Iron Ore ($Fe_3O_4 = Fe_2O_3 + FeO$).—This mineral, as its name imports, has a powerful action on the magnetic needle, which is not only exhibited by simple attraction, but some varieties possess the property of alternately attracting and repelling the needle, as a fragment is presented to either one or the other of its extremities. It has, indeed, polarity, and is commonly known under the name of loadstone, or natural magnet.

When pure, it is greyish-black, slightly metallic in appearance; its fracture is nearly always lamellar.

It occurs in three varieties. 1stly. In octahedral and dodecahedral crystals (see figs. 213, 214, and 215).

These crystals vary in size from that of a hemp-seed to that of a nut.

2ndly. In compact granular and sometimes scaly masses, and is rarely fibrous.

FIG. 213.

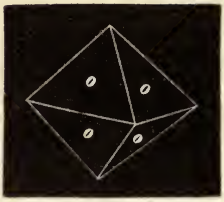

FIG. 214.

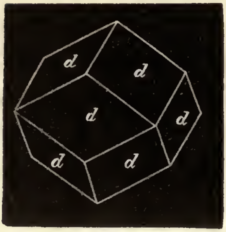

FIG. 215.

3rdly. In small irregular grains, forming nearly the whole bulk of certain sands.

The composition of the pure mineral is as follows :—

Iron	72·413
Oxygen	27·587
	100.000

Specular Iron, Elba Ore (Fe_2O_3).—This mineral is pure peroxide of iron. It, however, is usually slightly magnetic, due to a very minute admixture of the former mineral, magnetic iron ore. It has commonly a steel-grey colour, and very brilliant lustre; its powder is always red. It generally exists in very thick beds, forming even entire mountains, and is pierced by a multitude of fissures, which are covered with crystals more or less large, of a brilliant burnished steel appearance, relieved by the richest tints of the rainbow. It crystallizes in many forms, derived from a slightly acute rhomboid very nearly approaching the cube. For some of the forms see figs. 216 and 217.

FIG. 216.

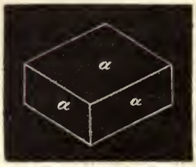

FIG. 217.

Composition of pure peroxide :—

Iron	70·000
Oxygen	30·000
	100·000

Red and Brown Hæmatites; Red Hæmatite.—The earthy appearance and red colour of this mineral, or at least that of its powder, suffice to characterize and distinguish it from the preceding species. It may be divided into the following varieties :—

1. *Compact Fibrous Red Hæmatite.*—Has somewhat of a liver colour, and a kind of brilliant metallic lustre. Its texture appears woody, so that when broken it exhibits a kind of silky or radiated structure, by which this variety is readily recognized. The powder is deep red. The external form of the mineral is often mammillated and concretionary.

2. *Compact Red Hæmatite.*—The colour of this mineral varies from iron-grey to red. The smallest blow or friction occasions a red spot. Its fracture is more often smooth than waving. It is interiorly compact, and difficult to break. It forms veins and beds of great extent and thickness, and is exceedingly heavy.

Ochreous Red Hæmatite.—This mineral has a very bright red colour; it is soft; its appearance dull and earthy. It imparts a very deep and permanent stain to the fingers or paper, and neither effervesces with acids nor forms a paste with water. By these means it may be distinguished from the earthy ochres into which it passes by insensible degrees.

These varieties yield from 60 to 70 per cent. of metallic iron.

Brown Hæmatite.—A brownish-yellow colour is as constant in this species as the red in the preceding: if a fragment be struck or pulverized, this colour is immediately developed, even if the sample has exteriorly a velvety black colour, which it sometimes assumes.

This mineral differs from the former in containing from 5 to 16 per cent. of water chemically combined. This water is expelled at a red heat, and the calcined sample then assumes a more or less reddish tinge. The following are its chief varieties :—

Compact Fibrous Brown Hæmatite.—A little softer than the red hæmatite; of the same internal structure, and, with the exception of colour, external appearance.

Compact Brown Hæmatite.—Its colour is deep brown, surface sometimes reddish, but its powder is always brownish yellow. It has all the characters of the preceding variety with the exception of texture, which is compact and never fibrous.

Granular Iron Ore.—This ore is made up by the union of an immense quantity of spherical globules; the exterior a compact brown colour, with shining fracture. These globules sometimes occur detached; it is then called " pea iron-stone."

Bog Iron Ore.—This mineral possesses a brownish-yellow colour, similar to that of rust; it is never compact. It is generally found in tuberculous or perfectly irregular masses: the internal structure presents a multitude of cavities or sinuous zones, which envelope a kind of ochre. The two last varieties usually contain phosphorus, but, as they are composed essentially of hydrated oxide of iron, they are included in the first class. The brown hæmatites give from 40 to 50 per cent. of iron.

All the minerals just described may be more or less mixed with silica: they then belong to the second class.

The following are Berthier's directions for operating in the ordinary manner:—

"In the assay of iron ores, naked crucibles, either of clay or black-lead, or crucibles lined with charcoal, are employed.

"The button of metal does not adhere to naked pots, but the slag adheres very strongly; so much so, that it cannot be detached with any degree of accuracy for weighing (which in some of M. Berthier's processes is of importance). Black-lead pots allow neither the slag nor button to adhere, but the former dissolves much argillaceous matter from the pot, so that its weight is greatly increased, and the assay cannot be verified. In naked crucibles, charcoal is always obliged to be added to the assay, to reduce the oxide of iron; in which case, if an excess be added, it prevents the button from completely forming, so that globules remain in the slag (I have found, however, that this may be avoided). Neither do naked crucibles resist the fire as well as those lined with charcoal, because the lining supports the sides when they soften. The charcoal lining also allows us to finish the assay without adding any re-agent to the ore; the button can be readily taken out, because it does not adhere to the charcoal; and lastly, the earthy matters in the ore, which have formed a slag, may be collected and weighed; or, if we have added any flux to the ore, the total weight can also be ascertained.

"After having finely powdered and sifted the iron ore, a determinate weight must be taken (I find 200 grains to be the most convenient quantity in ordinary cases); a certain weight of the requisite flux must be well mixed with the ore in a mortar, and the whole placed in the crucible (which must be lined with charcoal), in which it is firmly pressed by a pestle or other appropriate instrument. The crucible is then filled with successive layers of charcoal powder, slightly moistened with water; a cover luted on it, and the whole placed in the fire. The fire is allowed to burn gently for about an hour, and the heat is raised to whiteness for about the same time, or an hour and a quarter; the crucibles are taken out, allowed to cool, broken, and the button and flux removed.

"The whole fused mass is then weighed, and then the button of metal carefully separated from the flux, and weighed; sometimes small globules of iron are found adhering to the flux, in which case they must be removed, and added to the button before weighing. Even when very small, their removal can be readily effected; the flux is finely pulverized, and placed on a sheet of paper; a magnet is then drawn gently over its surface, which method of procedure will ensure the separation of all metallic particles. If the weight of metal obtained be now deducted from the weight obtained in the first weighing, the difference will be the weight of flux.

"Good buttons of metal, when wrapped in pieces of thin tin-plate, and struck with a heavy hammer, on the anvil, flatten slightly before they break; they ought to be grey or greyish-white, and the grain fine, or tolerably fine. Bad buttons break readily, without changing form, some even pulverize; they are generally very white and crystalline on the surface."

METHOD OF CONDUCTING THE ANALYTICAL ASSAY.

By the method just pointed out, we have no means of ascertaining whether the per centage of metal obtained is exact or not; and the accuracy of the result cannot be reckoned on without a second assay. But by performing simple operations on the mineral before fusion, a double assay may be dispensed with, and much useful knowledge gained as to the nature of the body; indeed, this method is only second to an analysis by the humid method. These operations are comprised in roasting or calcining, to drive off any volatile or combustible matters, in treating the ore with certain acids, the object of which is to ascertain the amount of insoluble matter, by difference of weight, before and after the action has taken place.

The hydrated ores are calcined to estimate water; those ores containing manganese, to reduce it to a fixed and known state of oxidation (sesquioxide). The carbonates are roasted to expel carbonic acid, and the ores from the coal formations to burn the combustible matter with which they are mixed.

Slags and dross are also roasted to free them from charcoal. A simple calcination sometimes is sufficient, as in the case of carbonates; but where mixtures of per and protoxide of iron are to be assayed, they must be subjected to a long roasting, in order to convert all the contained protoxide into peroxide.

Diluted and cold nitric and acetic acids are employed for minerals whose matrix is purely calcareous or magnesian, as these acids dissolve the earthy carbonates, without attacking either stones, clays, or the oxides of iron. The residue is to be well washed, dried, and weighed, and the amount of carbonates calculated by the difference. It is now to be treated with boiling hydrochloric acid, or what is preferable, by *aqua regia.* The ores which contain substances insoluble in these acids are generally of a clayey or flinty nature. These are to be weighed, and according to their weight that of the flux to be added in the assay is determined, as will be shown hereafter.

It must be borne in mind, however, that the clays are not absolutely insoluble in hydrochloric acid, for a certain quantity of alumina is always dissolved, which is greater in proportion to the proportion existing in the clay.

The ores containing titanium are boiled with concentrated sulphuric acid, after they have been reduced to the finest possible state of division. All the oxides of iron, titanium, and manganese, are dissolved, and the stony gangues which resist the action of this acid can be estimated. The utiltty of this estimation will be pointed out as we proceed.

When all the operations necessary for each particular case have been completed, we know the proportion of volatile substances, of substances soluble in acetic acid, and those insoluble in hydrochloric and sulphuric acids, contained in the substance under assay.

The suitable flux is then added, and the fusion proceeded with as usual. In general we have a choice of a variety of fluxes; but if the assay is to be verified and made as accurately as possible, fixed fluxes must be employed, or fluxes which lose only a determinate amount of volatile matter. Carbonate of lime and carbonate of magnesia are examples of this sort of flux.

Let A be the weight of the rough or non-calcined ore; B the weight of the same calcined; C the weight of the fluxes in a rough state; D the weight of the same calcined; P the weight of matter insoluble in hydrochloric or sulphuric acids; R the weight of the fixed substances soluble in acetic or nitric acids,—a weight which can be readily calculated when we know the loss which the ore, not treated by acids, suffers by calcination, and the residue of the treatment of this substance by acetic or nitric acid; M the weight of the button of metal and scattered globules; S the weight of the slag; and O the loss of weight in the assay which represents the quantity of oxygen disengaged during the reduction.

The following is the disposition of the data from which, at one view, all the useful results of the assay can be determined.

In the assay has been employed:

A, rough ore = calcined ore	B
B, of rough fluxes added = fixed flux.	D
Total of fixed matter	B + D

The result has been:

$\left.\begin{array}{r}\text{Metal — M}\\ \text{Slag — S}\end{array}\right\}$ Total	M + S
Loss	O
Fluxes	D
Vitrifiable matters	S — D
Substances insoluble in hydrochloric acid, &c.	T
Substances soluble in hydrochloric acid, &c.	S—D—T
Substances soluble in acetic acid	R
Substances insoluble in acetic acid, and soluble in hydrochloric acid	S—D—T—R

When the iron in the substance assayed is in a known degree of oxidation, and when but little manganese is present, the quantity of oxygen O ought to correspond very nearly with the quantity of metal M produced; if it does, the assay must be correct.

A rigorous correspondence between the two numbers, however, cannot always be obtained, because the iron is not pure, but always contains carbon, so that in ordinary assays the peroxide of iron loses but from twenty-eight to twenty-nine per cent. of oxygen.

On the other hand, the quantity of iron remaining in the slag makes up in part for the carbon combined with the metal reduced; but when the assay has been made with a suitable flux, the quantity of oxide remaining is very small, and never exceeds one per cent. of the weight of the slag. When the iron is in an unknown degree of oxidation, the loss O produced in the assay gives the degree, if it has been made without accident; but if there is any doubt, and the result is of importance, the assay must be recommenced for verification. If the ferruginous matter contain manganese, and if that metal be in the state of protoxide, the verification just described can be made without modification, because the manganese dissolved in the slag is always at the *minimum* of oxidation; and when a sufficient quantity of flux is employed, the amount reduced is of no consequence. But when the manganese is in the state of red oxide, it parts with a certain quantity of oxygen on being reduced to the *minimum* of oxidation, and which quantity is estimated in the loss O, so that a perfectly accurate verification cannot be made. Nevertheless, the difference between the loss O, and the quantity of oxygen calculated from the metal M, cannot be very great, because the red oxide of manganese loses but ·068 of oxygen in its transformation to protoxide.

Titanic acid behaves in iron assays exactly as the oxides of manganese; it disengages at most but ·06 of oxygen when dissolved in the earthy glasses in contact with charcoal.

It sometimes happens that the assay is not fused, or but imperfectly so. This can happen from two causes; firstly, because the heat has not been sufficiently strong or continued; secondly, because the flux has not been employed in proper proportion, or has not been calculated to form fusible compounds with the foreign matters mixed with the oxide of iron. In both cases the oxide of iron is completely reduced; and if the assay has been made with care, the loss of oxygen indicates the amount of iron in a very approximative manner, and nearly always with an exactitude which is surprising to those not accustomed to this kind of operation.

The assay buttons which are not fused have a grey and homogeneous appearance. They flatten under the hammer, take a metallic lustre by friction with a file, and disengage hydrogen on being moistened with hydrochloric acid. The iron they contain is in imperceptible particles.

In the imperfectly fused buttons the iron is disseminated in globules throughout the whole mass of slag, or form a scoriform button mixed with much slag, without the possibility of complete separation.

Sometimes there is not even an agglomeration, and the mixture submitted to assay forms but a greyish metallic powder, in which case the assay is useless, as it is impossible to collect the whole without loss, even by washing the charcoal lining with the greatest care.

This method of assay, says Berthier, cannot be too much recommended to iron-masters, for all the facts necessary to be gotten, in relation to the ores they smelt, are imparted in a very simple and expeditious manner; and by varying the experiment, and by employing as fluxes the ordinary substances used for that purpose, a knowledge of the mixtures which will answer best in the high furnace may be obtained without loss of metal, or much expense.

The Assay of Substances of the First Class

May be effected in charcoal-lined crucibles without the addition of any flux, because the foreign matters found in ores of this class are generally fusible *per se*; nevertheless, it is always better to add a flux; first, because there is no risk incurred of being obliged to recommence the assay; and, secondly, because a certain amount of slag is always very useful, by enabling the metal to form into one single button. Borax may be employed for this purpose; but it is better to use some very fusible earthy silicate. A silicate of lime is a very useful flux in iron assays; it should consist of 400 parts of white sand and 240 parts of lime well mixed: equal weights of this flux and ore may be used.

Assay of Ores of the Second Class.

In order to render fusible the silicious matters constituting this class, carbonate of soda may be employed, a mixture of chalk and alumina or clay; or a mixture of carbonate of lime and dolomite. (*Magnesian limestone.*)

Class 3.—This class includes the kind of ironstone most employed in England,—viz., the argillaceous or clay ironstone. This mineral sometimes resembles compact limestone, sometimes greyish hardened clay. The iron exists in the state of carbonate. The great specific gravity, its effervescing on the addition of an acid, and acquiring a brown-red colour on roasting, are sufficient means of identifying this from the previous varieties.

The following is the result of an analysis of this class of ore by the Author: the specimen was from Ireland, county Leitrim:—

Protoxide of iron	51·653
Peroxide of iron	3·742
Oxide of manganese	·976
Alumina	1·849
Magnesia	·284
Lime	·410
Potash	·274
Soda	·372
Sulphur	·214
Phosphoric acid	·284
Carbonic acid	31·142
Silica	6·640
Carbonaceous matter and loss	2·160
	100·000

Blackband is a combustible schistose variety of this ore. The following analysis is also by the Author:—

Protoxide of iron	20·924
Peroxide of iron	·741
Oxide of manganese	1·742
Alumina	14·974
Magnesia	·987
Lime	·881
Potash Soda	traces
Phosphoric acid	·114
Silica	26·179
Sulphur	·098
Carbonic acid	14·000
Carbonaceous matter	16·940
Water and loss	2·420
	100·000

Assay of Ores of the Third Class.

The ores belonging to this class are the most common of all. They all fuse exceedingly well by the addition of carbonate of lime, amounting to about half or three-fourths of the weight of gangue mixed with the oxide of iron. The ores of this class may also be assayed by the addition of carbonate of soda.

We shall here give the result of an actual assay made after the manner described further on.

The Assay of an Argillaceous Iron Ore.—

Loss by calcination and roasting		33 per cent.
Insoluble in hydrochloric acid		14·2 do. of clay.
100 grs. of the crude ore give of calcined ore		67 grs.
10 grs. of carbonate of lime = lime		5·6
Total		72·6
Amount of metal	36·3 grs.	= 57·0
Do. slag	20·7 grs.	
Oxygen		15·6
Flux added	5·6 grs.	
Vitrifiable matter	15·1 grs.	
Insoluble matters	14·2 grs.	
Soluble matters.	·9 grs.	

Class 4.—*Spathose Iron, Steel Ore.*—The general formula of this ore may be thus expressed:

$$\left.\begin{array}{l} \mathrm{Fe\ O} \\ \mathrm{Mn\ O} \\ \mathrm{Ca\ O} \\ \mathrm{Mg\ O} \end{array}\right\} ,CO_2.$$

The structure of this mineral is lamellar, brilliant, and often rhomboidal, like carbonate of lime. Its colour at the moment of extraction from the mine is greyish or whitish yellow; but by exposure to the air it deepens and passes insensibly to a reddish brown or maroon colour. It undergoes the same change when exposed to heat; and at the same time, in the latter case, becomes influenced by the magnet,—a property it does not possess in its natural state.

It is composed essentially of protoxide of iron and carbonic acid; but it nearly always contains lime, manganese, and magnesia.

FIG. 218.

Carbonate of iron is found in regular crystals; and mineralogists have remarked that not only does it cleave into perfect rhomboids like carbonate of lime, but that it possesses the same secondary forms as that substance.

Fig. 218 is one of its forms.

Analysis of two samples by Beudent and Klaproth:—

	Beudent.	Klaproth.
Protoxide of iron	59·97	57·50
Carbonic acid	38·72	36·00
Oxide of manganese	·39	3·30
Lime	·92	1·25
	100·00	98·05

Assay of Substances of the Fourth Class.

In the assay of these ferruginous matters, which are not fusible because there is a deficiency of silica, a certain amount of silicious sand must be added; but it is nearly always necessary to add at the same time either lime or some other base, or even two bases at once.

The spathose iron ores containing much manganese fuse with the addition of quartz alone; on the contrary, those which contain much magnesia require besides quartz a certain amount of lime.

When the spathose irons are mixed with stony gangues, the proportion of the latter is determined by treatment with aqua regia, and as these gangues are nearly always quartzose, besides the suitable amount of silica which must be added, an amount of lime equal or nearly equal in weight to the whole amount of silicious matter contained in the ore must be superadded.

For aluminous minerals a mixture of silica and lime is necessary. Although silica and lime alone may be employed in the assay of titaniferous minerals, it is always better to add a small quantity of alumina or magnesia, as such an addition renders the slag more fusible. Lastly, very calcareous ores are often rendered fusible by the mere addition of silica, because they contain nearly always a certain amount of alumina or another base; but it is always better to add, as a flux, a very silicious white clay.

Iron Ores of the Fifth Class.

These merely require fusion in a charcoal crucible, without the addition of any flux.

The method of assay I pursue in my own laboratory is readier of execution than that just described, and I find it applicable to all kinds of ores; at least all those kinds which generally fall to the lot of the ironmaster or assayer to examine.

The furnace I employ is the ordinary wind furnace, capable of producing a full white heat; the crucibles, those termed "London pots," which are decidedly more refractory than either the Cornish or the Hessian; indeed, pieces of either of the last-named crucibles can be softened in a London pot, without any alteration in the shape of the latter. I do not usually employ the crucibles lined with charcoal, but in a naked state.

The treatment of the ore is as follows:—Very finely pulverize the sample to be assayed, and weigh out 200 grs., which mix in a mortar with 100 grs. of quick-lime, and from 20 to 40 grs. of charcoal, in proportion to the apparent richness of the ore: it is always advisable to have a slight excess of charcoal. When well mixed, place in a crucible, and cover over with about 300 grs. of powdered bottle glass, taking especial care that it contains no lead; or better still, the same quantity of the silicate of lime, mentioned at page 229. Two crucibles must be prepared in this manner, and both placed in the furnace when it is at a dull red heat. Allow the heat gradually to increase in intensity, until it arrives at a very bright red, or yellowish white heat, which ought to be in about three quarters of an hour, then increase the heat to whiteness for half an hour, and take the pots out gently; tap their bottoms on a brick, in order that the fluid metal may collect in a single button, and allow them to cool gradually. When perfectly cold, break them; and if the assay has been well conducted, the two buttons will not differ ⅛th of a per cent. from each other, and the result is certain to be accurate. This (the double assay) is the only method of verification I find it necessary to adopt. Some advise the addition of borax, but I do not find it useful; it is, in fact, rather injurious, as it alters somewhat the character of the obtained metal. If the nature of the gangues, &c., be wished to be ascertained, the humid method of analysis must be had recourse to after the manner described below; also, if it be necessary to weigh the flux, a black-lead or charcoal crucible must be employed.

Humid Assay for the determination of the quantity of iron only.—Within the last few years much attention has been called to the use of standard solutions for the estimation of various substances. A standard solution is a solution of such a strength that a given weight or volume will by a particular behaviour indicate a given weight of the substance to be determined. Sometimes this indication is furnished by the non-formation of a precipitate; a change in colour of the solution itself; or, lastly, by the solution of the metal or other substance after the addition of a certain quantity of the standard solution ceasing to produce a particular effect with a certain test. The apparatus necessary for using standard solutions will be fully described in the chapter devoted to the Assay of Silver.

Two excellent and ready processes for the estimation of iron by the above means have been published; the one is due to M. Marguerite, the other to Dr. Penny. The author will here transcribe both, as there are points in each which may be advantageously studied.

M. Marguerite's Process.—This method of analysis is based on the reciprocal action of salts of the protoxide of iron and mineral chameleon (permanganate of potash—KO,Mn_2O_7), whereby a quantity of the mineral chameleon is decomposed exactly proportionate to the quantity of iron.

Thus, in any given solution of iron at its maximum of oxidation, such as it more commonly exists in the mineral, it is only necessary to bring it to the minimum of oxidation, and then to add gradually a solution of permanganate of potash of a known strength. As long as a trace of protoxide remains to be peroxidised the colour of the chameleon is destroyed; but it is at length noticed that the colour of the last drop added is no longer destroyed, but communicates a pink tint to the whole of the solution. This reaction indicates that the operation is terminated, and the quantity of iron in solution corresponds to the amount of permanganate added.

This reaction may be expressed by the following equation:—

$$KO,Mn_2O_7 + 10(FeO) = 2(MnO) + KO + 5(Fe_2O_3).$$

It will be seen that 1 equiv. of permanganate of potash is capable of peroxidising 10 equivs. of protoxide of iron. It hardly is necessary to mention that the solution of the iron should contain a sufficient excess of acid to hold in solution the peroxide of iron formed, and also the protoxide of manganese and potash resulting from the decomposition of the permanganate.

If now we consider the various operations in the process, we shall find they consist in the following:—

1. In dissolving the ore in an acid; hydrochloric acid, for example.

2. In treating the solution of the persalt of iron which results by sulphite of soda, to reduce it to the state of protosalt, and to boil it in order to expel the excess of sulphurous acid.*

3. In adding afterwards with precaution the solution of permanganate of potash until the pink tint appears, and then reading off on the graduated tube the number of divisions used.

Now it will be perceived there are two conditions to fulfil; the first, to effect a complete reduction, for the persalts of iron do not react on the chameleon,—all that remained at the maximum of oxidation would escape the action of the chameleon, and consequently would not be estimated as iron; the second, to expel by ebullition the whole of the sulphurous acid in excess, which, in contact with the permanganate, would take from it the oxygen necessary to form sulphuric acid; and thus react in the same manner as the iron. But it is easily demonstrated by experiment, that the solution of a persalt of iron, treated with a sufficient quantity of sulphite of soda, is on the one hand completely reduced to its minimum of oxidation, and on the other does not contain the most minute trace of sulphurous acid after a few minutes' ebullition.

A question here naturally presents itself, whether the salts of iron, reduced to their minimum, do not absorb oxygen again with great rapidity, and thus exert an influence on the results of the analysis: the following experiment, however, will remove all doubts on this head:—At this stage of the operation the solution was exposed to the contact of air for four hours, and the test liquor then added, a quantity of which was required exactly equal to that which was necessary when the analysis was prosecuted without any delay. This fact proves that the protosalts of iron in an acid solution are converted into persalts very slowly.

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* As it is important to employ a sufficient quantity of the sulphite of soda to render the reduction of the persalt of iron to the state of protosalt complete, and yet to leave sufficient hydrochloric acid in excess in the solution, it is advantageous to use a definite and known quantity. For this purpose 4 oz. of crystallized sulphite of soda are dissolved in a quart of water, and a pipette which contains 2 oz. is used to measure the quantity added to each assay. 87½ grs., which are contained in the 2 oz. of the pipette, are more than sufficient to reduce 20 grs of iron; but this excess is necessary to ensure the entire reduction of the persalt to protosalt.

It becomes important to ascertain whether, in the ores of iron, there may not exist substances capable of reacting on the chameleon, and thus rendering the estimation of the metal erroneous.

On examining the composition of the greater number of the ores described by various authors, and particularly by MM. Berthier and Karsten, we find that they are most ordinarily composed of the following substances :—

Ores.		Metals.
Iron.	Phosphoric acid.	Cobalt.
Manganese.	Lime.	Nickel.
Zinc.	Alumina.	Titanium.
Arsenic.	Magnesia.	Chromium.
Copper.	Silica.	Tungsten.

The presence of zinc, manganese, titanium, tungsten, phosphoric acid, lime, magnesia, alumina, and silica, do not at all interfere with the accuracy of the results. Cobalt, nickel, and chrome, notwithstanding the peculiar colour of their solutions, do not in the least prevent the appreciation of the peculiar rose-pink tint of the mineral chameleon.

Arsenic and copper, then, are the only substances among those designated capable of producing a discrepancy in the analysis, as under the influence of the sulphurous acid the arsenic acid becomes arsenious acid, and the salts of peroxide of copper become salts of the protoxide, and afterwards withdraw oxygen from the permanganate of potash.

It is true that the ores containing arsenic are of little importance in a commercial point of view, for the iron produced from them is of so inferior quality as to be generally rejected; nevertheless, I have considered it right to give the method of analysis in cases where it occurs, and a slight modification of the general process is sufficient.

The operation is carried on as usual, except that, after having boiled the solution to expel the excess of sulphurous acid, a piece of pure laminated zinc is added, which, acting upon the hydrochloric acid, disengages hydrogen; arsenic and copper are hereby reduced and precipitated in the metallic state. When the solution of the zinc is complete, the solution is filtered from the precipitated particles of arsenic and copper, which would otherwise be re-oxidized; and, after washing the filter three or four times with common water, the addition of the normal test liquor is proceeded with.

Preparation of the Normal Test Liquor.—There are several methods of preparing mineral chameleon. The most simple is that of Prof. Gregory. It consists in fusing together 1 atom of chlorate of potash, 3 atoms of hydrate of potash, and 3 atoms of peroxide of manganese reduced to a fine powder. The mass is afterwards mixed with so much water as to obtain as concentrated a solution as possible, to which dilute nitric acid is added until the colour becomes of a beautiful violet, and it is afterwards filtered through asbestos, in order to separate the peroxide of manganese which it holds in suspension. In this state the permanganate may be employed in the analysis. I have described the method of preparing mineral chameleon for those who have no opportunity of procuring it ready-made; but it is well to mention that it is always to be met with among the chemical manufacturers, and I now employ the chameleon procured from this source.

The permanganate of potash is a preparation of great stability, and may be preserved for a very long time without undergoing any alteration, provided it be defended from the contact of organic matters and kept in a glass-stoppered bottle. To convert its solution into a test liquor of known value, 20 grs. of pure iron, such as harpsichord wire, are dissolved in about 1 oz. of strong hydrochloric acid, free from iron; after the disengagement of the hydrogen has ceased, and the solution is complete, the liquid is diluted with about 1 pint of common water.*

The solution of permanganate of potash is then added, drop by drop, until a slight pink colour is manifest, and the number of divisions on the tube necessary to produce this effect carefully noted; this number is then employed to reduce into weight the result of an analysis of an ore.

When the solution of chameleon is too concentrated, it is easy, by adding the proper quantity of water, to reduce it to one-half, one-fourth, or one-fifth, so that 2 oz. shall be as nearly as possible equivalent to 20 grs. of iron.—*Comptes Rendus,* No. xiv.

Dr. Penny's Process.—The following method of determining the amount of iron in a sample by means of a normal solution has been contrived by Dr. F. Penny, who was led to substitute chromate of

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* It is necessary to use solutions very dilute and cold, in order to prevent the hydrochloric acid in excess from reacting on the chameleon and disengaging chlorine.

potash for hypermanganate of potash, as recommended by Marguerite, and just described. The reason of employing the chromate is, that it is an unchangeable salt, whilst the hypermanganate undergoes spontaneous decomposition, so that its strength is variable; and each series of experiments made with it requires a separate verification by means of a weighed quantity of pure iron. This inconvenience is avoided in Dr. Penny's method, which is described in his own words as under :—

"In the first series of experiments, pure harpsichord wire was dissolved with every care in hydrochloric acid, and bichromate of potash added to the solution until the conversion of the protochloride of iron into the perchloride was complete. I obtained the following results :—

	Iron.		Bichromate.
"Exp. I.	50	grains required	44·4 grains.
„ II.	39·7	„ „	35·2 „
„ III.	48·3	„ „	42·8 „
„ IV.	55·3	„ „	49·2 „

"The mean of these results is, 100 parts of iron to 88·75 of bichromate.

"In the second series of experiments protosulphate of iron was employed. This salt was made from protosulphuret of iron, and purified most carefully by repeated crystallization. A known quantity of it was dissolved in water, acidulated with either pure hydrochloric or sulphuric acid, and the solution treated with bichromate :—

	Sulphate of Iron.		Bichromate.
"Exp. I.	100	grains required	17·90 grains.
„ II.	180	„ „	32·10 „
„ III.	150	„ „	26·82 „
„ IV.	120	„ „	21·40 „

"These experiments give the ratio of 100 parts of sulphate of iron to 17·867 of bichromate, or 100 of iron to 88·71, which corresponds very closely to the mean result obtained with the metallic iron. Moreover, I performed a series of similar experiments with the neutral chromate of potash, and obtained results completely confirmatory of the general accuracy of the foregoing experiments. We may, therefore, I think, safely conclude that 100 parts of metallic iron correspond to 88·75 of the bichromate of potash, and that 100 of the latter are equal to 112·67 of the former.

"I shall now proceed to describe the method of employing the bichromate of potash for the determination of the amount of iron in clay-band and black-band ironstone. I shall be purposely minute, as I particularly desire that the process may be serviceable to those who, from their pursuits in life, are interested in the value and quality of ironstone, and who may be imperfectly acquainted with analytical operations.

"A convenient quantity of the specimen is reduced to coarse powder, and one-half at least of this still further pulverized, until it is no longer gritty between the fingers. The test solution of bichromate of potash is next prepared. 44·4 grs. of the salt in fine powder are weighed out, and put into an alkalimeter (graduated into 100 equal divisions), and tepid distilled water afterwards poured in until the instrument is filled to 0. The palm of the hand is then securely placed on the top, and the contents agitated by repeatedly inverting the instrument, until the salt is dissolved and the solution rendered of uniform density throughout. It is obvious that each division of the solution thus prepared contains 0·444 gr. of bichromate, which corresponds to ½ a grain of metallic iron. The bichromate of potash used for this process must of course be purchased pure, or made so by repeated crystallization, and it should be thoroughly dried by being heated to incipient fusion.

"100 grs. of the pulverized ironstone are now introduced into a Florence flask, with 1½ oz. by measure of strong hydrochloric acid, and ½ an ounce of distilled water. Heat is cautiously applied, and the mixture occasionally agitated, until the effervescence caused by the escape of the carbonic acid ceases; the heat is then increased, and the mixture made to boil, and kept at moderate ebullition for ten minutes or a quarter of an hour. During these operations it will be advisable to incline the flask, in order to avoid the projection, and consequent loss, of any portion of the liquid by spirting. About 6 oz. of water are next added, and mixed with the contents of the flask, and the whole rapidly transferred to an evaporating basin. The flask is rinsed several times with water, to remove all adhering solution.

"Several small portions of a weak solution of pure red prussiate of potash (containing one part of the salt to 40 of water) are now dropped upon a white porcelain slab, which is conveniently placed for testing the solution in the basin during the next operation.

The prepared solution of bichromate of potash in the alkalimeter is then added very cautiously to the solution of iron, which must be repeatedly stirred, and as soon as it assumes a dark greenish shade it should be occasionally tested with the red prussiate of potash. This may be easily done by taking out a small quantity on the end of a glass rod, and mixing it with a drop of the solution on the porcelain slab. When it is noticed that the last drop communicates a distinct red tinge, the operation is terminated. The alkalimeter is allowed to drain for a few minutes, and the number of divisions of the test liquor consumed read off. This number multiplied by two gives the amount of iron per cent. in the specimen of ironstone, assuming that, as directed, 100 grs. have been used for the experiment. The necessary calculation for ascertaining the corresponding quantity of protoxide is obvious.

"When black-band ironstone is the subject of analysis, or when the ore affords indications, by its appearance or during the treatment with hydrochloric acid, that it contains an appreciable quantity of carbonaceous matter, then the hydrochloric acid solution must be filtered before being transferred to the basin, and the filter with the insoluble ingredients must be washed in the usual way with warm distilled water, slightly acidulated with hydrochloric acid, until the filtrate ceases to give a blue colour with the red prussiate of potash. In those cases, also, where the presence of iron pyrites in the ironstone is suspected, it will be necessary to remove the insoluble matter by filtering before applying the bichromate solution; but with ironstones in which the insoluble ingredients are merely clay and silica, filtration is not essential.

"Now it is evident that the foregoing process, so far as I have described it, serves for the determination of that portion of iron only which exists in the ore in the state of protoxide. But many specimens of the common ironstone of this country contain appreciable quantities of peroxide of iron, which, being unacted upon by the bichromate of potash, would escape estimation by the present method. By an additional and easy operation, however, the amount of metallic iron in this ingredient may be likewise determined. It is only necessary to reduce it to the minimum state of oxidation, and then to add the bichromate as previously directed.

"The best and most convenient agent for effecting the reduction of the persalts of iron is sulphite of soda. The only precaution to be observed is to use it in sufficient quantity, and at the same time to take care that the iron solution contains excess of acid. When the reduction is complete, a few minutes' ebullition suffices to decompose the excess of sulphite of soda, and effectually to expel every trace of sulphurous acid.

"In order to test the exactness of this mode of estimating the iron in the peroxide, I made several experiments with peroxide prepared from known quantities of pure iron wire. The peroxide was thoroughly washed, dissolved in hydrochloric acid, reduced with sulphite of soda, and after complete expulsion of the excess of sulphurous acid, the solution was diluted with water and treated with bichromate of potash. I select three of the experiments:—

"Exp. I. 10 grains of iron consumed 8·87 of bichromate.
„ II. 18 „ „ „ 15·94 „
„ III. 25 „ „ „ 22·15 „

"The mean of all my experiments on this point gives the ratio of 100 of iron to 88·6 of bichromate, which is in close accordance with the former results.

"Whenever, therefore, the ore of iron contains peroxide, it will be necessary to add sulphite of soda to the hydrochloric acid solution before the addition of the test liquor from the alkalimeter. The sulphite should be dissolved in distilled water, and added to the solution of iron in small successive portions, until a drop of the liquor gives merely a rose-pink colour with sulphocyanide of potassium, which indicates that the reduction of the persalt of iron is sufficiently perfect. The liquor is now heated till the odour of sulphurous acid is no longer perceptible. These operations should be performed while the solution is in the flask, and before it is filtered or transferred to the basin.

"I will here mention, for the guidance of those who may not be fully aware of the reactions of the oxides of iron, that the existence of an appreciable quantity of peroxide in the ironstone may be readily discovered by dissolving (as directed in the process) 30 or 40 grs. of the ore in hydrochloric acid, diluting with about 8 oz. of water, filtering and testing a portion of the solution with sulphocyanide of potassium. If a decided dark blood-red colour is produced, the quantity of peroxide in the stone must be determined; but if the colour is only light red or rose-pink, the proportion is exceedingly small, and for practical purposes not worth estimating. Of course, when the specimen of ironstone has an ochrey or a reddish appearance on the surface or in the fracture, the presence of a large proportion of peroxide is indicated, and its exact quantity must be determined.

"In conclusion, I must not omit to notice one or two circumstances which appear at first to militate against the accuracy of this process. It may be questioned whether solutions of the protosalts of iron do not absorb oxygen so rapidly from the air as to influence the results obtained by this method. Marguerite has shown [see ante], and my own observations completely confirm his statement, that protosalts of iron, in an acid solution, become peroxidised very slowly; and, in a particular experiment, I found that contact with the air during several hours caused no diminution in the quantity of bichromate of potash required. As the process may be completed in a few minutes, it is certain that no inaccuracy can arise from this cause.

"It is also important to inquire whether the chromic acid in the chromates of potash may not be partially deoxidised by hydrochloric acid alone without the presence of a protosalt of iron. Such a reaction would obviously give rise to a serious error. It is well known that concentrated hydrochloric acid rapidly decomposes the chromic acid of the chromates when aided by the application of heat. But I have satisfied myself, by numerous experiments, that this acid exerts very little appreciable action upon dilute solutions of the chromates of potash, either cold or warm, and that the action is only partial even after continued ebullition; so that the present method is free from inaccuracy on this account."

Quantitative Determination of all the Constituents usually present in an Iron Ore.—The ordinary constituents of clay ironstone (which is about the most complex, and the detail of whose analysis will be the most useful) are the per and protoxides of iron, oxide of manganese, alumina, magnesia, lime, potash, soda, sulphur, phosphoric acid, carbonic acid, silica, and water.

Some iron ores dissolve very readily in hydrochloric acid or in *aqua regia;* others do not, even when they are in a very fine state of division; but all do readily after fusion with an alkali, or an alkaline carbonate,—as of potash or soda: hence it is advisable to fuse the finely pulverised ore with an alkali previous to attempting its solution in an acid.

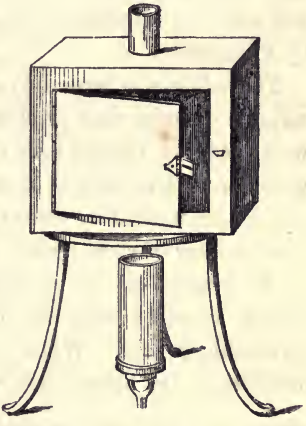
In determining the amount of iron, the author recommends Dr. Penny's process.

Determination of Silica, Oxide of Iron, and Oxide of Manganese.—The ore must be reduced to the finest possible state of division, a small quantity placed in a test-tube, and boiled for some time with hydrochloric acid. If it completely decomposes it need not be submitted to fusion with carbonate of soda, but 100 grains may be at once weighed off, and treated in a Florence flask with about 2 ounces of hydrochloric acid, gradually heated to ebullition, and that temperature maintained until perfect decomposition has ensued. If, on the other hand, the ore does not completely decompose, 100 grains must be carefully mixed with 500 or 600 grains of carbonate of soda placed in a platinum crucible and fused at a bright red heat; the fusion must continue about half an hour. It may be here mentioned that the platinum crucible, previous to its submission to the furnace, must be placed in one of clay furnished with a cover, to protect it from the injurious effect of contact with the fuel.

When the platinum crucible and its contents are cold, it is placed in a large evaporating basin, and pure dilute hydrochloric acid poured over it: the fused mass dissolves with effervescence, and more acid must be gradually added, as seems necessary, until no further action takes place. The solution being finished, the crucible is removed, washed with distilled water, and the whole, together with the washings, evaporated to dryness. The solution obtained in the first case, in which the ore was wholly decomposable by hydrochloric acid alone, is also to be evaporated to dryness. The object of this evaporation is the conversion of the silica the ore may contain from a partially soluble to a completely insoluble state, so that the whole of it may be collected and weighed.

Towards the end of the operation, the partially-dried mass must be continually stirred, in order to prevent losses by the spirting which will otherwise take place. When cold, the contents of the basin are moistened with hydrochloric acid, and the whole left to itself for about one hour. It is then mixed with a small quantity of distilled water, gently warmed and thrown upon a filter. Every constituent of the ore, with the exception of the silica, will pass through the filter in a liquid state. The silica remaining in the filter is to be well washed with hot water, dried,* ignited in a platinum crucible, and weighed.

FIG. 219.



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* The most convenient form of apparatus for drying precipitates, filters, &c. in analysis, is a little water-oven, called a "water-bath" (see fig. 219). It consists of a double box of

To the liquid filtered from the silica, and with which the washings have been incorporated, add a few drops of nitric acid, and boil; when cool, add gradually pure precipitated carbonate of baryta until in excess, which point may be ascertained by cessation of effervescence, and by some of the carbonate remaining undissolved. The whole is now to be kept at a gentle heat for about an hour, and then poured on a filter, in which will remain the peroxide of iron, alumina, and phosphoric acid, together with the excess of carbonate of baryta employed. The liquid which has passed through the filter is mixed with excess of sulphuret of ammonium, covered with a glass plate to exclude air, and left to itself for four or five hours. If any manganese were present in the ore, it will now be thrown down as a flesh-red precipitate, which must be collected on a filter, washed, dissolved in a small quantity of hydrochloric acid, the solution filtered, and excess of carbonate of soda added: carbonate of manganese is precipitated, which is collected on a filter, washed, dried, ignited and weighed as red oxide, every 100 parts of which correspond to 93 parts of the protoxide of manganese, in which state it usually exists in the ore. The weight so obtained gives the per-centage. The mixed precipitate of oxide of iron, alumina, carbonate of baryta, and phosphoric acid remaining on the filter, is dissolved in a small quantity of hydrochloric acid, and the amount of iron ascertained by Dr. Penny's process, as already described. As the iron is in the state of peroxide, its reduction to protoxide must be effected by sulphite of soda, according to the method already given.

Determination of Lime and Magnesia, and part of Phosphoric Acid.—Dissolve another 100 grains of ore with the precautions already pointed out, only in this case the silica may be rejected, and treat the solution by the following process, which was contrived by Fresenius:—

The solution is heated to ebullition in a flask, and reduced with sulphite of soda, then precipitated with carbonate of soda, and boiled with excess of caustic soda until the precipitate appears black and granular. It is allowed to subside, the clear liquid poured off, the precipitate washed by decantation with hot water, and finally brought upon a filter of close texture and washed with hot water.

Treatment of the precipitate.—The precipitate is again transferred, together with the filter, into the flask, and digested with hydrochloric acid. When no more black particles are perceptible it is filtered; the filter is left whole, a little water poured over it, the

copper or tin plate about six inches square, with water between the casings, which is kept in a state of ebullition by means of a gas flame or spirit lamp.

flask inclined so that it remains hanging by the side while the liquid runs off: in this manner it may be quickly and completely washed. The filtered solution is reduced with sulphite of soda, heated to boiling, mixed with a few drops of chlorine water, then with an excess of acetate of soda; and when the liquid or precipitate has not a reddish tint, chlorine water is added until this is the case. The whole is boiled until the precipitate has separated, filtered hot, and the precipitate, consisting of phosphate and some basic acetate of the peroxide of iron, washed.

To the solution just filtered from the phosphate of iron, add ammonia and sulphuret of ammonium, and filter while hot; this removes manganese and iron, leaving lime and magnesia alone in solution. The whole is filtered while hot, and the precipitate remaining on the filter rejected. To the filtered solution is added excess of solution of oxalate of ammonia: this throws down insoluble oxalate of lime, which must be collected on a filter, washed, dried, and ignited at a low red heat. The residue is now carbonate of lime, every 100 parts of which correspond to 56·29 parts of lime.

To the solution filtered from the oxalate of lime, and which contains the magnesia, add excess of phosphate of soda, agitate briskly, and set aside for twelve hours; then collect the crystalline precipitate of ammonio-phosphate of magnesia on a filter, wash it with water containing a little ammonia, dry and ignite it; weigh the resulting pyro-phosphate of magnesia: every 100 parts correspond to 36·67 parts of magnesia.

The precipitate containing the perphosphate and basic acetate of soda is dissolved in hydrochloric acid, reduced with sulphite of soda, boiled for some time with excess of caustic soda, and filtered. The filtered solution which contains the phosphoric acid is supersaturated with hydrochloric acid, and placed aside for future operation.

Treatment of the alkaline solution poured off from the first black precipitate. Determination of Alumina and remainder of Phosphoric Acid.—The solution is acidulated with hydrochloric acid, a little chlorate of potash added, and then boiled; it is then precipitated with ammonia (avoiding a large excess), and chloride of barium added as long as a precipitate appears. After digesting for some time it is filtered. The precipitate, which contains the whole of the alumina and phosphoric acid, is collected on a filter, washed with a little water, and dissolved in as little hydrochloric acid as possible. The solution is saturated with precipitated carbonate of baryta, gently warming; an excess of caustic soda is added, and the heat still kept up. Any baryta contained in the solution is removed by carbonate of soda, which is added until no further precipitation takes place. The whole of the alumina is now in solution, and the whole of the phosphoric acid in the precipitate.

The solution is rendered acid with a little hydrochloric acid, boiled with a small quantity of chlorate of potash, precipitated with excess of ammonia, and allowed to stand for a few hours; after which the precipitated alumina is collected on a filter, washed, dried, ignited, and weighed: its amount represents the per-centage of alumina in the ore.

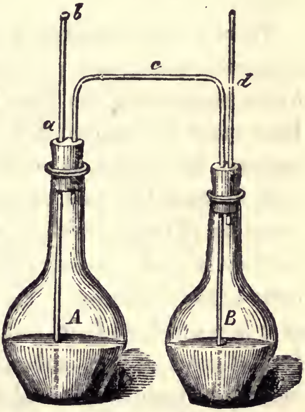
The precipitate containing the phosphoric acid is dissolved in hydrochloric acid, the baryta precipitated with dilute sulphuric acid, which is added until no further precipitate ensues; the liquid and precipitate placed in a warm situation until the former is quite bright; it is then filtered, and to the filtered liquid is added, the small portion reserved as before directed: excess of ammonia is added to the mixture, then some chloride of ammonia, and lastly sulphate of magnesia. The phosphoric acid is precipitated as the ammonio-phosphate of magnesia, which is washed, dried, and ignited, with the precautions already pointed out. Every 100 parts correspond to 63·33 parts of phosphoric acid.

Determination of Potash and Soda.—If the ore be completely decomposable by hydrochloric acid, dissolve at once 100 grains in that liquid; if not, fuse the same quantity with four times its weight of hydrate of baryta in a platinum crucible: treat with hydrochloric acid, and separate the silica precisely as already described. To the filtered solution add an excess of baryta water: this precipitates everything but the potash and soda and part of the lime. Throw the whole on a filter, well wash the precipitate, and add the washings to the bulk of the filtered liquid; to which add excess of ammonia and carbonate of ammonia: by these reagents the small quantity of lime and the excess of baryta in solution are precipitated. The solution must now be filtered, evaporated to dryness, and ignited. The dry residue consists of chlorides of potassium and sodium, which must be weighed, then dissolved in water to which a little hydrochloric acid is added, then excess of chloride of platinum, and the whole evaporated to dryness in the water bath; alcohol is now added, and the whole thrown on a small filter. The yellow precipitate of platino-chloride of potassium on the filter is washed with alcohol until the latter passes off colourless. The filter and its contents are then dried and weighed. Every 100 parts of platino-chloride of potassium correspond to 30·56 parts of chloride of potassium. The quantity of chloride of potassium thus obtained is deducted from the weight of the mixed chlorides of sodium and potassium as obtained above; the difference will be the amount of chloride of sodium. Every 100 parts of chloride of sodium correspond to 53·28 of soda, and every 100 parts of chloride of potassium to 63·25 of potash.

Determination of Sulphur.—Dissolve 100 grains of the ore in either of the manners already described, separating the silica; in this case, however, a little nitric acid must be added to the hydrochloric acid previous to its mixture with the ore. To the filtered solution, made somewhat dilute, add excess of chloride of barium, and allow to stand in a warm place for a few hours. Collect the precipitate of sulphate of baryta on a filter, wash, dry, ignite, and weigh. Every 100 parts correspond to 13·79 parts of sulphur.

Determination of Carbonic Acid.—The most convenient apparatus for the determination of this gas is that invented by Fresenius and Will, of which the following is a description. Fig. 220 shows its construction. A is a large flask of about two ounces capacity, in which the decomposition of the carbonate is effected; B a somewhat smaller flask, containing strong sulphuric acid: both are supplied with doubly pierced corks, for the reception of the three tubes *a*, *c*, and *d*. The tube *a* is confined to the flask A, being immersed below the level of the fluid: in the same manner, *d* is only connected with the flask B, and only extends just below the cork. Lastly, the tube *c* enters the neck of A on the one side, but does not extend further, and, by a double bend, is brought into connection with B, which it enters, dipping into the sulphuric acid. The mouth of *a* is closed with wax during the experiment, so that no orifice is left in the whole apparatus but the mouth of the tube *d*.

FIG. 220.



The large assay balance, represented by fig. 179, is admirably suited for weighing this apparatus.

100 grains of the ore are introduced into the flask A, which is then filled with water to about one-third; the apparatus is closed by the wax stopper, and brought into equilibrium on the balance by a counterpoise. The decomposition of the carbonate under examina-

tion is now induced by sucking out a small quantity of air with the mouth from the tube *d*. The air is thus drawn not only from B, but also from A, both flasks being connected by the tube *c*; bubbles of air are therefore seen passing from A through the sulphuric acid; and in order to restore the equilibrium of pressure, a small quantity of sulphuric acid is forced from flask B into flask A, where coming in contact with the carbonate under examination, it decomposes it; and the carbonic acid evolved with effervescence in A can only escape by the tube *c* into the flask B, whence it must pass through the remainder of the sulphuric acid and the tube *d* into the air. This sulphuric acid condenses with great energy all the aqueous vapour, and retains everything that the current of gas might possibly carry with it. When the operation of removing a small quantity of air by the mouth, and the consequent addition of corresponding quantities of sulphuric acid to the contents of flask A, have been repeated until no more effervescence ensues, the decomposition is complete.

There is still, however, a portion of carbonic acid remaining in the apparatus which was previously filled with air, and some still clings to the solution in the flask A, which by this time has become cold. Both must be removed before the apparatus is re-weighed. For this purpose, by suction, as in the commencement, at *d*, so much sulphuric acid is caused to pass over at once as will give rise to a considerable elevation of temperature in A, by which means the carbonic acid in solution is evolved, and with it that portion still clinging to the other parts of the apparatus. By removing the wax stopper *b*, the mouth of *a* is opened, and air may then be drawn through the apparatus from *d* until all the carbonic acid is expelled. Here, too, all the moisture which is removed by the current of air from A will remain in the sulphuric acid in B. When the whole apparatus has cooled it is placed upon the scale, and the amount of carbonic acid is ascertained by the weights which must be added to reestablish the equilibrium.

Determination of Water.—Weigh 100 grains of the ore, and ignite for a quarter of an hour in a lightly covered platinum crucible. When cold, weigh the ignited ore; the loss is carbonic acid and water. Deduct the amount of carbonic acid previously obtained from the total loss, and the remainder represents the quantity of water.

CHAPTER IX.

THE ASSAY OF COPPER.

In the assay of copper by the dry way, all minerals and substances containing that metal are divided into four classes.

Class 1 comprises substances containing neither sulphur nor arsenic, nor any foreign metals but iron.

Class 2 comprises ores, &c., containing sulphur, but no other metal than iron.

Class 3 comprises the sulphurets which contain other metals than iron,—as arsenic, antimony, lead, &c.

Class 4.—Various alloys.

Class 1.—The minerals belonging to this class are the following:

Native Copper.
Suboxide of Copper, Ruby Copper.
Oxide of Copper.
Oxy-chloride of Copper.
The Silicates of Copper.
Anhydrous Carbonate of Copper.
Blue Carbonate of Copper, Azurite.
Green Carbonate of Copper, Malachite.

Native Copper (Cu).—This substance possesses all the properties of the manufactured metal; colour, aspect, odour, flexibility, and sonorous properties, are pefectly the same. Native copper occurs in many forms; it is found in regular crystals in the cube and octahedron and their modifications: thus (see figs. 221, 222, 223, 224, and 225).

Fig. 221.

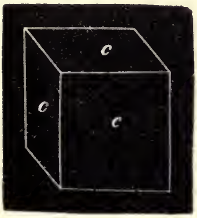


Fig. 222.

Fig. 223.

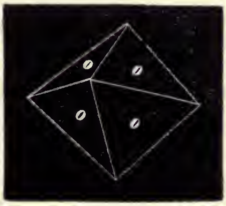


FIG. 224.

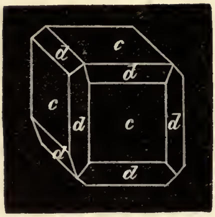


FIG. 225.

It also occurs in thin leaves in the fissures of rocks and other minerals; in an aggregation of small scales (it is then called "moss copper"), or in large masses from 1 lb. to 60 and 70 tons, and upwards. It is usually very nearly pure, but sometimes contains a considerable quantity of silver.

Sub-oxide of Copper, Ruby Copper (Cu_2O).—Its colour is usually a very intense deep red; it occasionally, though, assumes a fine crimson tint when it occurs in silky or capillary crystals. When in masses its tint is darker, but pulverisation is sufficient to develop its fine colour. It is exceedingly friable. It also occurs in octahedral and cubical crystals (see figs. 226 to 228).

FIG. 226.

FIG. 227.

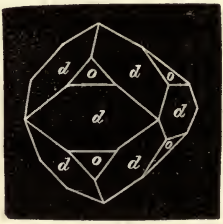


FIG. 228.

These crystals are sometimes covered with a greenish crust: this is due to the presence of a little carbonate of copper.

Composition:—

Copper	88·82
Oxygen	11·18
	100·00

There is also another variety of this ore called *Ferruginous Red Oxide of Copper,* or *Tile Ore.* It differs only from the ruby copper in containing some oxide of iron.

Oxide of Copper, Black Copper (CuO).—This is a brownish-black or black earthy substance, very friable; does not crystallize. It accompanies nearly all copper ores, but does not exist in any quantity. It is a product of decomposition of the sulphuret and sulphate of copper.

Composition :—

Copper	77·05
Oxygen	22·95
	100.00

Oxy-chloride of Copper ($CuCl,3(CuO),3(HO)$).—A green mineral, crystallizing in right rhomboidal prisms. It is translucent, sometimes transparent; soft, and brittle. Its streak is apple-green, and lustre vitreous.

Composition :—

Chloride of copper	30·12
Oxide of copper	54·22
Water	14·16
Oxide of iron (accidental)	1·50
	100·00

Silicates of Copper ($3CuO,2SiO_3,2HO$).—This mineral much resembles the green carbonate of copper; but it is remarkable for its great compactness, and for its peculiar appearance, which causes it to resemble an enamel or well-fused slag. It has a beautiful bluish-green colour, and it is occasionally mixed with a considerable amount of carbonate of copper (malachite). A very powerful vein of this mineral has lately been discovered in Jamaica.

Composition of sample admixed with a little carbonate of copper:—

Oxide of copper	40·00
Silicic acid	40·00
Water	12·00
Carbonic acid	8·00
	100·00

Anhydrous Carbonate of Copper is exceedingly rare. It is a deep brownish-black, in compact earthy-like masses, occasionally mixed with malachite.

Composition :—

Oxide of copper	60·75
Carbonic acid	16·70
Peroxide of iron	19·50
Silica	2·11
	99·06

Blue Carbonate of Copper, Azurite ($2(CuO,CO_2),CuO,HO$).—This mineral is distinguished from all others by its fine blue colour. It is found in perfectly regular crystals, which are sometimes isolated. The finest crystals are found in groups enveloped in a fine clay, in which are found globular masses presenting a radiated structure; the surface is spotted with crystals. These occur frequently in the Burra Burra Mine, and are locally and quaintly termed "she oak apples," from a fancied resemblance in shape to the ordinary oak apple The following are some of its crystalline forms (figs. 229 and 230).

FIG. 229.

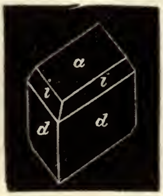
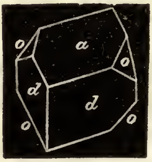


FIG. 230.



The green carbonate and red oxide usually accompany this mineral.

Composition of a specimen from Bannat :—

Oxide of copper	69·08
Carbonic acid	25·72
Water	5·20
	100·00

Green Carbonate of Copper, Malachite (CuO,CO_2,CuO,HO).—This mineral always possesses a fine velvety green colour, varying from apple-green to emerald-green. It has sometimes a blackish-green tinge. It is rarely crystalline, but appears to affect the same forms as the preceding variety. Some crystals have been found possessing both the blue and green colours. Malachite is ordinarily presented under the form of mammellated concretions; the interior is very compact, and lustre shining. This mineral is nearly always accompanied by other ores of copper.

Composition of a sample from Siberia:—

Oxide of copper	71·70
Carbonic acid	20·50
Water	7·80
	100·00

Assay of Ores of the First Class.

Native Copper.—The weight of the whole sample is to be taken. Any oxide, carbonate, or sulphuret of copper or gangue that may accompany it must be carefully detached by hammering, or otherwise, and its weight estimated and deducted from the total weight as before obtained. There will now be three weights—weight of metallic copper, weight of ore and gangue, and total weight of sample: these must be entered in the assayer's note-book thus:—

Total weight of sample (say)	5680 grains.
Weight of rough metallic copper (say)	3580 ,,
Weight of ore and gangue	2100 ,,

200 grains of the rough metallic copper must then be treated as described under Refining and Assay of the Fourth Class, and the quantity of fine copper noted.

If the mixture of ore and gangue broken from the rough metallic copper contain any sulphuret of copper, it must be assayed as directed for Class 2; if not, and it is rich (say apparently above 10 per cent.), it, as well as all the varieties of Class No. 1, may, if as rich as just stated, be thus assayed:—

200 grains must be gently calcined to expel water and carbonic acid. The calcined ore, when cold, is mixed with the following flux:—

300 grains of carbonate of soda,
300 grains of argol,
50 grains of lime.

After intimate mixture, it is placed in a suitable crucible, which it ought not to more than two-thirds fill, covered with a small quantity of an equal admixture of carbonate of soda and argol, and on the top of all 200 grains of borax. The crucible is then set on the furnace with all the precautions mentioned in the article on reduction, and allowed to remain at a gradually increasing heat until the whole contents flow freely, and the upper surface of the flux assumes a peculiar wavy appearance, which needs only once be seen to know the term of the assay.

When this appearance is produced the crucible may be seized with the tongs, its contents agitated by a circular or washing motion, which, after a little precaution, is easily imparted to it by means of a gentle movement of the tongs; it is then gently tapped against the furnace top, to facilitate the collection of any small globules floating in the flux, and allowed to cool.

If the assay has been successful, the upper part of the inside of the crucible will have been scarcely touched by the flux; and where it is stained, the colour is black or brownish-black, and not green or red: if either green or red, a small quantity of oxide of copper has escaped decomposition, and if the mass of the flux be thus coloured the assay is useless, and must be recommenced. This imperfection in the assay may arise from one or more of three causes:—1stly, too small a quantity of reducing agent (argol) may have been employed; 2dly, the fusion may have been too rapid, in which case some of the oxide of copper has been taken up by the boracic acid of the borax, and is then difficultly reducible by means of carbonaceous matter,—that is to say, to the metallic state; but the green borate of copper formed by the union of oxide of copper (CuO) with boracic acid is readily reduced to the state of subborate, or a compound of the sub or red oxide of copper (Cu_2O) with boracic acid, which compound has a fine red tinge, and is the cause of the red spots found intermingled with green either on the side of the crucible, or in the mass of the flux in an imperfect assay. This may be avoided by very gradually increasing the heat from the commencement, and, if possible, keeping the whole in a state of dull redness, below the fusing point, for about a quarter of an hour, a time sufficiently ample for the total reduction of the contained oxide of copper to the metallic state; after which no fear need be entertained of the success of the assay if the next source of error be carefully guarded against, which is, 3rd and lastly, the assay may be kept in the fire after it is completed, in which case a portion of copper is oxidised, and the assay is again rendered incorrect. This happens from the oxidising power of carbonate of soda on copper, and will be explained in the refining process.

After the crucible has been thoroughly examined as to the above appearances, it may be broken. The button of copper found at the bottom should be well fused into one compact bead or prill, not adhering either to the crucible or slag. The outer surface should be perfectly smooth, and of the purest copper colour; it should flatten considerably under the hammer without splitting at the edges, and finally bend slightly before breaking.

Two assays must be made at the same time, and the resulting buttons not differ from each other more than the eighth of a grain $=\frac{1}{16}$th per cent.

To calculate the assay when native copper is mixed with ore, proceed thus, taking the numbers given before :—

Total weight of sample	5680 grains.
Weight of rough metallic copper . . .	3580 ,,
Weight of ore and gangue .	2100 ,,

Suppose we have found by experiment that 200 grains of rough copper give 198 grains fine copper = 99 per cent., and that 200 grains of ore and gangue give 124 grains fine copper = 62 per cent. : the per-centage is thus calculated :—

Let A represent the total weight of sample,
,, B ,, ,, ,, copper,
,, C ,, ,, ,, ore and gangue,
,, D ,, per-centage of fine copper in rough copper, and
,, E ,, per-centage of fine copper in ore and gangue;

$$\frac{\mathrm{B}\times\mathrm{D}+\mathrm{C}\times\mathrm{E}}{\mathrm{A}} = \text{per-centage of copper in the whole sample.}$$

The following is worked out, according to the above rule, from the numbers already given :—

Weight of rough copper	3580	×	99	=	354420
Weight of ore and gangue	2100	×	62	=	130200
	354420	+	130200	=	484620

$$\frac{484620}{5680} = 85{\cdot}14 \left\{ \begin{array}{l} \text{per cent. of fine copper} \\ \text{in mixture of native} \\ \text{copper and ore.} \end{array} \right.$$

The same rule is also applicable in calculating the mixture of granular metallic copper or tin in rich copper or tin slags. It is also exceedingly useful in calculating the per-centages of silver and gold in admixtures of the native metals with rich or poor gangues, and will be again referred to under the heads Silver and Gold Assay.

Poor Ores, &c.—Poor ores and slags cannot be accurately assayed in the furnace by the process already described as applicable to rich ores, as it is very difficult to collect all the copper into one button, more especially as a very large amount of flux in proportion to a very small amount of copper always induces the retention by the former of a comparatively large per-centage of the latter; so that it is found advisable in practice to concentrate the copper by separating it in the form of sulphuret, or as a mixed sulphuret of iron and copper, rather than attempting to obtain it directly in the metallic state. The best method of operating is to mix 500 or 1000 grains of the ore or slag with 50 to 100 grains of iron pyrites (mundic) free from copper, and 300 to 600 grains of pulverized fused borax (glass of borax); fuse the mixture in a crucible with the precautions already pointed out. When perfectly fused, take from the furnace, tap it to collect all globules, and allow to cool. When cold, break, and a regulus, or mixture of sulphurets of iron and copper, will be found in the form of a button, which should not adhere either to flux or crucible.

The reaction in this operation is thus—

$$2(CuO) + 3(FeS_2) = 2(CuS),3(FeS) + SO_2.$$

In this case the oxygen of the oxide of copper in the poor ore or slag oxidises a portion of the sulphur in the pyrites, whilst the sulphuret of copper combines with the sulphuret of iron it finds itself in contact with, and is thus collected into one tolerably large button, whilst the portion of sulphur oxidised passes off as sulphurous acid. This mode of concentration is exceedingly simple.

The button of regulus so obtained now no longer belongs to the first class, but must be transferred to the second, and treated as there directed.

The assay of most of the ores and substances belonging to this class can be very readily performed by the wet way: thus—

Dissolve 100 grs. if rich (200 or 300 if poor) in hydrochloric acid. The ore, previous to solution, must be finely pulverized, placed in a flask, and about 2 oz. of hydrochloric acid added, a gentle heat applied until all action ceases, and the residue, if any, is quite white. The solution is then allowed to cool, diluted with about 3 oz. of water, and filtered into a beaker glass or precipitating glass, and the filter thoroughly washed, so as to remove all the cupreous solution: the washings are to be added to the bulk of the solution. In case the substance is not decomposable by hydrochloric acid, it must be fused with carbonate of soda (see Analysis of Iron Ore, page 243), and then treated with hydrochloric acid as above directed.

To the filtered solution, (however obtained), a few pieces of bright and clean iron or zinc are added (the author prefers the latter); effervescence ensues, and metallic copper is deposited. If when the whole of the zinc or iron added is dissolved the solution is not colourless, more iron or zinc is added, and the action kept up, when required, by the admixture of a little more hydrochloric acid until the solution is colourless, and all the zinc or iron dissolved. When this happens, the liquid must be finally tested, to ascertain if all the copper is thrown down in the metallic state. To this end, file a nail perfectly bright, and immerse it in the solution for a few minutes: if no copper be present in solution the nail will remain unaltered; if there be, however, the smallest quantity there, the nail will become covered with a reddish film of metallic copper, which is easily recognisable. If this be the case, more zinc and acid must be added until no traces of copper remain in solution. The whole must then be filtered, and the metallic copper on the filter washed with hot water until the latter passes off tasteless. The filter containing the copper is then, in company with another filter of precisely the same weight, transferred to the water bath, and there dried until it ceases to lose weight. The weight, if 100 grains have been employed, gives the per-centage; if more, the weight obtained must be divided according to quantity.

The following equation will represent the reactions occurring during the assay, supposing malachite or green carbonate of copper the substance assayed:—

$$(CuOCO_2,CuO,HO) + 2HCl = 2(CuCl) + 3(HO) + CO_2.$$

In this case the carbonate of copper is decomposed, the carbonic acid being evolved; the oxide of copper is also decomposed, chloride of copper and water being formed. The result is solution of chloride of copper, which, being acted on by metallic zinc, gives up metallic copper: thus—

$$2(\mathrm{CuCl}) + 2\mathrm{Zn} = 2(\mathrm{ZnCl}) + 2\mathrm{Cu}.$$

Here we have zinc merely replacing the copper,—chloride of copper and metallic zinc before, and chloride of zinc and metallic copper after the reaction.

Methods of obtaining the amount of copper by means of standard solutions will be given at the termination of this chapter.

Class 2 comprises the following minerals:—

Sulphuret of Copper, Vitreous Copper.
Copper Pyrites (Yellow Ore).
Peacock Copper Ore, Horse-flesh Ore.
Sulphates of Copper.
Seleniuret of Copper.
The above ores calcined on the large scale; and
Regulus and Coarse Copper from any of the above ores.

Sulphuret of Copper (Cu_2S).—This mineral is generally lead-coloured, sometimes iron-grey, with a bluish tint on its surface analogous to that of tempered steel. It is compact, rarely lamellar, and very often shining: hence the name "vitreous copper." It is usually found in small amorphous masses disseminated in various gangues, but is sometimes found regularly crystallised. It crystallises in the rhombohedric system (see figs. 231, 232, and 233).

FIG. 231.

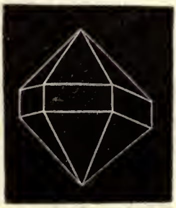


FIG. 232.

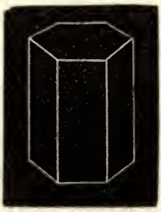


FIG. 233.

Composition :—

Copper	79·82
Sulphur	20·18
	100·00

Copper Pyrites, Yellow Ore (FeS,CuS).—This is the most common ore of copper, and nearly the whole of the ore raised in Cornwall, and in the United Kingdom generally, is of this species. It has a brass-yellow colour, sometimes passing to a golden tinge; on exposure to moist air it becomes iridescent on its surface. It occurs crystallised, and in the amorphous state, in powerful veins or lodes.

Its crystalline form is an octahedron with square base, passing into the tetrahedron.

Composition of a crystalline specimen analysed by Rose :—

Copper	34·40
Iron	30·47
Sulphur	35·87
	100·74

Peacock Copper Ore, Horse-flesh Ore.—This ore has no fixed formula, as it is composed of variable mixtures of sulphuret of copper and sulphuret of iron. It occurs both massive and crystalline. When crystalline, it usually affects the cubical form, with the angles more or less replaced: a variety of these forms, denoting the passage of the cube to the octahedron, will be found in the chapter on Crystallography, under that portion relating to the modifications of the cubical system. When massive, its colour is copper-red, to a peculiar reddish-brown, which has induced the name "horse-flesh." This latter colour and its darker modifications characterise the crystalline varieties, which, together with the amorphous, have always an iridescent tarnish, mostly blue, green, and yellow: hence the term "peacock ore."

The following analyses give an idea of its usual composition. Sample 1, from Norway; sample 2, from Killarney; sample 3, from Germany :—

	1.	2.	3.
Copper . .	69·5	61·07	70·0
Iron . . .	7·5	14·00	7·9
Sulphur . .	19·0	23·75	20·0
Silica . . .	0·0	0·50	·2
Oxygen . .	4·0	0·00	0·0
	100·0	99·32	98·1

Sulphate of Copper ($CuO,SO_3,6HO$).—This salt is a constant ingredient of the water pumped from copper mines; it is due to the decomposition of the sulphurets of copper. It is a bright-blue salt, not found distinctly crystallised in the native state, but occurs massive or stalactitic; its fracture is conchoidal, and it is soluble in water.

Composition:—

Oxide of copper	31·86
Sulphuric acid	32·24
Water	35·90
	100·00

Sub-sulphate of Copper ($4CuO,SO_3+4HO$).—This is a greenish insoluble mineral, crystallising as a right rhomboidal prism. It is very rare.

Seleniuret of Copper (Cu_2Se).—A silver-white ductile mineral, also very rare.

Composition:—

Copper	44·45
Seleniuret	55·55
	100·00

The other substances belonging to this class are the minerals already mentioned in their roughly calcined states; also the regulus and coarse metal derived from the fusion of such minerals, or roughly calcined minerals, or a mixture of both.

Assay of Ores of the Second Class.

Ores of this class, with the exception of the sulphates, roughly calcined ores, and coarse metal, are assayed for two very different ends; the one in order to ascertain the amount of regulus or coarse metal obtainable from a given weight, the other to ascertain the per-centage, or, in commercial language, the produce of fine or metallic copper.

Assay for Regulus.—The assay for regulus serves to determine the relative quantity of sulphurets and gangue in the ore submitted to experiment, and consequently the quantity of regulus a given ore would produce in the large way.

This assay is very simple and ready of execution, and has been partially described when treating of the method of concentrating the copper in poor ores of the first class.

The operation consists in acting on the ore with a substance capable of determining the fusion of the gangue, but exercising no decomposing action on the sulphurets. No flux fulfils these conditions better than fused borax, which must be thus employed:—

200 grains of finely pulverised ore
„ „ „ „ glass of borax,

well mixed, and placed in a crucible, which should not be more than half filled. The fusion must be effected with the precautions already pointed out. When the crucible is cold it is broken, and the button of regulus weighed.

The assay may be conducted with the fluxes used on the large scale,—as lime, &c., in which case the ore must be mixed with three times its weight of the silicate of lime advised in the assay of iron. It may be here mentioned that, in case this flux is used, the temperature must be a full white heat.

It is essential to remark that the regulus produced by this process is composed of sulphurets containing the minimum amount of sulphur. The reaction is thus, supposing the ore to be assayed consists of a mixture of sulphuret of copper and iron pyrites with gangue,—

$$\mathrm{CuS + FeS_2 + NaO_2(BO_3) + Gangue}$$

$$\begin{array}{l} \qquad\quad \text{Regulus.} \qquad\qquad\qquad \text{Slag.} \\ = \mathrm{(CuS,FeS) + (NaO_2BO_3 + Gangue) + S} \end{array}$$

Assay for Fine Copper.—This assay may be divided into three distinct operations:—1stly. Roasting, or the total and complete separation of the sulphur contained in the ore (in a state of combination with copper, or with copper and iron, as simple or compound sulphurets),—as sulphurous and sulphuric acids, and at the same time the complete oxidation of the copper and iron present is effected. 2ndly. Reduction, or the separation of the oxygen from the oxides of copper and iron by means of carbonaceous or hydrocarbonaceous matter. And 3dly and lastly. Fusion, or the collecting the reduced copper into one metallic mass or bead for the convenience of weighing.

Many experimenters have endeavoured to reduce the labour and tedium of the assay of ores of this class by attempting the suppression of the roasting process, but to my knowledge have not yet been successful; there always being a small loss of metal even with the most happy operators.

The following are the results of some of the reactions of various agents which have been employed with the view of superseding the roasting:—

Carbonate of Soda decomposes copper pyrites, but without the production of metallic copper. A black crystalline homogeneous slag is formed, which contains an alkaline sulphuret, a sulphuret of iron, sulphuret of copper, and oxide of iron.

Argol, Black Flux.—Copper pyrites fused with either of these substances gives a very fluid homogeneous slag, the colour of which is black, with a metallic lustre, but in which not the slightest trace of metallic copper can be detected.

Carbonate of Soda and Metallic Iron.—A mixture of these two substances separates a certain quantity of copper from copper pyrites, but this quantity never exceeds three-fourths of that contained. This maximum is obtained by using 4 parts of carbonate of soda, and 30 to 40 per cent. of iron filings. The slag is black and homogeneous.

Nitrate of Potash.—This is the most successful reagent for the abridgment of the roasting process, and is much used in the Cornish method of assay for that purpose. With nitre, all the copper can be extracted from the sulphuret, but with considerable difficulty, on account of its requiring repeated experiments to discover the amount of nitre producing the maximum result.

So that the slag may be very fluid, it is necessary to add some borax to the mixture of ore and nitre, or ore, nitre, and alkaline carbonate; so that the reduced copper may collect in a button or prill. With two parts of nitre, two parts of carbonate of soda, and one part of borax, pure copper pyrites gives about 30 per cent. of metallic copper, or rather less than the actual quantity by 4 per cent.

In the Cornish assay by imperfect roastings, aided by fusion with nitre, the trouble attendant on the ordinary roasting process is much abridged; but the actual time consumed in the assay is greater than by the process to be presently described: besides, the result is not so accurate, as there is necessarily a small loss on every one of the fusions and roastings, so that the produce is never so high as it should be.

Roasting.—If the ore contain 10 or more per cent. of copper, it may be at once submitted to the roasting operation, with all the precautions pointed out under that head at p. 79, *et seq.* If poorer than above, it is best submitted to the regulus fusion (with its own weight of glass of borax), and the button of regulus roasted. 200 grains, if the ore be tolerably rich, are sufficient for assay; if it be poor, 400 grains are necessary.

During the roasting oxides of copper and iron are formed; at the same time, also, a considerable quantity of sulphate and subsulphate of copper is produced, while during the whole operation sulphurous acid is evolved. The lower the temperature employed in roasting, the larger the amount of sulphates produced. The following is the *rationale* of the production of the above substances during the roasting of copper pyrites. It may be mentioned that the formation of oxides of iron and copper, sulphate and subsulphate of copper, and sulphurous acid, go on simultaneously; but the student will better understand the reactions if they are given separately.

Production of oxides of copper and iron, and sulphurous acid, from copper pyrites—

$$2(\mathrm{CuS,FeS})+13\mathrm{O}=2(\mathrm{CuO})+\mathrm{Fe_2O_3}+4(\mathrm{SO_2}).$$

Production of sulphate of copper, oxide of iron, and sulphurous acid, from copper pyrites—

$$2(\mathrm{CuS,FeS})+18\mathrm{O}=2(\mathrm{CuO,SO_3})+\mathrm{Fe_2O_3}+2(\mathrm{SO_2}).$$

Production of subsulphate of copper, oxide of iron, and sulphurous acid, from copper pyrites—

$$4(\mathrm{CuS,FeS})+33\mathrm{O}=4\mathrm{CuO,SO_3}+4(\mathrm{Fe_2O},+7(\mathrm{SO_2}).$$

The formation of the sulphates of copper interferes very materially with the second operation in the assay,—viz. the reduction of the oxide of copper contained in the roasted mass to the metallic state; for to ensure perfect success in this portion of the work it is absolutely necessary the whole of the sulphur should be eliminated: in fact, that the result of the roasting should be the formation of pure oxide of copper, or a mixture of it with oxide of iron. For if, during the reduction, any sulphuric acid were present, it would, as well as the copper, be reduced by the carbonaceous matter, and the sulphur so eliminated would combine with its equivalent proportion of copper, and thus sulphuret of copper would be again re-formed, whereas the final result of the reduction must be pure copper perfectly free from sulphur.

The reaction of carbon on sulphate of copper may be thus explained. It is supposed, in the present case, that the mixture to be reduced contains 4 equivalents of oxide of copper, and 1 equivalent of sulphate of copper—

$$4(CuO) + CuO,SO_3 + 4C = 3Cu + Cu_2S + 4(CO_2);$$

so that two-fifths of the whole of the copper is lost as regulus.

In order to avoid this source of error, advantage is sometimes taken of the fact, that at a certain temperature sulphate of copper is decomposed; the temperature is, however, so very high, that there is great fear of fusing the assay: it is therefore not advisable to pursue this plan, but to avail ourselves of the reaction occurring between sulphate of copper and carbonate of ammonia at a tolerably low temperature: in this case the sulphuric acid combines with the ammonia, forming sulphate of ammonia, which is volatile, leaving pure oxide of copper as a fixed residual matter in the crucible: thus—

$$CuO,SO_3 + NH_4O,CO_2 = CuO + NH_4O,SO_3 + CO_2.$$

Resumé of the operation of assaying ores of the second class.

Rich Ores.—Calcine 200 grains with the necessary precautions, taking care to continue the calcination at the highest possible temparature the ore will bear without agglutinating, until it no longer smells of sulphurous acid. Remove the crucible from the fire, and allow it to become nearly cold; then place on the top of the calcined mass a small lump of carbonate of ammonia weighing about 30 grains. Cover the crucible by the inversion of a smaller one, and again submit to a dull red heat until the whole of the carbonate of ammonia has disappeared. This point can be readily ascertained by lifting up from time to time the smaller crucible. When the volatilisation is complete the roasting is finished, and the crucible contains nothing but oxide of copper and gangue, or a mixture of oxides of iron and copper, and gangue. When cold, the roasted ore is to carefully removed from the calcining test or crucible, in whichever vessel the operation was performed, placed in a mortar, and intimately mixed with the flux recommended for the reduction of the ores of Class No. 1., to which this thoroughly calcined ore now belongs. The fusion is to be effected as stated under that head, and the resulting button of copper weighed.

Poor Ores.—To be assayed for regulus by fusion with glass of borax, and the resulting button pulverised, roasted, and fused, as if it had been originally a rich ore.

Assay of the Sulphates.—200 grains are heated to dull redness with 100 grains of carbonate of ammonia, and the fusion proceeded with as already shown.

Humid Determination of Copper in Ores of this class.—The following is the method usually recommended :—Place 100 grains of the finely-pulverised ore in a flask, and add either 2 ounces of strong nitric acid, or a mixture of 1 ounce of strong nitric acid with 1 ounce of strong hydrochloric acid. Apply a gentle heat until all the ore is decomposed. This point can be determined by the absence of a coloured residuum, and by the separated sulphur swimming on the surface of the hot liquid in bright amber-coloured drops. When this occurs, the flask and contents must be left to cool, the liquid poured off from the sulphur into an evaporating basin, and the flask well rinsed with water, which must be added to the fluid already in the basin, taking great care not to allow the sulphur to pass over with the solution of copper.

The solution and washings in the basin must now be evaporated to complete dryness, the object of which is to expel the last traces of nitric acid, the presence of which would prevent the precipitation of metallic copper by either iron or zinc; inasmuch as copper is soluble in nitric acid, and the moment it was precipitated by the iron or zinc it would be re-dissolved by the nitric acid in solution.

After evaporation to dryness, the contents of the basin must be moistened with hydrochloric acid, and allowed to stand for an hour; then water is added, and the whole gradually warmed, the solution filtered, and the filtered solution treated with zinc, and the resulting copper washed, dried, and weighed, as described under the head Humid Assay of Ores of Class 1.

It often happens, however, that several hours boiling is required for the complete decomposition of ores of this, the second class. Moreover, the evaporation to dryness, &c., to expel excess of nitric acid, consumes much time: the author therefore recommends the following process:—

Calcine 100 grains of the ore in either a crucible, small porcelain capsule, or platinum capsule. The operation must be continued at a low temperature until no more sulphurous acid is perceived. The roasted ore, when cold, is to be transferred to a flask, boiled with two ounces of hydrochloric acid (in which, after roasting, it is invariably perfectly decomposed), the solution allowed to cool, diluted with water, and filtered. The copper is separated in the usual manner from the filtered liquid. The whole operation does not occupy more than two or three hours.

Sulphate of Copper needs only to be dissolved in water to which a little hydrochloric acid has been added, the solution filtered, and treated with zinc as above.

Class 3 includes the following minerals:—

Stanniferous Sulphuret of Copper.
Bismuthic Sulphuret of Copper.

Multiple Sulphurets of Copper, Grey Copper.	Arsenical. Antimonial. Plumbiferous.

Phosphates of Copper.
Arseniates of Copper.
Arsenite of Copper.

Stanniferous Sulphuret of Copper.—This mineral appears to be a compound of the sulphuret of copper and sulphuret of tin. Its colour is greyish-yellow. It is compact, and has a semi-granular fracture, sometimes passing to the conchoidal. It is very rare.

Composition.—A specimen from Cornwall gave the following results:—

Copper	30·0
Tin	26·5
Sulphur	30·5
Iron	12·0
	99·0

Bismuthic Sulphuret of Copper.—This mineral is also very rare. It is found both in amorphous masses and in congregated needles. It has a shining steel-grey lustre, which changes in the air to a reddish or bluish tint.

Composition:—

Copper	34·66
Bismuth	45·24
Sulphur	12·52
	92·42

Multiple Sulphurets of Copper, Grey Copper.—Under this head is included a very great variety of minerals, which are all more or less argentiferous. They may be divided into three groups, as in the heading of the ores of the second class:—1st, the arsenical; 2nd, the antimonial; and 3rd, the plumbiferous.

Arsenical Sulphuret of Copper ($Cu_2S,FeAs,Agn$).—This is the formula derived from the first analysis, quoted below, but by no means represents the formula of all the ores of this class, as the varying proportions of their constituents seem to point out that many of them are mixtures of various quantities of the different sulphurets and arsenurets. These remarks apply, more or less, to all ores coming under the generic name Grey Copper. The minerals containing the four above-mentioned elements as their chief constituents crystallise in forms derived from the regular tetrahedron; they are bright steel-grey in colour on a freshly broken surface, but soon tarnish in the air. Their fracture is uneven or conchoidal. The following analyses represent some members of this group whose composition has a certain degree of fixity. Nos. 1 and 2 samples of Freyburg, No. 3 from Cornwall:—

	1.	2.	3.
Copper	41·0	42·5	45·3
Iron	22·5	27·5	9·3
Arsenic	24·1	15·6	11·8
Silver	·4	·9	0·0
Sulphur	10·0	10·0	28·8
Gangue	0·0	0·0	5·0
	98·0	96·5	100·2

Antimonial Sulphurets of Copper.—There is little external difference between this group and the preceding. They can be, however, readily distinguished by their behaviour before the blow-pipe, the former giving off no antimonial smoke, the latter abundance.

The following three analyses will give the student a good idea of the usual constituents of this class:—

	1.	2.	3.
Copper .	38·4	38·6	34·5
Iron . .	1·5	4·9	2·3
Zinc . .	6·8	2·7	5·5
Silver . .	·8	2·7	4·9
Antimony	25·3	16·5	28·2
Arsenic .	2·3	7·2	0·0
Sulphur .	25·0	26·3	24·7
	100·1	98.6	100·1

Plumbiferous Sulphurets of Copper, Bournonite ($3(Cu_2S) Sb_2S_3 + 6(PbS)Sb_2S_3$. The above is the composition of the pure bournonite; but, as before stated, all ores of these varieties differ much in composition.—The colour of this class is generally deep lead-grey; fracture uneven; usually soft, so as to be readily cut by a knife. When crystalline, the crystals are derived from the right rectangular prismatic system.

The three appended analyses will fairly represent the average composition of this group:—

	1.	2.	3.
Copper .	13·5	12·8	12·6
Lead . .	39·0	42·6	40·8
Iron . .	1·0	1·2	0·0
Antimony	28·5	24·2	26·3
Sulphur .	16·0	17·0	20·3
	98·0	97·8	100·0

Phosphates of Copper ($4CuO,PO_5,2HO$, and $5CuO,HO_5,5HO$.) These formulæ are referrible to analyses Nos. 1 and 2. This mineral occurs in radiated masses, also in crystals, which are of a green or blackish-green colour, and splendent; they are frequently prismatic, but sometimes approach the octahedral form. When massive, the colour is green and black intermixed.

Composition :—

	1.	2.
Oxide of copper	63·9	62·9
Phosphoric acid	28·7	22·7
Water	7·4	14·4
	100·0	100·0

Arseniates of Copper.—There are many minerals belonging to this class. Their colour is usually greenish; but, as they do not accompany the ordinary ores to any extent, there is no necessity to dwell further on them, giving only the following analysis of a specimen from Cornwall :—

Oxide of copper	54·0
Arsenious acid	30·0
Water	16·0
	100·0

Assay of Ores of the Third Class.

In conducting the assay of the ores of this class, it is always better, whether they be rich or poor, to obtain a regulus before roasting, as most of them are very difficult to roast, on account of their fusibility from containing lead and antimony. A little silver sand may be advantageously mixed before roasting. 200 grains are enough for assay if the ore appear rich, 400 if poor.

The roasting, treatment with carbonate of ammonia, and fusion, are conducted precisely as described in the treatment of first and second class ores. The resulting button, however, differs materially; that from the two previous classes extending considerably under the hammer before cracking at the edges, and even where cracked the fracture is a fine copper colour. The button from the third class ores will scarcely flatten at all under the hammer; it more usually breaks to pieces without flattening, or at best, if it do flatten, it cracks extensively. It must now be refined, for which the student is referred to the assay of substances of the fourth class.

Humid Determination of Metallic Copper in Ores of the Third Class.—Dissolve 100 grains of the ore by either of the processes pointed out for ores of the second class, and to the unfiltered solution add solution of ammonia until it is in considerable excess, which may be readily recognised by the liquid smelling strongly of it. The whole must then be thrown upon a large filter, and the precipitate of oxide of iron, &c., on the filter well washed with water containing a little ammonia, until the liquid passes through colourless. The filtered liquid and washings must now be mixed, strongly acidulated with hydrochloric acid, zinc added, and the separation and estimation of the copper proceeded with as already described.

Class 4 comprises all the various alloys of copper which may proceed either from works on the large scale, or from small assays of ores of the preceding class.

Assay of Substances of the Fourth Class.

There are two methods of conducting this assay, but both based on the fact that in a mixture of copper with antimony, arsenic, lead, iron, sulphur, &c., the latter substances are more readily oxidisable than the copper itself, and that the copper does not appear very amenable to the action of oxygen or oxidising agents, whilst any of the above metals are alloyed with it, and that oxygen and oxidising agents only commence to take any very perceptible effect after they are entirely or very nearly separated.

The oxidising agents employed are—1stly, the oxygen of the atmosphere in conjunction with lead and oxide of lead; 2ndly, carbonate of soda, or potash and nitre; and 3rdly, carbonate of soda alone. The merits of each will now be discussed, and the mode of operation given.

Refining, or the Assay of Substances of the Fourth Class by Oxygen and Lead.—This method is entirely employed in Hungary and Saxony, and is thus performed:—

Refining is analogous to cupellation; in fact, it is a true cupellation made on copper, and has for its object the separation of all the metals with which the copper may be alloyed.

The operation does not, however, give all the copper in a state of purity, and the estimation can only be made approximately. Nevertheless, it is of great use, as it has an analogy with the refining on the large scale, and affords the opportunity of determining the quantity of copper which an alloy would furnish by treatment on the large scale.

The refining of copper is carried on in an ordinary cupel furnace; but as it requires a very high temperature, one possessing more than the ordinary draught must be employed.

The ordinary bone-ash cupel is generally used.

When the furnace and cupels have arrived at the proper temperature, the copper is introduced; when it is fused, lead, if it is judged necessary, is added. The refining then commences. The lead, the alloyed metals, and part of the copper, oxidise, and form a fusible combination, which envelopes the circumference of the metallic button, and which the cupel partly absorbs. The button appears agitated, and revolves rapidly, being constantly covered by a brilliant iridescent pellicle. At the instant the operation is about to be finished the movement becomes quicker, and the pellicle more shining; then, all at once, the movement and pellicle disappear together, and the button becomes solid.

These phenomena constitute what is termed the *brightening*. When the brightening takes place the refining is finished, and the cupel may be removed from the fire.

The refined button is covered with a fine crust of protoxide of copper, which cannot be detached without difficulty, if it be cooled slowly; but if it be plunged as hot as possible into water, the oxide is easily removable by the hammer.

It is generally preferable to sprinkle the button with glass of borax, in the proportion of about 7 per cent., as soon as possible after the brightening; and if the button be plunged into water whilst very hot, the newly formed borate of copper may be detached by the first blow of the hammer. The copper is known to be pure when it is of a fine red colour, and malleable.

In order to arrive at the proportion of copper in the substance assayed, it is not sufficient to weigh the assay button, because a part of it is carried away in the state of oxide, either with the other metallic oxides, or with the borax added to cleanse it.

The alloys of copper submitted to the refining process may or may not contain lead. When they contain none, a tenth of their weight is added successively, until the copper be pure. In order to arrive at the true proportion of copper in the alloy one eleventh of the weight of all oxidisable materials (including the lead added), and one tenth of the weight of the borax are to be added to the weight of the assay button obtained.*

When the copper alloy contains lead, it may contain just sufficient for the assay, or it may contain too little, or too much. In the former case there is nothing to add; in the second lead must be

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* Berthier.

added by tenths until the copper remains pure; and in the third, instead of adding lead, a determinate weight of pure copper must be added, the assay concluded as usual, and the quantity added deducted from the quantity obtained, all corrections having been previously made.

The proportion of copper contained in an alloy can be found, however, without making any suppositions as to the quantity of that metal scorified by the lead, by refining as follows: Place in two cupels, side by side, in a well heated muffle, 4 parts of pure lead, and, as soon as melted, place in one of the cupels 1 part of pure copper, and in the other 1 part of the alloy to be assayed, and conduct the refining as usual.

The assay buttons are then weighed: that from the pure copper weighs more than the other. Supposing, then, that the difference of weight represents the quantity of foreign metal the alloy contained, and that the absolute quantity of copper oxidised is the same in both cupels, it suffices to add to the weight of the button the loss which the pure copper has undergone, in order to arrive at the proportion of copper contained in the alloy. This supposition is not strictly true, and it seems more probable that the exact result is to be arrived at by adding one eleventh the weight of the alloyed metals, and one seventh of the borax to the copper obtained. However, where the alloy is rich, this does not matter very much.

For cupriferous leads, cupel at the same time 1 part of pure copper, with 4 parts of pure lead on the one hand, and on the other with 4 parts of the cupriferous lead. The second assay gives more copper than the first, and the difference of weight between the two assay buttons gives the quantity of copper contained in the alloy.

Refining by Carbonate of Potash and Nitrate of Potash.—This method is generally employed in Cornwall. The flux for this purpose is a mixture of nitrate of potash and argol. The mixture is ignited, and the result is the formation of carbonate of potash with an excess of nitrate of potash. If the student refer to page 138, he will there find described in what way the alkaline carbonates act as oxidising agents, as well also as nitrate of potash.

The operation is thus conducted:—200 grains of the alloy, or the button obtained in the assay of an ore of the third class, must be fused in an earthenware crucible. When completely fluid, about 100 grains of the flux are added, the furnace cover put on, and a strong heat kept up for about five minutes. The contents of the crucible must then be rapidly poured into an ingot mould, and the crucible returned to the fire, so that it should not chill, and run the risk of cracking; because it is just possible that the sample may require more than one refining. When the metal and the slag in the mould are cold, they must be examined. If the slag be green or red, then too much flux has been added, or the assay has been kept in the fire too long, both circumstances producing precisely the same effects; indeed, one is only a modification of the other. Thus, if too much flux be added, all the foreign metals are oxidised and removed, and the excess of flux acts on the copper, it not being protected by the alloy; also, if it be kept in too long, the same result will ensue, if there be the slightest excess of flux, from the same cause. This also explains why the copper ore assay (the reducing assay) should not be kept in the fire too long, because as soon as the whole of the carbonaceous matter is expended, either in reducing the ore, or by too long exposure to the fire, the alkaline carbonate in excess in the flux reacts on the copper, oxidising a portion, becoming itself red, either partially or throughout its whole bulk, in proportion as the action has continued.

To return to the examination of flux and refined button of copper. If the flux be not coloured green or red, it is a clear evidence that neither too much has been used, nor the assay kept too long. The button is now our next care. If its colour be bright copper red, and if it flatten under the hammer, as already described, the process has been successfully conducted, and the weight of the button will represent the amount of fine copper in the quantity of ore or metal submitted to assay. If, on the other hand, the flux be coloured green or red, a loss of copper has been sustained, and the assay should be recommenced; or, if the button should not flatten under the hammer, it must be returned to the crucible which had been previously employed and placed in the fire, and when again fully fused more flux added, and the operations of pouring, examining, re-melting, and adding flux, repeated until the desired result is obtained.

Refining by Carbonate of Soda.—This is the least objectionable process, as this substance is a much more gentle oxidising agent than the mixture just described. The operation is carried on exactly as above, and is the one recommended by the author.

Determination of Copper in the Humid Way by Standard Solutions and Colorimeters.—Many have lately turned their attention to a rapid method of determining the amounts of copper in solutions by means of standard solutions, or by the intensity of colour of an ammoniacal solution.

Pelouze and Parkes have been eminently successful in this branch of the use of standard solutions, and Jaquelain by the colour of an ammoniacal solution, for the determination of copper. The processes are thus carried into effect:—

Pelouze's Process.—This is dependent on the decolorisation of an ammoniacal solution of copper by sulphuret of sodium. The standard solution of sulphuret of sodium may be made by dissolving four ounces of crystallised sulphuret of sodium in a quart of water. To determine the strength of this solution proceed as follows:—

Dissolve 20 grains of pure copper in nitric acid, dilute the solution with water, add excess of ammonia, and make up the deep blue solution thus afforded to about half a pint, which introduce into a suitable flask, and heat to ebullition. Whilst the contents of the flask are in process of boiling, pour into a burette, divided into 100 parts, 100 measures of the solution of sulphuret of sodium, and when the cupreous solution is boiling, gradually add the sulphuret of sodium until the liquid in the flask becomes colourless: it must be kept in a constant state of ebullition. When this is the case, the whole of the copper is thrown down as a black precipitate of oxysulphuret of copper ($5CuS,CuO$).

The number of degrees of solution of sulphuret of sodium required to produce this effect must be noted, and the numbers so used are equivalent to and represent 20 grains of copper.

Suppose 186 measures or degrees had been necessary, then as

$$186 : 1 :: 20 \text{ to } x.$$

$$\frac{20 \times 1}{186} = \cdot 1 \cdot 075$$

so that every division or degree in the burette corresponds to ·1·075 grains of copper; and in the assay proper the operator has only to multiply the number of divisions used by the number obtained as above, and the result will be the amount of copper in the quantity of ore or other material operated on.

The assay of the ore is thus made:—50 grains are dissolved in nitric acid, or in nitro-hydrochloric acid (*aqua regia*), as may be found most advantageous. When the solution is complete, the flask is allowed to cool, water added, and then considerable excess of ammonia. If the precipitate thus produced be very bulky it must be separated by filtration, well washed, and the washings added to the filtrate; if not, the small amount need not be separated. The solution must now be boiled, and the sulphuret of sodium added as just described. When the blue colour of the solution in the flask has disappeared, the number of divisions is noted, and multiplied by the number obtained in standardising the solution as already described. The result is the quantity of copper in 50 grains: this multiplied by 2 gives the per-centage.

Pelouze made a great number of experiments to ascertain how far the presence of other metals might interfere with the accuracy of this process, and his results assure him that nickel and cobalt alone have any injurious effects; and fortunately these occur but seldom, and in small quantities, in copper ores and their products.

Parkes' Process.—This process is to be preferred to that just described; but, as the substance employed is not so readily obtainable in many districts as the sulphuret of sodium, Pelouze's has also been described. The author prefers Parkes' process, inasmuch as the operation may be performed at the ordinary temperature, and the final term is more readily distinguishable.

The following is Mr. Parkes' description, from the "Mining Journal:"—

"The process is based upon the decolorisation of an ammoniacal solution of copper by cyanide of potassium (KCy) or sodium, or ammonia and hydrocyanic acid, in a free state; but I prefer to use cyanide of potassium as being less subject to decomposition, and more readily obtained in a state of purity in commerce than the other substances named.

"The method of operating is as follows:—Take a given quantity of pure copper (say, for instance, 10 grains), place it in a flask, and dissolve it in nitric acid, add ammonia in excess, and then make it into a bulk of 2500 grains by measure (about one-third of a pint) by the addition of water, although this is not absolutely necessary. Dissolve 1 ounce (avoirdupois) of pure cyanide of potassium, free from ferrocyanide or sulphuret of potassium, in 5 ounces by measure of water; filter if necessary, and place the solution in a well-stoppered bottle till required for use. I then ascertain the quantity of this solution of cyanide of potassium required to decolorise the solution of copper by taking a given quantity in any graduated vessel,—as a burette,—and pour it by degrees into the solution of copper, adding the last quantity drop by drop until it is decolorized. This is very easily perceived, as there is no precipitate to interfere, and the operation is conducted at the ordinary atmospheric temperature. I mark down the quantity required (say 500 grains) by volume. After having established this datum it is very easy to estimate the quantity of copper contained in any ore or cupriferous product by dissolving a given quantity (say 20 grains in nitric or nitro-hydrochloric acid) with the assistance of heat if required,—as in the case of some sulphurets. The addition of ammonia in excess is necessary, and if any considerable quantity of iron or alumina was present in the sample, it should be allowed to digest under ebullition, to make sure that all the copper is taken up by the ammonia; filter into a flask, wash the precipitate with water, and make it into a bulk of 2500 grains, as when taking the standard of the solution of pure copper. All that now remains to be done is to allow it to get cold, and add the cyanide of potassium until decolorised, noticing the quantity taken. I will suppose it required 400 grains by volume of the cyanide solution, then from the proportion—

500 grs. KCy : 10Cu :: KCy 400 to Cu 8

the quantity of copper contained in the 20 grains of material taken for analysis, or 40 per cent. If the ore taken was a sulphuret, it is sometimes advisable to filter, in order to separate the sulphur before adding the ammonia; or else use a dilute solution of ammonia and a gentle heat when digesting, or small quantities of sulphuret of copper might be reproduced, especially when the precipitate produced by the ammonia is a bulky one.

"When manganese is present in the ore,—easily ascertained by preliminary examination by the blowpipe,—it is best to employ carbonate of ammonia to form the ammoniacal solution, as the carbonate of manganese is very little soluble in this reagent. The reason for this modification is, that on adding cyanide of potassium to an ammoniacal solution of copper containing that metal, it assumes a slightly yellowish tint, which would interfere a little with the estimation of the last few $\frac{1}{100}$ths of copper.

"The above remarks also apply to arsenic when present simultaneously with iron in the sample, as the nitric acid converts it into arsenic acid, and this forms with the iron a salt,—arseniate of iron,—which is soluble. I have easily obviated this, by adding to the nitric or nitro-hydrochloric acid solution of the substance a little protosalt of tin or sulphate of magnesia; the arsenic is thus rendered insoluble on afterwards adding the ammonia."

Jaquelain's Process.—This process is the most simple of all, and is sufficiently accurate for most purposes. It is exceedingly useful in the smelting-house for ascertaining the contents of slags, &c., in copper. In this process there is no need of preparing a test liquor, nor of verifying its strength for each analysis; it merely requires the dissolving the alloy or ore, rendering the solution ammoniacal, measuring, and lastly, the addition of water to a known volume of the blue liquid, until the tint resembles that of a normal solution enclosed in a sealed tube. The weight of the copper is directly proportional to the total volume of the solution diluted until the tints are uniform. M. Jaquelain says that by this process the weight of copper can be ascertained to within three-thousandths. In the following description the process is somewhat modified:—

Three glass tubes of equal internal and external diameter have to be provided; they must be closed by the blowpipe at one end. In lieu of these tubes, three moulded glass bottles, furnished with accurately ground stoppers, may be substituted, and are handier in use, inasmuch as no sealing at the blowpipe is required. It will be supposed, in this description, that bottles are employed; also a burette divided into 100 parts, and a glass vessel divided in parts, one of which corresponds to ten divisions of the burette: this must hold twenty burettesful.

20 grains of pure copper are dissolved in nitric acid, the solution diluted with water, excess of ammonia added, and the whole poured into the larger graduated vessel, which must be now filled up to the mark indicating the measure of the contents of 20 burettes: thus each buretteful indicates or represents 1 grain of pure copper.

This quantity of the solution so prepared is placed in one of the stoppered bottles, the stopper firmly put in, and tied over with bladder or vulcanised India-rubber, and labelled "one grain." Half a buretteful of the liquid must now be diluted with an equal bulk of water, so that the liquid contained in the burette is tinged with half a grain of copper instead of 1 grain, as in the former case. This mixture is to be placed in another of the bottles, the same precautions as to the fixing the stopper taken, and it is labelled, "half a grain." These are now two standard solutions which cannot change; hence no correction is required for them when they are used.

The liquid in the large graduated vessel may now be rejected.

We have now two test-bottles: one containing a solution of a certain intensity of colour produced by the solution of 1 grain of copper in nitric acid, the addition of ammonia, and subsequent dilution to 1 buretteful, or 100 divisions; and the other containing only half a grain. This being accomplished, the assay is thus conducted:—

100 grains of the substance to be assayed are dissolved in nitric acid and treated with ammonia, filtered into the large graduated vessel, the precipitate on the filter well washed, the washings added to the first strong blue solution obtained, and the whole made up to the bulk of 20 burettes in the larger vessel.

A portion of this diluted solution is now placed in the third stoppered bottle, and its tint compared with the 1-grain standard solution; if it exactly correspond with it, the 100 grains of substance dissolved contain exactly 20 grains or 20 per cent. of fine copper, as 20 grains of fine copper furnished the original solution. If, however, it be darker than No 1 standard solution, it must be diluted with water until it has the same tint, and the whole measured. Supposing it has required 10 burettesful of water to effect this, then as 20 burettes : 20 grains of copper :: 30 burettes to 30 grains of copper, or 30 per cent.: and so on. If, however, it be not so dark as No. 1, then compare it with the half-grain standard, and proceed as before.

With a little practice, an assay may be made in this way in less than an hour, including the solution and filtration.

CHAPTER X.

ASSAY OF LEAD.

All minerals and substances containing lead may for the purposes of the assayer by the dry way be divided into three classes:—

Class 1st comprises all plumbiferous matters containing neither sulphur nor arsenic, or mere traces only, of those elements.

Class 2nd includes all sulphurets, antimonial or otherwise.

Class 3rd, substances into whose composition either arsenious, arsenic, or sulphuric acids, or a mixture of either, enters.

Class 1st. The following are the substances belonging to this class:—

Litharge.
Minium.
Carbonate of lead, native.
" " artificial (ceruse).
Oxychloride of lead.
Chlorocarbonate of lead.
Aluminate of lead.
Cupel bottoms.
Lead fume (non-antimonial)
" " (non-sulphurised), and
Siliceous slags.

Litharge, Oxide of Lead (PbO).—This substance is found native, but is very rare; the artificial oxide of lead, however, very often falls under the assayer's hands, and is produced in large quantities in the smelting-houses, where silver-lead is refined.

Composition :—

Lead	92·82
Oxygen	7·18
	100·00

Minium, Red Oxide of Lead (probable formula, $2PbO, PbO_2$).—This is a bright red substance, commonly known as "red lead;" it, like the former, is occasionally found native.

Composition :—

Lead	90·66
Oxygen	9·34
	100·00

Carbonate of Lead (PbO,CO_2).—This mineral is very variable in its appearance, colour, and structure. It occurs,—

1stly. In prismatic needles deeply striated in the direction of their longitudinal axis. It is of a pearly white colour, fracture vitreous, with a greasy lustre.

2ndly. In very fine needles of a pearly lustre, crossing each other in every direction, or forming radiated masses.

3rdly. In plates or compressed crystals, perfectly transparent, but not readily mistaken for quartz by its great specific gravity.

4thly. And lastly, as amorphous or earthy carbonate of lead. This variety is mostly compact and friable, but its aspect is always more or less greasy. It is very variable in its colour, passing from white to sulphur yellow, straw yellow, dull grey, lavender blue, brown, and red.

Composition of two varieties; the first pure crystalline, the second amorphous and mixed with earthy matter:—

	1.	2.
Oxide of Lead	82	66·0
Carbonic acid	16	13·0
Clay	—	15·3
Oxide of Iron	—	2·3
Water	—	2·2
	98	98·8

Artificial ceruse is used by the assayer as a flux rather than as a substance under assay. For its nature and composition see p. 125.

Oxychloride of Lead (PbCl,2PbO).—This is a rare mineral of a straw yellow colour.

Composition of a specimen from Mendip Hill:—

Lead	85·69
Chlorine	9·87
Oxygen	4·44
	100·00

Aluminate of Lead ($PbO, Al_2O_3 + 6HO$).—This is also a rare mineral. It is amorphous, and in appearance much like gum. The following is an analysis of a specimen by Berzelius:—

Oxide of lead	40·14
Alumina	37·00
Water	18·80
Sulphurous acid	·20
Sand	·60
Oxide of iron and manganese	1·80
	98·54

Cupel bottoms, lead fumes, and slags, are of very variable composition; and it would tend but little to the advantage of the student to reproduce here any analyses which have been made, as special instruction will be given to conduct an accurate assay of all those substances.

Assay of Substances of the First Class.

The assay of these substances is very simple indeed. Litharge, minium, carbonate of lead, &c., may be assayed by simple fusion with carbonaceous matter; but when the operation is thus conducted, loss of lead is sustained: it is therefore better to add some flux which will readily fuse, and allow the globules of reduced lead to collect into one button. No flux fulfils this condition better than a mixture of carbonate of soda and argol, which is to be intimately mixed with the assay. The following is the best mode of procedure:—To 200 grains of the finely-pulverised substance add 100 grains of argol, and 300 of carbonate of soda, and intimately mix; place the mixture in a crucible which it about half fills, and cover with a layer of common salt about ¼ inch thick; submit the crucible to a very gradually increasing temperature, keeping the heat at low redness for about a quarter of an hour; then urging it to bright red until the contents of the crucible flow freely; take it from the fire and shake, tap it as directed in the copper assay, and either pour the contents into the mould (see p. 98, fig. 195), or allow to cool in the crucible. If the operator be pressed for time, the mould may be used, but it is recommended to allow the assay to cool in the crucible, for unless the operator be very careful, and have had some considerable practice, he is very liable to lose a small quantity of metal in the pouring. After the contents of the mould or crucible, as the case may be, are cold, the lead may be separated from the slag by repeated gentle blows from the hammer: if any of the slag or crucible adhere to the button, the latter may be readily freed from it by placing the button between the finger and thumb with its edge on the anvil, and then gently hammering it. The lead will be so altered in shape under the hammer that the slag or crucible readily falls off; and by continuing the process, the whole may be removed. The cleaned button may then be hammered into a cubical form, and is ready for weighing.

In the assay of lead great care must be taken in the management of the temperature, as lead is sensibly volatile above a bright red heat, even when covered with flux, and still more so if any portion be uncovered from want of sufficient quantity of flux; neither must the assay remain in after the flux flows freely, for a loss may thereby occur from oxidation, by decomposition of carbonate of soda, as explained in the reduction of copper ores and the copper-refining process.

For the *rationale* of this mode of assay refer to the formula at p. 81, which explains the decomposition of oxide of lead, with the production of metallic lead, carbonic acid, and water, by the agency of a substance, like argol, containing both carbon and hydrogen.

Cupel bottoms, some lead fumes, and siliceous slags, require a modified treatment in their assay, as the substances mixed with the oxide of lead (more particularly bone-ash in the cupel bottoms) are very infusible; and if the flux already mentioned as applicable to the other matters belonging to this class were employed, a very high temperature would be necessary; and as lead, as already stated, is sensibly volatile above a bright red heat, an evident loss of that metal would be the result.

Cupel bottoms may be thus assayed: 400 grains of the finely-pulverised bottoms to be mixed with 200 grains of argol, 400 grains of carbonate of soda, and 400 grains of pulverised fused borax; the mixture placed in a crucible as already directed, covered with salt, and the fusion conducted as just described.

Lead fumes and siliceous slags require only half their weight of fused borax, with 200 argol, 400 carbonate of soda, and 400 substance (fume or slag) covered with salt.

The addition of the borax, which is a most powerful flux, causes the fusion of the assay to take place almost as readily with the last-named intractable substances, as with the former easily fusible and reducible matters. The assay, however, is rather more subject to ebullition or boiling over the sides of the crucible; hence it must be carefully watched, and the instant it appears likely to do so the crucible must be removed from the fire, gently tapped on the furnace top, and when the effervescence has subsided returned to the furnace, and this operation repeated until the fusion proceeds tranquilly.

The lead obtained in these assays, if the ore or substance contained any foreign metal, is never pure: if silver, copper, tin, or antimony be present, the whole of either of these metals will be found alloyed with the lead produced; but if the ore contains zinc, and it be heated sufficiently, but a trace remains; nevertheless the zinc carries off with it a considerable quantity of lead.

The following experiments will show what an influence the presence of zinc has upon the return of lead:—

100 parts of litharge,
100 parts of oxide of zinc,
300 parts of black flux,

were fused together, and 84 parts of lead were the result.

100 parts of litharge,
100 parts of oxide of zinc,
600 parts of black flux,

were fused together, and but 70 parts of lead were produced, instead of 90, which the pure litharge ought to have given. Hence it will be seen that, the more zinc reduced, the more lead is volatilised.

If oxide of iron be present in the assay, it is reduced, but it remains in suspension in the slag, and the lead does not contain a trace when it has not been too strongly heated. If the assay be made at a very high temperature, the iron may be fused, and then the lead will be ferruginous; this may be ascertained by means of the magnet. A similar result was obtained by many assayers, who thought for a long time that lead and iron could combine together; but by careful examination it is easily ascertained that the ferruginous buttons are but mechanical mixtures of lead and iron in grains. Indeed, by careful hammering, nearly all the iron may be removed from the lead, so that it loses its magnetic properties.

The oxides of manganese, when mixed with the ore, are changed into protoxide, which remains in the flux, and is not reduced.

Humid Assay of Ores of the First Class.

Pulverise the substance very finely, and to 100 grains placed in a flask add one ounce of nitric acid diluted with two ounces of water (if minium be the substance to be analysed, it must be first heated to redness, so as to reduce the whole of the lead it contains to the state of protoxide), and gently heat, gradually raising the temperature to the boiling point: when all action seems to have ceased, pour the contents of the flask into an evaporating basin, and evaporate to dryness with the precautions directed in the analysis of iron ore. Allow the dry mass to cool, add a little dilute nitric acid, gently warm for an hour, then add water, boil, and filter. The whole of the lead now exists in the solution as nitrate: thus, say carbonate of lead had been the substance under analysis, then—

$$PbO,CO_2 + NO_5 = PbO,NO_5 + CO_2.$$

To the filtered solution containing the nitrate as above, add solution of sulphate of soda, or dilute sulphuric acid, until no further precipitation takes place: insoluble sulphate of lead will now be thrown down: this must be allowed to completely subside by standing in a warm place; and when the supernatant liquid is quite bright the sulphate may be collected on a filter, washed, dried in the water-bath, and weighed. It contains 68·28 per cent. of metallic lead.

The decomposition of the nitrate of lead by sulphate of soda may be thus expressed—

$$PbO,NO_5 + NaO,SO_3 = PbO,SO_3 + NaO,NO_5.$$

Determination of lead by standard solution will be described at the end of this chapter.

Class 2nd comprises the following minerals and substances:—

Sulphuret of lead (galena),
„ „ antimonial,
„ „ cupriferous,
„ „ argentiferous,
„ „ fused,
Seleniuret of lead.

Sulphuret of Lead, Galena (PbS).—This is the most common ore of lead, and is that from which nearly all the lead of commerce is procured. It is brittle, has a metallic lustre, and the colour of freshly-cut lead, or rather brighter; it crystallises in the cubical system as cubes, octahedrons, and dodecahedrons. The following are some of its forms (see figs. 234, 235, 236):—

FIG. 234.

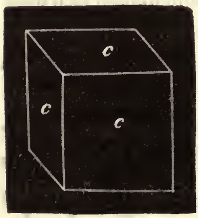


FIG. 235.

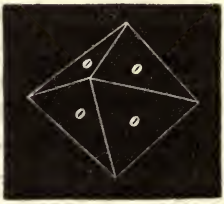
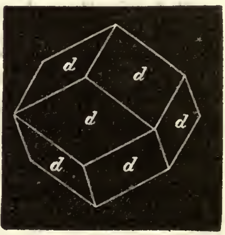


FIG. 236.



It also occurs in the granular or compact form. The grain in this variety varies in size from that of the worst iron to that of fine steel: hence the name this latter kind of ore has acquired, "steel grained ore."

Sulphuret of lead contains nearly always a certain quantity of silver. This association is so intimate and so constant, that it is a matter of extreme difficulty to obtain lead perfectly silver-free. The quantity of the latter metal is usually so great that it may be profitably separated. This, however, will be fully entered into under the head Silver Assay.

Composition:—

Lead	86·67
Sulphur	13·33
	100·00

Sulphuret of Lead, Antimonial ($3PbS,2(Sb_2S_3)$). This is the formula of Jamesonite; but, like all the mineral double sulphurets, the admixtures of each occur in every variety of quantity.—These minerals, more especially when they contain much antimony, have a striated appearance like sulphuret of antimony alone, but less fibrous.

The *Cupriferous Sulphurets of Lead* have already been described in the list of copper minerals, page 268. For the argentiferous sulphurets, refer to Silver Assay.

Fused Sulphurets of Lead from the Smelting-house.—These are combinations of various sulphurets at the minimum of sulphurisation (see Assay for Regulus, Copper Assay, page 261) with variable quantities of sulphuret of lead; their analyses will not, therefore, be reproduced.

Seleniuret of Lead.—This is a very rare mineral, and is not usually met with in the assay office: it will not, therefore, be described.

Assay of Ores of the Second Class.

In the assay of ores of the first class, oxygen was the substance to be removed, so that the lead might assume its metallic state. In this case it is sulphur; and it will be as well to pass in review the action of various re-agents on sulphuret of lead, in order that the student may better appreciate the *rationale* of the assay of ores of this class.

Action of Oxygen.—If galena be roasted at a very gentle temperature, care being taken to avoid fusion, it will be converted into a mixture of oxide of lead and sulphate of lead, with evolution of sulphurous acid, thus:—

$$2(PbS)+7O=PbO+PbO,SO_3+SO_2.$$

Action of Metallic Iron.—This metal completely and readily decomposes sulphuret of lead, giving metallic lead in a pure state, thus:—

$$PbS + Fe = Pb + FeS.$$

On the one side we have sulphuret of lead and metallic iron, on the other metallic lead and sulphuret of iron.

The Alkalies and Alkaline Carbonates decompose sulphuret of lead, but only partially; pure lead is separated, and at the same time a very fusible grey slag is formed, which contains an alkaline sulphate, and a compound of sulphuret of lead and an alkaline sulphuret. A certain proportion of the alkali is reduced by the sulphur, which is converted into sulphuric acid, so that no oxide of lead is produced. This re-action may be thus expressed:—

$$7(PbS) + 4(KO) = 4Pb + KO,SO_3 + 3(PbS,KS).$$

Nitrate of Potash completely decomposes sulphuret of lead, with the reduction of metallic lead and formation of sulphate of potash and sulphurous acid, thus:—

$$2(PbS) + KO,NO_5 = 2Pb + KO,SO_3 + SO_2 + N.$$

If the nitre be in excess, the lead will be oxidised in proportion to the excess present, and if there be a sufficiency added, no metallic lead at all will be produced.

Argol.—The presence of carbonaceous matter much favours the decomposition of galena, by determining the reduction of a larger quantity of potassium to the metallic state, and thereby the formation of a larger quantity of alkaline sulphuret. With 4 parts of argol to 1 part of sulphuret, 80 parts of lead are reduced. If the reaction were complete, the decomposition would be as follows:—

$$PbS + KO + C = Pb + KS + CO.$$

For the reactions of oxide of lead (litharge) and the sulphate of lead on sulphuret of lead, see pages 138 and 139.

From the reactions above given, it will be seen that there are many substances capable of completely reducing the lead from its sulphuret, and yet few can be used safely with any advantage, as so to use them would imply a knowledge of how much sulphur and lead were in the ore to be assayed, in order to tell the precise quantity of either of the reagents required; for it is evident that if either more or less of some were added, a faulty result would be the consequence: so that some systematic mode of assay, which may be suitable for all classes of galena, whether mixed with other sulphurets or with gangue, may be contrived. To facilitate this we now proceed to give an outline of the processes generally adopted in the assay of lead ores by various persons. The ores to be assayed may be fused:—

Firstly, with black flux after roasting.

Secondly, without roasting, with black flux, carbonate of soda, or argol.

Thirdly, with metallic iron.

Fourthly, with carbonate of soda, or black flux, and iron.

Fifthly, with black flux, oxide of iron, or oxide of zinc.

Sixthly, with black flux, protosulphuret of iron, or sulphuret of zinc.

Seventhly, and lastly, with a mixture of carbonate of soda and nitre.

1st Process. Roasting and black flux.—This method is the oldest, and was for a length of time exclusively employed. It is the longest, most troublesome, and least exact of all the known methods.

The sulphuret, reduced to powder, is roasted by heating in a current of air, and continual stirring with an iron rod. The operation is difficult, because the sulphuret and oxide of lead being very fusible, the requisite degree of heat cannot be at all exceeded without the substance softening and agglomerating into small clots, the roasting of which is very tedious and difficult. When the galena is roasted as completely as possible, it is mixed with from two to three times its weight of black flux, and gives only from 66 to 69 per cent. of lead when the galena is pure.

2d Process. Fusion with an alkaline flux without roasting.—In this process the sulphuret is fused with from 3 to 4 parts of carbonate of soda or potash. The crucible it is made in must always be left uncovered. It is slowly and gradually heated until the substance becomes perfectly liquid; the crucible is then to be removed, and allowed to cool; on being broken it will afford, from pure galena, as much as from 75 to even 80 per cent. of lead. One-tenth is always allowed for loss in the assays made in the Hartz.

Instead of an alkaline carbonate, black flux or argol may be employed in the same proportions. When the latter flux is used, the operation is longer, but the produce is a little greater.

3d Process. Fusion with metallic iron.—Schlutter and many of the older assayers were aware that iron would desulphurise galena, and ever after advised the addition of a certain quantity of that metal to the different fluxes, which they used in lead assays; but it was at the Practical School of Mines, at Montiers, that iron was first employed alone.

The process is extremely convenient and easy of execution; it always succeeds, and requires no troublesome attention. The fusion takes place quietly, without frothing or bubbling; and as the whole substance employed requires but little space, very small pots may be employed, or a very large quantity assayed. But this process can only be employed for pure galenas, or those which contain at most a few per cent. of gangue.

When galena is heated with iron, the metal is transformed into protosulphuret, from whence it follows, that to desulphurise galena 22·6 per cent. is required; but experience has shown that it is better to employ a little more, and 30 per cent. can be used without inconvenience. The iron employed ought to be in the state of filings, or wire cut very small. The mixture is placed in a crucible, which is three-fourths filled; the whole is covered with a layer of salt, carbonate of soda, or black flux, and exposed to a full red heat. After the flux is perfectly fused, the pot may be cooled and broken, and a button is obtained, which at first sight has a homogeneous aspect, but on being struck with the hammer separates into two distinct parts. The lower part is ductile lead; the upper a very brittle matt, of a deep bronze colour, and slightly magnetic. Pure galena yields, by this process, 72 to 79 per cent. of lead, so that there is a considerable loss, which loss is entirely due to volatilisation. Berthier says that it does not appear possible to avoid this loss, which amounts from 6 to 13 per cent., giving as a reason that it is probable galena begins to sublime before it arrives at the proper heat for decomposition.

Antimonial galenas, or galenas mixed with iron pyrites, may be assayed in the same manner; but then a sufficiency of iron must be added to reduce the antimony to the metallic state, as well as to reduce the iron pyrites to the minimum of sulphuration. If the galena be mixed with blende, the greater portion remains in the slag, because it is only decomposed by iron at a very high temperature. Blende being infusible by itself, much diminishes the fusibility of the matts produced; and if it exists in very large quantity, it can even hinder their full fusion; in which case, some protosulphuret of iron and metallic iron must be added to the assay, to make the slag more fusible.

All minerals are at a minimum of sulphuration, when existing in matts from metallurgical works; so, much less iron may be used in their assay than if they were pure ores. In very rich lead matts, in which the lead exists as subsulphuret, from 10 to 12 per cent. is sufficient. A small excess of iron may be employed without inconvenience; but if a larger proportion be added than is necessary to execute the desulphuration, the matt contains a large quantity in the metallic state, and loses its liquidity, and in consequence retains some globules of lead.

The usual mode of assaying lead ores (galena) in the lead mills is by a modification of this process: in lieu of placing the ore in an earthen crucible, and adding nails or filings, a given weight of the ore is projected into a red-hot wrought-iron crucible, which is kept in the fire for about a quarter of an hour, or until all the galena seems decomposed. The lead thus reduced is poured into a mould; and if the scoriaceous matter be not well fused, the iron crucible is returned to the fire and heated still more strongly, and any lead that may be separated is poured into the mould and weighed with the rest. This is a very rude and imperfect process, and gives only tolerable results with pure galenas, but is perfectly unsatisfactory with those containing much earthy matter, as not above half the lead is obtained, owing to volatilization and exposure to the air, and the loss of globules in the slag. This process succeeds much better when a flux is added: this may be argol, or carbonate of soda, or a mixture of both (see next process).

4th Process. Fusion with carbonate of soda, or black flux, and metallic iron.—When galena is heated with an alkaline flux, out of contact of air, the slag contains a double sulphuret of lead and the alkaline metal employed: if iron be thrown into this fused mixture, metallic lead separates, and the iron combines with the sulphur formerly combined with the lead, and the slag will contain a double alkaline sulphuret, containing sulphuret of iron instead of sulphuret of lead, thus:—

$$PbS + KS + Fe = Pb + FeS + KS$$

Any earthy substances the ore may contain will be dissolved by the alkaline flux, without very much impairing its fluidity. All these facts being considered, it may be readily seen that the assay of all earthy bodies containing sulphuret of lead may be made in this manner, with as much accuracy as this method of assay can be capable of. Either carbonate of soda or black flux may be employed as the alkaline re-agent, and more of either of those substances must be employed, in proportion to the increased quantity of earthy matters the ore contains. Two parts are nearly always more than sufficient for poor ores, and is best for all cases, because an excess of flux does not diminish the yield of lead; nevertheless, it is sometimes convenient to employ, for the latter class, but half a part. As to the iron, it is employed only to separate that part of the lead which has been dissolved in the state of sulphuret by the alkali, but not decomposed; so that much less may be employed than is necessary for the decomposition of the whole amount.

Experiment has shown that the maximum amount of lead from pure galena may be obtained by the use of the following mixtures:—

2 parts of black flux, or carbonate of soda, and 10 to 12 per cent. of iron.

1 part of black flux, or carbonate of soda, and 20 per cent. of iron.

½ a part of black flux, or carbonate of soda, and from 25 to 30 per cent. of iron.

When black flux is employed, and the iron is in the state of filings, it would be inconvenient to employ too much of the latter, especially if the assay were heated very strongly, because the button of lead might be contaminated with iron; but when carbonate of soda is used with small iron nails instead of filings, the excess of iron is not inconvenient, but rather useful, because the desulphuration is certain to be complete.

The following changes take place in both cases. That portion of iron filings mixed with the carbonate of soda which has not been sulphuretted, is reduced to the state of oxide by the carbonic acid of the alkaline carbonate, and remains combined or suspended in the slag; so that the proportion of iron is never too great, and never becomes mixed with the lead. When black flux is employed, the same oxidation does not take place, on account of the presence of carbonaceous matter, so that the portion of filings not combined with sulphur, and which is merely held in suspension in the flux, passes through it with the globules of lead to the bottom of the crucible; but if, instead of filings, small nails are employed, they only suffer corrosion at their surface, without change of form or softening, and after the assay are found fixed in the surface of the button of lead, so that they can be detached very readily, and without loss of lead.* This, however, I have found no easy task, and have always sustained a notable loss.

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* Berthier.

5th Process. Fusion with black flux, or carbonate of soda, and oxide of iron or zinc. — Oxide of iron and oxide of zinc being readily reducible by charcoal, it might be surmised that a mixture of either of these oxides and black flux would be equivalent in effect to metallic iron or zinc, and carbonate of potash, and consequently would answer the same purpose.

When we fuse together—

100 parts of pure galena,
100 to 200 parts of carbonate of soda,
3 parts of iron scales, in powder,
½ part of charcoal,

76 parts of lead were obtained, and a very fluid slag, which retained no metallic globules.

Oxide of zinc produces the same desulphuration; but too much must not be employed, because, if much zinc be volatilized, much lead will be lost. It is also necessary to add 2 parts of black flux, as the sulphuret of zinc formed is not very fusible.

100 parts of pure galena,
200 parts of black flux,
3 parts of oxide of zinc,

gave, in one experiment, 78 of lead and a very fusible flux.

Oxide of iron and oxide of zinc may be employed with carbonate of soda alone, without the mixture of charcoal. It appears that the presence of an alkali determines an action which would not otherwise take place, between the oxides and galena.

Pure galena affords, with 1 part of carbonate of soda and from 1 to 3 per cent. of iron scales, 73 to 74 of lead. With 1 part of carbonate of soda and 10 per cent. of oxide of zinc, 77 of lead are obtained.

The same result is obtained by means of peroxide of manganese.

6th Process. Fusion with black flux and protosulphuret of iron, or sulphuret of zinc.—Sulphuret of iron and zinc are partially decomposed by the alkaline carbonates, so that a portion of iron or zinc is set free, which forms a compound of an alkaline sulphuret and sulphuret of iron or zinc, as the case may be. That portion of metal set free is oxidized by the carbonic acid of the alkaline carbonate when there is no charcoal, but remains in the metallic state when a reducing agent is present; but in either case it reacts on the sulphuret of lead, and sets lead in the metallic state at liberty. If there be an excess of metallic iron, oxide of iron, or oxide of zinc, they will remain suspended in the flux, as they are in a state of extreme division, and do not mix with the lead; if there be an excess of metallic zinc, it volatilizes. The following is the result of an experiment conducted on this principle:—

100 parts of pure galena,
100 parts of black flux,
5 parts of artificial protosulphuret of iron,

gave very readily 77 to 78 parts of lead. The fusion took place without bubbling or boiling, and the slag was compact, slightly crystalline, and of a metallic black appearance.

The same proportion of lead was obtained by the substitution of blende for protosulphuret of iron; but when only 1 part of black flux is employed, the slag is pasty, and may contain globules of lead. The proportion of flux must be doubled to avoid this.

These experiments show that it is altogether superfluous to employ iron in the assay of matts from metallurgical works which contain much sulphuret of iron or sulphuret of zinc; because by fusion with 1 or 2 parts of black flux, nearly all the lead they contain may be extracted. Iron must, however, be employed, if perfect accuracy be requisite, as I shall hereafter show. Berthier further says:—"It shows also, that in order to assay a galena containing much blende, that it need only be fused with 2 parts of black flux."

The same course of procedure does not succeed, however, with galena mixed with much iron pyrites, because the latter forms with alkalies a large quantity of an alkaline sulphuret, which not only holds in combination all the sulphuret of iron reduced to a minimum, but a considerable portion of sulphuret of lead also; so that but very little metallic lead is obtained; for instance,

100 parts of galena,
100 parts of black flux,
5 parts of natural pyrites,

produced but 38 of lead. When pyrites is present, it is necessary to employ metallic iron in the assay; the proportion of which ought to vary with that of the pyrites, and ought to be at least sufficient to reduce the latter to the state of protosulphuret.

7th Process. Fusion with a mixture of carbonate of soda and nitre.—When nitre is made to act upon galena, all its sulphur is transformed into sulphuric acid before the lead is oxidised; and, in consequence, if a suitable proportion be employed, it may be used in the desulphuration of plumbiferous matters. In order to avoid the losses which might be occasioned by deflagration, the ore must be mixed with twice its weight of carbonate of soda; and to extract from the galena the largest possible proportion of lead, from thirty to forty per cent. of nitre must be employed.

This mode of assay is not useful for the estimation of the true quantity of lead, because it gives variable results; and were these results constant it would not be available, because in each assay the quantity of nitre employed would have to be guessed.

But it is, on the contrary, an excellent process, and one much to be recommended for the assay of the sulphurets of lead, when only the silver they may contain is to be estimated. The fusion takes place easily, speedily, and without bubbling. The slag is very fluid, and retains no globules. The proportion of nitre ought to be so managed, that the greatest possible proportion of lead be obtained; but it is especially essential that sufficient be added to destroy all the sulphuret in the slag, which otherwise would retain a notable proportion of silver. There is no inconvenience, however, in the estimation of the silver, by placing an excess of nitre with the mixture: less lead would be obtained, but it would be more pure, and always contain all the silver present in the galena.

Such is an outline of the processes which may be employed in the assay of ordinary lead ores containing that metal in a state of sulphuret.

Pure galena, as seen by the analysis at page 285, contains 86·67 parts of lead, and by the mode of assay to be described at least 85 can be obtained.

The assay is thus conducted:—To 200 grains of the galena so pulverised that it will pass through the sieve of forty holes to the linear inch, add 50 grains of argol, and 200 grains of carbonate of soda, mix the whole well together and place the mixture in a crucible the interior of which has been smeared with black-lead (that employed for household purposes answers admirably), then at each angle of the crucible introduce a common tenpenny-nail head downwards, tap the crucible on the mixing-bench so that the contents shall occupy as little space as may be, cover with about 200 grains of salt, and over that 200 grains of ordinary borax in crystal: two crucibles should be thus prepared. When ready place them in the furnace with the precautions already described, raise the heat rapidly to nearly a bright red, then remove the cover of the furnace and allow the crucibles to remain for about eight or ten minutes; again cover the furnace and raise to a bright red, and the crucibles will be ready for removal. Beside the time occupied the term of the assay can be judged by the flux flowing smoothly. When this occurs, seize one of the crucibles with the large tongs, and with a smaller and light pair take hold of one of the nails, well wash and rinse it in the molten flux to remove any small globules of lead that may be adhering to it, and when clean reject it. The two other nails are now to be treated in the same manner, and the crucible tapped on the furnace top to collect all globules, and set aside to cool. The nails are removed with the like precautions from the other crucible. When both are cold, they are broken, the buttons hammered from the flux as in the assay of ores of the first class, and weighed; they should correspond within $\frac{1}{8}$ of a grain.

If the ore be mixed with much gangue or stony matter, 50 grains of lime may be advantageously added to the flux.

It may be here mentioned that, if blende in any quantity co-exists in the assay with the galena, no argol must be added, as a loss of lead will thereby ensue.

Several objections have been urged against this process, but unnecessarily,—for if the directions given be accurately followed, the result will be as stated; cases of failure are alone traceable to imperfect manipulation.

Argentiferous galenas are treated by the mode of assay just given; as also are the seleniurets of lead or their admixtures with galena.

The Assay of Galenas containing Antimony.—Sulphuret of lead is often combined with sulphuret of antimony, and the mixture behaves in the manner presently to be described. Either pure lead, or lead containing the largest possible quantity of antimony, can be extracted at will.

In order to extract pure lead the ore must be fused with three or four parts of carbonate of soda; then all the antimony remains in the slag partly as sulphuret and partly as oxide; and it is owing to the presence of antimony that the slag will retain no lead. If black flux be substituted for carbonate of soda, the lead obtained contains much antimony, because then that metal cannot remain as oxide in the slag. But in order to separate from the substance assayed the greatest possible proportion of antimony with the lead, it is necessary to have recourse to the aid of metallic iron. It may be employed either alone or mixed with black flux; in either case the proportion must be exactly determined by repeated guessing. If not enough be added, antimony remains in the slag; if too much, an antimoniuret of iron is formed, which separates tolerably well in matt, but is partly absorbed by the slag.

The following experiments were made by Berthier on a substance having the following compositions:—

Lead	49·8
Antimony	31·0
Sulphur	19·2
	100·0

100 parts of the above compound, which is a double sulphuret of antimony and lead, and

400 of carbonate of soda, gave 48 of pure lead.

100 of the double sulphuret, and

200 of black flux, gave 57 of a semi-ductile lead, which contained at least 7 per cent. of antimony.

100 of the double sulphuret, and

200 of black flux, and

1 metallic iron, gave 60 of a very brittle lead.

100 of the double sulphuret,

33 of metallic iron, gave an alloy of lead and antimony weighing 75. The desulphuration was complete in this experiment. The loss is due to volatilization. The whole of the lead and antimony may, however, be obtained by fusion with equal weights of cyanide of potassium and carbonate of soda.

Both the lead and antimony can be extracted from an antimonial sulphuret, by roasting and then fusing with two parts of black flux; but this operation is unfortunately tedious, owing to the length of the roasting.

Lastly, by fusing an antimonial sulphuret with carbonate of soda and a suitable proportion of nitre, all the lead can be separated in a state of purity; in this case the antimony is converted into antimonic acid, and the sulphur into sulphuric acid; both of which are found in the slag. When the substance assayed contains silver, that substance alloys wholly with the lead, and none remains in the slag; but when the latter contains sulphuret of antimony, a considerable proportion is retained. On this account this process is preferable to all others.

Humid Assay of Ores of the Second Class.

Pulverise the ore very finely, weigh off 100 grains, place them in a flask and add about 1 ounce of the strongest nitric acid, heat on a sand bath, and evaporate to dryness; when the mass is cold, boil it with a concentrated solution of carbonate of soda, filter, and thorougly well wash the white mass in the filter; dissolve it in dilute acetic acid. If necessary, filter the solution, then add excess of dilute sulphuric acid, or solution of sulphate of soda, as in the precipitation of sulphate of lead under the head "Humid Assay of Ores of First Class;" and the precipitate so obtained must be treated as there directed. The *rationale* of the process is as follows:—Strong nitric acid attacks sulphuret of lead, oxidising both the lead and the sulphur, forming sulphate of lead, thus,—

$$PbS + 2(NO_5) = PbO,SO_3 + 2NO_3.$$

The sulphate of lead so formed is separated from the excess of nitric acid by evaporation to dryness. The sulphate of lead so obtained is, however, always mixed with a little nitrate of lead (the decomposition not being practically so perfect as expressed) and the earthy matter, &c., that the sample contained. It is now necessary to separate these, the object being to obtain all the lead in solution, and the impurities in the insoluble form. To this end the sulphate of lead is converted into carbonate by boiling with solution of carbonate of soda, thus,—

$$PbO,SO_3 + NaO,CO_2 = PbO,CO_2 + NaO,SO_3.$$

The carbonate of lead thus obtained is (after thorough washing to remove sulphate of soda and excess of carbonate of soda) dissolved in acetic acid with the formation of acetate of lead and evolution of carbonic acid.

This reaction is the same as that given at p. 283, substituting acetic for nitric acid, and the subsequent precipitation of sulphate is given at p. 286.

Class 3rd.—The following substances belong to this class:—

Sulphate of lead (native).
,, ,, (artificial).
Sulphato-carbonate of lead.
Roasted galena and matts.
Lead fume containing sulphur.
,, ,, ,, arsenic.
,, slags ,, sulphur.
,, ,, ,, arsenic.
Chloro-arseniate of lead.
Chloro-phosphate of lead.

Sulphate of Lead, native (PbO,SO_3).—This mineral is rather rare, and in outward appearance may be readily confounded with the carbonate. Its lustre, however, is rather brighter, and it has not that peculiar greasy appearance which characterises carbonate of lead. It often occurs in small octahedral crystals surcharged with facets, but more generally in laminar masses.

The following is an analysis of a specimen from Zillerféld:—

Protoxide of lead	72·46
Sulphuric acid	26·09
Water	·12
Oxide of iron	·08
Oxide of manganese, and traces of alumina	·06
Silica	·50
	99·30

Sulphate of Lead, artificial.—This is a waste product of calico-printers, and is formed in considerable quantity, as already described, in calcining galena.

Sulphato-carbonate of Lead ($3PbO,CO_2+PbO,SO_3$).—This is also a rare mineral; it occurs in greenish, yellowish, and brownish crystals—the rhombohedron predominates.

Composition:—

Sulphate of lead	27·5
Carbonate of lead	72·5
	100·0

Roasted Galena, Lead Fumes and Slags.—These substances have varying compositions, but are generally made up of sulphurets, sulphates, and arseniates of lead.

Chloro-arseniate of Lead and Chloro-phosphate of Lead are so rare that they will not be specially described. The mode of assay to be hereafter described is suitable for such compounds.

Assay of Substances of the Third Class.

In the assay of bodies belonging to this class, a reducing agent must be employed; but if that be alone used, the sulphates and arseniates produce sulphurets and arseniurets, and not pure lead. The action of another re-agent is therefore necessary, in order to deprive the lead of sulphur and arsenic with which it is combined.

There are two reagents known for the sulphates,—they are the alkaline carbonates or metallic iron; but for the arseniates and arsenites iron must be employed, because the alkaline carbonates have no action on the arseniurets.

In all cases black flux is employed: this furnishes a reducing agent for the oxides, and a flux for the earthy matters. Iron is added when the arsenites or arseniates are assayed; but that metal may either be employed or not, when the sulphates are operated upon. (It is always better to use it.)

When a mixture of black flux and iron is employed, the assay is made in exactly the same manner as that of the sulphurets (large nails, as recommended in my method of assay, are preferable whenever the use of iron is indicated in a lead assay). With the sulphate, the sulphuret of iron formed combines in the slag with the alkaline sulphuret; but it is not so with the arseniates and arsenites. The arseniuret produced mixes neither with the lead nor the slag, but gives rise to the formation of a brittle matter which adheres slightly to the button of lead.

When only black flux is employed, either of the two following processes may be adopted:—First, the ore can be fused with four parts of common black flux; then, as in the case of sulphuret, the excess of carbon determines the formation of a large quantity of an alkaline sulphuret; and consequently produces a desulphuration of the lead. Secondly, it may be fused with such a proportion of black flux, containing only the requisite proportion of carbon to reduce the oxide of lead, or with an equivalent mixture of carbonate of soda and charcoal. Pure sulphate of lead fused with one part of carbonate of soda and four per cent. of charcoal gives 66 of lead; but in order to employ this method the richness of the ore must be known, and the dry way is then useless, excepting for the estimation of the silver these substances always contain.

Humid Assay of Substances of the Third Class.—These are treated in precisely the same manner as those of the preceding class.

Determination of Lead by means of Standard Solutions.—This process is due to M. Flores Dumonté, and may be thus described:—This mode of analysis is analogous to that proposed by Pelouze for the determination of copper, and advantage is taken of the fact that oxide of lead is soluble in caustic potash in the same manner that oxide of copper is soluble in ammonia; and from either solution the respective metal is precipitated by means of a standard solution of sulphuret of sodinm.

The solution of sulphuret of sodium may be conveniently made by dissolving one ounce of sulphuret of sodium in one quart of water, and determining how much of it is necessary to precipitate twenty grains of lead. To this end weigh off twenty grains of lead, dissolve them in nitric acid, dilute with water, add excess of caustic potash until the oxide of lead first thrown down is completely dissolved. The solution must now be heated to ebullition, and the sulphuret of sodium gradually added from the burette: at each addition a black precipitate of sulphuret of lead falls. The liquid is then boiled for a short time, by which means it brightens; more sulphuret of sodium is then added, and the whole again boiled, and these operations alternately continued until no further coloration or blackening is produced by the last drop of sulphuret. The number of divisions used is then read off, and the calculation made as at page 274 for copper.

Having thus standardised the solution of sulphuret of sodium, the assay of a sample of ore may be thus made:—If the ore belong to the first class, dissolve in dilute nitric acid and evaporate to dryness; to the dry mass add excess of caustic potash solution, and boil; after about a quarter of an hour's ebullition, filter, and throw down the lead as directed with the standard solution: from the amount used calculate the quantity of lead present; if the ore be of the second or third class, treat with strong nitric acid and carbonate of soda as already directed. The carbonate of lead so produced may be dissolved in either nitric or acetic acid, and to the solution thus obtained add caustic potash, &c.

CHAPTER II.

THE ASSAY OF TIN.

THIS metal is always found by the assayer in the state of oxide.

Oxide of Tin (SnO_2).—The appearance of this mineral gives no indication, excepting to an experienced eye, that metallic matter enters largely into its composition; yet its great density would lead one to suppose such to be the case. Its colour varies from limpid yellowish white to brownish black and opaque, passing from one to the other by all intermediate shades. It usually possesses a peculiar kind of lustre which cannot be readily described, but once seen can scarcely be mistaken. It occurs crystallised in square prisms, terminated by more or less complicated pyramids. These crystals, derived from the octahedron, are often macled or hemitropic (see p. 47-8), so that they often possess re-entrant angles, which is to a certain extent characteristic. The principal varieties are the following:—

1stly. *Crystallised Oxide of Tin* is found in more or less voluminous crystals of the colour and form as above.

2ndly. *Disseminated Oxide of Tin.*—This variety occurs in grains of various sizes, sometimes so small as not to be visible to the naked eye. It is found in the primitive rocks.

3rdly. *Sandy Oxide of Tin* forms pulverulent masses often of great extent; in appearance it is merely a brown sand.

4thly. *Concretionary Oxide of Tin, Wood Tin.*—This variety occurs in small mamellated masses, the fibrous texture of which resembles that of wood: hence the name.

The following is an analysis of a sample of oxide of tin from Cornwall:—

Tin	77·50
Oxygen	21·50
Iron	·25
Silica	·75
	100·00

Assay of Pure Oxide of Tin.—Pure oxide of tin may be very readily assayed in the following manner:—Weigh off 400 grains, place in either a black-lead or charcoal-lined crucible, cement on a cover by means of Stourbridge clay, and subject to the fire. The heat should for the first quarter of an hour be a dull red, after which it may be raised to a full bright red for ten minutes, and the crucible removed with care so as not to agitate or disturb the contents: tapping in this case must not be resorted to. When the crucible is cold, remove the cover, and a button of pure tin will result: this weighed and divided by four gives the per centage. If the operation has not been carefully conducted, it sometimes happens the tin is not in one button, but disseminated in globules either on the charcoal lining or on the sides of the black-lead pot; in this case the charcoal on the one hand, or the black-lead crucible on the other, must be pulverised in the mortar and passed through a sieve; the flattened particles of tin will be retained by the sieve, and can be collected and weighed. If any small particles escape the sieve they may be separated from the lining or crucible by vanning as described at page 64 *et seq.*

If a charcoal or black-lead crucible be not at hand, an ordinary clay pot may be used, but not so successfully, excepting under certain circumstances to be hereafter described. Indeed, in Cornwall the ordinary mode of conducting this assay is in a naked crucible, thus: About 2 ounces of the ore are mixed with a small quantity of culm, and projected into a red-hot crucible. If the ore seems to fuse or work sluggishly, a little fluor spar is added, and after about a quarter of an hour's fusing at a good high temperature the reduced and fused tin is poured into a small ingot mould, and the slag examined for metal by pounding and vanning. This method never gives the whole of the metal. To effect this, without fear of mischance in the assay sometimes occurring, as already described with both black-lead and charcoal lined crucibles, it may be thus conducted; always supposing the oxide to be pure, or nearly so, or at least containing little or no siliceous matter.

To 400 grains of ore add 100 grains of argol, 300 grains of carbonate of soda, and 50 grains of lime; mix well together, place in a crucible, which the mixture half fills, cover with a small quantity of carbonate of soda and 200 grains of borax. Place the whole in the furnace with the necessary precautions, raise the heat very gently, and keep it at or below a dull red heat for at least twenty minutes; then gradually increase until the whole flows freely. Remove the crucible, tap it as for copper assay, and allow to cool. When cold, break it, and a button of pure metallic tin will be found at the bottom, and a flux perfectly free from globules, and containing no tin.

There is yet another process, which is more easy of execution; but the reagent employed is more expensive, not so readily obtainable, and more difficult to keep without decomposing than any of the substances above employed. The reagent now to be discussed has been introduced to the notice of the student, in another part of this volume, as a blowpipe flux, and in the assay of copper ores by standard solutions as "cyanide of potassium." This is the most effective reducing flux for tin ores yet known. It acts by absorbing oxygen to form a compound known as cyanate of potash: thus—

$$SnO_2 + KCy = Sn + KO,CyO.$$

The assay, by means of this substance, may be made in ten minutes: thus—

To 400 grains of ore add 200 grains of cyanide of potassium and 200 grains of carbonate of soda. Well mix, place in a crucible, submit to the furnace; raise the heat as rapidly as is consistent with the safety of the crucible, and when the whole contents have been in a state of fusion for about five minutes, the assay is complete. The crucible may be removed, the proper precautions taken to ensure the subsidence of any globules of tin which may either be floating in the flux or adhering to the sides of the crucible, and the whole allowed to cool. When cold, the crucible is to be broken as usual.

Assay of Oxide of Tin admixed with Silica.—Although oxide of tin is completely reducible by charcoal or other carbonaceous matter, yet it has such an affinity for silica, that whenever that substance is present, the metal cannot be wholly reduced, excepting at the highest temperature of a wind furnace. The following experiments will shew the influence of silica on the return of tin in an assay of oxide of that metal with black flux:—

Ore	100	100	100	100	100
Quartz	25	66	100	150	300

The first gave 52 per cent. of tin; the second, 43 per cent.; the third, 28 per cent.; the fourth, 10 per cent.; and the last nothing.

The slags also produced in the treatment of tin ores in the large way give no return with black flux. This mode of assay, however, has been recommended by some, but, from the foregone experiments, is proved to be perfectly fallacious; that is, unless the quantity of silica present be very small in comparison to the amount of oxide of tin; and even when the latter is present in four times the quantity of the silica, as in experiment No. 1, a loss of 20 per cent. of tin is sustained.

Assay of Tin Ores containing Silica and Tin Slags.—It having just been shown how injuriously the presence of silica influences the produce of tin, both in ores and slags, other methods of assay than those just described must be adopted for such substances. These will be now detailed.

Tin ores containing silica may be treated by two methods: in the first the silica must be carefully separated by vanning; if the ore be well pulverised this is the best and most expeditious method. In conducting this assay take 400 or more grains of the pulverised ore according to its richness (if poor, as much as 2000 grains may be taken), van in carefully, dry the enriched product, which will, if the operation has been properly conducted, be nearly pure oxide of tin, and assay it as already described for ores containing no silica. The other process of assay may be thus conducted, and is dependent upon the fact that iron displaces tin in its combination with silica: thus, if a compound of oxide of tin and silica be heated to whiteness with metallic iron, a portion of the iron oxidises and replaces the oxide of tin, which was previously in combination with the silica as a silicate of tin, and metallic tin and silicate of iron result, the tin so reduced combining with any metallic iron that may be in excess, and the button thus obtained is an alloy of tin and iron, whilst the slag is entirely deprived of tin.

In this kind of assay mix 400 grains of the silicated oxide of tin with 200 grains of oxide of iron (either pulverised hæmatite or forge-scales will answer this purpose), 100 grains of pounded fluor spar, and 100 grains of charcoal powder; place the mixture in a crucible, and cover with a lid, gradually heat to dull redness, and keep at that temperature for half an hour, then heat to whiteness for another half hour, and remove the crucible from the furnace, allow to cool, and break. The button so obtained is to be treated in the humid way, as hereafter described.

The assay of tin slags is conducted in the same manner, or simply by mixing the pulverised slag with 20 per cent. of iron filings, and fusing.

Assay of Tin Ores containing Arsenic, Sulphur, and Tungsten (*Wolfram*).—In the assay of such ores it is necessary to remove arsenic, sulphur, and tungsten, before attempting to obtain the tin in a pure state by dry assay. Ores of tin which contain either one or all of these substances are most common: hence this mode of treatment will be generally required.

Most assayers usually submit the ore to the same mode of treatment undergoes on the large scale by calcination, or rather roasting, by which the greater part of the arsenical and pyritic matter is removed: this process fails, however, to remove the whole of these substances, and does not at all affect the tungsten. The following process, adopted by the author, is therefore preferable, and is founded on the fact that arsenical and other pyrites, as well as tungstate of iron (wolfram usually accompanying tin ores), are completely decomposed by nitro-hydrochloric acid (*aqua regia*) at the boiling temperature, the oxide of tin alone not being affected:—Take 400 grains or more of the impure tin sample, place them in a flask, and add 1½ ounce of hydrochloric acid, and ½ an ounce of nitric acid, heat gently for about half an hour, and then boil until the greater part of the mixed acids have evaporated; the sulphur and arsenic will by this time be converted into sulphuric and arsenic acid, and the wolfram completely decomposed, its iron and manganese having become soluble, and its tungstic acid remaining in the insoluble state with the oxide of tin and any silica that may be present. Allow the flask and contents to cool, add water, allow to settle, and decant, and so on until the water passes off tasteless. The insoluble matter in the flask is now oxide of tin, silica, and tungstic acid: to remove the latter digest for an hour at a very gentle heat with one ounce of solution of caustic ammonia, with occasional agitation; add water, and van the remainder to separate silica: nothing remains now but oxide of tin with perhaps a little silica: this is now to be dried and assayed as directed for ores containing little or no silica.

If only an approximative assay be needed, it may be accomplished after this treatment by taking the specific quantity of the remaining oxide, so that all ores of tin may be thus roughly assayed, it being premised that the above operation has been so carefully performed that nothing but oxide of tin and silica remain. The specific gravity of the thus purified ore is to be taken in the bottle as described at pp. 203 and 204. All now that is necessary to be known is the specific gravity of oxide of tin, its per-centage of pure tin, and the specific gravity of silica, and a simple calculation gives the result. The following is the formula:—

Let a represent the specific gravity of oxide of tin.
,, b ,, ,, ,, silica.
,, c ,, ,, ,, the mixture left after treatment with acid, &c.
,, w ,, weight of rough oxide of tin or mixture left after treatment with acid, &c.
,, x ,, ,, oxide of tin.
,, y ,, ,, silica.

$$\text{Then } x = \frac{a\,(c - b)}{c\,(a - b)}\,w;$$

$$\text{And } y = \frac{b\,(a - c)}{c\,(a - b)}\,w.$$

Or in arithmetical form, thus,—

1. From the specific gravity of the rough oxide of tin (mixture of oxide of tin and silica) deduct the specific gravity of the silica.

2. Multiply the remainder by the specific gravity of the oxide of tin.

3. Multiply the weight of the rough oxide of tin by the last product, which will make a second product which may be called P.

4. From the specific gravity of oxide of tin deduct the specific gravity of silica.

5. Multiply the difference by the specific gravity of the rough oxide of tin.

6. Take this product for a divisor to divide the above product P: the quotient will be the weight of pure oxide of tin in the rough oxide, and the quantity of metal can now be readily calculated.

The following is an assay worked out in this manner:—

400 grains of the ore are treated with nitro-hydrochloric acid and ammonia as above described, washed and dried. Suppose the dried matter weighed 250 grains. The 250 grains thus obtained are placed in the specific gravity bottle, and the specific gravity is found to be 5·4.

Specific gravity of tin oxide (approximate) . .	6·9
„ silica „ . .	2·6

Sp. Gr. Rough Oxide.		Sp. Gr. Silica.		
5·4	—	2·6	=	2·8

		Sp. Gr. Pure Oxide.		
2.8	×	6·9	=	19·32

Weight of Rough Oxide.				P
250	×	19·32	=	4830

Sp. Gr. Pure Oxide.		Sp. Gr. Silica.		
6·9	—	2·6	=	4 3

		Sp. Gr. Rough Oxide.		
4·3	×	5.4	=	23·22

$$\frac{4830}{23\cdot22} = 208\cdot4$$

208·4 grains is therefore the weight of pure oxide in the 400 grains of ore.

Now oxide of tin contains 78·61 parts of pure tin, and a

$$\frac{208\cdot4 \times 78\cdot61}{100} = 163\cdot72$$

So that 400 grains of rough tin ore contain 163·72 grains of pure tin, and

$$\frac{163{\cdot}72}{4} = 40{\cdot}93$$

The rough sample first operated on contains, therefore, 40·93 per cent. of metallic tin.

Estimation of Tin by the Humid Method.—There are several methods of effecting this analysis, the chief difficulty being found in the intractable nature of the oxide of tin, it resisting the action of all acids. This, however, may be overcome as first shewn by Klaproth, who found that very finely levigated oxide of tin was soluble in hydrochloric acid after a prolonged fusion with caustic potash: the following is his process:—

50 grains of the tin ore, reduced to the most minute state of division by levigation or otherwise, is mixed with four times its weight of caustic potash. The best mode of mixing is to place the caustic potash in a silver crucible, add its own weight of water, and apply a gentle heat until the potash is dissolved; then stir in tin ore, and gradually evaporate to dryness, stirring all the time to prevent loss by spitting as in the analysis of iron stone: when thoroughly dry, enclose the silver crucible in one of clay, and submit the whole to a dull red heat for at least half an hour: rather more than less renders the perfect solution of the oxide of tin more certain. When cold, act on the contents of the crucible with dilute hydrochloric acid, transfer the liquid and any undissolved matter to a flask, add some strong hydrochloric acid, and boil for half an hour. If at the end of this time any of the tin ore remains unacted on, it must be separated by decantation or otherwise from the solution, dried, again fused with potash, and then treated with hydrochloric acid, in which it will now be found totally soluble. This second operation will not be needed if care has been taken to reduce the ore to the finest possible state of division at first. The solution, however, obtained is to be evaporated to dryness, and when cold treated with a small quantity of hydrochloric acid, allowed to stand for half an hour, then water added, boiled and filtered: the whole of the tin will pass through in solution as chloride of tin, and any silica or tungstic acid that may be present will remain in the filter. If the ore contained copper, lead, and iron, these metals will also be in

solution,—at all events, the lead partially so; but if the ore had, previously to its fusion with caustic potash, been treated with *aqua regia,* as already described, then it will contain tin alone. It is always better thus to separate foreign matters before attempting the solution of the tin, as the after process is thereby simplified. Supposing, however, that the rough ore had been submitted to fusion with potash and then dissolved, the solution must be thus treated:—A bar of zinc must be placed in the solution, which will in course of time precipitate tin, copper, and lead; when all the metals are thus thrown down the zinc is washed and removed, the precipitated metals well washed and dried. To the dried metals strong nitric acid is now to be added, the mass gently heated, and then evaporated to dryness: when cold, it is moistened with dilute nitric acid, water added, and the whole filtered. Lead and copper will pass through the filter as soluble nitrates, and the tin will be found in the filter as insoluble peroxide: this is to be well washed, dried, ignited, and weighed. It contains 78·61 parts of metallic tin. The amount of tin thus obtained, when multiplied by 2, will represent the per-centage of the ore.

If, before the action of caustic potash, the ore had been submitted to the action of *aqua regia*—sulphuretted hydrogen may be passed through the solution of chloride of tin—sulphuret of tin will be precipitated; this is to be washed, dried, gently calcined in a platinum crucible until all smell of sulphurous acid has ceased, allowed to cool, reheated with a fragment of carbonate of ammonia, as in the case of roasting sulphuret of copper, and when cold weighed as pure oxide of tin. The calculation for metal is made as above.

Humid Analysis of the Alloy of Tin and Iron as obtained in the Treatment of Siliceous Ores and Slags.—The alloy obtained as already directed is dissolved in boiling hydrochloric acid diluted with water, and the solution, if necessary, filtered. To the filtered solution add a little hydrochloric acid and pass an excess of sulphuretted hydrogen through it, collect the precipitated sulphuret of tin, and proceed according to the directions already given.

Estimation of Tin by means of a Standard Solution.—This process is due to M. Gaultier de Claubry, and may be thus performed:—The standard solution is made by dissolving 100 grains of iodine in 1 quart of proof spirit (spirit of wine having a specific gravity of ·920), and is thus standardised. Ten grains of pure tin are dissolved in excess of hydrochloric acid, the solution boiled, and allowed to cool: the burette is now filled with the solution of iodine, which is gradually added to that of the tin until the former ceases to be decolorised: as soon, therefore, as the tin solution assumes a faint yellow tinge, sufficient iodine has been added: the quantity thus found sufficient is then noted, and the amount of tin each divisionful of iodine solution is equivalent to, is calculated as for iron, copper, and the other standard solutions.

In the actual assay of tin ore by means of this solution it is necessary the whole of the tin present be reduced to the state of protochloride: this may be readily effected by boiling the solution of tin for a quarter of an hour with excess of metallic iron, and filtering. To the solution so obtained the iodine is added as above. The tin ore is dissolved by any of the methods already described.

CHAPTER XII.

THE ASSAY OF ANTIMONY.

ANTIMONIAL substances susceptible of being assayed by the dry way are divisible into two classes.

Class 1.—In this class are comprised native antimony and all antimonial substances containing oxygen or chlorine, and but little or no sulphur.

Class 2.—To this class belong the sulphuret of antimony and all antimonial ores containing much sulphur.

Class 1.—The minerals and substances belonging to this class are the following:—

Native Antimony.
Oxide of Antimony.
Antimonious Acid.
Antimonic Acid.

Native Antimony (Sb).—This is a silver-white metallic substance, cleavable into the octahedral form. It occurs in small lamellar masses usually accompanying veins of auriferous matters. It occasionally contains a notable quantity of silver, and is a rare mineral substance, as indeed are all the substances belonging to this class.

Oxide of Antimony (Sb_2O_3).—This is a white pearly substance, occurring sometimes in mass, sometimes in fine rhomboidal prisms, forming divergent groups. It usually accompanies deposits of arseniferous silver.

Antimonious Acid (Sb_2O_4).—This is a very brittle yellowish-white or grey earthy-looking substance. It is found accompanying sulphuret of antimony, of which it is most likely a product of decomposition.

Antimonic Acid (Sb_2O_5).—This is supposed to exist with the above mineral, but it is rather problematical.

Assay of Ores of the First Class.

All the oxides of antimony are very readily reduced by charcoal; so that their assay presents no difficulty. The assay is conducted in precisely the same manner as that of oxide of lead; only, as antimony is much more volatile than lead, the heat must be managed with care, and the assay taken from the fire as soon as finished. When all suitable precautions are taken, the loss of antimony is not very considerable; but Berthier says it is never less than from 5 to 6 per cent. This, I think, is too high. Thus the pure protoxide gives 77 per cent. of metal, and antimonious acid 75. The reduction is readily made, without addition, in a charcoal crucible; but when the substance to be assayed is mingled with impurities, some flux must be added. It succeeds equally well with 3 parts of black flux, with 1 part of tartar, with 1 part of carbonate of soda, and 15 per cent. of charcoal, or any other equivalent reducing flux.

When the substance under assay contains oxide of iron, the latter oxide is more or less reduced, and the metallic iron alloys with the antimony.

Oxidised matters which contain but a small quantity of sulphur can also be assayed in this manner; because the sulphuret gives up to black flux the small quantity of antimony which it contains, so that but little remains in the slag. The common glass of antimony produces by this method of assay 70 per cent. of antimony, and occasionally even more than that.

Class 2.—The minerals of this class are the following:

Sulphuret of Antimony.
Oxysulphuret of Antimony.
Haidingerite.

Antimonial Galena (see Lead).
Grey Copper (see Copper).
Antimonial Nickel (see Nickel).
Antimonial Silver, Red Silver, Grey Silver (see Silver).

Sulphuret of Antimony (Sb_2S_3).—This is the most common ore of this metal, and the one from which nearly all the metallic antimony of commerce is obtained. This mineral is remarkable for its fibrous texture, for its peculiar bluish-white colour, and by the brilliant lustre of its fracture, which generally presents the appearance of a vast number of needles soldered, so to speak, together, sometimes side by side, sometimes divergent, each one being free at its fractured extremity. Each of these needles has the form of a square prism terminated by four-faced pyramids. This mineral is very brittle; its powder has a bluish-black tinge, and stains the hands very strongly. Sulphuret of antimony often contains a little gold.

Composition :—

Antimony	72·78
Sulphur	27·22
	100·00

Oxysulphuret of Antimony ($Sb_2O_3 + 2Sb_2S_3$) is very rare, and appears to result from the decomposition of the sulphuret. It is very brittle, and of a bright shining red colour.

Composition :—

Antimony	74·45
Oxygen	4·27
Sulphur	20·47
	99·19

Haidingerite ($2Sb_2S_3 + 3FeS$) has a metallic lustre, iron-grey colour, and crystallizes in rhomboidal prisms. It is often found in confused lamellar masses. It is a compound of sulphuret of antimony with protosulphuret of iron.

Composition :—

Antimony	52·0
Iron	16·0
Zinc (accidental)	·3
Sulphur	30·3
	98·6

For the remaining antimonial ores, see Lead, Copper, Nickel, and Silver.

Assay of Ores of the Second Class.

The assay of the members of this class may be made in two ways: first, by roasting and fusing the oxidised matter with black flux; secondly, by fusing the crude ore with iron, or iron scales, with or without the addition of black flux.

The roasting of sulphuret of antimony requires much care, for it is very fusible and volatile, as is also the oxide its decomposition gives rise to. The heat ought to be very low during the operation, and the substance continually stirred. When no more sulphurous acid is given off, we may feel assured that it is perfectly roasted, because no sulphate is ever formed in this operation.

The roasted sulphuret is then fused with three parts of black flux, or its equivalent.

Metallic iron very readily separates all the sulphur from sulphuret of antimony; but as sulphuret of iron has a specific gravity very like that of antimony, the separation is very difficult to manage: a strong fire must be employed when the desulphurisation is complete, to keep the whole body in full fusion, for a considerable time. With these precautions two buttons are obtained, which separate very well: the one white, and in large plates, which is antimony; and the other is a bronze yellow, a little brighter than the ordinary sulphuret of iron, because it is mixed with a little metallic antimony. During the operation a very considerable portion of antimony is always volatilized, which, by this process, is an inconvenience impossible to avoid.

It is, nevertheless, practised in the large way in some factories; but a good result is not generally obtained. It, however, appears that when all the necessary precautions are taken, it can be employed with profit.

The first precaution which is indispensable is, mixing with the sulphuret only the precise proportion of iron necessary to effect its decomposition, which quantity amounts to about 42 per cent. of its weight. If more be placed, the antimony, having a great tendency to play the part of an electro-negative element will combine with the surplus, and an antimoniuret of iron result, part of which will remain in the antimony and part in the slag.

Further, the iron ought to be in the finest possible state of division. If the masses be large, a portion of sulphuret of antimony is volatilized before they can be fully attacked. In general 63 per cent. of antimony can be extracted from sulphuret by the aid of iron in the small way, but on the large scale it seems that 55 per cent. is the maximum.

Cast iron cannot be employed instead of wrought, because sulphur has very little action in it. The desulphurisation is imperfect, and the slag adheres to the reduced metal.

One of the greatest inconveniences in separating sulphur from antimony by means of iron is the strong heat necessary to separate the slag from the metal. This might be remedied by making the slag more fusible and less heavy, by the addition of some flux,—as an alkaline carbonate or sulphate.

If sulphuret of antimony be fused with an alkaline carbonate and charcoal, regulus is obtained, and a slag composed of an alkaline sulphuret and sulphuret of antimony. If metallic iron be thrown into this slag whilst in fusion all the antimony separates immediately, and a new slag is formed as fluid as the former, containing sulphuret of iron and sulphuret of the alkaline base employed. If, instead of the above process, the iron be mixed intimately with the sulphuret of antimony and carbonated alkali, the result is the same—100 parts of sulphuret, 42 of metallic iron, 50 of carbonate of soda mixed with one-tenth of its weight of charcoal, or 50 of black flux: give 65 to 66 of regulus with the same proportion of iron, and only 10 of flux, but 62 per cent. can be obtained. In these two cases the fusion takes place very rapidly and without bubbling, and the slag, which is very liquid, separates readily from the metal. By employing 1 part of alkaline flux the proportion of iron can be reduced from 25 to 30 per cent., and the product of metal is always from 65 to 66 per cent.

Hence, in making an assay of sulphuret of antimony, it is always better to employ a smaller quantity of iron than is necessary to complete the desulphurisation, and make up for it by increasing the quantity of flux: then it may be insured that no excess of iron will be present.

The alkaline sulphates are transposed into alkaline sulphurets by the agency of charcoal at a slightly elevated temperature. The sulphurets of the alkaline metals, by combining with the other metallic sulphurets, augment their fusibility very considerably. Thus when sulphate of soda, mixed with about one-fifth of its weight of charcoal, is added to a mixture of sulphuret of antimony and metallic iron, the metallic antimony separates very rapidly, and the slag almost instantly becomes perfectly fluid.

But it must be noted that the presence of an alkaline sulphuret diminishes the product of regulus, unless the proportion of iron be augmented at the same time.

For instance, with

100 parts of sulphuret of antimony,
42 parts of iron,
100 parts of sulphate of soda,
20 parts of charcoal,

but 22 parts of regulus were furnished; but with

100 parts of sulphuret of antimony,
42 parts of iron,
10 parts of sulphate of soda,
2 parts of charcoal,

62 parts of antimony were easily obtained.

Instead of metallic iron, pure oxide of iron may be used, or any ferruginous matter whatever, provided it is rich; but it is necessary to add, at the same time, an alkaline flux and charcoal to reduce the oxide of iron.

Not less than 40 parts of iron scales can be employed for 100 of sulphuret of antimony, and then, on the addition of 50 to 100 parts of carbonate of soda and 8 to 10 of charcoal, about 56 of regulus are obtained; but if with 100 parts of carbonate of soda from 14 to 15 parts of charcoal be employed, 65 parts of antimony are the result. By augmenting the proportion of scales, that of soda may be diminished. Thus, if from 56 to 60 parts of scales, 10 of soda, and 10 of charcoal be employed, 50 parts of regulus are the result; and if the proportion of soda be 50, and that of carbon 10, from 65 to 66, and even 67, parts of regulus are obtainable.

The fusion always takes place quickly, and the slags are very fluid.

When sulphuret of antimony is fused with forge slag (silicate of protoxide of iron), carbonate of soda, and charcoal, a very white crystalline regulus, in large plates, is obtained; a bronze yellow matter, and a black, opaque, vitreous slag, shining like jet, in which the greatest portion of the alkali employed appeared to be concentrated. These three substances separate very readily from each other.

100 parts of sulphuret of antimony,
80 parts of forge slag,
50 parts of carbonate of soda,
10 parts of charcoal,

produced very readily 60 parts of regulus.

The best method of assaying sulphuret of antimony seems to be one lately introduced, in which it is mixed with four parts of cyanide of potassium, and heated very gently in a crucible. The heat required in this case is so low, and the operation is made so quickly, that none, if any, of the antimony is lost: so that this process is decidedly preferable in the way of an assay. In particular methods, however, the wet method must be had recourse to.

The sulphuret of antimony is analysed by boiling with *aqua regia*. The residue consists of sulphur and gangue. It is to be washed and dried, then weighed and ignited. The loss gives the quantity of sulphur, and the remainder is pure gangue.

Water is then added to the filtered solution, which will cause the precipitation of some of its contained antimony as oxichloride: this must be separated by filtration. The solution is then to be saturated with carbonate of potash, and a new precipitate will be formed. The solution is to be filtered, and made slightly acid; then nitrate of baryta must be added to it to separate its sulphur as sulphate of baryta, which is to be washed, dried, and weighed: its weight indicates the amount of sulphur: 116 parts are equal to 16 parts of sulphur.

The precipitate by water of oxichloride which remains on the filter is redissolved by hydrochloric acid, and its antimony separated in the metallic state by means of zinc. The precipitate formed by carbonate of potash can contain lead, copper, iron, and antimony. It must be treated by nitric acid, which dissolves everything but the antimony, which may then be estimated as antimonic acid.

It is always best, before conducting the analysis of sulphuret of antimony, to affuse it with very dilute hydrochloric acid, in order to dissolve a portion of the carbonate of lime, which may form part of the gangue. As the composition of the sulphuret of antimony is constant, the following process is sufficient in the assay of an antimonial ore:—

Boil the ore, after treatment with dilute hydrochloric acid, with concentrated hydrochloric acid, which dissolves only sulphuret of antimony, and precipitate the metal as oxichloride by means of water.

Or, after all gangues soluble in dilute hydrochloric acid have been removed, the residue may be weighed, and then acted on by boiling hydrochloric acid, until all action ceases. The residue must be well washed with weak hydrochloric acid, dried, ignited, and weighed; the loss of weight corresponds to the per-centage of pure sulphuret of antimony, which contains 72·7 per cent. of metal.

CHAPTER XIII.

THE ASSAY OF ZINC.

All bodies containing zinc which are usually found in the assay office may be divided into four classes:—

Class 1.—Zinc ores in which the metal exists as oxide not combined with silica.

Class 2.—Zinc ores in which the metal exists as in the former class as oxide, but partly or wholly combined with silica.

Class 3.—Zinc ores in which the metal is partly or wholly combined with sulphur.

Class 4.—Alloys.

Class 1.—The substances belonging to this class are the following:—

Earthy Oxide of Zinc.
Manganiferous Oxide of Zinc, Brucite.
Aluminate of Zinc, Gahnite.
Franklinite.
Anhydrous Carbonate of Zinc.
Hydrated Carbonate of Zinc.

Earthy Oxide of Zinc (ZnO) is very rare, and appears to be a product of decomposition of the sulphuret.

Manganiferous Oxide of Zinc, Brucite ($ZnO + (MnO)^n$).—This ore is a mixture of oxide of zinc with a variable quantity of oxide of manganese. It occurs in foliated masses and disseminated grains, and cleaves like mica. Its lustre is brilliant, and colour deep or bright red. It occurs in New Jersey in great abundance, and is an excellent ore of zinc. Composition of a sample from the above locality:—

Oxide of zinc	93·5
,, manganese	5·5
Peroxide of iron	·4
	99·4

Aluminate of Zinc, Gahnite ($ZnO,6Al_2O_3$).—This mineral occurs in regular octahedra; it is nearly opaque, and of a dark bluish-green colour by transmitted light.

Composition :—

Oxide of zinc	24·25
Alumina	60·03
Oxide of iron	9·25
Silica	4·25
	98·25

Franklinite occurs in octahedral and dodecahedral crystals, also in coarse granular masses; its colour is iron-black, and it is exceedingly brittle.

Composition :—

Oxide of zinc	17·
Peroxide of iron	66·
Sesquioxide of manganese	16·
	99·

Anhydrous Carbonate of Zinc, Calamine (ZnO,CO_2).—This is the most common ore of zinc. It is found crystallized in forms derived from the rhomboid. The colour is white, yellowish-grey, or brown. It occurs semi-transparent and opaque: its lustre is vitreous, and its fracture even, or imperfectly conchoidal.

Composition of three varieties :—

	1.	2.	3.
Carbonate of zinc	93	95·0	90·5
„ iron	7	1·5	4·0
„ manganese	—	3·0	—
Gangue	—	—	5·0
	100	99·5	99·5

Hydrated Carbonate of Zinc ($ZnO,3HO+3ZnO,CO_2$).—This species is rare. It occurs in white opaque scales, having a dull and earthy fracture.

Composition :—

Oxide of zinc	72·85
Carbonic acid	14·94
Water	12·21
	100·00

Assay of Ores of the First Class.

In order to reduce the oxide of zinc contained in substances of this class, it is sufficient to mix them with charcoal, and expose them to a white heat.

At the moment of reduction the zinc is in a vaporised state. Its vapours, however, are readily condensible, so that the operation may be conducted in an ordinary retort, and all the metal is deposited in the neck without the slightest loss. It seems from this that nothing is so easy, at first sight, as the assay of an oxide of zinc; but it is not so. It is very easy to reduce all the oxide, but it is not so easy to collect all the zinc; nor is it easy to condense it all in the metallic state, and in consequence to determine the precise proportion in the ore submitted to assay.

This difficulty consists, firstly, in the deposit being extended over a large surface, and it often adheres very strongly to the sides of the retort, so that it is nearly impossible to detach it; and secondly, as the neck of the retort is open, the air having access to it, brings to the state of oxide all the vapour nearest the end of the neck. The proportion of zinc oxidised is larger in proportion to the smallness of the quantity submitted to assay, and is always very considerable where no more than 200 to 400 grains are operated upon.

It is not, therefore, in the extraction of the zinc from its oxide that the assay is rendered partially uncertain, but in its collection.

The distillation of zinc requires a very high temperature, and cannot be performed in retorts of glass; those of earthenware must be employed. It is not necessary to lute these retorts when they are of good quality; and they are better thin, because they heat more rapidly, and are not so likely to crack.

After the mixture of oxide and charcoal has been introduced into the retort, it is placed in the fire. The neck ought to have adapted to it a long tube of glass, with a narrow bore, so as to collect all the zinc which may escape from the wide part of the neck of the retort. This disposition is also convenient, as it does not allow such a free access of air.

It is heated gradually until it is white inside; the zinc is reduced and volatilized, and condensed in the neck: the greater the heat, the nearer the orifice. The metal can be detached readily from the neck, if it be well black-leaded inside. It is necessary, from time to time, to observe the state of the neck, because when very narrow it is often obstructed, and, if not cleaned out with an iron rod, might cause an explosion.

When the operation is finished the apparatus is allowed to cool, the retort taken out, placed carefully on its side, and broken, in order that if any particles of zinc have condensed in its dome, they may be removed.

If the approximate proportion of metallic zinc alone be the end, all is collected and fused at a very gentle heat in a crucible with some black flux; but if the true quantity of zinc is to be estimated it must be done in a more exact manner. The deposit must be collected with all possible care; the neck must then be broken to pieces, and every piece having adhering to it either zinc or oxide must be placed on one side, and digested in hot nitric acid, which takes up those substances. If any be in the glass tube, it must be carefully cleaned by means of acid, and the solution added to that produced by the digestion of the broken neck, and the deposit mechanically collected, in nitric acid. The solution is then evaporated gradually to dryness, and heated to redness. The nitrate, by these means, is decomposed, and transformed into oxide, four-fifths of the weight of which is equal to the quantity of metallic zinc produced in the assay.

The foregone is the method of estimation by distillation; the following is the method of estimation by difference. Two plans of assay in this manner may be adopted: firstly, at an ordinary assay temperature; secondly, at a very high temperature, as that of an iron assay. In all cases it is necessary to commence with the expulsion of all volatile bodies the ore may contain. If water or carbonic acid alone be present, simple calcination will do; but if carbonaceous matter, roasting must be had recourse to.

When the assay is made at an ordinary assay temperature, the sample is finely pulverised, and mixed with from 15 to 20 per cent. of equally finely pulverised charcoal, and pressed into a crucible, on which is placed a cover, but not luted, and rapidly heated to whiteness. When no more zinc vapour is disengaged it is cooled, and the mixture in the pot collected. The residue ought to be pulverulent; but as it is mixed with some charcoal, it is roasted, and then weighed. It is evident that the loss represents the oxide of zinc: the charcoal added, it is true, leaves a small quantity of ash, but it is too small to be accounted for.

In making the assay in the manner described it is to be feared that a small quantity of the oxide remains undecomposed, and that a part of the residue might adhere to the crucible, and could not be detached; and lastly, there is always a degree of uncertainty in the state of oxidation the iron the substance may contain will exist in it after roasting. No inconvenience of this nature presents itself when the assay is made at a very high temperature. This mode is the most exact of all, and leaves nothing to be desired.

The assays of zinc at a high temperature are made exactly as those of iron. They are made in a charcoal crucible, with the addition of fixed fluxes, suitable to effect the fusion of the gangues mixed with the oxide of zinc, if they be not fusible by themselves. The button is weighed; it is a compound of slag and grains of iron, which are collected and their weight ascertained, and, by the difference, that of the slag. The weight of oxygen which the iron has lost during its reduction is then added to it, and by deducting from the substance the weight of the button and the oxygen so obtained, we have the proportion of oxide of zinc reduced in the assay. On the other hand, by deducting from the weight of the slag the weight of flux added, the weight of earthy substances and irreducible oxides which were mixed with the oxide of zinc is ascertained.

These results can be shown in a tabular form, in the following manner:—

Let *m* be the weight of the crude ore, *n* the weight of the calcined ore, *r* the weight of the flux added, *f* the weight of the cast iron, *s* the weight of the slag, *o* the weight of oxygen combined with the iron, calculated from the weight of metal produced, *z* the weight of the oxide of zinc, then:

m crude ore = calcined ore . . . . n
r fixed fluxes . . . . . . r

$$\overline{\quad n+r \quad}$$

$$\left.\begin{array}{ll}\text{Gives metal . . .} & f\\ \text{Gives slag . . . .} & s\end{array}\right\}\ \left.\begin{array}{ll}\text{Total} & f+s\\ \text{Oxygen} & o\end{array}\right\}\ f+s+o$$

Oxide of zinc $n+r-f-s-o$

Flux added . . . r

Earthy matter . $s-r$.

The following is an actual experiment by Berthier:—

100 crude ore = calcined ore					83·3
10 kaolin (china clay) acted on by acids					10·0
7 marble = lime					4·0
					97·3
Gave metal	45·3	Total	61·3	Total	80·7
Gave slag	16·3	Oxygen	19·4		
				Oxide of zinc	16·6
		Fluxes added	14·0		
		Earthy matters	2·0		

The above result was confirmed by humid analysis, showing at once the exactitude of the process.

Determination of amount of Zinc by the Humid Process in Ores of the First Class.—Dissolve 50 grains of the finely pulverised ore in nitric acid, evaporate to dryness, allow to cool. Digest the cold mass with a little dilute nitric acid, gently warming during the digestion, add water, and then filter. To the filtered solution add excess of caustic ammonia, gently warm, and filter. The excess of caustic ammonia dissolves the oxide of zinc which it at first threw down, as well as any oxide of manganese that may be present. This solution containing the zinc, and probably manganese, must be separated from the precipitate produced by the ammonia by filtration, the insoluble matter in the filter washed with water containing a little ammonia, and the washings so obtained added to the first strong filtrate. If no manganese be present, sulphuret of ammonium may be now added to the filtered liquid until it produces no further white precipitate of oxide of zinc. The liquid and precipitate must now be allowed to stand in a warm place for about an hour, then filtered, and the sulphuret of zinc on the filter washed with water containing a little sulphuret of ammonium. After a few washings, it is to be dissolved in dilute hydrochleric acid, and, if necessary, the solution filtered. To the filtered solution is added excess of carbonate of soda: carbonate of zinc is thrown down, which in its turn is collected on a filter, washed, dried, separated from the filter, ignited, and weighed. Four-fifths of its weight is metallic zinc. If by previous experiment by blowpipe, or otherwise, manganese were found to be present, the ammoniacal solution containing the mixed oxides must be thus treated:—Excess of acetic acid is to be added to it, and a stream of sulphuretted hydrogen gas passed through it until no further precipitation takes place; by this means the whole of the zinc is deposited as sulphuret, whilst the manganese remains untouched in the liquid. The sulphuret of zinc is to be collected on a filter and treated with hydrochloric acid, &c., as just described.

Class 2.—The following minerals belong to this class:—

- Anhydrous silicate of zinc.
- Hydrated silicate of zinc.

Anhydrous Silicate of Zinc.—This species is not very common. It crystallises in yellow hexagonal prisms, terminated by dihedral summits. It has a greenish or reddish-yellow colour.

Composition:—

Oxide of zinc	71·3
Silica	25·0
Oxide of manganese	2·7
,, iron	·7
	99·7

Hydrated Silicate of Zinc, Electric Calamine ($ZnO_2SiO_3 + ZnO,HO$).—This mineral is rather difficult to discriminate, as it usually possesses no constant external character; sometimes it is a pale yellowish-grey in colour, sometimes a deep brown, and passes through all the intermediate shades. It is electric by heat; the smallest fragment heated always attracts light substances.

This mineral seldom occurs perfectly pure; it usually contains variable quantities of carbonate of zinc. The two following analyses will give a general idea of the composition of this mineral. The first is that of a pure sample:—

	1.	2.
Oxide of zinc	66·4	66·3
Silica	26·2	24·9
Water	7·4	7·4
Oxide of lead and tin	—	·3
Carbonate of zinc	—	1·1
	100·0	100·0

Assay of Ores of the Second Class.

The silicates of zinc are not reducible by charcoal alone; but when in contact with substances which have the property of combining with silica, they are reduced completely, even at a moderate temperature. All the modes of assay just described for ores of the first class apply to those of the second, with the exception that the flux, instead of being merely reducing, must have a true fluxing property also: lime or magnesia are good fluxes.

Humid determination of Zinc in Ores of the Second Class.—Ores of this class are best decomposed by strong hydrochloric acid with a small admixture of nitric acid. When thoroughly decomposed and the solution evaporated to dryness, it is moistened with hydrochloric acid, and treated exactly as described for Ores of the First Class.

Class 3.—The below-mentioned substances are of this class:—

The sulphuret of zinc, blende, Black Jack.
Oxisulphuret of zinc.
Sulphate of zinc.
Seleniuret of zinc.

Sulphuret of Zinc, Blende, Black Jack (ZnS).—The colour of this mineral is very variable, but its brilliant and lamellar aspect renders it easily recognisable. Whenever broken, regular faces always appear, the surfaces of which are even and shining; but however lustrous the mineral itself is, the colour of the powder is always greyish and dull in appearance. Blende nearly always accompanies galena.

This sulphuret very often occurs crystallised; the crystals are the rhomboidal dodecahedron, more or less surcharged with additional facets.

The more striking colours it assumes are topaz and sulphur-yellow, resin-brown, reddish-brown, and brown passing to black.

There are the following varieties:—

1. *Crystallised Sulphuret of Zinc.*—This usually accompanies sulphuret of lead, iron pyrites, grey copper, and many other crystalline minerals.

2. *Lamellar Sulphuret of Zinc,* disseminated in earthy matters in small amorphous masses. The fracture, however, presents large plane shining faces.

3. *Concretionary Sulphuret of Zinc.*—The colour of this is brownish-black: it occurs in compact masses whose interior presents the aspect of having been formed by concentric layers, like some kinds of malachite.

Composition :—

Zinc	70.4
Iron	4·0
Sulphur	35·6
	100·0

Oxisulphuret of Zinc.—This compound seems to result from the decomposition of sulphuret of zinc. It is rare.

Sulphate of Zinc ($ZnO,SO_3,7HO$).—This salt, like the above mineral, results from the decomposition of the sulphuret.

Seleniuret of Zinc ($ZnSe$).—This is a very rare mineral.

Assay of Ores of the Third Class.

In order to assay the substances containing sulphur which belong to this class, they must be roasted, and then treated as the ores of the first and second class. Sulphuret of zinc may be roasted without difficulty; and when the operation is made with care, the roasted ore contains neither sulphur nor sulphuric acid. The only precaution necessary to observe is, that the heat must be carefully regulated at first, in order to avoid fusion which might take place, especially when a certain amount of sulphuret of iron is present. Towards the end the heat may be increased, to decompose any sulphate that may be formed. Both a reducing and fusing substance must be added in this case, as in the last, in order to determine the fusion of the ganguey matters.

Humid Determination of Zinc in Ores of the Third Class.—These ores are to be finely pulverised, treated with strong nitric acid, at first with a gentle heat; and lastly, boiled until the sulphur separates in bright yellow transparent globules, as described under the Humid Assay of Copper Ores of the Second Class. The solution so obtained is to be evaporated to dryness, moistened with hydrochloric acid, and treated as described for ores of the first class.

If ores of this class, or of either of the two former, contain copper, they must be thus treated :—

The ore is to be decomposed by an appropriate acid, evaporated to dryness, moistened with hydrochloric acid, water added, and the solution filtered. A current of sulphuretted hydrogen gas is now to be passed through the solution until, even after violent agitation, it smells strongly of it. It is now to be filtered, and the black precipitate on the filter contains all the copper as sulphuret of copper, that substance being insoluble in dilute acid, whilst in a solution acidulated with either of the strong mineral acids,—as nitric, hydrochloric, or sulphuric,—zinc is not at all acted on by sulphuretted hydrogen. The solution, now freed from copper, is placed in an evaporating basin and boiled for about a quarter of an hour; nitric acid is then added to peroxidise all the iron present, and the solution allowed to cool. When cold, the zinc is separated by means of ammonia, and the ammoniacal solution treated as already described.

Fourth Class. Alloys.

The alloys of zinc with iron, copper, and tin, may be assayed by heating them to whiteness for about an hour in a charcoal crucible with an earthy flux (silicate of lime is the best), and weighing the resulting button: the loss will be nearly equivalent to the quantity of zinc present.

The Humid Determination of Zinc in Substances of the Fourth Class.—These substances are treated precisely as described under the heads Humid Determination of Zinc in First, Second, and Third Classes.

Determination of Zinc by means of Standard Solutions.—This operation is carried on precisely in the same manner as described for lead. The solution of sulphuret of sodium is to be standardised by dissolving 10 grains of zinc in nitric acid, adding excess of caustic potash, so as to dissolve the oxide of zinc at first precipitated, boiling the solution, and adding the sulphuret of sodium from the burette until no further white precipitate is formed. The strength of the sulphuret of sodium solution is calculated as already described.

In case lead accompanies the zinc ore, this metal will be taken into solution by the caustic potash in company with the zinc. Its presence, however, is of very little hindrance to the assay, as it is totally and completely precipitated before the zinc; so that if the sulphuret of sodium solution be added as long as a black precipitate is produced the lead is thrown down, and then only is an account to be taken of the number of divisions of the burette required to throw down the white sulphuret of zinc. The calculation for quantity of zinc is made as for lead, copper, &c.

CHAPTER XVI.

THE ASSAY OF BISMUTH, CHROMIUM, MANGANESE, NICKEL, AND COBALT.

The following varieties of bismuth ores are met with, but are very rare :—

Oxide of Bismuth.
Sulphuret of Bismuth.
Persulphuret of Bismuth.
Cupriferous Sulphuret of Bismuth.
Plumbo-cupriferous Sulphuret of Bismuth.
Plumbo-argentiferous Sulphuret of Bismuth.

Lastly, we have Native Bismuth, which, although far from common, is the only mineral hitherto found to supply the wants of commerce with the pure metal; and the only products of it are bismuth slags and cupel bottoms, in which oxide of bismuth is present in lieu of oxide of lead; it sometimes happening that bismuth is employed instead of lead in cupellation (see Silver Assay).

Native Bismuth (Bi) possesses a tolerably bright metallic lustre; its colour yellowish-white, often iridescent. It fuses in the candle flame. It is generally found in small amorphous lamellar masses, yet it occasionally occurs in acute rhomboidal as well as cubical and octahedral crystals.

This substance does not seem to form veins by itself, but generally accompanies other minerals, particularly those of cobalt, nickel, arsenic, and lead.

Assay of Native Bismuth.—200 grains of the pulverised material are mixed with 100 grains of fused borax, 100 grains of argol, and 200 grains of carbonate of soda, placed in a crucible which the mixture about half fills, and exposed to the lowest possible temperature that will effect the perfect fusion of the flux. This must be specially attended to, as bismuth is so exceedingly volatile; in lieu of 100 grains of argol, it is more advantageous to employ 100 grains of cyanide of potassium as the reducing agent. When the crucible is cold, it is to be broken in the usual manner.

Assay of Bismuth Residues, Cupel Bottoms, &c.—These substances must be finely pulverised, and from 200 to 400 grains mixed with three times its weight of fused borax, their own weight of carbonate of soda, and from 100 to 200 grains of cyanide of potassium, and proceed with all the precautions above pointed out.

Determination of amount of Bismuth by the Humid Process.—Act on 50 grains of the finely powdered substance with strong nitric acid until all action ceases, evaporate to dryness, add from 50 to 100 drops of strong sulphuric acid, well mix with a glass rod, and evaporate to dryness; add water, with a few drops of sulphuric acid, and boil. Filter the solution, and to the filtered solution add excess of carbonate of ammonia. Collect the oxide of bismuth thus thrown down on a filter, wash, and dry; separate it carefully from the filter, ignite it, and weigh: every 100 parts correspond to 89·87 of bismuth.

Or the bismuth may be obtained at once in the metallic state from the solution prepared as above: by adding to it metallic copper in the form of a small sheet, and gently heating, the bismuth will separate in the metallic state, and can be washed, dried, and weighed, as directed for copper under the Assay of that metal.

THE ASSAY OF CHROMIUM.

The only ore of this metal which occurs in commerce is known as chrome iron, or chrome iron ore. It is found in amorphous masses of a brownish-black colour, approaching an iron grey. Its fracture is uneven, sometimes lamellar; and its powder is greyish.

The two following analyses will give a general idea of its composition:—

Oxide of chromium	36·0	43·7	Cr^2O^3
Peroxide of iron	37·0	34·7	Fe^2O^3
Alumina	21·5	20·3	Al^2O^3
Silica	5·0	2·0	$Si O^2$
	99·5	100·7	

Assay of Chrome Ore.

Chrome iron ore, like native oxide of tin, is very difficultly decomposable by ordinary re-agents. The best method of operating is thus:—Mix 50 grains of ore, reduced to the utmost state of division, with 100 grains of nitrate of potash and 200 grains of carbonate of soda; place the mixture in a platinum crucible, and expose to a red heat for half an hour; remove the crucible, and allow it to cool. Place it, when cold, in an evaporating basin, and add enough water to cover the crucible: gradually heat the basin and contents to ebullition. The fused mass in the crucible will gradually dissolve, and if the operation has been successful there will be no undecomposed chrome ore: if, however, there be, it must be collected, as in the case of the analysis of tin ore, dried again, ignited with nitrate of potash and carbonate of soda, and treated with water, as just described. The solution which is obtained is deep yellow, its colour being due to chromate of potash and soda, which have been formed at the expense of the oxygen of the nitric acid, which has converted the oxide of chromium into chromic acid: thus—

$$Cr_2O_3 + 3O = 2CrO_3;$$

and the chromic acid so produced combines with potash and soda to form the chromates, having the following formula:—

$$KO,CrO_3 + NaO,CrO_3.$$

The solution is to be filtered from the insoluble residue, consisting principally of peroxide of iron, and evaporated to dryness with small excess of nitric acid: the dry mass is treated with water, and the whole boiled, and, if necessary, filtered. It must now be treated with solution of proto-nitrate of mercury, which throws down chromate of mercury: the proto-nitrate must be added as long as a precipitate is produced. The chromate of mercury is collected on a filter, well washed, dried, and ignited. During the process of ignition the chromate of mercury is decomposed into mercury and oxide of chromium of a pure bright green colour. 100 parts of this oxide correspond to 70 parts of metallic chromium.

Determination of Chromium by means of Standard Solution.—This process is the converse of the determination of iron by means of solution of chromate of potash.

The chrome ore is treated with nitrate of potash and carbonate of soda, as above described; and the solution of chromate of potash so obtained has an excess of hydrochloric acid added to it.

It is stated, at p. 241, under the head of Iron Assay by Standard Solution, that 100 parts of metallic iron correspond to and are represented by 88·6 grains of bichromate of potash: now 88·6 grains of bichromate of potash contain 32·96 grains of chromium; therefore 100 grains of iron are equal to 32·96 of chromium. From these data a standard solution can be readily made: thus—Dissolve 50 grains of harpsichord wire in excess of hydrochloric acid; place the solution in the burette, and fill up to 100 on the instrument with water, and well mix: it is now evident that every division of the burette will equal or represent ·1648 grains of chromium. The assay is now thus proceeded with: Gradually add the standard solution of iron to the solution of chromate of potash (or rather, now, bichromate of potash), acidulated with hydrochloric acid, until a drop of the solution mixed with a drop of solution of ferrocyanide of potassium gives a pale blue colour: a slight excess of protoxide of iron is then present, showing that all the chromic acid has been reduced to the state of oxide of chromium. Now observe how many divisions of the iron solution have been required, and multiply them by ·1648: the resulting number will represent the amount of metallic chromium in the sample submitted to assay.

ASSAY OF ARSENIC.

The minerals containing arsenic are very varied, and will be found in the lists of minerals of other metals elsewhere described.

Assay for Arsenic.—50 grains of the finely pulverised mineral are deflagrated with 200 of nitrate of potash and 200 of carbonate of soda in a porcelain crucible. When the crucible is cold, it and its contents are to be treated with water, as in the case of chromium. The solution will contain arseniate and (if the ore had in its constitution sulphur, which is most likely) sulphate of potash. Nitrate of lead must be added to the solution (made neutral with nitric acid, if requisite): a mixture of arseniate and sulphate of lead is precipitated: this precipitate is well washed on a filter, and digested with dilute nitric acid: this agent dissolves out the arseniate of lead, and leaves the sulphate. Filter, and saturate the filtered solution with soda, which will throw down the arseniate: this must be collected on a filter, washed, dried, and weighed. Every 100 parts correspond to

22·2 of metallic arsenic, or 29 parts of arsenious acid (the common white arsenic of the shops).

This method is only approximative: the following is the better plan to follow:—

Digest the ore in strong nitric acid until nothing more is taken up (the action may be facilitated by the occasional addition of a crystal or two of chlorate of potash), and all action on the addition of fresh acid is at an end: dilute with water, and filter: to the filtered solution add nitrate of lead, and proceed as above.

ASSAY FOR SULPHUR.

Minerals containing sulphur have also been elsewhere described.

Mode of Assay.—Act upon 50 grains by repeated doses of aqua regia, or better still, strong nitric acid and chlorate of potash, until the ore is entirely decomposed; and if any sulphur remains unacted on, it is quite bright and of a fine amber colour, as described in the Humid Assay of Copper Ores of the Second and Third Classes. When all action has ceased, carefully filter, wash, dry, and weigh the residue; ignite it in a small porcelain dish, weigh again, and the loss of weight will be sulphur. Add to the filtered solution chloride of barium, until no further precipitation takes place; let the whole stand in a warm situation for an hour or so; collect the precipitate on a filter, wash, dry, and ignite it. Every 116 parts of this precipitate of sulphate of baryta correspond to 16 parts of sulphur. The quantity obtained in this manner, added to that obtained in the first part of the operation by the ignition of the insoluble residue, will give the amount of sulphur in the portion of ore operated on.

ASSAY OF MANGANESE.

Many minerals contain manganese, but the only commercially valuable ore is the *Peroxide* or *Pyrolusite* (MnO_2). It occurs sometimes massive, sometimes fibrous. It also crystallises in small rectangular prisms more or less modified. . Its colour is iron-black, but varies much, according to its purity.

Composition :—

Manganese	63·36
Oxygen	36·64
	100·00

Assay of Manganese Ores.—The assay of this metal is confined to the amount of peroxide any one of its ores may contain. There are several methods of effecting this, and the best of these will be described below.

The following method is described in Graham's "Elements of Chemistry," page 536 :—

The value of the oxides of manganese is exactly proportioned to the quantity of chlorine they produce when dissolved in hydrochloric acid, and the chlorine can be estimated by the quantity of protosulphate of iron it peroxidises. Of pure peroxide of manganese, 545·9 parts produce 442·6 parts of chlorine, which peroxidise 3456 parts of crystallised protosulphate of iron. Hence 50 grains of peroxide of manganese yield chlorine sufficient to peroxidise 317 grains of protosulphate of iron.

50 grains of the powdered oxide of manganese to be examined are weighed out, and also any known quantity, not less than 317 grains, of sulphate of iron. The oxide of manganese is thrown into a flask containing 1½ oz. of strong hydrochloric acid, diluted with ½ oz. of water, and a gentle heat applied. The sulphate of iron is gradually added in small quantities to the acid, so as to absorb the chlorine as it is evolved; and the addition of that salt continued till the liquid, after being heated, gives a blue precipitate with the red prussiate of potash, and has no smell of chlorine, which are indications that the protosulphate of iron is in excess. By weighing what remains of the sulphate of iron, the quantity added is ascertained,—say *m* grains. If the whole manganese were peroxide, it would require 317 grains of sulphate of iron, and that quantity would therefore indicate 100 per cent. of peroxide in the specimen; but if a portion of the manganese only is peroxide, it will consume a proportionally small quantity of the sulphate, which quantity will give the proportion of the peroxide, by the proportion as 317 : 100 : : m : per-centage required. The per-centage of peroxide of manganese is thus obtained by multiplying the number of grains of sulphate of iron peroxidised by 0·317. It also follows, that the per-centage of chlorine which the same

specimen of manganese would afford, is obtained by multiplying the number of grains of sulphate of iron peroxidised by 0·2588.

The quantity of oxygen which any peroxide of manganese loses by becoming protoxide, can be arrived at very exactly, and in a very convenient manner, by heating it, in a finely powdered state, with a solution of oxalic acid. The action commences even in the cold; a part of the oxalic acid is converted into carbonic acid, and an oxalate of the protoxide of manganese is formed. Oxalic acid contains 3 atoms of oxygen to 2 atoms of carbon, since carbonic acid contains 4 atoms of oxygen to 2 atoms of carbon: it may be seen that the oxygen which is estimated is equal to one-fourth of that contained in the carbonic acid. The carbonic acid is collected as carbonate of baryta, and the operation performed as follows:—

Place in a small flask 1 part of the pulverised mineral, 4 or 5 parts of oxalic acid, and 10 parts of water; adapt immediately to the matrass a recurved tube of small diameter, placing its open end into a vessel holding about half a pint of saturated baryta water, which must be frequently agitated in order to favour the combination of the evolved carbonic acid with the baryta in solution. When the disengagement of gas nearly ceases, the contents of the flask must be made to boil in order to expel all carbonic acid. It sometimes happens that all the peroxide of manganese assayed is not decomposed by the oxalic acid, which can be ascertained if it has not changed colour, in which case the operation must be repeated.

The following is a method contrived by Dr. Thompson, and is a modification of the one just described. When ordinary care is taken, it is nearly as accurate as assays made in a more expensive manner and with more troublesome apparatus.

Take 50 grains of the finely powdered mineral, and place it in a small flat-bottomed flask (capable of standing the heat of a sand-bath), together with about 1½ oz. of water, and a ¼ oz. of sulphuric acid. Then place loosely a plug of cotton-wool in the neck to absorb any moisture which the carbonic acid evolved in the course of the experiment might carry over. A tube containing dry chloride of calcium may be adapted to the neck of the flask by means of a perforated cork: this method will ensure greater accuracy. The flask (whether fitted up with the tube or cotton-wool) containing the water, oxide of manganese, and sulphuric acid, is now to be weighed, and 100 grains of oxalic acid placed in it: the tube or wool must be replaced, and the effervescence produced be allowed to proceed as long as it will without the aid of heat: when it ceases, a very gentle heat must be applied for a few minutes, and when cold the flask must be weighed: the loss of weight corresponds to the amount of peroxide present. Thus, supposing

The flask, water, peroxide of manganese, sulphuric acid, and tube or wool, weighed	2000 grs.
Oxalic acid added	100
	2100
And the weight after the operation to be	2060
Loss	40

The sample under assay would contain 40 grains of peroxide in the 50 grains of ore employed: hence the per-centage of pure peroxide would be 80.

In case more exact results are required, the following plan, by Fresenius and Will, may be advantageously employed. The apparatus for this experiment has been already described, as well as its mode of use, at pages 247-8. The only modifications for determining the value of manganese ore is to place 50 grains of the finely-pulverised ore and 150 grains of neutral oxalate of potash in the flask A, and proceed as already described for determining carbonic acid in carbonate of iron. Every grain of carbonic acid liberated indicates, as in the simple oxalic process, 1 grain of pure peroxide of manganese.

CHAPTER XVIII.

ASSAY OF COBALT AND NICKEL ORES.

Although cobalt and nickel usually accompany each other, yet it will be more convenient to give the ores of both separately, commencing with those of cobalt.

Ores of Cobalt.

Oxide of cobalt.
Sulphuret of cobalt.
Sulphate of cobalt.
The arseniurets of cobalt.
The arsenio-sulphuret, or grey cobalt.
Arseniate of cobalt.
Arsenite of cobalt.

Oxide of Cobalt (CoO, when pure).—This is generally found on the surface of some of the ores of cobalt, more particularly of the sulphurets and arseniurets, from whose decomposition it appears to result. There is found, however, a manganesiferous oxide of cobalt of the following composition:—

Oxide of cobalt	19·4
Oxide of copper	·2
Oxide of manganese	16·0
Silica	24·8
Alumina	20·4
Water	17·0
	97·8

Sulphuret of Cobalt; Koboldine (Co_2S_3 pure, but usually occurs mixed with sulphurets of copper and iron).—This mineral has a steel-grey colour, more or less bright, uneven fracture, and crystallises in the regular octahedron.

Composition of impure mineral:—

Cobalt	43·86
Iron	5·31
Copper	4·10
Sulphur	41·00
Gangue	·67
	94·94

A pure sulphuret of cobalt, having the following formula, CoS, has, however, been lately discovered in India.

Sulphate of Cobalt (CoO,SO_3).—This salt is occasionally found coating sulphuret of cobalt, evidently a product of decomposition. It is reddish in colour, and crystallises in oblique rhomboidal prisms.

Composition:—

Oxide of cobalt	28·7
Oxide of iron	·9
Sulphuric acid	30·2
Water	41·2
	101·0

Arseniurets of Cobalt.—The formula of this class of minerals is, like that of the varieties of grey copper, very uncertain: they are generally mixtures of arseniurets of cobalt, nickel, copper, and iron, in various proportions. The three following analyses will give an idea of their composition:—

Cobalt . . .	12·7	9·6	13·9
Nickel . . .	—	—	1·8
Copper . . .	—	—	1·4
Iron . . .	12·5	9·7	11·7
Arsenic . . .	50·0	68·5	70·3
Sulphur . . .	—	7·0	·7
Gangue . . .	25·0	5·2	—
	100·2	100·0	99·8

The ores of this class have generally a whitish-grey colour, sometimes very lustrous.

Arsenio-sulphuret of Cobalt ($CoAs_2 + CoS_2$).—This mineral, in its external appearance, much resembles that of the last-named varieties, but is generally much brighter. It crystallises in cubes and regular octahedrons.

Composition of two varieties:—

Cobalt . . .	39·0	32·6
Iron . . .	2·0	6·2
Arsenic . . .	34·7	60·0
Sulphur . . .	21·7	19·6
	97·4	98·4

The *Arseniate* and *Arsenite* are exceedingly rare.

Assay for Cobalt.—The analysis of cobalt ores is the most tedious, with the exception of those of platinum, of any that fall under the assayer's notice,—the greatest difficulty being in the separation of cobalt and nickel. The following process, however, is the most ready that has yet been devised:—Very carefully roast, in a porcelain capsule or crucible, 100 or more grains of the sample to be examined. (In case, however, any of the rich ores are under assay, 25 to 50 grains will suffice.) When no more vapours of arsenious acid are evolved, add a little finely-powdered charcoal, and again roast, and so on until no arsenical smell is perceptible. Allow the roasted mass to cool, and then gently heat it in a flask with hydrochloric acid until all but silica is dissolved; evaporate to dryness; allow to cool; moisten with hydrochloric acid; let stand for an hour; then add water, boil, and filter. To the cold filtered solution add a little hydrochloric acid, and pass into this acidulated solution sulphuretted hydrogen gas until in great excess; allow the solution so saturated with gas to remain at rest for two or three hours, then filter it, add a little nitric acid to the filtered solution, and boil so as to peroxidise all the iron present: this point must be carefully attended to, and may be recognised by the addition of a few drops of nitric acid to the hot solution, giving no dark tinge. Allow the solution to cool, and if not quite bright, filter it. To the filtered solution add excess of carbonate of baryta. Iron and alumina will be removed after a digestion of three or four hours. Again filter, and to the solution add sulphuret of ammonium in excess, gently warm and filter, wash the precipitate, dissolve it in hydrochloric acid; if not bright, filter, and to the filtered solution add cyanide of potassium in excess, and boil. To the boiling solution add a little carbonate of soda,—this will precipitate manganese, if present,—and filter. The solution now contains nothing but cobalt and nickel. These may be separated as follows:—Warm the solution, and add to it excess of pulverised peroxide of mercury: this decomposes the potassio-cyanide of nickel, and the whole of the nickel precipitates, the cobalt alone remaining in solution. Remove the nickel by filtration, and neutralise as nearly as possible the filtered solution containing the cobalt by the aid of nitric acid; then add neutral nitrate of mercury solution as long as a white precipitate forms: this precipitate is cyanide of mercury and cobalt. It is collected in a filter, well washed, dried, and then ignited, with free access of atmospheric air, which converts it into black peroxide of cobalt, which is weighed. The nickel precipitate collected in the filter is treated in the same manner: every 100 parts of oxide of nickel correspond to 78·7 parts of metallic nickel. It may be here mentioned, that cobalt is always estimated commercially as oxide, and nickel as metal.

Ores of Nickel.—The ores of nickel comprise the following varieties:—

Oxide of nickel.
Sulphuret of nickel.
Arseniuret of nickel; kupfernickel.
Arsenio-sulphuret of nickel; grey nickel.
Antimonio-sulphuret of nickel.
Arseniate of nickel.
Arsenite of nickel.
Silicate of nickel.

Oxide of Nickel (NiO).—This, like the oxide of cobalt, occurs only as a product of decomposition.

Sulphuret of Nickel (NiS).—This mineral is very rare.

Arseniuret of Nickel; Kupfernickel ($NiAs_2$) is the most commonly occurring ore of nickel. It occurs of a greyish metallic-red appearance, very brittle, amorphous, having a conchoidal fracture.

Composition.—The three following analyses give an idea of its general composition :—

Nickel	44·2	30·6	15·6
Cobalt	—	2·2	4·6
Iron	·6	8·6	16·6
Arsenic	54·8	51·0	46·0
Antimony	—	—	1·4
Sulphur	·4	4·2	8·6
Gangue	—	·4	5·8
	100·0	97·0	98·6

Arsenio-sulphuret of Nickel; Grey Nickel (NiS_2+NiAs).—This mineral has, when pure, a shining grey colour, but is not common. It more frequently occurs mixed with the last-named mineral.

The following are two analyses of this species :—

Nickel	35·5	29·9
Cobalt	—	·9
Iron	—	4·1
Arsenic	45·2	45·4
Sulphur	19·3	19·3
Gangue	—	·9
	100·0	100·5

Antimonio-sulphuret of Nickel (NiS_2+NiSb).—This has the same appearance as the last-mentioned mineral.

Composition of two specimens :—

Nickel	26·9	28·0
Antimony	58·5	54·5
Sulphur	14·6	15·5
	100·0	98·0

The *Arseniate, Arsenite,* and *Silicate of Nickel* are exceedingly rare.

Assay of Nickel Ores.—This class of assay has already been fully described under the head *Cobalt Assay.*

CHAPTER XVIII.

ASSAY OF MERCURY.

Mercury is found in the native or metallic state, and as sulphuret or cinnabar:—

Native Mercury.
Sulphuret of Mercury, Cinnabar.
Bituminous Sulphuret of Mercury.

There are other minerals of mercury met with, but hitherto not in sufficient quantity to be worked for the metal. They are:—

Zinciferous Subsulphuret of Mercury.
Zinciferous Sulphuret of Mercury.
Seleniuret of Mercury.
Subchloride of Mercury.
Iodide of Mercury.
Silver Amalgam (see Silver).

Metallic or Native Mercury (Hg) is found in small drops disseminated in the body of the metalliferous rock, or in pyrites or cinnabar. Its appearance is so characteristic that it cannot be mistaken.

Sulphuret of Mercury, Cinnabar (Hg_2S).—This ore is the substance from which nearly the whole of the mercury of commerce is extracted. Its colour is red, more or less deep; varying from the most lively and brightest tint to the dull red of coagulated blood. The principal varieties of this mineral are—

1st. *Crystallized Sulphuret of Mercury.*—Occurs in very small flattened crystals, derived from the hexahedral prism; colour dull ed, covered with a metallic-looking coating. These crystals, when pulverized, yield a scarlet red powder.

2d. *Lamellar Sulphuret of Mercury,* in small masses, composed of interlaced or divergent plates.

3d. *Granular Sulphuret of Mercury.*—Has the appearance of a sandstone, and is composed of grains of quartz, iron pyrites, and sulphuret of mercury.

4th. *Amorphous Sulphuret of Mercury,* in small masses, with a vitreous fracture. It is remarkable for its great specific gravity.

5th. *Fibrous Sulphuret of Mercury.*—Is silky and soft; it stains the fingers strongly, and passes into the following variety:—

6th. *Pulverulent Sulphuret of Mercury.*—This variety is also known as *native vermilion.*

7th. *Bituminous Sulphuret of Mercury.*—Its colour varies from dull red or reddish brown, to lead grey and even black. It is very brittle, and its interior texture is finely granular. This mineral is usually very rich.

Composition of the pure sulphuret:—

Mercury	86·29
Sulphur	13·71
	100·00

The other minerals of mercury mentioned at the commencement of this chapter are so rare, that it will answer no useful purpose to describe them.

Assay of Mercurial Ores.—The determination of mercury is always made by distillation. In case the mercury is present in the form of native mercury, or oxide of mercury, it is distilled without any addition. The ore (say from 500 to 1000 grains) is placed in an iron or earthenware retort, which is set over a suitable fire, and the heat raised gradually, and kept up, until the whole of the mercury has passed over. The mercury which passes over is collected either in the neck of the retort, or a receiver fitted for that purpose,—such as a glass flask kept cool by affusion with water. When but a small quantity is operated upon (say 150 to 200 grains), it is most convenient to use a glass retort, or bent tube retort, heating it gradually over a charcoal fire, taking care to keep the upper part so hot, that no metallic mercury may adhere to it. It must be heated nearly to the melting point of the glass, and until all the mercury has come over.

When the operation is finished, the neck is cut off, weighed, the mercury detached, and weighed again: the loss of weight is the amount of mercury. Or the metal may be detached by means of a feather, and allowed to fall into a basin of water, which, if heated for a few seconds, will cause the mercury to collect into one globule: the water may be decanted, and the mercury dried at the ordinary temperature, and weighed.

The mercury wholly condenses in the neck of the retort, under the form of a metallic dew. Some may by chance pass off; but in order to prevent such an occurrence, the beak of the retort is plunged into water, or a small dossil of linen, moistened with water, introduced into the neck, the end of which is plunged into water, by which means the neck of the retort is kept constantly cool, and the mercury is found deposited on the linen, from which it may be detached by shaking in water.

When large quantities of substances containing mercury are operated upon, it is necessary to heat very strongly towards the end, in order that the centre of the mass may receive a sufficient amount of heat to effect its decomposition. Naked glass retorts cannot be used; and either coated glass or porcelain retorts must be employed. In the large way, as in the distillation of amalgams, &c. cast iron retorts are used.

As before stated, all substances containing mercury, either in its metallic state or as oxide, are distilled without addition, but with the others it is necessary to employ some reagent, which will separate and retain the sulphur, selenium, &c.; which reagent may be a metal, as iron, copper, or tin; or black flux, or a mixture of quicklime and charcoal: iron filings are most often used. For cinnabar about 50 per cent. of iron filings is required, in order to prevent any of it being sublimed; the true quantity required is only about 24 per cent., but an excess is necessary, in order, as before stated, to prevent loss: 50 per cent of iron filings may be employed for the seleniurets, &c. When black flux is used, from about 50 to 70 per cent. is employed. Caustic lime may be employed in the proportion of 30 per cent. mixed with 30 per cent. its weight of charcoal. After the ore to be assayed is carefully mixed with any of the above fluxes, it is always advisable to cover it, when in the retort, with a thin layer of the flux employed, in order to avoid all chance of any loss.

Assay for the Amount of Cinnabar in an Ore.—The ore to be assayed is distilled, without addition, in a glass retort, and the sublimed cinnabar collected and weighed. The ores containing mercury combined with sulphur are often mixed with bituminous matters and carbonate of lime: then, when an assay is to be made for cinnabar, it often happens that a portion of it is decomposed, either by the carbon present, or by the aid of the bituminous matter and lime, and a little metallic mercury is driven off with the cinnabar. In this case, having weighed the mixture of cinnabar and mercury, the mixture is treated by nitric acid, which dissolves only the latter, and pure cinnabar remains, whose weight is taken, and the quantity of mercury dissolved ascertained by the difference; and from that the quantity of cinnabar calculated which that quantity of mercury would yield. Every 86 parts of mercury furnish about 100 of cinnabar.

If the gangue of the ore be fixed in the fire, the assay may be made by mere calcination, and the loss of weight will correspond either to the metallic mercury, oxide, or sulphuret it may contain.

CHAPTER XIX.

ASSAY OF PLATINUM.

Platinum is only found in the native or metallic state. As far as our present experience has gone it occurs very rarely; yet it is exceedingly probable that wherever gold is found this metal will more or less accompany it.

It is found disseminated in sand in the form of grains varying in size from gunpowder to hempseed: this last size they rarely exceed; yet, as in the case of gold, *pepites* or *nuggets* have been found of large size and weight. Its colour is steel grey, or rather a tinge between silver white and steel grey.

The sands from which platinum is derived are remarkable from the number and importance of their principal constituents. With the platinum may be found gold, silver, mercury, iron, copper, chromium, titanium, iridium, osmium, rhodium, and palladium. Besides all these metals, precious stones have also been found associated with it.

Analysis of Platinum Ores.—The following is the method proposed by Berzelius. The operator first separates mechanically the particles of ore which differ in appearance. All those which are attractable by the magnet are next removed. Independently of the spangles of metallic iron which were first detected by Osann, the platinum sands often contain metallic compounds of iron and platinum, not only capable of being attracted by the magnet, but possessed even of polarity. These grains have a different composition from those not magnetic, as shown in the two following analyses by Berzelius.

Analysis of the non-magnetic grains:—

Platinum		78·94
Iridium		4·97
Rhodium		·86
Palladium		·28
Iron		11·04
Copper		·70
Osmiuret of Iridium	in grains	1·00
	in scales	·96
		98·75

Analysis of the magnetic grains:—

Platinum	73·58
Iridium	2·35
Rhodium	1·15
Palladium	·30
Iron	12·98
Copper	5·20
Insoluble matters	2·30
	97·86

These grains being separated, their relative proportion is estimated.

The ore is to be treated with diluted hydrochoric acid. The object of this is to free it from the coating of peroxide of iron with which it is often covered, and to dissolve the metallic iron. The quantity of iron separated from the ore in this manner is to be estimated.

The ore must not be ignited until it has previously been weighed; for during the ignition it generally acquires a coating of peroxide of iron, and a consequent increase of weight. It is sufficient to dry it upon a hot sand-bath.

The operator must not employ too large a quantity of the ore for analysis. Berzelius thinks about 30 grains is the best quantity. Sometimes, however, when the object is to determine with great accuracy the quantity of a constituent which occcurs, but in a very small relative proportion, a larger quantity of the ore must be dissolved; but, in such a case, every other constituent is to be neglected.

Berzelius determines the solution of the weighed metal by *aqua regia,* in a glass retort furnished with a receiver, which is kept constantly cool. The acid distilled over during the solution is yellow, which colour does not proceed merely from the presence of chlorine, but from the constituents of the solution which are carried over mechanically.

The acid is distilled until the liquid has a syrupy consistence, and congeals on cooling. The saline mass so formed is dissolved in the smallest possible quantity of water, and the solution is poured off with all due precaution. The acid distilled over into the receiver is poured upon the undissolved portion of the ore in the retort, and again distilled. The second distillation generally effects the complete solution of the platiniferous matter.

If the distilled liquor be not colourless it must be returned into the retort and redistilled. The residue must be evaporated to a syrupy consistence as before, and treated with water. The distilled liquid generally contains a small portion of peroxide of osmium, of which a part is lost by the redistillation; its quantity, however, is in general very small.

The colourless distilled liquid is diluted with water, and saturated either with ammonia or with hydrate of lime. The acid, however, must remain a little in excess. The object of this saturation is to prevent the decomposition of the sulphuretted hydrogen gas, with which the solution is afterwards to be precipitated.

The precipitation is to be made in a flask which can be closely stopped, and of such a size as to be nearly filled with the solution. When the solution contains free hydrosulphuric acid, the flask is stopped, and left to itself until it is perfectly bright, which will be in about two days. The clear liquid is removed by a pipette, and the sulphuret of osmium collected in a weighed filter, in which it is washed, dried, and weighed. According to theory the resulting sulphuret of osmium should contain 60·6 per cent. of that metal; but it is not obtained free either from moisture or excess of sulphur: it is also slightly oxidised during the process of drying. According to some experiments made by Berzelius with weighed quantities of this substance, it appears that the sulphuret of osmium obtained by the operation just described contains from 50 to 52 per cent. of osmium. In general, however, the quantity of osmium is so small, that an error of a few hundredths in the reckoning of the quantity of osmium contained in this preparation is of no importance in regard to the analysis.

Respecting the metallic solution from the retort, it sometimes happens that after the saline mass has been dissolved in water, it smells slightly of chlorine.

This happens through the decomposition of a portion of the chloride of palladium. The solution must be allowed to digest until it no longer smells of chlorine. If the solution became troubled during the digestion, a portion of oxide of palladium is precipitated, which must be redissolved. The solution is filtered through a weighed filter, upon which is collected that portion which is undissolved. This portion consists of grains of osmiuret of iridium, of spangles, of the same alloy, and of grains of sand, which could not be separated mechanically before the analysis. Sometimes, in addition to these, a black powder is found, which has the appearance of charcoal, and capable of passing through the filter during the washing of the other grains. This is peroxide of iridium, and is due to the presence of too much nitric acid in the *aqua regia*. As this occasions much extra work in the analysis, an excess of hydrochloric acid must be employed in making the *aqua regia*.

The filtered solution is now mixed with twice its bulk of alcohol, specific gravity ·833; so that the mixture may contain about 60 per cent. of its volume of alcohol. A very concentrated solution of chloride of potassium is now added, as long as it determines any precipitate.

The precipitate consists of the double chlorides of potassium and platinum, and of potassium and iridium, contaminated with that of rhodium, and a little of that of palladium.

The precipitate has a fine lemon yellow colour when it is free from iridium; but when iridium is present it presents all shades, from deep yellow to cinnabar red.

It is placed upon a filter and washed with a mixture of alcohol (containing about 60 per cent. of anhydrous alcohol) and a small proportion of concentrated solution of chloride of potassium. The precipitate must be washed until the liquid passing through gives no precipitate with sulphuretted hydrogen.

The analysis is now divided into two distinct parts. The examination of the washed precipitate A, and treatment of the alcoholic liquid B.

A. The washed salt is dried, and carefully mixed with an equal weight of carbonate of soda. The filter, with that portion of the precipitate which it is impossible to separate from it, must be burnt, and the ashes mixed with a little carbonate of soda, and added to that mixed before. The whole is very gently heated in a porcelain crucible, until the mass is black through and through.

By acting thus the double salts are decomposed, and the platinum, whose oxygen passes away with the carbonic acid, is reduced. The rhodium and iridium meanwhile become oxidised, and remain in such a state as to permit of their separation from the platinum by solution.

When, instead of following the process just recommended, the precipitation of the double salts is effected by muriate of ammonia, the heating of the precipitate in a crucible not only reduces the platinum, but the rhodium and iridium also; so that on treating the heated mass with *aqua regia* all three are dissolved.

The heated saline mass is washed with water until the greater mass of the saline contents is dissolved; diluted hydrochloric acid is then added to the remainder to extract the alkali, combined with the oxides of iridium and rhodium. The mass is washed, dried, and ignited. The filter may be burnt, and an allowance made for the weight of the ashes; but it is to be noted that the filter must be burnt by itself, lest the metallic oxides be reduced. The mass is afterwards weighed.

When this is done the mass is mixed with five or six times its weight of bisulphate of potash, and fused in a platinum crucible. During the ignition the rhodium dissolves, and its solution is accompanied by an evolution of sulphurous acid gas. The platinum crucible must be kept closed during the ignition, by a cover which fits well, to check the too rapid volatilization of the acid. As soon as the saline mass becomes fixed and crystalline at the surface when the cover is removed, the crucible must be taken from the fire and cooled. The salt is then dissolved in boiling water, and the undissolved residue is treated again with bisulphate of potash. The melted salt is red and transparent when it contains but little rhodium, but appears dark and black when it is nearly saturated with the metal. So long as the salt continues to receive colour, the re-melting must be repeated.

In order to avoid in analysis the employment of too large a quantity of bisulphate of potash, the operator may supply sulphuric acid as follows. When the bisulphate of potash appears to have lost the greater part of its free acid, weighed portions of the distilled sulphuric acid may be added to the mixture, the whole cautiously heated until the water of the acid be expelled, and the fusion thereupon be continued.

The quantity of rhodium can be determined by two methods. According to the first, the undissolved platinum is washed, ignited, and weighed, and the quantity dissolved is equal to the peroxide of rhodium, which contains 71 per cent. of metal; or the washings which contain the rhodium are supersaturated with carbonate of soda, evaporated to dryness, and ignited in a platinum capsule. If the mass be now acted on by water, peroxide of rhodium will remain. It may be collected in a filter, washed, dried, ignited, and finally reduced, by means of hydrogen gas. The resulting metal is weighed. The rhodium thus obtained sometimes contains palladium. This is extracted by *aqua regia.* The solution of palladium is then neutralized and precipitated by cyanide of mercury: the precipitate is to be washed, dried, and ignited. The residual mass is metallic palladium, which may be weighed.

After the separation of the rhodium, the metallic mass is treated with very weak *aqua regia,* by digestion with which pure platinum is dissolved. The solution has a very deep colour, which is owing to the peroxide of iridium in suspension; but when it has become bright by deposition it has a pure yellow colour. It is then decanted, and concentrated *aqua regia,* mixed with chloride of sodium, poured upon the residue. The solution is now evaporated to dryness. The addition of the chloride of sodium is to hinder the production of proto-chloride of platinum. A small quantity of iridium is dissolved in the very concentrated acid; but, if it were not used, a considerable portion of platinum would remain mixed with the iridium.

When the dry mass is acted on by water, peroxide of iridium remains unacted upon. If it were washed with pure water to dissolve out all the platinum, it would be carried through the pores of the filter; to prevent which a dilute solution of chloride of sodium must be employed; and to remove the least traces of that, solution of muriate of ammonia is used. The filter is now to be burnt, and the peroxide of iridium remaining, with its ashes, reduced to the metallic state by a current of hydrogen gas, and weighed.

The solution of chloride of sodium containing a small quantity of iridium is mixed with carbonate of soda, dried, and ignited. The product, freed from soda salts by water, and from platinum by weak *aqua regia,* leaves peroxide of iridium, which must be reduced to the metallic state, and added to that already obtained.

In order to arrive at the weight of platinum, the operator must deduct the weight of the peroxide of rhodium from the united weight of the peroxide of rhodium, peroxide of iridium, and platinum. He must then add to the weight of the iridium obtained 12 per cent. of the weight of that metal, to produce the weight of peroxide of iridium which must be deducted from the weight of the platinum.

The reduction of the platinum from its solution would only increase the length of the operation, without adding anything to its accuracy.

B. *Treatment of the Alcoholic Solution.*—This solution is poured into a flask capable of being well stopped, and sulphuretted hydrogen passed in unto saturation. It is then stopped, and allowed to remain at rest for twelve hours in a warm place; at the end of which time all its metallic sulphurets will be precipitated. Sometimes the solution is red, owing either to the presence of rhodium or sesquichloride of iridium.

The solution must now be filtered and evaporated to expel all alcohol, during which operation a little more metallic sulphuret will be precipitated, and which must be added to that already obtained. The mixture of sulphurets thus obtained consists of the sulphurets of iridium, rhodium, palladium, and copper; while the filtered solution contains iron, rhodium, iridium, and a trace of manganese. During the evaporation of the alcohol a greasy-like metallic sulphuret, of a disagreeable odour, is deposited, which cannot be washed out. After the solution has been entirely washed away from this substance, it can be dissolved by pouring a little caustic ammonia into the capsule. The solution is now poured into a platinum crucible, and evaporated to dryness. The moist metallic sulphurets are then placed in also, and roasted until all sulphurous acid is expelled. On the cessation of roasting, concentrated hydrochloric acid is poured over the mass; which, owing to the solution of subsulphate of copper and palladium, is coloured green or yellowish green. Oxide of iridium and rhodium, with a little platinum, remain unacted upon.

The solution in hydrochloric acid is mixed with chloride of potassium and nitric acid, and evaporated nearly to dryness; a dark saline mass is the result, and which is composed of chloride of potassium and cupreo-chloride of potassium, with palladio-chloride of potassium. The two first of these salts are dissolved out in alcohol, specific gravity ·833, and the palladium salt is placed on a filter washed with alcohol of the same specific gravity. It contains 28·84 per cent. of palladium when dried and ignited.

The spirituous solution, which contains the copper salt, is evaporated to get rid of alcohol; and the contained copper is precipitated, either by means of pure potash, or by adding sulphuric acid and a plate of zinc.

That portion of the roasted sulphurets which was insoluble in hydrochloric acid is fused with bisulphate of potash until it ceases to become coloured. The mixture, in this case, contains much more rhodium than the precipitate obtained at the commencement of the analysis. The residue undissolved by bisulphate of potash, which is peroxide of iridium with a little platinum, is treated with *aqua regia,* and the peroxide reduced by hydrogen gas, as stated in a former part of the analysis.

The concentrated solution from which the sulphurets were precipitated contains only iron in a state of protochloride, with a small quantity of iridium and rhodium, with a trace of manganese. It must be mixed with a proper quantity of nitric acid, and boiled till the iron is fully oxidised. The peroxide of iron is then precipitated by caustic ammonia, and the precipitate washed, ignited, and weighed.

This peroxide of iron, however, contains a small quantity of iridium and rhodium, to separate which, after weighing the peroxide, it must be reduced by hydrogen gas. The reduced metal is treated with hydrochloric acid to dissolve iron, and the black undissolved portion is collected on a filter, ignited with exposure to air, and weighed; its weight deducted from that of the peroxide of iron, previously obtained, leaves the quantity of the latter in a pure state. The solution, filtered from the precipitate by ammonia, is mixed with carbonate of soda in sufficient quantity to decompose the ammoniacal salts, and evaporated to dryness. On treating the residue with water, after a gentle ignition, peroxides of iridium and rhodium remain undissolved; but they are generally too small for separation.

The following plan will serve to detect platinum in admixture with gold and other heavy matters obtained by washing or vanning sands, earths, &c.:—

Act on a small quantity by mercury, and separate the amalgam: by this means the gold is removed. To the residue add *aqua regia,* and boil; evaporate the solution to dryness; add a little muriatic acid and water; boil and filter. To the filtered solution add a strong solution of sal ammoniac (chloride of ammonium). If a bright yellow, or reddish yellow, granular precipitate falls, platinum is present in the sand.

A still more ready method is the following:—Separate as much earthy matter as possible by careful washing. If gold is present, separate that by amalgamation. Dry the residue, and take its specific gravity: if it be above 10, platinum is most likely present. The specific gravity of native platinum, free from earthy matter, is from 16 to 19.

CHAPTER XX.

ASSAY OF SILVER.

ALL argentiferous substances may be divided into two classes, thus—

Class 1. All minerals containing silver, slags, cupel bottoms, dross, litharge, and other manufacturing products, not alloys.

Class 2. Alloys of silver, either native or otherwise.

Minerals of the First Class.

Sulphuret of Silver.
Cupriferous Sulphuret of Silver.
Antimonial Sulphuret of Silver.

Arsenical Sulphuret of Silver.
Sulphurets of Silver, Copper, and Antimony.
Sulphurets of Silver, Lead, and Antimony.
Sulphurets of Silver, Lead, and Bismuth.
Seleniuret of Silver.
Cupriferous Seleniuret of Silver.
Carbonate of Silver.
Chloride of Silver.
Iodide of Silver.

Sulphuret of Silver (AgS).—The property this mineral possesses of being cut by a knife like lead, and its capability of receiving the imprint of any hard body, always renders its recognition from other minerals that are grey like it a very easy matter.

Sulphuret of silver is frequently found crystallised under the form of cubes, octahedra, and dodecahedra. (See figs. 237, 238, and 239.)

FIG. 237.

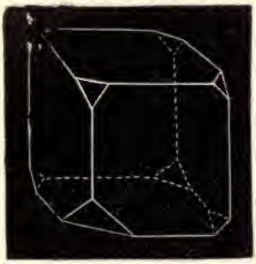
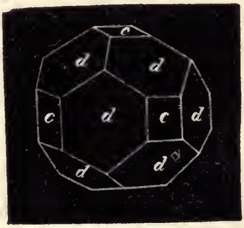


FIG. 238.

FIG. 239.



Composition of a specimen from Himmelfurst:—

Silver	13·5
Sulphur	86·5
	100·0

Cupriferous Sulphuret of Silver ($AgS+Cu_2S$).—This is a shining steel-grey looking mineral, very brittle, and has an imperfectly conchoidal fracture. It usually occurs in small compact masses.

Composition:—

Silver	52·87
Copper	30·83
Sulphur	15·96
Iron	·34
	100·00

Antimonial Sulphurets of Silver. Dark Red Silver.—There are three varieties of this mineral, thus:—

1. Black Antimonial Silver.
2. Red Antimonial Silver.
3. Brittle Antimonial Silver.

Black Antimonial Silver ($Sb_2S_3 + AgS$).—This is black in colour, having a semi-metallic lustre. Its fracture is conchoidal, and it crystallizes in oblique rhomboidal prisms.

Composition:—

Silver	36·40
Antimony	39·14
Copper	1·06
Iron	·62
Sulphur	21·95
	99·17

Red Antimonial Silver ($Sb_2S_3 + 3AgS$).—This mineral, which possesses a more or less intensely red colour, is scratched easily by the knife. Its powder is a fine crimson red colour, which is also apparent on the surface of the solid mineral; sometimes a very deep red, sometimes a metallic looking reddish black. It crystallizes in hexagonal prisms, either simple or modified by rhombohedral or dodecahedral summits. All these forms are singularly like those of carbonate of lime.

Composition:—

Silver	58·94
Antimony	22·84
Sulphur	16·61
Earthy matter	·30
Loss	1·31
	100·00

Brittle Antimonial Silver (Sb_2S_3+6AgS).—This is an iron-grey metallic looking mineral. It is very brittle and fragile, and its powder black. Its crystals appear derivable from a right rhomboidal prism.

Composition :—

Silver	68·54
Antimony	14·68
Copper	·64
Sulphur	16·42
	100·28

Arsenical Sulphuret of Silver. Light Red Silver (As_2S_3+3AgS).—This is a red non-metallic looking mineral, crystallizing in the rhombohedric system, and derived from a rhombohedron very nearly allied to that of red antimonial silver. It is brittle, and its powder is light red.

Composition :—

Silver	64·67
Arsenic	15·09
Antimony	·69
Sulphur	19·51
	99·96

Sulphurets of Silver, Copper, and Antimony.—These ores are known as grey copper, Fahlerz, argentiferous grey copper, &c. They have most generally the physical characters of grey copper, as already described. The following analyses will give an idea of their composition :—

	1.	2.	3.
Silver	13·4	·83	17·71
Copper	26·0	38·42	25·23
Iron	7·0	1·52	3·72
Zinc	—	6·85	3 10
Antimony	27·0	25·27	26·63
Arsenic	—	2·26	—
Sulphur	25·5	25·03	23·52
	98·9	100·18	99·91

Sulphurets of Silver, Lead, and Antimony.—These are in general the antimonial silver lead ores, more or less rich in the precious metal.

Sulphuret of Silver, Lead, and Bismuth ($AgS + 2PbS + 2Bi_2S_3$).—This substance possesses a metallic leaden hue, and occurs in small crystalline needles. It is brittle, and has an even fracture.

Composition :—

Silver	15·0
Lead	33·0
Bismuth	27·0
Iron	4·3
Copper	·9
Sulphur	16·3
	96·5

Seleniuret of Silver (AgSe).—This mineral occurs in small hexagonal tables, of a lead-grey colour, and very ductile.

Cupriferous Seleniuret of Silver ($AgSe + Cu_2Se$).—Colour lead-grey, very ductile, and can be cut with a knife.

Composition :—

Silver	33·93
Copper	28·05
Selenium	26·00
Gangue	12·02
	100·00

Carbonate of Silver.—This is a very rare mineral. It has a blackish-grey metallic appearance, and is very brittle.

Composition :—

Oxide of silver	72·5
Carbonic acid	12·2
Oxide of antimony	15·3
	100·0

Chloride of Silver, Horn Silver (AgCl).—This mineral is remarkable for its yellowish or greenish colour, its semi-transparency, and more especially by its softness, which is so great as to allow it to be marked by the nail. It fuses in a candle-flame, and becomes covered by a coating of silver when rubbed with a moistened plate of zinc or iron.

Chloride of silver is rarely found crystalline, although it sometimes occurs in cubical crystals; it more generally presents itself in small masses or in thin layers on the surface of metallic silver.

Composition :—

Silver	75·32
Chlorine	24·67
	100·00

Iodide of Silver (AgI).—A rare mineral, having a whitish aspect exteriorly and an interior yellowish aspect. Its structure is lamellar.

General Observations on the Assay of Ores and Substances of Class No. 1.

In order to separate silver from this class of substances, an alloy of the precious metal with lead must be formed. The different methods by which this object can be attained are the following: firstly, fusion with a reducing flux; secondly, fusion with oxidising re-agents; thirdly, scorification.

All substances containing lead in the state of oxide, such as carbonates, phosphates, &c., are fused directly with a reducing flux, as also are slags, old cupels, litharge, &c. All plumbiferous sulphurets, &c., containing silver, are assayed as for lead by the processes already pointed out, taking care to follow the method which gives the largest proportion of lead.

All argentiferous minerals containing copper may be assayed as copper ores; because an alloy of copper and silver can be cupelled by means of lead.

In making assays of silver with lead or copper, it is sometimes necessary to commence the operation by roasting the ore; under other circumstances, also, argentiferous matters are roasted.

There is nothing very particular to be observed in this roasting; the temperature alone requires attention by managing well at the commencement of the operation, in order to avoid softening, and especially to avoid a very rapid disengagement of arsenical vapours, because a very considerable amount of silver may be lost by that means.

All substances which contain reducible oxides are fused with a reducing flux, as also those from which charcoal separates metals which alloy with lead, or metals which do not hinder the process of cupellation; but it is necessary to add to the reducing flux a certain proportion of litharge, in order to produce metallic lead, with which the silver may alloy. A mixture of metallic lead and any suitable flux may be substituted for that of litharge and a reducing flux; but the latter is preferable, because the lead produced is uniformly diffused throughout the whole mass of flux, &c., not allowing a particle of silver to escape its action.

The reducing agent employed in nearly all assays is charcoal, either in its ordinary state, or as it is found in black flux. Starch and other analogous substances may be, as before mentioned, substituted for it: crude argol is, however, the best reducing agent. The proportion employed must be varied according to circumstances, so that the silver-lead produced be not too rich, or that too great a proportion of lead be reduced. If the silver-lead be too rich, much of the precious metal may be lost in the slag, and if too great a quantity of lead be produced, silver is again lost, owing to the long exposure to the fire during cupellation; and indeed this is the most fruitful cause of loss, for more is lost in this manner than by having too little lead produced. In order to know the right proportions, the following data will serve as a guide:—1 part of charcoal reduces about 30 parts of lead from litharge, and 1 part of black flux reduces about 1 part of lead.

The fluxes employed in this kind of assay are litharge, black flux, carbonate of potash or soda, and borax. Litharge is an exceedingly convenient flux, because it occupies very little room, and fuses without bubbling, producing very liquid scoriæ with nearly every substance. Experiment has shown that nearly all argillaceous, stony, and ferruginous substances fuse very well with from 8 to 12 or more parts of litharge. If from ½ to 1 part of black flux, or $\frac{1}{30}$th to $\frac{1}{25}$th of charcoal, be added to 1 of ore, from ½ a part to 1 part of silver-lead will be produced.

Black flux is employed in the fusion of all substances containing a large proportion of alumina, or in which lime is the predominant substance: from 2 to 3 parts of this flux generally suffice: 1 part of litharge is added to the assay, which is wholly reduced, producing nothing but lead.

The carbonates of potash or soda produce exactly the same effects as the alkali of the black flux. A certain quantity of charcoal must, in this case, be added to the assay.

Schlutter fuses the poor refuse of goldsmiths' workshops, mixtures of fragments of crucibles, glass, &c., with 2 parts of carbonate of potash, when they are very earthy, and with 1 part only when they contain much glass, adding, at the same time, to the mixture, a little litharge and granulated lead.

Borax has, like litharge, the advantage of being an universal flux; it is useful especially for the fusion of substances containing much lime; but it is necessary to take great care in the assay, in order to avoid the loss which its boiling up might occasion. This only applies, however, to its use in its ordinary state; if previously fused, that is, used as glass of borax, no particular care need be taken.

FUSION WITH OXIDISING RE-AGENTS.

Litharge.—The oxidising agents employed in the assay of argentiferous substances are litharge and nitre. Litharge attacks all the sulphurets, arsenio-sulphurets, &c., and oxidises nearly all the elements, excepting silver, when employed in sufficient quantity, and a quantity of lead equivalent to the oxidisable matters present is reduced, so that there results from the assay a slag containing an excess of oxide of lead, and an alloy of lead and silver, very little contaminated with foreign metals, if no copper be present, and which can be submitted directly to cupellation. This method of assay is exceedingly convenient and quick.

The pulverized mineral is well mixed with litharge, and the mixture placed in a crucible, which may be very nearly filled, as there is scarcely any boiling up when the pot and its contents are submitted to the fire. A thin layer of pure litharge is placed above the mixture, the whole is then heated rapidly, and as soon as the litharge, &c., is completely fused, the crucible is taken from the fire. It is inconvenient to heat it for any length of time, on account of the corrosive action litharge has on the substance of the crucible, which it rapidly destroys.

The proportion of litharge which must be employed depends upon the nature and quantity of oxidisable matters present in the ore. It ought in general to be very great, because it is absolutely necessary that no sulphurous matters be present, so that the slag may not contain the least trace of silver. But it is known how much litharge is required to decompose the metallic sulphurets. Pyrites requires about 50 parts; mispickel, blende, sulphuret of antimony, copper pyrites, grey cobalt, and grey copper, require from about twenty-five to forty times their weight. For sulphuret of bismuth 10 are sufficient, and for galena or sulphuret of silver but 4 or 5 parts need be employed. The proportion of litharge will not be so great for a mineral containing much stony gangue as for one entirely metallic.

Experiment has proved, that the assay of rough schlichs, such as those treated in the large way by amalgamation, can be made very exactly with from 10 to 12 parts of litharge.

Alloys of silver with the very oxidisable metals can be assayed by means of litharge, such as those of iron, antimony, tin, zinc, &c.; but in order to have a successful result the alloys should be reduced to a very fine state of division, so that they must be at least granulated; and it is very often necessary to repeat the operation several times on the fresh alloy of lead produced.

The method of assay just pointed out is inconvenient, on account of the large quantity of lead it produces; pyrites giving 8½ parts, copper pyrites and blende 7 parts, sulphuret of antimony and grey copper about 6 parts, &c. In order to avoid this inconvenience, part of the oxidation can be performed by means of nitre. Nitre alone, employed in excess, oxidises all metallic and combustible substances found with silver, and even, under certain circumstances, a portion of silver itself; but when the proportion is insufficient to oxidise the whole, and when the mixture contains at the same time litharge, after the nitre has produced its action, the litharge acts in its turn on the remainder of the oxidisable substances, and the resulting lead carries down the silver set free. So that, by employing suitable proportions of nitre and litharge, all the silver contained in oxidisable minerals may be extracted, and any quantity of lead required may be thus alloyed with it.

As to the requisite proportion of nitre, it can be come at by practice, aided by the following data. It requires about 2½ parts of nitre to completely oxidise iron pyrites, 1½ for sulphuret of antimony, and ⅔ for galena.

This determination can be ascertained at once as follows: fuse 1 part of the mineral with 30 of litharge, and weigh the resulting button of lead; and having fixed upon the quantity of lead necessary to carry on the cupellation properly, deduct it from the whole weight of the button, and the difference will be the amount of lead necessary to leave the slag in the state of oxide; and as it has been proved by experiment that 1 part of lead requires ·25 to ·30 of nitre, that is, from 25 to 30 per cent., it is easy to calculate the quantity necessary to be added.

When the ore contains sulphur, the latter forms with the nitre sulphate of potash, which swims on the slag without combining with it.

The assay of silver ores by means of nitre is advantageous and useful in a variety of cases. If we wish to determine, for example, very exactly, the per centage of silver in a poor galena, a large quantity, say $\frac{1}{4}$ of a pound, must be fused with about an ounce or an ounce and a half of nitre, and a quarter of a pound of carbonate of soda, or better still the same quantity of litharge, one of either of which must be employed to flux the gangue and temper the deflagration. After the fusion, all the contained silver will be found alloyed with a very small quantity of lead.

Sometimes the assay is made with a larger quantity of nitre than is requisite for the oxidation, and when the mixture is perfectly fused a certain quantity of metallic lead is added, taking care to cover the whole surface of the mixture, either by using granulated lead or a convenient mixture of litharge and charcoal, or litharge and galena. The shower of metallic lead passing through the fluid mass alloys with all the silver it finds in its passage, and so concentrates it.

This process, however, cannot always be confidently employed. If an excess of nitre be employed with substances susceptible of forming peroxides capable of attacking silver, such as some cupreous substances, the lead added reduces the greater part, but not the whole of the silver in the ore, so that the assay will not be perfect.

Special Directions for the Crucible Assay of Ores and Substances of the First Class.

The ores and substances belonging to this class may, for the convenience of assay, be further subdivided on the following principle. It has already been seen that sulphur, and other substances having a great affinity for oxygen, reduce metallic lead from litharge in proportion to the amount of reducing matter present; and as it is necessary in this kind of assay that no more than a certain quantity of lead alloy should be submitted to cupellation, some kind of control must be exercised by the assayer, to keep the quantity of lead reduced in due and proper bounds. This is readily accomplished by what the author calls a "preliminary assay," by which all ores and substances of this class are divided into three sections :—1stly, Ores which, on fusion with excess of litharge, give no metallic lead, or less than their own weight. 2dly, Those which give their own weight, or nearly their own weight, of metallic lead. 3dly, Those which give more than their own weight of metallic lead. The preliminary or classification assay is thus conducted :—

Carefully mix 20 grains of the finely pulverised ore (all silver ores must be passed through a sieve with 80 meshes to the linear inch), with 500 grains of litharge; place the mixture in a crucible which it only half fills; set the crucible, after careful warming, in a perfectly bright fire, and get up the heat as rapidly as possible, so as to finish the operation in a short time, to prevent the action of the reducing gases of the furnace on the oxide of lead, because, if a great length of time were taken in the operation, a portion of the lead reduced might be traceable to the furnace gases, and the result of the experiment vitiated. After the contents of the crucible are fully fused, and the surface perfectly smooth, the crucible may be removed and allowed to cool, and when cold broken. One of three circumstances may now present itself to the assayer: 1stly, no lead, or less than 20 grains, have been reduced; 2dly, 20 or nearly 20 grains, more or less, may be reduced; and 3dly, more than 20 grains may have been reduced.

Now, as it has been already stated, 200 grains of lead alloy is a suitable amount to cupel; and as 200 grains is the best quantity of ore to submit to assay, it will be evident that ores and substances of the second section, or those bodies which give their own weight, or nearly their own weight, of lead alloy, simply require fusion with a suitable quantity of litharge and an appropriate flux. Ores of the first section require the addition of a reducing agent, in quantity equivalent to the standard amount of lead alloy (200 grains); and ores of the third section require an equivalent quantity of an oxidising agent, or an amount of some body which will oxidise the lead in excess of 200 grains of alloy.

The reducing agent employed is argol; the oxidising agent, nitrate of potash. It is necessary, before commencing an assay of a silver ore, to determine how much lead a given weight of the argol the assayer has in use will reduce, as also how much lead a given weight of nitrate of potash will oxidise. These assays are thus made:—

Assay of Reducing Power of Argol.—Carefully mix 20 grains of the argol to be tested with 500 grains of litharge and 200 grains of carbonate of soda; place the mixture in a suitable crucible, and cover with 200 grains of common salt. (It is best to mix two such quantities, and take the mean of the results.) Fuse with the precautions pointed out in assay of substances of the first class, containing lead.

Weigh the resulting buttons, and take a note of the mean weight, which will represent the amount of lead reducible by 20 grains of argol.

Assay of Oxidising Power of Nitrate of Potash.—Mix 20 grains of finely powdered nitrate of potash, 50 grains of argol, 500 grains of litharge, and 200 grains of carbonate of soda; cover with 200 grains of common salt, and fuse as above. Weigh the resulting button. Now calculate the amount of lead which should have been reduced by 50 grains of argol, and the difference between that and the amount of lead reduced in this experiment will represent the amount of lead oxidised by 20 grains of nitrate of potash.

30 to 32 grains of ordinary red argol reduce about 200 grains of lead; and 23 grains of pure nitrate of potash oxidise about 100 grains of lead. The assayer must, however, adopt the numbers found by himself by experiment, as some samples of argol and nitre are more or less impure. He must also examine every fresh supply of litharge for the amount of silver it contains, in the following manner:—

Assay of Litharge for Silver.—Mix 1000 grains of litharge with 30 grains (or any other quantity that may be, by experiment, found requisite) of argol, 200 grains of carbonate of soda, and cover with salt, as already directed. Fuse the mixture in a suitable crucible; allow it to cool; break and cupel the button obtained, as hereafter to be described; take a note of the amount of silver obtained; and as 1000 grains of litharge is the standard quantity for a silver assay, the amount of silver, indicated as above, is to be deducted from the amount of silver obtained in the assay of any silver ore, until that quantity of litharge is consumed.

Assay of Ores of the First Section.—Make a preliminary assay, as already described. Suppose 10 grains of lead result; then, as 20 have furnished 10 grains, so 200 grains of ore would furnish 100 grains of lead, or 100 grains less than the quantity best adapted for cupellation; so that, referring to the assay of argol, and finding that from 30 to 32 grains reduce 200 grains of lead, then it is clear that the reducing power of from 15 to 16 grains of argol, in addition to the reducing power of 200 grains of ore, is necessary to furnish 200 grains of lead alloy. In this case the ingredients required in the actual assay, or "assay proper," would stand thus—

200	grains of ore.
200	grains of carbonate of soda.
1000	grains of litharge.
15	to 16 grains of argol.

These materials are to be thoroughly well mixed, placed in a crucible which they about half fill, and covered first with 200 grains of common salt, and then 200 grains of borax, and submitted to the fire with the usual precautions: when the flux flows smoothly the assay is complete; it may be removed and allowed to cool, the crucible broken, and the button obtained must be hammered into a cubical form, and should approximate to 200 grains, either more or less within 10 grains. Two crucibles must always be prepared. It will also be here convenient to mention that the argol and nitrate of potash are the only substances whose quantities vary in the assay of silver ores, the amount of these variations being determined by the preliminary or classification assay.

Assay of Ores of the Second Section.—If the preliminary assay of the sample submitted to assay furnish from 18 to 22 grains of lead, then the assay proper may be thus made:—

200 grains of the ore.
200 grains of carbonate of soda.
1000 grains of litharge.

Well mixed, and covered with salt and borax as above. Fuse with due care, and reserve buttons of lead alloy for cupellation.

Assay of Ores of the Third Section.—If the sample on preliminary assay furnished 40 grains of lead, then the 200 grains employed in assay proper would give 400 grains or 200 grains of lead in excess: refer now to note-book for quantity of lead oxidised by nitre: suppose the nitre pure as just stated, 23 grains will oxidise 100, therefore 46 grains are equivalent to 200, and the assay proper will stand thus:—

200 grains of the ore.
200 grains of carbonate of soda.
1000 grains of litharge.
46 grains of nitrate of potash.

The nitrate of potash to be weighed first, finely pulverised, and then well mixed with the remaining substances, and covered with salt and borax. The crucible in this assay must be larger than in the two preceding cases; the mixture should not more than one-third fill it, as there is a considerable action set up between the oxygen of the nitre, and the sulphur or arsenic, or any other substance that may be the reducing agent in the ore; for in fact the nitre does not directly oxidise the lead, which sulphur, &c. might have reduced, but oxidises its equivalent quantity of sulphur, or whatever other reducing substance there may be in the ore, so as only to leave a sufficient amount to reduce 200 grains of lead, in lieu of the 400 as indicated by preliminary assay, or when the reducing power of the ore was allowed to come into full play. The buttons obtained in this case are also to be reserved for cupellation.

Scorification.—Scorification has, like fusion with litharge, the effect of producing an alloy of lead capable of cupellation, and a very fusible slag composed of oxide of lead, and all the matters foreign to silver, converted into the state of oxide. In the crucible assay as just described the oxidation of these substances takes place by the action of the litharge, which furnishes at the same time by its reduction the lead necessary to form the alloy, whilst in scorification all the substances susceptible of oxidation are oxidised in the roasting by means of the oxygen of the air, and the litharge itself is produced by the oxidation of part of the lead mixed with the ore to be assayed.

In this operation vessels termed scorifiers (see page 113) are employed. They are heated in the muffle of the cupelling furnace, and as many assays may be made at one time as the muffle holds scorifiers.

Before introducing the scorifiers into the muffle, a given weight of the ore reduced to powder is mixed intimately with a certain quantity of granulated lead, and placed in each. They must then be heated gradually for about a quarter of an hour, with the door of the muffle closed, in order to fuse the lead; then diminish the heat, and allow access of air by opening the door. The current thus established in the muffle soon causes the commencement of the roasting; and this roasting goes on without its being necessary to continually agitate the mass, as in the case of pulverulent substances.

During the oxidation, a slag is formed on the fluid metal, which is thrown towards the edges, and which, by continually augmenting, at last entirely covers the bath. This slag, which is often solid at the commencement, becomes softer and softer, and at last becomes perfectly fluid; because, in proportion to the advance of the operation, the proportion of oxide of lead continually increases. When it is judged that the scorification has been carried far enough, the melted matter is stirred with a rod of iron, in order to mix with the mass the hard or pasty parts attached to the bottom or sides of the scorifier. The fire is then urged so as to completely liquefy the slags. It may be ascertained when they are sufficiently fluid by plunging into them a red hot iron rod, which must only be covered with a slight coating, capable of running off, and not solidifying into a drop at the end.

This condition of liquidity is indispensable, in order to enable the metallic globules to unite into a single button. When this end is not attained, it is because the scorification has not been carried sufficiently far; or, because a sufficient quantity of lead has not been added to form the flux, in which case a fresh quantity must be added, or, what is preferable, the assay recommenced with larger proportions.

When the operation is finished, the scorifier must be removed, and its contents immediately poured into a circular or hemispherical ingot mould (see fig. 195, page 198). The metallic particles fall to the bottom, and as the cooling proceeds they form a button covered by the slag, which is readily detachable by a blow of a hammer: it ought to be very homogeneous and vitreous, and its colour varying from brown to greenish.

It is always advisable to examine it, and ascertain if it contain metallic globules. The button ought to be as ductile as ordinary lead; if not it cannot be cupelled, and must be submitted to a fresh operation. It is in general advantageous to push the scorification to its greatest extent, because experiment has proved that less silver is lost than when a large button is cupelled. Nevertheless, there is a limit, because if the silver-lead produced be too rich, the least loss in the shape of globules would cause a notable one in the silver. Besides, as litharge exercises a very corrosive action on earthy matters, if the scorification be continued for a great length of time it sometimes happens the vessel is pierced, and the assay has to be recommenced. The button of lead remaining ought to weigh about 200 to 300 grs., when the ores treated are of ordinary richness. The length of time a scorification takes is from half an hour to an hour. The scorifier can be rendered less permeable to the litharge by being rubbed inside with chalk or blood, better still red ochre.

There may be distinguished three distinct periods in the operation, viz. the roasting, the fusion, and the scorification. At first a strong fire is employed; but the doors of the furnace are opened as soon as the mixture is fused. The mineral, being specifically lighter than the lead, is then seen floating on its surface, or forming masses in it; the roasting then commences, and from the appearance of the vapours the nature of the combustible matter it contains may be judged. Sulphur produces clear grey vapours; zinc, blackish white vapours, and a brilliant white flame; arsenic, whitish grey vapours; antimony, fine red vapours, &c. When no more fumes are seen, the mineral has disappeared, and the fused lead perfectly uncovered, the roasting has terminated: this generally requires from eighteen to twenty minutes. At this time the fire is urged, so as to cause all the substances in the scorifier to fuse. It can be ascertained that the fusion is complete, by the following signs: at the instant the muffle is opened, the button becomes whitish red, with a greyish black band, and there arise from the melted mass clear white fumes of lead, and the slag appears like a ring encircling the metal. The third period then commences: the furnace is cooled, as in the roasting, and the lead is allowed to scorify until it is entirely covered with fused oxide: this last period generally lasts about fifteen minutes. The fire is then increased for about five minutes, and the contents of the scorifier poured into the mould.

The process of scorification is applicable to all argentiferous matters, and is at the same time the most exact method of assay, as also the most convenient, when a large number of assays are required at the same time, because they are entirely executed in the muffle, which, with most assayers, is generally hot: it, however, requires a greater number of vessels,—as cupels, &c.

When the silver ores are stony, the oxide of lead formed during the roasting combines with the gangue, forming a fusible compound, whilst the remaining lead alloys with the silver. When the ores are metallic, the oxidisable bodies absorb oxygen from the atmosphere; and the oxides so formed combine with the litharge produced at the same time, forming a compound which becomes very fusible in proportion as the oxide of lead increases; and if the scorification has not been pushed sufficiently far, the button will contain, besides silver and lead, a little copper, which will not, however, interfere with the cupellation. There is this one peculiarity about scorification, that however small the proportion of lead may be that is used, at the end of the operation the slag does not contain any oxysulphuret. For instance, even when oxysulphurets are produced in the course of scorification, they are completely decomposed in the roasting, and in consequence it is very rarely that the slag retains any proportion of silver; and as to the proportion of lead employed, only just enough to render the slag liquid, and to produce sufficient lead for cupellation, is necessary.

It is different, however, when the sulphurets and arsenio-sulphurets are assayed by means of litharge; for from 30 to 50 parts of that substance must be employed to prevent the scoriæ retaining any silver, or, as already pointed out, the addition of a certain proportion of nitre.

All scorifications may be conducted by the simple addition of lead; but it has been proved that the operation proceeds more quickly, and with less danger to the scorifier, when borax is employed. This salt dissolves the oxides in proportion as they are produced, as also the gangues, and forms a very liquid slag from the commencement of the operation, which does not happen when lead alone is used, because litharge, which can alone cause the fusion, is not present in the slag in sufficient proportion, but at a very advanced stage of the operation.

When the slag is liquid at the beginning of the operation (as occurs in the use of borax), it is continually thrown on the sides of the scorifier, and forms a ring on the surface of the bath, leaving in the centre the metallic substance, having a considerable extent of surface, which is continually diminishing.

The current of air being thus directly in contact with the fused metals, rapidly causes their oxidation, which does not take place when the semifluid substances float here and there on the metallic bath. The proportion of lead and borax necessary for a scorification varies exceedingly, according to the nature of the substance under assay, and ought to be greater in proportion as the substances, or resulting oxides, are difficult of fusion. In ordinary cases 12 parts of lead, and 1 of glass of borax, are employed; but sometimes 32 of lead, and 3 of borax, are required. A large proportion of borax is useful, especially when the substances contain much lime, oxide of zinc, or oxide of tin.

Instead of borax, glass of lead may be employed. It acts as a flux on silica; but its action is much less effective than that of borax.

There are some substances which scorify with a small proportion of lead. Thus, for galena and sulphuret of copper, 2 parts of lead suffice; but 8 parts are required for ores which contain much gangue.

Antimoniuret of silver can be scorified with 8 parts of lead; but according to experiments made in the Hartz, it appears that the slag retains about $\frac{1}{140}$th of silver; with 16 parts of lead $\frac{1}{200}$th of fine metal is still lost; but with 3 of borax and 16 of lead not the slightest trace remains in the slag.

It is very difficult to separate tin and silver by the dry way. The best method is to roast the alloy in a scorifier, adding to it 16 parts of lead and 3 of borax at least, and operating as before described.

Speiss very nearly always contains silver, and is one of the most difficult substances to assay. If nickel be present, the button cannot be cupelled. Generally, speiss may be scorified with 16 parts of lead; and the same operation is gone through twice or thrice, adding each time a fresh quantity of lead. The operation would probably succeed by roasting the speiss in the scorifier before adding the lead.

Special Instructions for the Scorification Assay of Ores of the First Class.—This mode of assay has an advantage over the crucible assay just described, inasmuch as if properly conducted no preliminary assay is required: but this is greatly counterbalanced by the fact that not more than 50 grains of ore can be operated on in one scorifier, and that good or trustworthy results cannot be obtained by this method unless four scorifiers are employed for each assay, so that in all 200 grains of ore may be employed. There are thus employed four scorifiers to three crucibles, and four cupels to two cupels; as in one case four buttons are to be submitted to cupellation, and in the other only two. When very rich copper ores, however, have to be assayed for silver, the plan by scorification is very useful, as in the crucible operation much copper is reduced with the lead, so as to require a very large quantity of lead for its conveyance as oxide into the cupel This class of assay will however be particularly noticed under the head Assay of the Alloys of Silver.

Assay in Scorifier.—Weigh out 300 grains of granulated lead, place them in a scorifier, then add 50 grains of pulverized fused borax, and 50 grains of the ore to be assayed, well mix them in the scorifier by aid of a spatula, and cover the mixture with other 300 grains of granulated lead: prepare in this way four scorifiers, place them in the muffle with the tongs *b*, page 97, Fig. 194, and carefully watch them with all the precautions before pointed out: when the surface of the metal is quite covered with fused oxide, pour the contents of each scorifier into one of the hollows of the mould depicted at page 98, fig. 195. When the mass of slag and metal is cold, separate the latter from the former by means of the hammer and anvil, hammer the metal into the form of a cube, and reserve it for cupellation.

Assay of Substances of the First Class admixed with Native or Metallic Silver.—The same kind of calculation is necessary in the assay of ores as above, as in the case of copper ores containing metallic copper (see pp. 255–6). The sample must be carefully weighed. Suppose it to weigh 2500 grains. It must be pulverised, and as much as possible passed through the sieve with eighty meshes to the linear inch. It will be thus divided into two parts: the one passing through the sieve is mineralised silver,—that is, silver ore of various kinds mixed with earthy matter, and a very small quantity of metallic silver which has been sufficiently divided to pass through a sieve of such a degree of fineness;—the other, impure metallic silver, which has been unable to pass through the sieve. The weights of both portions are carefully taken, and thus noted—

Rough metallic silver . . .	5·07 grs.
Ore through sieve . . .	2494·93 "
Total weight of sample . .	2500·00 "

Assay the ore which passed through the sieve as already directed, and the rough silver as directed under the head assay of silver alloys. Note the quantity of silver obtained in each experiment. Thus: suppose 200 grains of ore yielded 2 grains of fine silver, and the 5·07 grains of rough silver 4 grains of fine silver by cupellation, the number of ounces of fine silver in the ton is thus calculated.

On referring to Table III., page xlv. in Appendix, it will be found, that if 200 grains of ore yield 2 grains of fine silver, 1 ton will yield 326 oz. 13 dwts. 8 grs. of fine silver; so that the average produce of the ore is the above amount.

Then, if 5·07 grains of rough silver yield 4 grains of fine silver, 200 grains would yield, by calculation, 159·763 grains of fine silver. Thus—

$$\frac{200 \times 4}{5{\cdot}07} = 159{\cdot}763$$

Now, by referring to Table III. in the Appendix, it will be found that 159 grains of fine silver give 200 grains of ore, =25,970 ounces per ton; and that ·763 grains of fine silver give 200 grains of ore, =124 oz. 12 dwts. 11 grains: therefore, the 5·07 grains of rough silver contain after the rate of 26094 oz. 12 dwts. 11 grs. per ton. Thus—

25970 oz. + 124 oz. 12 dwts. 11 grs. = 26094 oz. 12 dwts. 11 grs.

Thus we have—

	oz.	dwts.	grs.
Average produce of ore . . .	326	13	8
Average produce of rough silver .	26094	12	11

per ton of 20 cwts.

Then, as in the case of the copper, multiply the weight and produce of each portion together, add the resulting total products, and divide the sum by the weight of the sample. For this purpose it is better to reduce the pennyweights and grains to their decimal values. Thus 13 dwts. 8 grs. is nearly equal to ·67 of an ounce, and 12 dwts. 11 grs. to ·62 of an ounce; therefore the quantities above will stand thus—326·67 oz., and 26094·62 oz.

$$\begin{array}{ll} \text{Then} & 326{\cdot}67 \times 2494{\cdot}93 = 815018{\cdot}7831 \\ \text{and} & 26094{\cdot}62 \times \quad 5{\cdot}07 = 132296{\cdot}7234 \\ \text{and} & \dfrac{815018{\cdot}7831 + 132299{\cdot}7234}{2500} = 378{\cdot}9 \text{ oz.} \end{array}$$

or 378 oz. 18 dwts. (nearly) per ton of the original sample, before pulverising and sifting.

In every case of assay yet described, it may be mentioned that if the sample contained gold, the whole of that metal will be found with the silver, as obtained by cupellation, and may be separated as stated under the head Gold Assay.

Cupellation.—Cupellation is one of the most ingenious operations that can be imagined; it has been known from time immemorial, has many characters in common with scorification, and is effected in nearly the same manner. Like that, it has for its end the separation of silver and gold from different foreign substances, by means of lead; but it differs in this, that the scoriæ produced are absorbed by the substance of the vessel named a cupel, in which the operation is made, instead of remaining on the melted metal, the latter remaining uncovered and in contact with the air, so that the extraneous metals are not only oxidised, but also all the lead; and there remains nothing but the pure metals, silver and gold, or an alloy of them in the cupel.

Cupellation requires, as an indispensable condition, that the slag should have the property of penetrating and soaking into the body of the substance forming the cupel; it is, therefore, applicable to a certain number of substances, and not to all, like scorification. The oxides of lead and bismuth, in a state of purity, are the only oxides which possess the property of soaking into the cupel; but by the aid of one or the other, various oxides which by themselves form infusible scoriæ on the cupel acquire the property of passing through it: so that, on making a cupellation, it is necessary to fuse the substance with a sufficient proportion of lead or bismuth, so that the oxides they produce may combine with the oxides of all the foreign metals produced in the operation, and carry them into the body of the cupel.

This proportion varies with the nature of the substances cupelled, and to other circumstances. The quantity required in ordinary cases will be mentioned hereafter.

The cupels, or porous vessels in which the operation is made, ought to have a sufficiently loose texture to allow the fused oxides to penetrate them easily, and at the same time to possess sufficient solidity to enable them to bear handling without fracture; and, moreover, they ought to be of such a nature as not to enter into fusion with either oxide of lead or bismuth.

The following is the method in which an ordinary cupellation is conducted:—The furnace being heated, the bottom of the muffle is covered with cupels, placing the largest towards the end; and if they are required to be heated as quickly as possible, they may be placed topsy-turvy, and turned, at the instant of use, by means of the tongs. When the interior of the muffle is reddish white, the matters to be cupelled may be introduced. When the cupels have been placed in their proper position, great care must be taken from the commencement to blow out of them all cinders, ashes, and other extraneous substances, which may have fallen into them

The substance to be cupelled is sometimes an alloy, which can pass without addition, and sometimes a compound, to which lead must be added. In the first case, the alloy is laid hold of by a small pair of forceps, and deposited gently in the cupel. In the second case, the substance to be cupelled is enveloped in a sheet of lead of suitable weight, and placed, as before, in the cupel; or the necessary quantity of lead may be first placed in the cupel, and when the lead is fused, the substance to be cupelled added, taking care not to agitate the melted mass, and cause loss by splashing. If the substance to be cupelled is in very small pieces, as grains or powder, it must be enveloped in a small piece of blotting paper, or still better, in a piece of very thin sheet lead, giving it a slightly spherical form, and dropping it gently into the mass of molten metal in the cupel. Sometimes the substance is gradually added, by means of a small iron spoon; but it is preferable to use paper, or thin lead, as just recommended.

When the cupels are filled, the furnace is closed, either by the door or by pieces of lighted fuel, so that the fused metals may become of the same temperature as the muffle. When this point has been gained, air is allowed to pass into the furnace; the metallic bath is then in the state termed *uncovered;* that is, it presents a convex surface, very smooth, and without slag. When the air comes in contact with it, it becomes very lustrous, and is covered with luminous and iridescent patches, which move on the surface, and are thrown towards the sides. These spots are occasioned by the fused oxide of lead which is continually forming, and which, covering the bath with a very thin coating of variable thickness, presents the phenomenon of coloured rings.

The fused litharge, possessing the power of moistening (so to speak) the cupel, is rapidly absorbed by it when sufficiently porous, so that the metallic alloy is covered and uncovered every instant, which establishes on its surface a continual motion from the centre to the circumference. At the same time a vapour rises from the cupels which fills the muffle, and is produced by the vapour of lead burning in the atmosphere. An annular spot is soon observed on the cupel around the metal, and this spot increases incessantly until it has reached the edges.

In proportion as the operation proceeds, the metallic bath of silver-lead diminishes, becoming more and more rounded; the shining points with which it is covered become larger, and move more rapidly; lastly, when the whole of the lead separates, the button seems agitated by a rapid movement, by which it is made to turn on its axis; it becomes very lustrous, and presents over its whole surface all the tints of the rainbow: suddenly the agitation ceases, the button becomes dull and immoveable, and after a few instants it takes the look of pure silver. This last part in the operation of cupellation is termed the ***brightening, fulguration,*** or ***coruscation.***

If the button be taken from the muffle directly after the brightening, it may throw off portions of its substance; this must be avoided, especially when the button is large. The button, when covered by mammellated and crystalline asperities, is said to have "vegetated." The cause of this effect seems to be, that when the fused buttons are suddenly exposed to the cold air, the silver solidifies on the surface, whilst that in the interior remains liquid. The solid crust, contracted by cooling, strongly compresses the liquid interior, which opens passages for itself, through which it passes out, and around which it solidifies when in contact with the cool air. But it sometimes happens that, when the contraction is very strong, a small portion of the silver is thrown off in the shape of grains, which are lost.

After brightening, the cupels must be left for a few minutes in the furnace, and drawn gradually to the mouth, before they are taken out, so that the cooling may be slow and gradual. These precautions are nearly superfluous when the buttons are not larger than the head of an ordinary pin.

As silver is sensibly volatile, it is essential, in order that the smallest possible quantity be lost, to make the cupellation at as low a temperature as may be. On the other hand, the heat ought to be sufficiently great, so that the litharge may be well fused and absorbed by the cupel; and, moreover, if the temperature be too low, the operation lasts a very long time, and the loss by volatilization will be more considerable than if the assay had been made rapidly at a much higher temperature.

Experience has proved that the heat is too great when the cupels are whitish, and the metallic matter they contain can scarcely be seen, and when the fume is scarcely visible and rises rapidly to the arch of the muffle. On the contrary, the heat is not strong enough when the smoke is thick and heavy, falling in the muffle, and when the litharge can be seen not liquid enough to be absorbed, forming lumps and scales about the assay. When the degree of heat is suitable the cupel is red, and the fused metal very luminous and clear.

In general it is good to give a strong heat at the commencement, so as to well uncover the bath, then to cool down, and increase the heat at the end of the operation for a few minutes, in order to aid the brightening. There can be no inconvenience in urging the temperature at first, because the silver-lead is then poor, and much precious metal cannot be lost by volatilization. The increase of fire given towards the end is for the purpose of separating the last traces of lead, from which it is very difficult to free the silver; but this strong fire must not be continued long, otherwise there might be a notable loss by volatilization. When the assay of very poor argentiferous matters is made, the heat can be kept up nearly all through the cupellation. It generally succeeds better when the temperature is too high than too low.

The force of the current of air which passes through the muffle is another very important thing in the success of the operation. Too strong a current cools the cupel, oxidises too rapidly, and the assay would be spoilt. With a too feeble current the operation proceeds slowly, the assay remains a long time in the fire, and much silver is lost by volatilization.

When the litharge is produced more rapidly than it can be absorbed by the cupel, or when it is not liquid enough, which may happen from the furnace being too cold, or when other oxides, produced at the same time, diminish its fusibility, it accumulates gradually on the fluid metal, forming, at first, a ring, which envelopes its circumference, and which, gradually extending, covers the whole surface: at this period the assay becomes dull, and all movement ceases. When the operation is carefully attended to, it is nearly always possible to avoid this accident. If, at the first moment, any signs are manifested of this evil, the temperature of the muffle must be raised, either by shutting the door, or placing in it burning fuel: the assay will, in a little time, resume its ordinary course, But when the cause of the mishap is supposed to be the abundance of foreign oxides in the assay, a fresh proportion of lead must be added.

It can be ascertained whether an assay has *passed* well by the aspect of the button. It ought to be well rounded, white, and clear, to be crystalline below, and readily detached from the cupel. When it retains lead, it is brilliant below and livid above, and does not adhere at all to the cupel.

In order to detach the button, seize it with a fine strong pair of pliers (see fig. 210, page 161) and examine with a microscope (see fig. 212, page 163), brushing it to detach small particles of litharge which may adhere to it, and place it into the pan of a balance (fig. 181, page 69) which will indicate the $\frac{1}{1000}$th of a grain. The weight of the silver furnished by the lead or litharge employed in the operation ought to be subtracted from the amount of silver obtained; so that it is necessary to ascertain the richness of these matters beforehand, as they are never completely free from silver. The poorest of them contain from $\frac{1}{100,000}$th to $\frac{1}{10,000}$th.

Sometimes an equal quantity of lead is placed in another cupel, and the silver thus obtained placed in the balance pan containing the weights.

Cupellation does not give the exact proportion of silver contained in an alloy. There is always a loss, and this loss is always greater than that which takes place in the large way, as in the latter process a greater quantity is always obtained than that determined by the assay. The loss of silver is traceable to three causes; 1st, volatilization; 2ndly, to oxidation; 3rdly, and lastly, to the absorption of minute globules of silver into the body of the cupel. It is certain volatilization takes place, because a notable quantity of silver is always found deposited on the sides of the furnace and chimney in the shape of dust, and silver, which is volatile by itself, becomes much more so when alloyed with lead, and is carried away by the vapours of the latter, and found in the pulverulent deposits, termed *lead smoke or fume,* which proceeds from the combustion of the latter metal in the air. Nevertheless, this cause of loss is not very important, for it is rare that the fume contains more than $\frac{1}{10,000}$th of silver, and accurate experiments have proved that in cupellation in the small way not more than two to three per cent. of lead is volatilized. It is certain that a portion of the silver found in cupels which have been used for assays exists in the state of oxide, for no part of their mass is free,—it is found even in the bottom: besides, it is known that the carbonate of lead precipitated from acetate of lead made from litharge contains silver, and a notable quantity of that metal is found even in the sulphate of lead prepared by means of alum from the acetate (excepting the sulphate is repeatedly washed with water); for silver cannot exist in the acetate, carbonate, or sulphate, but as oxide.

It has been remarked that the centres of cupels which have been used for assays are richer in silver than the parts nearer the circumference, and that under the button there is a spot of bright yellow, which appears to be oxide of silver. But the most important cause of loss in an assay is the property which the alloys of silver and lead possess of introducing themselves into the pores of the cupel. The quantity thus lost is in proportion to the coarseness of the cupel. For the same quantity of silver, the loss which takes place in an assay varies according to the nature of the alloy, and the circumstances under which the assay is made; so that it is not possible to form accurate tables of correction. This loss is much augmented with the quantity of lead employed, but without its being proportionate; so that when scorification is had recourse to it is advantageous to continue the operation for some length of time, in order that the metallic button may be reduced to the smallest suitable volume.

In the assay of rich alloys, the proportion to the total amount of silver is very small, but notable; and it has been calculated for the alloys of copper employed in the arts at $\frac{1}{3,000}$th; but in the assay of poor ores, such as galena and other minerals treated in the large way, the loss is very great, for it is usually as high as $\frac{1}{500}$th.

By extracting the lead from cupels used in this class of assay, the metal furnished contains from about $\frac{1}{300,000}$th to $\frac{1}{500,000}$th of silver. The following experiment will give an idea of the influence of the proportion of lead on the loss of silver: 100 grains of commercial litharge were fused with 10 grains of black flux, and gave 27 grains of lead, and a slag which was pulverized and reduced in the same crucible with 15 grains of black flux, and a second button was produced weighing 45 grains. These two buttons being cupelled separately, gave the first ·0035 and the second ·001 only of silver. Three new quantities of 100 grains of the same litharge were fused; the first with $\frac{1}{2}$ a part of starch, the second with $2\frac{1}{2}$, and the third with 10 of the same reducing agent. The resulting buttons of lead weighed respectively 5·28 and 79 grains. These buttons were cupelled, and furnished ·0035, ·0035, and ·003 respectively. From these experiments it will be seen that when the litharge is not reduced completely, there remains a notable proportion of silver in the scoriæ; but, nevertheless, in order to extract the largest possible quantity, the whole must not be reduced. Indeed, but a twentieth part need only be reduced, because more precious metal is lost in the cupellation of a large quantity of lead than remains in the portion not reduced. The loss of silver in large cupellations is less than that which takes place in an assay, because in the large way the litharge, or the greater part of it, is run off; whilst in an assay the cupel totally absorbs it, so that the latter presents, relatively to the same mass of lead, a very much smaller surface in the large than in the small way: now it can be readily seen that the quantity of silver lost by absorption into the pores of the cupel must be proportioned to its surface, all things being equal.

It has been ascertained by experiment that a cupel absorbs about its own weight of litharge; so that from this fact a cupel of the proper size may be chosen, when the weight of lead to be cupelled is ascertained. It is always better to have the cupel about $\frac{1}{3}$ or $\frac{1}{4}$ as heavy again as the lead to be cupelled.

The various metals found in an alloy, which can be submitted to cupellation, scorify in proportion to their oxidisability. Those most oxidisable scorify with the greatest rapidity, and *vice versâ*; so that those which have the greatest affinity for oxygen accumulate in the first portions of litharge formed, which, by that means becoming less fusible, sometimes lose the property of penetrating the cupel: hence the reason why cupellations always present more difficulties at the commencement of the operation than towards the end, when the litharge formed is nearly pure oxide of lead, and which can contain only oxide of copper.

The appearance of the cupel used in an assay will give indications of the metals the alloy contained. Pure lead colours the cupel straw-yellow, verging on lemon-yellow. Bismuth, straw-yellow passing into orange-yellow. Copper gives a grey, dirty red, or brown, according to its proportion. Iron gives black scoriæ, which form at the commencement of the operation, and are generally found at the circumference of the cupel. Tin gives a grey slag. Zinc leaves a yellowish ring on the cupel, producing a very luminous flame, and occasioning losses by carrying in its vapour silver, and by projecting it from the cupel in its ebullition. Antimony and sulphate of lead in excess give litharge-yellow scoriæ, which crack the cupel; but, when not produced in too great a proportion, are gradually absorbed by the litharge. If the lead alloy submitted to cupellation is found to produce this effect, a fresh portion must be mixed with its own weight of lead and scorified: the button so obtained can now be cupelled.

Amalgamation.—There are a certain number of argentiferous matters which can be assayed by amalgamation, as they are treated in the large way by that method. Amongst these are native silver chlorides, sulphurets, and arsenio-sulphurets, which contain neither lead nor copper.

But this process is seldom had recourse to, because it is long, troublesome, and less exact than those just described.

Substances of the Second Class.

Native Silver.
Alloys of Copper and Silver.
Alloys of other metals and Silver (artificial).
Antimoniuret of Silver.
Arseniuret of Silver.
Telluret of Silver.
Auriferous Telluret of Silver (see Gold).
Hydrarguret of Silver (Amalgam).
Aururet of Silver (see Gold).

Native Silver, Virgin Silver (Ag).—Native silver is nearly as white and as brilliant as manufactured silver, but it is not so flexible or malleable; the foreign metals with which it is combined rendering it harder and more brittle. Gold, copper, arsenic, and iron, are its most constant associates.

Native silver is usually found in twisted filaments, the size varying from an inch and upwards in thickness to the fineness of hair. At other times it is found in branches made up of a multitude of small octahedral crystals, which seem to have been deposited on the supporting gangue or matrix. In other samples the metal occurs in the form of fern leaves, also made up of more or less perfect octahedral crystals. Sometimes the metal appears to have infiltrated, and sometimes it is disseminated in its gangues, which are exceedingly variable; such as quartz, carbonate of lime, fluor spar, sulphate of baryta, and many other stony and earthy matters. It is more rarely found in grains, or in isolated cubical crystals.

The following is an analysis of native silver:—

Silver	93·00
Copper	2·13
Lead	1·60
Arsenic	1·40
Zinc	1·00
Iron	·50
Antimony	trace—99·63

Alloys of Silver (*Standard Silver*).—Every 12 ounces troy of standard silver is composed of 11 ounces 2 pennyweights of fine silver, and 18 pennyweights of copper. Many other alloys of silver and copper, as well as of other metals with silver, occur as commercial products. Their mode of assay, as well as that of standard silver, will be fully treated.

Antimoniuret of Silver.—There are two varieties of this mineral; the formula of one is Ag_2Sb—of the other, Ag_3Sb. The mineral (Ag_2Sb) is a silver-white metallic-looking substance, crystallising in rectangular prisms. Composition:—

Silver	77
Antimony	23—100

Composition of the mineral Ag_3Sb:—

Silver	86
Antimony	16—100

Arseniuret of Silver.—This mineral is tin-white and lamellar. It is brittle, and crystallises in prisms. Composition:—

Silver	12·75
Arsenic	35·00
Iron	44·35
Antimony	4·00—96·10

Telluret of Silver (AgTe).—Colour between lead-grey and steel-grey; it is malleable. It occurs in large prisms, and has a metallic appearance. Composition:—

Silver	62·42
Tellurium	36·92
Iron	·24—99·58

Hydrarguret of Silver, Amalgam (Hg_2Ag) is a silver-white solid metallic-looking substance: crystallises in rhomboidal dodecahedrons.

Composition:—

Silver	36
Mercury	64—100

General Remarks on the Assay of the Alloys of Silver and Copper.—The assay of these alloys is nearly always accomplished (at least in England) by cupellation. This assay is most important, as it is by the results obtained in the manner hereafter described that the price or value of all kinds of silver bullion is determined.

This class of cupellation is effected without difficulty, because the oxide of copper forms so slowly, that the litharge is always enabled to pass it into the body of the cupel. After having weighed the lead and placed it in the cupel, as soon as it is perfectly fused place in it the alloy to be assayed, wrapped either in blotting-paper or thin leaf-lead. It is essential, in this class of assay, to employ a sufficient quantity of lead to carry away all the copper. We may always be sure of succeeding, whatever the alloy may be, by employing the maximum proportion of lead, that is to say, the quantity necessary to pass pure copper; but as the loss which the silver undergoes increases with the length of the operation and with the mass of the oxidised matters, it is indispensable to reduce this loss as much as possible by reducing the proportion of lead to that which is strictly necessary. Long experience has proved that silver opposes the oxidation of copper by its affinity, so that it is necessary to add a larger amount of lead in proportion to the quantity of silver present.

M. D'Arcet has obtained the following results by the most accurate experiments:—

Standard of silver.	Quantity of copper alloyed.	Quantity of lead necessary.	Relation of lead to copper.
1000	0	$\frac{3}{10}$ths	
950	50	3	60 to 1
900	100	7	70 — 1
800	200	10	50 — 1
700	300	12	40 — 1
600	400	14	35 — 1
500	500	16 to 17	32 — 1
400	600	16 — 17	27 — 1
300	700	16 — 17	23 — 1
200	800	16 — 17	20 — 1
100	900	16 — 17	18 — 1
pure copper	1000	16 — 17	16 — 1

It is remarkable that below the standard of 500, the same proportion of lead must be employed, whatever that of copper. This fact is repeatedly verified by experiment. Whenever fine silver is fused in a cupel, it is always necessary to add lead, in order to cause the button to unite and form well. If less than $\frac{3}{10}$ths of lead be employed, the button will be badly formed; the litharge cannot separate but by the action of a very strong heat, and a considerable loss of silver ensues. If, on the contrary, $\frac{3}{10}$ths of lead is exceeded, the cupellation goes on well, but the loss is greater, on account of the duration of the process. These proportions also ought to vary with the temperature. M. Chaudet has found, that to cupel an alloy containing $\frac{900}{1000}$ths of silver, 5 parts of lead are required in the middle of the muffle, 10 in the front, and only 3 at the back.

The proportion of copper carried off by litharge varies not only with the temperature, but even for the same temperature in relation to the amount of copper and lead the alloy contains. By cupelling 100 parts of copper with different proportions of lead in the same furnace, M. Karsten obtained the following results:—

Lead added.	Copper remaining after cupellation.	Quantity of lead consumed in carrying off 1 of copper.
100	78·75	3
200	70·12	7·1
300	60 12	7·7
400	49·40	7·9
500	38·75	8·1
600	26·25	8·15
700	19·75	8·00
800	8·75	8·70
900	5·62	9·50
1000	1·25	10·10
1050	0·00	10·50

From which we see that the lead carried away from $\frac{1}{15}$th to $\frac{1}{10}$th of its weight of copper. Much less lead can be employed in a cupellation by making the alloy maintain its richness of copper throughout the operation. This can be accomplished by adding to the alloy in the cupel small doses of lead, in proportion as that first added disappears by oxidation. If, for example, an alloy composed of 4 parts of copper and 1 of silver be fused with 10 of lead, by adding successive small doses of the latter, as already pointed out, but 7 parts will be consumed, although in the regular way from 16 to 17 would be employed.

The proportion of oxide of copper contained in the litharge increases each instant, and goes on incessantly increasing when an alloy of copper and lead is cupelled which contains an excess of copper. According to M. Karsten, this proportion is always about 13 per cent. at the commencement, and 36, or more than a third, at the end of the operation.

In the assay of the coined alloys of copper and silver, the loss of silver may even amount to five thousandths; but the loss is variable, and is proportionally greater as the standard of the alloy is lower.

The following Table contains the results of many experiments made on this subject:—

Exact standard.	Standard found by cupellation.	Loss, or the quantity of fine metal to be added to the standard as obtained by cupellation.
1000	998·97	1·03
975	973·24	1·76
950	947·50	2·50
925	921·75	3·25
900	896·00	4·00
875	870·93	4·07
850	845·85	4·13
825	820·78	4·22
800	795·70	4·30
775	770·59	4·41
750	745·38	4·52
725	720·36	4·64
700	695·25	4·75
675	670·27	4·73
650	645·29	4·71
625	620·30	4·70
600	595·32	4·68
575	570·32	4·68
550	545·32	4·68
525	520·32	4·68
500	495·32	4·68
475	470·50	4·50
450	445·69	4·31
425	420·87	4·13
400	396·05	3·95
375	371·39	3·61
350	346·73	3·27
325	322·06	2·94
300	297·40	2·60
275	272·42	2·58
250	247·44	2·56
225	222·45	2·55
200	197·47	2·55
175	173·88	2·12
150	148·30	1·70
125	123·71	1·29
100	99·12	0·88
75	74·34	0·66
50	49·56	0·44
25	24·78	0·22

These numbers, however, are not constant, and vary with the circumstances under which the assays are made: two assays made from the same ingot, by the same assayer, can differ as much as four or five thousandths. Tillet has remarked that the cupels can retain double as much silver as is lost; which proves, as has already been mentioned, that the silver obtained by cupellation is not perfectly pure, but may retain as much as 1 per cent. of lead.

Special Instructions for the Assay of the Alloys of Silver and Copper.

As before stated, peculiar weights are employed in the assay of silver bullion; and the silver assay pound, with its divisions, will be found described at page 74.

In the "General Remarks on the Assay of the Alloys of Silver and Copper," it will be seen that the alloy must be cupelled with a quantity of lead, varying with the amount of copper present in the alloy. Standard silver cupels very well with five times its weight of lead; but when the approximative quantity of alloy present is not known, it must be determined by a preliminary assay.

Assay for Approximative Quantity of Alloy.—Weigh off 50 grains of pure or test lead; place them in a cupel previously made red hot; when the lead is fused, and its surface covered with oxide, place in it by means of the light tongs (*a*, fig. 194) 2 grains of the alloy under assay, wrapped in a small piece of thin paper. Allow the cupellation to go on according to the instructions, and with all the precautions already given, and when complete, weigh the resulting button, and, according to its weight, add lead in the actual assay in the quantity that is sufficient, as exhibited in the Table at page 376.

Assay Proper of Silver Bullion.—In this assay the operator requires silver known to be standard, and pure lead. With the possession of the above substances the assay is thus proceeded with:—Place the 12 grains weight, = 1 lb., in the scale pan, and exactly counterbalance it with standard silver. This is to serve as a check. Remove the weight, and in its place add so much of the alloy to be assayed that the balance is again equal. In one cupel, that destined to receive the check sample, place 60 grains of lead; and in another cupel place such a number of grains of lead as may be found necessary by the preliminary assay. When the lead in both cupels is fused, add the silver alloy, and cupel with the necessary precautions. When the buttons in the cupels are cold, seize them with the pliers, and if necessary cleanse them with a hard brush, and place one in each balance pan. If they exactly balance each other, the alloy operated on is standard silver; if, however, it weighs less than the button produced from the check sample by the weight equivalent to 2 pennyweights, then it is 2 pennyweights worse than standard: on the other hand, if it be heavier by the same weight, it is 2 pennyweights better than standard. Silver is also reported as so much fine: thus, standard silver may be reported as 11 ounces 2 pennyweights fine, and so on. In case extreme accuracy be required, correction must be made according to the standard as shown by the Table at page 378. The standard silver in England is $\frac{975}{1000}$ fine.

Assay of Alloys of Copper and Silver.—In the treatment on the large scale of copper ores containing silver, the contained silver is found alloyed with the copper, and it often falls under the assayer's province to determine the quantity of precious metal. An assay of this kind is most conveniently accomplished by scorification before cupellation, thus:—Prepare four scorifiers; weigh into each of them 50 grains of the alloy, 50 grains of fused borax, and 600 grains of lead, and proceed as already described under the head "Assay of Ores of the First Class by Scorification." When the four buttons of lead are obtained, place them together in another scorifier, and submit to the furnace until the contents of the scorifier are completely covered with oxide; pour as usual, and cupel the resulting mass of lead.

Alloys of Platinum and Silver.—If any substance containing platinum as well as silver were assayed as already described, the button resulting from the cupellation would, in addition to the silver, contain the whole of the platinum. In such a case the button so obtained must be thus treated:—

If the alloy contain much platinum, it must be fused with twice its weight of silver; then treated with hot nitric acid; evaporate the solution nearly to dryness; add water and hydrochloric acid, until no further precipitation of silver as a white curdy precipitate (chloride of silver) takes place. The chloride of silver may be collected either on a filter or by decantation. The solution containing the platinum is treated with excess of sal-ammoniac solution until no further precipitation takes place; the solution evaporated to dryness. When cold, dilute alcohol is added; and the insoluble yellow matter (ammonio-chloride of platinum) collected on a filter, washed with alcohol, dried, and ignited. The ignited residue is metallic platinum, which is weighed. The loss of weight which the alloy from cupel has sustained represents the amount of silver previously alloyed with it.

Alloy of Platinum, Silver, and Copper.—Treat such an alloy as above; and the liquid, filtered from the ammonio-chloride of platinum, will contain the copper. Acidulate it with hydrochloric acid, add metallic zinc, and proceed as directed under the head "Humid Copper Assay."

Native Silver, Rough Silver left on Sieve during Pulverisation of Silver Ores of First Class, and Native Alloys of Silver,—as Antimoniuret, &c.—are treated by scorification and cupellation in precisely the same manner as just described for alloys of copper and silver.

Assay of Silver Bullion by the Wet Method.—From that which has been stated under the head "Cupellation," it will be observed that there are many sources of error; such as volatilization of the precious metal, its oxidation in the presence of excess of oxide of lead and atmospheric oxygen, and lastly, its absorption into the body of the cupel either as oxide or metal, or in both states. These losses, as before stated, vary with the temperature, the amount of lead employed, and the texture of the cupel; and, as may be seen from the table of corrections as drawn up by D'Arcet, give a very erroneous assay, unless the addition necessary for each standard be made.

Considerable attention was called to this matter in France some years since, and a Special Commission was appointed to examine the subject thoroughly, and, if possible, to devise some means of assay which might be both easy and accurate. The result of this examination was the invention of a process of assay at once elegant and trustworthy; and as a full account of this method has not, to the author's knowledge, been translated and published in this country,* he has prepared the present from M. Gay-Lussac's Report, which formed a part of a communication from M. Thiers to Earl Granville, and which appeared in the original language in the year 1837, in a Report on the Royal Mint.

The new process of assay about to be described consists in determining the fineness of silver bullion by the quantity of a standard solution of common salt (NaCl) necessary to fully and exactly precipitate the silver contained in a known weight of alloy. This process is based on the following principles:—

The alloy, previously dissolved in nitric acid (NO_5), is mixed with a standard solution of common salt, which precipitates the silver as chloride, a compound perfectly insoluble in water, and even in acids.

The quantity of chloride of silver precipitated is determined not by its weight, which would be less exact and occupy too much time,

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* Some portion of this report has been published in Dr. Ure's Dictionary of Arts, Mines, and Manufactures.

but by the weight or volume of the standard solution of common salt necessary to exactly precipitate the silver previously dissolved in nitric acid.

The term of complete precipitation of the silver can be readily recognised by the cessation of all cloudiness when the salt solution is gradually poured into that of the nitrate of silver. One milligramme of that metal is readily detected in 150 grammes of liquid; and even a half or a quarter of a milligramme may be detected, if the liquid be perfectly bright before the addition of the salt solution.

By violent agitation during a minute or two, the liquid, rendered milky by the precipitation of chloride of silver, becomes sufficiently bright after a few moments' repose to allow of the effect of the addition of half of a milligramme of silver to be perceptible. Filtration of the liquid is more efficacious than agitation; but the latter, which is much more rapid, generally suffices. The presence of copper, lead, or any other metal, with the exception of mercury (the presence of the latter metal requires a slight modification of the process, which will be hereafter pointed out), in the silver solution, has no sensible influence on the quantity of salt required for precipitation: in other words, the same quantity of silver, pure or alloyed, requires for its precipitation a constant quantity of the standard salt solution.

Supposing that 1 gramme of pure silver be the quantity operated on, the solution of salt required to exactly precipitate the whole of the silver ought to be of such strength that, if it be measured by weight, it shall weigh exactly 100 grammes, or if by measure 100 cubic centimeters. This quantity of salt solution is divided into 1000 parts, called thousandths.

The standard of an alloy of silver is generally the number of thousandths of solution of salt necessary to precipitate the silver contained in a gramme of the alloy.

Measurement of the Solution of Common Salt.—The solution of common salt will hereafter be termed the *normal* solution of common salt. It can be measured by weight or volume. The measure by weight gives greater precision, and it has the special advantage of being independent of temperature; but it requires too much time in numerous assays. The measure by volume gives a sufficient exactitude, and requires much less time than the measure by weight; it is, indeed, liable to the influence of temperature, but tables for correction will be appended.

Measure of the Normal Solution of Salt by Weight.—This solution should be so made that 100 grammes will exactly precipitate 1 gramme of pure silver dissolved in nitric acid. In order to point out the method of taking the weight it must be supposed to have been previously prepared. After taking the weight is described, the mode of preparing the solution will be given.

The solution is weighed in a burette (fig. 240), whose capacity is from 115 to 120 grammes of the solution, and divided into grammes. These divisions are for the purpose of approximatively determining the weight of solution, so as to shorten the operation of weighing. The burette is represented as closed by a cork, *B*, in order to prevent evaporation of the solution when the instrument is not in use. It is also easy to remedy the inconvenience of evaporation, by rinsing the burette with a small quantity of the fresh solution. On pouring the solution from the orifice, *O*, of the burette, each division will furnish from 8 to 10 drops; and consequently the weight of a drop is about a decigramme. The burette is filled with solution to the division *o*; it is then tared in a balance capable of turning with a centigramme. The burette is then removed, and its place supplied with a weight equivalent to the amount of solution required—100 grammes, for instance. The solution is then gradually poured from the burette into a bottle appointed for its reception, until the equilibrium is nearly established. It is not easy to attain the point exactly, as no smaller quantity than a drop can be poured from the burette. This, however, is a matter of indifference; it suffices to know the exact weight of the solution poured out: suppose it to be 99 gr. 85 c.: the mode of more nearly approximating the required weight of 100 grammes will now be pointed out.

FIG. 240.

It must be remarked that it is not the amount of water contained in the 100 grammes that is of consequence, but only the quantity of salt found in solution; this should exactly represent 1000 thousandths of pure silver. If near 100 grammes of the normal solution be mixed with 900 grammes of water, it is evident that 1 gramme of this new solution is equivalent to a decigramme of the first, and consequently it will be easy to obtain 100 grammes of the normal solution, or rather the 1000 thousandths of salt it ought to contain: it will now be sufficient to add to the 99

FIG. 241.

grammes already poured from the burette, $1\frac{1}{2}$ gramme of the new solution. It can be weighed, like the normal solution, to a drop nearly, in the burette, (fig. 241,) of such a diameter that each small division represents a decigramme of liquid, and consequently a centigramme of the normal solution; but it is more readily measured by volume, preparing it in the manner to be hereafter pointed out. To avoid all confusion, a solution to be termed a *decime* solution of common salt is one containing the same quantity of salt as the normal solution, in a weight or volume ten times greater.

A *decime* solution of silver is a solution of silver equivalent to the latter, both mutually suffering complete decomposition.

FIG. 242.

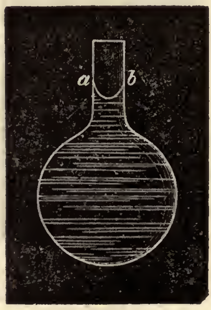
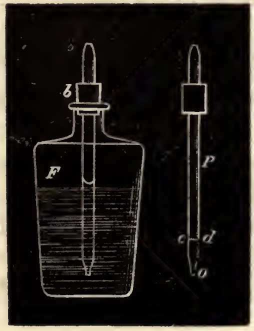


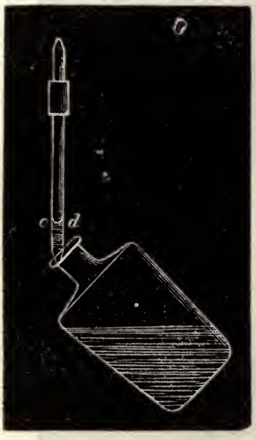
FIG. 243.



Preparation of the Decime Solution of Common Salt.—One hundred grammes of the normal solution of common salt are weighed in a flask (fig. 242) containing a kilogramme of pure water; when filled up to the mark *a b*, or 1000 cubic centimeters, this quantity is made up with pure water, taking care to agitate the whole well, to render the mixture homogeneous. A cubic centimeter of this solution represents 1 thousandth of silver. This quantity is readily obtained by means of a pipette (fig. 243), gauged so that when filled up with water to the mark *c d*, it shall allow 1 gramme, or 1 cubic centimeter, to run freely, the small quantity of liquid remaining in the pipette not forming part of the gramme. In pouring the liquid by drops, a little more or a little less than twenty may be counted, according to the size of the orifice, *o*. This number will not vary more than one drop. Half a cubic centimeter will consequently be represented by 10 drops, and a quarter by 5. The precision arrived at by this method of measurement suffices, since the possible error on the cubic centimeter will be but one-twentieth of that quantity, or one-twentieth of a thousandth; if however many measures be required, then compensation must be made.

The decime solution of common salt requisite for assays must be kept in a bottle (fig. 243) closed by a cork, traversed by the pipette firmly fixed in a hole bored for that purpose. To measure a thousandth with the pipette, the bottle is held with one hand, and the pipette with the other (fig. 244). The pipette is taken from the solution after its upper orifice has been closed by the forefinger; the lower orifice is then inclined against the edge of the flask to remove the liquid, which without this precaution would remain there: the mark *c d* is then raised to the level of the eye, and by a suitable pressure of the forefinger on the upper orifice, which may be obtained by giving the pipette a slight alternating circular movement between the fingers, the solution is allowed to run out gradually. The instant the concave surface of the liquid is at the level *c d*, the pipette is firmly closed by pressure of the forefinger on its orifice, which is held above the bottle into which the solution is to be poured, and the forefinger removed so that it can be emptied. It is here necessary to remark, that in order to regulate the slow and regular runnings of the liquid from the pipette, by the pressure of the fore-finger, the latter ought to be neither too moist nor too dry: if too dry it will not perfectly close the orifice, even by strong pressure; if too moist, it prevents the entrance of air, and the liquid will not run, or, if it do, it will be irregularly. This observation should not be lost sight of in the use of the large burettes mentioned hereafter.

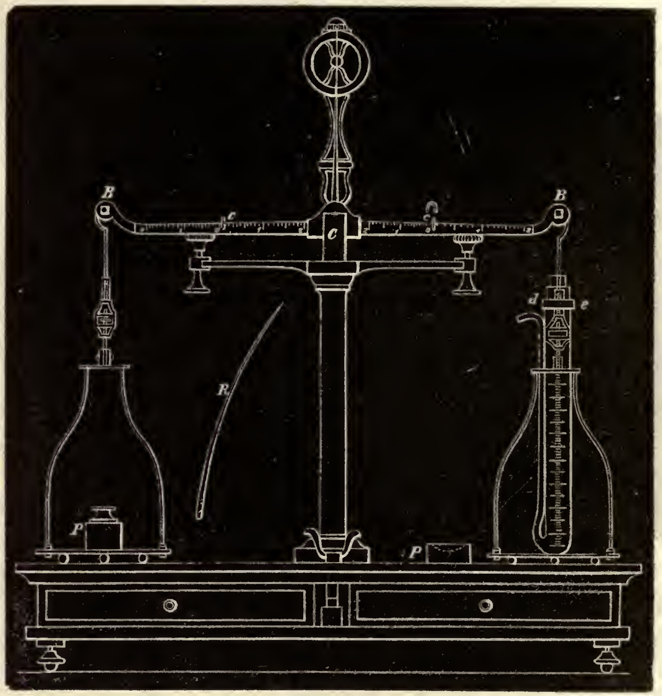
FIG. 244.



Preparation of the Decime Solution of Silver.—The decime solution of silver is prepared by dissolving 1 gramme of pure silver in nitric acid, in a flask holding 1 litre (see fig. 242), and then diluting the solution with distilled water, so that, cooled at the ordinary temperature of the air, it shall occupy exactly the volume of one litre. It is measured in precisely the same manner as the decime salt solution.

Weighing the Normal Solution of Common Salt.—To execute this operation with rapidity, a balance similar to that represented at fig. 245 is employed. The arms are divided, as in the assay balance described at p. 69; each of the arms, *C B* and *C B′*, are furnished with a rider, *c*, of such a weight (about 5 decigrammes) that moved from the right or the left of the centre *o*, of each arm, it indicates two decigrammes. The space traversed by the rider is divided into twenty equal parts, representing an equal number of centigrammes.

Fig. 245.



We will take for example the weighing of 100 grammes of normal solution of common salt, which is that most frequently made in the determination of the standard of all varieties of argentiferous matters.

There are two weights, one *P*, equal to the tare of the burette when full of solution to the mark *o*, the other *P′*, equals 100 grammes. The burette is filled with solution, and placed on the right hand pan of the balance, on which it is kept in position by the collar *d e*, and through which it is passed before placing it on the pan. The tare, *P*, of the burette is supposed to be on the opposite side. If the equilibrium be not perfect, it is effected by the rider on the left; the burette is then removed, and 100 grammes of the solution (either more or less to one or two decigrammes) poured out. The burette is then again placed in the balance, with the 100 gramme weight *P′*, the upper part of which is slightly concave, to receive the bottom of the burette, in order to prevent it sliding off. The equilibrium is again established by the aid of the rider on the right. If, for instance, it is found necessary to remove the rider 15 divisions towards *B*, which represents 15 centigrammes, the weight of the solution poured out of the burette will be equal to 100 gr. 00—0 gr. 15 =99 gr. 85. If, on the other hand, it is necessary to move the rider six divisions towards *C*, the weight of the solution will be 100 gr. 0+0 gr. 06=100 gr. 06.

The above method of weighing the salt solution appears to be the most convenient that can be employed, although it is not very expeditious. Other methods of weighing and measuring will be given in an appendix to this article.

Preparation of the Normal Solution of Common Salt when measured by weight.—After having pointed out the method of weighing the normal solution of salt, and of taking very small quantities, its preparation will be described.

Supposing the salt as well as the water to be employed are pure, the two substances have only to be taken in the following proportions:—0·5427 kilogrammes of salt, and 99·4573 kilogrammes of water, to from 100 kilogrammes of solution, of which 100 grammes will exactly precipitate 1 gramme of silver. But instead of pure salt, which is difficult to procure, and which besides rapidly alters by the absorption of atmospheric moisture, it is preferable to employ a concentrated solution of commercial salt, which can be prepared in large quantities, and kept for use as needed. The quantity of salt it contains can be ascertained by evaporating a portion to dryness, and by a few experiments it is easy to determine in what proportion it shall be mixed with water to produce a solution, 100 grammes of which shall exactly precipitate 1 gramme of silver.

Suppose, for example, that the salt solution contains 250 grammes of salt per kilogramme, and that it is necessary to prepare 100 kilogrammes of the normal solution. Now, since for the preparation of this quantity 0·5427 kilogrammes of pure salt is required, we have the following proportion:—

$$0{\cdot}250 : 1 :: 0{\cdot}5427 : x = 2{\cdot}1708 \text{ kilogs.}$$

To this last weight enough water is added to make up 100 kilogrammes, that is to say 97·8292 kilogrammes, which quantity can be readily measured by means of a flask containing 5 or 6 kilogrammes previously gauged.

The mixture must be well agitated by means of the agitator fig. 246), which is made of an ozier twig, split into four branches, to the extremities of which is attached a small square piece of silk. This substance is employed to avoid the separation of filaments which would ensue from the use of any other material. This agitator can be introduced into very small openings, and is exceedingly serviceable in agitating large masses of liquid.

FIG. 246.

When well mixed, the solution must be assayed. To effect this, dissolve 1 gramme of silver in nitric acid, sp. gr. 1·290, in a stoppered bottle (fig. 247) holding about 200 grammes of water, tare the burette, fig. 240, filled with the solution, and pour rather more than less into the bottle; in proportion as the salt employed is impure, more than 100 grammes will be required to precipitate 1 gramme of silver. The mixture is at first milky, but, by vigorously shaking the bottle, having its stopper firmly fixed, for about a minute, and then allowing it to remain at rest for a short time, the liquid will become perfectly bright; two drops of the solution must then be poured into it from the burette: if a cloudiness is produced, it is agitated again to brighten it, and two drops more added. This must be continued until the last two drops added give no precipitate. The operation is then terminated, and nothing remains but to state the result.

FIG. 247.

Supposing the total weight of solution poured from the burette is 101·880 grammes, the last two drops must not be reckoned, because they produced no effect; the two preceding drops were necessary, but in part only; that is to say, that the number of drops to be deducted is less than four, and more than two, or rather that it is the mean term, three. Or the weight of a drop can be known exactly by taking that of a dozen: suppose it is equal to 0·082 gramme, three times that number must be deducted, or 0·255 grammes from 101·880 grammes: there will remain 101·625 grammes, representing the quantity of normal solution necessary to precipitate 1 gramme of silver.

The solution is thus found to be too weak; to bring it to its proper standard it is necessary to remove 1·625 grammes of water from the 101·625 grammes of solution, or, what is the same thing, to add to the normal solution a certain quantity of the concentrated solution of common salt, which quantity may be found by the following proportion:—

100 : 1·625 :: 2·1708 kilogrs. of silver solution : $x=0·0353$

After the addition of this quantity of salt to the normal solution, a fresh assay is made, proceeding in precisely the same manner as before; taking care, however, to pour from the burette a weight of solution slightly under 100 grammes, or 1000 decigrammes, for instance 998·4 decigrammes, because it is not possible, in pouring the solution by drops, to arrive at the exact weight, 1000 decigrammes. To ascertain the true standard in the most exact manner possible, a decime solution must be prepared by weighing 100 grammes of the normal solution, and diluting it with pure water, so that it shall occupy one litre: a cubic centimeter of this solution will represent a decigramme of the normal solution. This decime solution will not be rigorously exact, since the normal solution has not been truly standardised; but it is easily perceived that the error thus committed is very small, and that it may be neglected. Nevertheless, as soon as the normal solution is perfectly standardised, it is better to prepare another decime solution.

A decime solution may be immediately obtained by dissolving 0·5427 gramme of pure sea salt in such a quantity of water that the whole shall occupy one litre; yet the first process is preferable.

With the decime solution the assay may be thus continued, remembering that the pipette described at fig. 243 is a cubic centimeter containing 20 drops; that the half therefore is represented by 10 drops, and the fourth by 5.

To the 998·4 decigrammes of normal solution already added, pour one pipette and 12 drops of the decime solution, which will exactly complete the weight of 1000 decigrammes of normal solution. The mixture is agitated to brighten it, and one-thousandth of common salt or one pipette of the decime solution added. If this causes a cloudiness, it is agitated and a second thousandth added. This last should produce no opalescence. The weight of normal solution necessary to exactly precipitate one gramme of silver will be between 1000 and 1001 decigrammes; that is to say, the mean will be equal to 1000½. The standard of the normal solution is then too weak by half a thousandth: to correct this a quantity of concentrated salt solution must be added equal to half a thousandth of that already added (2·1708 + 0·0353 = 2·2061 kilogrammes); that is to say, 1·1 gramme.

A new assay is then made for verification.

When the standard of a solution is very nearly arrived at, it is well to employ filtration to detect the slightest opalescence, at least when sufficient time is not allowed for the liquid to become perfectly bright. The surest method, when the standard is nearly attained, is to place some of the liquid in two test glasses, and pour into one a few drops of the decime solution of common salt, and into the other a corresponding number of drops of the decime solution of nitrate of silver. It may then be determined on which side the opalescence is manifested, and the assay of the normal solution may be continued after the mixture of the liquids in the two glasses, since the two quantities of the decime solutions of common salt and nitrate of silver mutually decompose each other, and do not interfere with the assay. Once the standard of the normal solution being definitely fixed, the sum of the quantities of the concentrated solution of common salt which have been employed, as well as those of the water, must be noted, and in the preparation of a new normal solution the proportions found as above would only have to be mixed to obtain at once a solution having very nearly its true standard.

In determining the standard of the normal solution, suppose that it were always too weak, it would be necessary to add to the solution a certain quantity of common salt; but if the true amount had been exceeded, and it had been found too strong, the solution would have to be precipitated with the decime solution of silver; and knowing the number of cubic centimeters or thousandths of silver which had been necessary to precipitate the excess of common salt, it could be determined what amount of water must be added to reduce the normal solution to standard. For instance, if 2 thousandths of the decime solution of silver had been consumed, 2 thousandths of its weight of water would have to be added to the total amount of solution; that is to say, 0·2 kilogramme or 200 grammes.

Preservation of the Normal Solution of Common Salt.—The most suitable vessel for containing the normal solution of common salt is one of glass, because that cannot affect the standard. Large black glass bottles, termed *carboys,* are found in commerce. These bottles contain from 50 to 60 litres, and are very applicable for this purpose. Fig. 248 represents one of these bottles fixed in a stand formed of a sieve hoop. It is graduated into litres or kilogrammes of water, and a paper scale fixed on its side shows at any time the quantity of contained liquid. It is closed by an hydraulic valve, made of sheet-iron, but the bell or cover is of glass. The detail of this valve is shewn at fig. 249. The air can only enter the bottle by the narrow tube *T*, and cannot pass out by it; consequently, evaporation is not to be feared. The neck of the valve should be about a decimeter deep, into which mercury should be poured, but only to about one-third of its height.

FIG. 248.

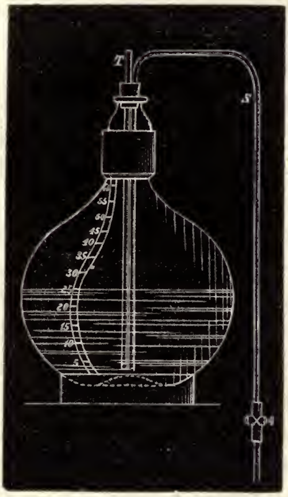
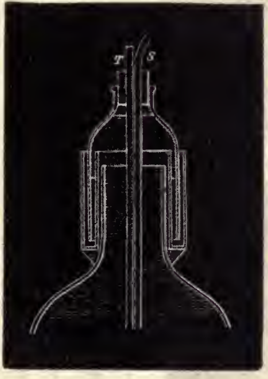
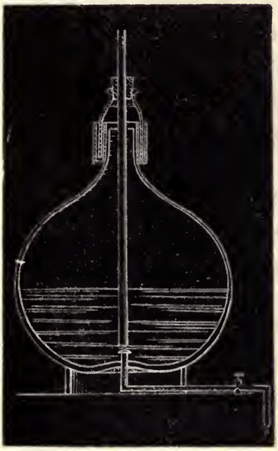


FIG. 249.



The solution is drawn from the bottle by the syphon *S*. This is furnished with a stopcock; but this syphon being brittle, at least when not of metal, is not convenient in use, since it is incorporated with the bell of the valve: it is, therefore, preferable to pierce the bottom of the bottle (fig. 250), and fix a metal tube (*T*) by means of a plate moulded on the bottom, and cemented to it. This tube is raised a little above the bottom of the bottle, and covered by a small hood, the object of which is to protect it from any of the mercury which might fall into it. It is terminated at its other extremity by a very narrow tube, so that the flow of the solution may not be too rapid. Hereafter a metal reservoir will be described

FIG. 250.



which has all the advantages of a glass vessel without its inconveniences.

Application of the Process described in the Determination of the Standard of a Silver Alloy.—The alloy is supposed to be that made into coin, the mean standard of which is fixed at 900 thousandths, but which may vary from 897 to 903 thousandths without ceasing to be legal (French standard for coin). One gramme is dissolved in the bottle (fig. 247) by about 10 grammes of nitric acid, sp. gr. 1·290. This quantity of nitric acid can be readily taken by means of the pipette *P* (fig. 251), which contains 7·7 grammes of water to the mark *a b*. The solution may be accelerated by placing the bottle in a small saucepan of hot water, the bottom of which must be covered with a piece of cloth, so as to prevent contact of the glass and metal. The solution finished, and the flask slightly cooled, the nitrous vapour must be removed by a blower (see fig. 252), the nozzle of which is formed of a piece of bent glass tube, connected by a cork with a copper socket *D*, having a screw inside. This operation ought to be effected, as well as the solution of the alloy in nitric acid, under a chimney with a strong current of air, to carry off the nitrous vapour.

FIG. 251.

FIG. 252.

The burette (fig. 240), being filled with the normal solution of common salt, and tared, about 90 grammes are poured into the solution of the alloy; say 89·85 grammes. After agitating the liquor, a cubic centimeter of the decime solution of common salt is added, representing one thousandth of silver. If a cloudiness be observed, agitate again, and add a second thousandth of common salt, and so on until the last thousandth gives no precipitate. Suppose it to be the fourth: that must not be counted, because it has produced no effect; and only half of the third must be taken, because only a portion of that was necessary. The standard of the alloy would be consequently equal to nearly half a thousandth, to $898·5+2·5=901$.

If it be desirable to approach still nearer to the true standard of the alloy, half-thousandths must be added until the last half thousandth gives no precipitate; and in order to avoid all confusion it is better to write with chalk on a black board the thousandths of common salt, preceding them by the plus sign +, and on the other side the thousandths of nitrate of silver, preceding them by the sign — minus.

In the above example, after the addition of the 4 thousandths of common salt, the last of which has produced no cloudiness, 1½ thousandths of nitrate of silver are added, which destroy 1½ thousandths of common salt, and brighten the liquid. If another half thousandth of nitrate of silver produce no precipitate, it is not taken into account, and is struck off from the table. From whence is concluded that the quantity of nitrate of silver necessary to destroy the excess of common salt is more than 1 and less than 1½; that is to say, nearly the ¼ of a thousandth, and is equal to 1¼. Thus the number of thousandths of salt really used is $4-1{\cdot}25=2{\cdot}75$. The standard of the alloy, therefore, is $898{\cdot}50+2{\cdot}75=901{\cdot}25$.

Another example, everything else remaining as above; but the first thousandth of salt did not precipitate. This is a proof that too much normal solution of common salt has been employed, and that there is an excess of salt in the liquid. Add one thousandth of silver, and agitate: things are now as at first, but it is nevertheless known that it is with nitrate of silver the process must be continued. One thousandth has been added, which produced a precipitate; the second does not. The standard of the alloy is consequently $898{\cdot}50-0{\cdot}5=898$. To approach still nearer to the real standard, destroy the last two thousandths of silver by two thousandths of common salt, and add half a thousandth of silver—a cloudiness is produced, as already known; but another half thousandth does not precipitate. The standard of the alloy is therefore $898{\cdot}50-0{\cdot}25=898{\cdot}25$.

This process, on which it would be useless to enlarge further at present, because many other parts of the process to be presently described apply to it, is general, and gives exactly the standard of an alloy when it is known approximatively, which can always be ascertained by a previous rough assay.

ASSAY BY THE HUMID METHOD, MEASURING THE NORMAL SOLUTION OF COMMON SALT BY VOLUME.

The measurement by weight of the normal solution of common salt has, as already stated, the advantage of being independent of temperature, of having the same degree of precision as the balance, and of requiring no correction. The measurement by volume has not all these advantages; but, by ensuring an adequate amount of accuracy, it has that of being more rapid, and renders the new process applicable to numerous and daily assays.

The normal solution of common salt measured by volume is so prepared that it has a volume equal to that of 100 grammes of water, or 100 cubic centimeters, and at a determinate temperature exactly precipitates 1 gramme of silver. The solution can be kept at a constant temperature, in which case the assay requires no correction; or, if the temperature be variable, its influence on the assay must be corrected. These two circumstances do not change the principle of the process; but they are sufficiently important to require some changes in the apparatus, and that each of the two processes should be treated separately: one, in which the normal temperature is constantly maintained; the other, in which it is variable. Experience has shewn the latter to be preferable, and it will be first detailed; the other will be described hereafter.

Methods of Measurement in the employment of Volumes instead of Weights.—It will be here admitted, in pointing out the methods of measuring the normal solution of common salt by volume, that it has been already prepared, and even, that it is kept at a constant temperature. It will afterwards be very easy to describe the method of preparation, and give the corrections of which it is susceptible when its temperature varies.

A volume of solution of 100 cubic centimeters is readily obtained by means of a pipette (fig. 253), graduated so that, filled with water to the mark *a b*, and the point or jet well wiped, it will allow 100 grammes of water, at a temperature of 15° (Centigrade), to flow in a continuous stream. A continuous stream is expressly mentioned, because sometimes after the cessation of the jet the pipette will yet give two or three drops of liquid, which must not be counted. The weight of the volume of normal solution taken in this manner with suitable precautions will be constant, from one extreme to another, to $2\frac{1}{2}$ centigrammes, or rather to $\frac{1}{4}$th of a thousandth.

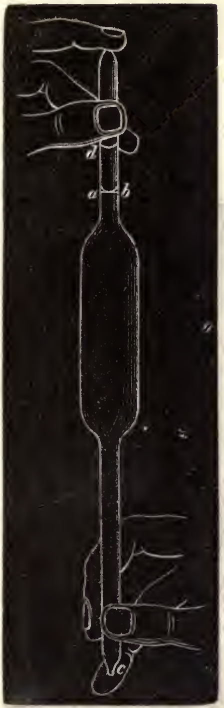
The following is the most simple method of taking a measure of the normal solution of salt:—

Immerse the jet (*c*) of the pipette in the solution, apply the mouth to the upper orifice, and draw the

FIG. 253.

liquid into *d*, above the circular mark *a b*. Dexterously apply the forefinger of one of the hands to this orifice, remove the pipette from the liquid, and hold it as represented at fig. 254. The mark *a b* is held on a level with the eye, and the surface of the solution allowed to descend until it forms a tangent with the plane *a b*. At this instant the jet (*c*) of the pipette is set at liberty by removing the finger against which it had been pressed, and, without otherwise changing the position of the hands, the contents are allowed to run into the bottle appropriated for that purpose, taking care to remove the pipette as soon as the stream stops.

FIG. 254.



If, after having filled the pipette by aspiration, there is any difficulty found in a sufficiently rapid application of the forefinger to the superior orifice to prevent the fall of the liquid below the mark *a b*, the pipette must be removed from the liquid, the orifice being closed by pressing the tongue against it: then apply the middle finger of one of the hands to the lower orifice, remove the tongue, and apply the forefinger of the other hand to the larger orifice, previously wiped dry.

The process just described for obtaining a measure of normal solution of salt is exceedingly simple, because it requires but little apparatus; but another, of more easy execution, will now be mentioned, and which is at the same time more exact.

In this process the pipette is filled from above, like a bottle, instead of by aspiration; furthermore, it is a fixed apparatus. The figure 255 represents this apparatus. *D D′* are two sockets, separated by a stopcock *R*. The upper one, which is screwed inside, is connected by means of a cork, *L*, with the tube *T*, which conducts the solution of salt. The lower socket is cemented to the pipette; it is furnished with an air-tap *R′*, and a screw *V*, which serves to regulate the admission of air into the pipette by a small opening provided for that purpose. Below the stopcock *R′*, and soldered to the socket, is a very narrow silver tube *N*, conducting the solution into the pipette, and allowing the escape of displaced air by the air-tap *R′*.

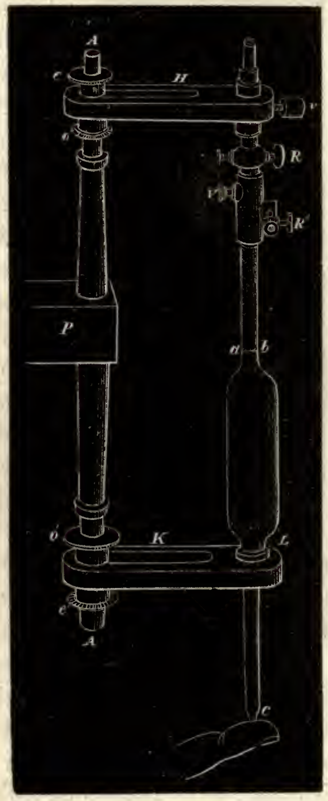
The thumbscrew V' replaces the ordinary screw, by means of which the key of the cork is adjusted on its seat.

The figure 256 represents the above-described apparatus on the other side. There will in this be noticed on the air-cork R', an opening m, into which is ground by its extremity Q the conical tube T (same figure). By this, air can be drawn out of the pipette whenever it is desirable to fill it from below.

FIG. 255.

FIG. 256.

FIG. 257.



The pipette is carried by two horizontal arms, *H K*, fig. 257. These arms are moveable around a common axis *A A*, and are also capable of moving in the two longitudinal slots.

They are fixed by two nuts, *e e'*, and their distance can be changed by means of pieces of wood or cork interposed, or even by the other nuts, *o o'*. In the upper arm, *H*, is a hole, in which is fixed by a wooden thumb-screw, *v*, the socket of the pipette; the corresponding hole of the lower arm is larger; the jet of the pipette is kept in position by a cork, *L*. The apparatus is fixed by its appendage, *P*, by means of a screw on an angle of the wall, or any other support.

The method of filling this pipette is very simple: apply the forefinger of the left hand to the orifice, *c*, then open the two stopcocks, *R*, and *R′*; when the liquid nears the neck of the pipette its flow is moderated, and as soon as it is a little above the mark *a b*, the stopcocks are shut, and the forefinger removed. The pipette must now be accurately adjusted, so that the liquid touches the mark *a b*, and none remains on the outside of the jet *c*.

This last condition is easily fulfilled: after having removed the finger by which the orifice *c* of the pipette was closed, a moist sponge, *m*, fig. 258, enveloped in linen, is then applied, which absorbs the excess of liquid. To abridge the description, this sponge will be termed "the handkerchief," and the pipette is said to be clean when no liquid adheres exteriorly to the orifice.

FIG. 258.

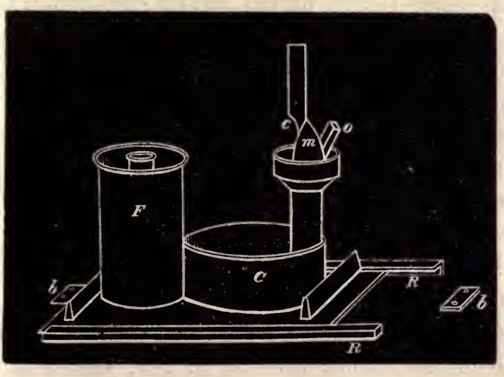
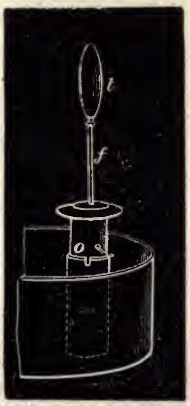


FIG. 259.



For convenience in use the handkerchief is forced into a tube of tin-plate, terminated by a little cup, open below, so that the liquid may run into the vessel *C*, on which the tube is soldered: the liquid from the handkerchief is rejected: it can be easily removed to wash it, and if necessary it can be pushed towards the pipette by a small wedge of wood, *o*.

At a later period the following mode of making the handkerchief has been found preferable: on a double iron wire (fig. 259) forming a spring, a small band of tin-plate *t*, is rolled; the iron wire is cemented into a tin-plate cylinder, closed on the lower end, and furnished on the upper with a border to convey the liquid which runs from the handkerchief in the vessel *C*. This cylinder passes into another soldered to the bottom of the vessel, and can be kept in position by two projections, *o*, which work in two slots cut in the other cylinder.

To complete the adjustment of the pipette, the liquid must be made to fall to the level *a b*. To this end, whilst the handkerchief is in contact with the jet of the pipette, air is allowed to enter slowly by unscrewing the screw *v*, (fig. 257) and the instant the level is attained the handkerchief is removed, and the bottle *F*, (fig. 258,) which is employed to receive the solution placed under the jet of the pipette. This must be accomplished rapidly, and without hesitation. The bottle is then placed in a cylinder of tin-plate, whose diameter is just a little larger, and which forms part and parcel of the vessel *C*, and the handkerchief. The whole of this apparatus has a sheet of tin-plate for a base, moveable between two wooden rods, *R R*, each having a slot in which the tin-plate moves. The extent of its movements is determined by two pieces of wood, *b b*, so placed that when it is stopped by one of them, the jet of the pipette corresponds to the centre of the neck of the bottle, or by the other in contact with the handkerchief. This arrangement is exceedingly handy for wiping and emptying the pipette, and has a sufficient amount of solidity to allow of its being removed and replaced without injury. It will be readily seen that when the admission of air into the pipette has been once regulated by the screw *v*, it will be advantageous to leave it so, because the movement of the handkerchief or bottle can be so rapidly effected, that a drop of the liquid has not time to accumulate and fall.

Temperature of the Solution.—Having described the method of measuring the volume of the normal solution of salt, that which appears the most suitable method of obtaining the temperature will be pointed out.

The thermometer is placed in a glass tube, *T* (fig. 260), through which the solution passes, running into the pipette. It is suspended by a cork having four channels cut in it to allow the free passage of the liquid. The scale is engraved on the tube itself, and is repeated on the opposite side, so as to fix the eye by this double scale to the height of the thermometric column. The tube is fused at its lower end to a narrower tube, which is fixed by means of a cork into the socket of the stopcock of the pipette. The upper part of this tube is cemented to a socket of copper, tapped inside, which in its turn is fastened by a cock *B*, with the extremity (also tapped) of the tube *T′*, communicating with the reservoir of normal solution. The corks used as joints between the parts of the apparatus retain a certain amount of flexibility, and allow it being taken to pieces and put together again in a short space of time; but it is essential to pass them into a hollow tube of glass or metal, to prevent them giving way under the pressure they have to sustain. If care be taken to coat them with a little tallow to stop the pores, no escape need be apprehended.

FIG. 260.

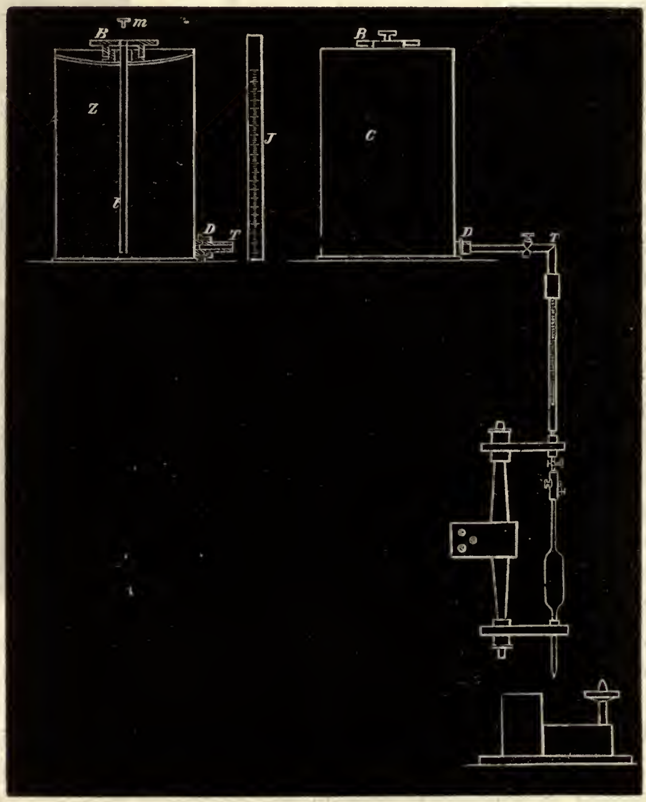
Preservation of the Normal Solution of Salt in Metallic Vessels.—This subject has already been discussed, and it may appear unnecessary to again refer to it; but as it is here a question of metallic vessels, some details seem necessary.

The figure 261 represents a cylindrical copper vessel, *C*, holding about 110 litres. It is seen in section, *Z*, same figure. To its base is soldered a socket, *D*, to which is adapted a tube, with stopcock, *T*, through which the solution passes into the pipette; the upper part, which is slightly concave, having an opening closed by a screw stopper, *B*, the edges of which press on a washer. This stopper is traversed by the tube *t*, which passes nearly to the bottom of the vessel, and through which air enters the apparatus, without the power of again passing out, so that evaporation is effectually prevented. This tube can be closed by a stopper, *m*, when the apparatus is not in use.

The quantity of liquid contained in the vessel can be determined at any time by the aid of a wooden gauge, *J*, graduated into litres. When used it is plunged vertically into the liquid, but is seldom needed.

Pure or tinned copper alters in contact with the solution of salt and air, and the solution continually decreases in strength. This inconvenience is remedied by coating the inside of the cylinder with a soft cement, such as described at page 103; or with that cement softened by the addition of one-third its weight of yellow wax. This operation may be performed by removing the tubes *T* and *t*, perfectly cleansing the inside of the cylinder, and heating it. About four or five pounds of the cement, made very hot, are run in, and the cylinder so turned round and inverted that the cement may run over every part. The turning is continued until the cement is cold. All the parts just described are united in the figure 261, forming a complete apparatus for the preservation of the normal solution of salt, for observing the temperature, and for measuring the volume.

Fig. 261.



Preparation of the Normal Solution of Salt, measuring by Volume.—The preparation of the normal solution of salt, measured by volume, is much the same as of the solution measured by weight; there is, consequently, very little to add to that already given at pages 387-390, and to which the reader is referred.

The cylinder, as already supposed, will contain about 110 kilogrammes of water: no more, however, than 105 are put in; so that sufficient space may remain in order to agitate the fluid without throwing any out. According to the condition imposed, that 100 cubic centimeters, or one-tenth of a litre, of solution, should contain sufficient salt to completely precipitate 1 gramme of pure silver; and further, admitting 13·516 for the equivalent of silver, and 7·335 for that of salt, the quantity of pure salt to be dissolved in 105 litres of water, and which corresponds to 105 × 10 = 1050 grammes of silver, will be found by the following equation:—

$$13{\cdot}516 : 7{\cdot}335 :: 1050 \text{ gram.} : x = 569{\cdot}83 \text{ gram.}$$

And as the solution of commercial salt employed, page 387, contains approximatively 250 grammes per kilogramme, 2279·3 grammes of this solution will be required to furnish 569·83 grammes of salt. As the 2279·3 grammes of solution contain 569·83 grammes of salt, it will consequently contain 1709·5 grammes of water, which must be taken into account in measuring the 105 litres: that is, no more than about 103·3 must be employed. The whole being well mixed, the tubes and pipette must be washed out several times, by allowing the solution to run through them. The solution so passed is again placed in the cylinder, and after each addition the contents are well agitated, and lastly, the standard of the solution is determined, the temperature being supposed to remain constant.

To accomplish this more readily, two decime solutions are prepared; one of silver, and the other of salt.

The decime solution of silver, as already stated, is obtained by dissolving a gramme of silver in nitric acid, and diluting the solution with water until its volume is one litre.

The decime solution of salt can be obtained by dissolving 0·543 grammes of pure salt in water, so that the solution fills a measure of one litre; but it is best prepared with the normal solution itself, which is to be standardised, by mixing one measure of the latter with nine measures of water. It must, however, be understood, that this solution is not rigorously equivalent to that of the silver, and only becomes so when the normal solution employed in its preparation becomes fixed at its true standard. If the normal solution be correct to ten thousandths, or one hundredth, the decime solution will be correct to the same degree. If ten thousandths of the latter solution be employed, the error committed will be one-tenth of a thousandth; and only one hundredth when one thousandth is employed. Such errors may be entirely neglected; nevertheless, after having exactly standardised the normal solution, it is better to prepare a new decime solution.

After the preparation of the decime solutions, several bottles, as at fig 247, must be prepared, each of which contains 1 gramme of pure silver dissolved in 8 or 10 grammes of nitric acid. To these will be given the name of check, or witness-assays.

To ascertain the standard of the normal solution pour a pipetteful into one of the check flasks, and agitate briskly until quite bright. After a few moments' repose, two thousandths of the decime solution of salt are added, which, by superposition, will produce a precipitate. The normal solution is consequently too weak, since the salt employed was not perfectly pure. It is again agitated, and two other thousandths are added, which produce a precipitate. The addition of successive two thousandths is thus continued until the last produce no precipitate. Suppose in all sixteen thousandths have been added: the two last which have been added are not reckoned, as they produced no precipitate: the two preceding have only been in part necessary; that is to say, that the acting thousandths added are above 12 and below 14, or, taking the mean, equal to 13.

Thus in the existing state of the normal solution 1013 parts are necessary to precipitate 1 gramme of silver, while only 1000 should be required. The quantity of concentrated solution of common salt to be added may be found by noting that the quantity of solution of common salt first employed—that is to say, 2279·3 grammes—has only produced a standard of $1000-13=987$ thousandths, and by the following equation:—

$$987 : 2279{\cdot}3 :: 13 : x = 30{\cdot}02 \text{ grammes.}$$

This quantity of solution of common salt must, therefore, be mixed with the normal solution.

After having washed the tubes and pipette with the new solution, another check gramme of silver is operated on. It is found, for instance, by proceeding but by one thousandths at a time, that the first precipitates, but the second does not. The standard of the solution is therefore too weak, being comprised between 1000 and 1001; that is to say, it is equal to 1000½: this, however, is not sufficiently near.

Pour into the assay flask two thousandths of the decime solution of silver: these will merely decompose the two thousandths of salt, and the operation will have retrograded by two thousandths; that is, it will be reduced to the point from which the thousandths were first employed. If, after brightening the liquor, half a thousandth of the decime solution is added, there will necessarily be a precipitate, as was before known; but a second half thousandth produces no cloudiness. The standard of the normal liquid is therefore between 1000 and $1000\frac{1}{2}$, or equal to $1000\frac{1}{4}$.

This for most purposes may be considered sufficiently near; but if it be desirable to correct it, it may be remembered that the two quantities of solution of common salt added,

$$2279{\cdot}3 \text{ gr.} + 30{\cdot}02 \text{ gr.} = 2309{\cdot}32 \text{ gr.}$$

have only produced 999·75 thousandths, and that it is necessary to add a fresh quantity corresponding to the quarter of a thousandth. The proportion is thus found :—

$$999{\cdot}75 : 2309{\cdot}32 :: 0{\cdot}25 : x.$$

But as the first term only slightly differs from 1000, it is necessary, in order to have x, to take $\frac{0{\cdot}25}{1000}$ of 2309·32, and 0·577 gr. will be found the quantity of solution of common salt to be added to the normal solution. It is not handy to exactly take so small a quantity of solution of common salt by means of the balance, but is more readily attained in the following manner :—

Weigh 50 grammes of the solution, and dilute with water until it occupies exactly half a litre, or 500 cubic centimeters. A pipette of this solution, containing a cubic centimeter, will give a decigramme of the primitive solution; and as the pipette is divided into 20 drops, each drop will represent 5 milligrammes of the solution. Still smaller quantities may be determined by still further dilution, but greater precision is useless.

The standardising of the normal solution is much less tedious than may be supposed; and it must be remarked, that the liquid for a thousand assays is prepared at once, and moreover, that in preparing a fresh solution, its true standard may be very nearly obtained at once, if the quantities of water and salt solution previously employed have been noted.

Correction of the Standard of the Normal Solution of Salt when the Temperature varies.—It has been admitted that, in the determination of the standard of the normal solution of salt, the temperature has remained constant. Assays made under these circumstances need no correction; but if the temperature changes, the same measure of solution will not contain the same amount of salt. Supposing the solution of salt has been standardised at 15°. If, at the time an experiment is made, the temperature is 18°, for instance, the solution will be found too weak, since it has become expanded, and the pipette holds less than its weight. If, on the other hand, the temperature falls to 12°, the solution becomes concentrated, and is found too strong. It is therefore necessary to determine the correction to be made for any variation of temperature that may occur.

To this end the temperature of a solution of common salt has been gradually raised from 0....5....10....15....20....25....30 degrees, and three pipettefuls of the solution exactly weighed at each of the above temperatures. One-third of the total weight gives the mean weight of the contents of a pipette. The corresponding weights of a pipetteful of solution are then entered, and form the second column of the following table, called "Table of Correction for the Variations of Temperature in the Normal Solution of Salt." By this table correction may be made for any temperature between 0 and 30 degrees, when the solution of salt has been standardised within the same limits. Suppose, for example, the solution had been standardised at 15°, and that at the time it was used its temperature was 18°. On referring to the second column of the table, it will be seen that the weight of a measure of solution at 15° is 100·099 gr., and at 18°, 100·065 gr.; the difference, 0·034 gr., is the quantity of solution taken too little, and consequently it must be added to the normal measure, so that it may be equal to one thousand thousandths. If the temperature of the solution had fallen to 10°, the difference of weight between a measure at 10° and a measure at 15° will be 0·019 gr., which must, on the contrary, be deducted from the measure, as it has been taken in excess. These differences of weight of a measure of solution at 15° and that of a measure for any other temperature, forms the column 15° in the Table, where they are expressed in thousandths. They are written on the same horizontal line as the temperatures to which each corresponds, with the sign + when they are to be added, and the sign — when to be subtracted. The columns 5°, 10°, 20°, 25°, 30°, have been calculated in the same manner, to meet cases in which the normal solution had been graduated at each of the above-named temperatures. Thus, to calculate the column 10°, take the number 100·118 from the column of weights as a point of departure, and find the difference for all the other numbers in the same column.

An application of this table will be given hereafter.

TABLE OF CORRECTION FOR VARIATIONS IN TEMPERATURE OF THE NORMAL SALT SOLUTION.

Temperature	Weight.	5°	10°	15°	20°	25°	30°
Degrees.	Grammes.	Mill.	Mill.	Mill.	Mill.	Mill.	Mill.
4	100·109	0·0	−0·1	+0·1	+0·7	+1·7	+2·7
5	100·113	0·0	−0·1	+0·1	+0·7	+1·7	+2·8
6	100·115	0·0	0·0	+0·2	+0·8	+1·7	+2·8
7	100·118	+0·1	0·0	+0·2	+0·8	+1·7	+2·8
8	100·120	+0·1	0·0	+0·2	+0·8	+1·8	+2·8
9	100·120	+0·1	0·0	+0·2	+0·8	+1·8	+2·8
10	100·118	+0·1	0·0	+0·2	+0·8	+1·7	+2·8
11	100·116	0·0	0·0	+0·2	+0·8	+1·7	+2·8
12	100·114	0·0	0·0	+0·2	+0·8	+1·7	+2·8
13	100·110	0·0	−0·1	+0·1	+0·7	+1·7	+2·7
14	100·106	−0·1	−0·1	+0·1	+0·7	+1·6	+2·7
15	100·099	−0·1	−0·2	0·0	+0·6	+1·6	+2·6
16	100·090	−0·2	−0·3	−0·1	+0·5	+1·5	+2·5
17	100·078	−0·4	−0·4	−0·2	+0·4	+1·3	+2·4
18	100·065	−0·5	−0·5	−0·3	+0·3	+1·2	+2·3
19	100·053	−0·6	−0·7	−0·5	+0·1	+1·1	+2·2
20	100·039	−0·7	−0·8	−0·6	0·0	+1·0	+2·0
21	100·021	−0·9	−1·0	−0·8	—0·2	+0·8	+1·9
22	100·001	−1·1	−1·2	−1·0	—0·4	+0·6	+1·7
23	99·983	−1·3	−1·4	−1·2	—0·6	+0·4	+1·5
24	99·964	−1·5	−1·5	−1·4	—0·8	+0·2	+1·3
25	99·944	−1·7	−1·7	−1·6	—1·0	0·0	+1·1
26	99·924	−1·9	−1·9	−1·8	—1·2	−0·2	+0·9
27	99·902	−2·1	−2·2	−2·0	—1·4	−0·4	+0·7
28	99·879	−2·3	−2·4	−2·2	—1·6	−0·7	+0·4
29	99·858	−2·6	−2·6	−2·4	—1·8	−0·9	+0·2
30	99·836	−2·8	−2·8	−2·6	—2·0	−1·1	0·0

TABLE FOR THE ASSAY, BY THE WET METHOD, OF AN ALLOY CONTAINING ANY PROPORTIONS WHATEVER OF SILVER, BY THE EMPLOYMENT OF A CONSTANT MEASURE OF THE NORMAL SOLUTION OF COMMON SALT.

The process by which the normal solution of salt is measured by weight is applicable to the assay of every kind of alloy, since it suffices to take a weight of the solution corresponding to the presumed standard of the silver, and complete the assay by means of the decime solution; the process by volume, however, has not the same advantage, because the volume of normal solution cannot be varied in the same manner as the weight. This inconvenience, however, is of no very great consequence, for by keeping the volume of normal solution constant, it suffices to vary the weight of the alloy, taking in each particular case a weight which contains approximatively one gramme of pure silver. Suppose the alloy has a standard of about 900 thousandths, we have the following proportion ·—

$$900 \text{ thousandths} : 1000 \text{ of allloy} :: 1000 \text{ thousandths} : x = 1111{\cdot}1$$

If that weight be now taken to ascertain the standard of the alloy, it may be found, for instance, that to the measure of 1000 thousandths of salt it is yet necessary to add 4 thousandths of salt to precipitate the whole of the silver; that is to say, that 1111·1 of alloy really contain 1004 of silver. From this result the real standard of the alloy may be found to be 903·6, by the following equation :—

$$1111{\cdot}1 : 1004 : 1000 : x = 903{\cdot}6$$

But such calculations, however simple, should be avoided where numerous daily assays are made, not only on account of the time consumed, but still more from the errors to which such operations are necessarily exposed. Fortunately all these inconveniences may be avoided by the use of tables, which entirely free the assayer from calculation.

Wishing in weighing the alloy to avoid fractions of thousandths, and only making use of tenths and half tenths of thousandths, the weight of alloy increases, starting from a gramme, from 5 to 5 thousandths, and the corresponding standard for each of these weights has been sought, all containing one gramme of pure silver. Thus the weight 1020 of alloy, in which there are 1000 of silver and 20 of copper, corresponds to the standard 980·39, obtained by the proportion—

$$1020 : 1000 : 1000 :: x = 980{\cdot}39$$

On this principle are formed the first and second columns of the Table marked Salt. The first contains the weight of each alloy, and the second its corresponding standard. The following columns, 1, 2, 3, to 10, give the standard of the alloy, when, instead of the 1000 milligrammes of silver it was supposed to contain, it really contained 1, 2, 3, &c. more, and consequently 1, 2, 3, &c. milligrammes of copper less.

Another Table, constructed in the same manner as the preceding, and marked Nitrate of Silver, gives the standard of the alloy when, under the weight given in the first column, it contains 1, 2, 3, &c. milligrammes less silver, and as much more copper. Thus, for example, an alloy of the weight of 1020 (1000 silver and 20 copper) has for its standard 980·4, in both tables. If it always contains in the same weight 4 more silver and consequently 4 less copper, its standard would be 984·3, and would be found in the "Salt" Table at the intersection of the column 4, and the horizontal line 1020. If, on the contrary, it contains 4 less of silver, and 4 more of copper, its standard will be 976·5, and will be found in the "Nitrate of Silver" Table, at the intersection of the column 4, and the horizontal line 1020.

Tables for Determining the Standard of any Silver approximatively containing

	NITRATE OF				
Weight of Assay in Milligrs.	0.	1.	2.	3.	4.
1000	1000·0	999·0	998·0	997·0	996·0
1005	995·0	994·0	993·0	992·0	991·0
1010	990·1	989·1	988·1	987·1	986·1
1015	985·2	984·2	983·2	982·3	981·3
1020	980·4	979·4	978·4	977·4	976·5
1025	975·6	974·6	973·7	972·7	971·7
1030	970·9	969·9	968·9	968·0	967·0
1035	966·2	965·2	964·2	963·3	962·3
1040	961·5	960·6	959·6	958·6	957·7
1045	956·9	956·0	955·0	954·1	953·1
1050	952·4	951·4	950·5	949·5	948·6
1055	947·9	946·9	946·0	945·0	944·1
1060	943·4	942·4	941·5	940·6	939·6
1065	939·0	938·0	937·1	936·1	935·2
1070	934·6	933·6	932·7	931·8	930·8
1075	930·2	929·3	928·4	927·4	926·5
1080	925·9	925·0	924·1	923·1	922·2
1085	921·7	920·7	919·8	918·9	918·0
1090	917·4	916·5	915·6	914·7	913·8
1095	913·2	912·3	911·4	910·5	909·6
1100	909·1	908·2	907·3	906·4	905·4
1105	905·0	904·1	903·2	902·3	901·4
1110	900·9	900·0	899·1	898·2	897·3
1115	896·9	896·0	895·1	894·2	893·3
1120	892·9	892·0	891·1	890·2	889·3
1125	888·9	888·0	887·1	886·2	885·3
1130	885·0	884·1	883·2	882·3	881·4
1135	881·1	880·2	879·3	878·4	877·5
1140	877·2	876·3	875·4	874·6	873·7
1145	873·4	872·5	871·6	870·7	869·9
1150	869·6	868·7	867·8	867·0	866·1
1155	865·8	864·9	864·1	863·2	862·3
1160	862·1	861·2	860·3	859·5	858·6
1165	858·4	857·5	856·6	855·8	854·9
1170	854·7	853·8	853·0	852·1	851·3
1175	851·1	850·2	849·4	848·5	847·7
1180	847·5	846·6	845·8	844·9	844·1
1185	843·9	843·0	842·2	841·3	840·5

Alloy by employing an Amount of Alloy always the same Amount of Silver.

SILVER.					
5.	6.	7.	8.	9.	10.
995·0	994·0	993·0	992·0	991·0	990·0
990·0	989·0	988·1	987·1	986·1	985·1
985·1	984·2	983·2	982·2	981·2	980·2
980·3	979·3	978·3	977·3	976·4	975·4
975·5	974·5	973·5	972·5	971·6	970·6
970·7	969·8	968·8	967·8	966·8	965·8
966·0	965·0	964·1	963·1	962·1	961·2
961·3	960·4	959·4	958·4	957·5	956·5
956·7	955·8	954·8	953·8	952·9	951·9
952·1	951·2	950·2	949·3	948·3	947·4
947·6	946·7	945·7	944·8	943·8	942·9
943·1	942·2	941·2	940·3	939·3	938·4
938·7	937·7	936·8	935·8	934·9	934·0
934·3	933·3	932·4	931·4	930·5	929·6
929·9	929·0	928·0	927·1	926·2	925·2
925·6	924·7	923·7	922·8	921·9	920·9
921·3	920·4	919·4	918·5	917·6	916·7
917·0	916·1	915·2	914·3	913·4	912·4
912·8	911·9	911·0	910·1	909·2	908·3
908·7	907·8	906·8	905·9	905·0	904·1
904·5	903·6	902·7	901·8	900·9	900·0
900·4	899·5	898·6	897·7	896·8	895·9
896·4	895·5	894·6	893·7	892·8	891·9
892·4	891·5	890·6	889·7	888·8	887·9
888·4	887·5	886·6	885·7	884·8	883·9
884·4	883·6	882·7	881·8	880·9	880·0
880·5	879·6	878·8	877·9	877·0	876·1
876·7	875·8	874·9	874·0	873·1	872·3
872·8	871·9	871·0	870·2	869·3	868·4
869·0	868·1	867·2	866·4	865·5	864·6
865·2	864·3	863·5	862·6	861·7	860·9
861·5	860·6	859·7	858·9	858·0	857·1
857·8	856·9	856·0	855·2	854·3	853·4
854·1	853·2	852·4	851·5	850·6	849·8
850·4	849·6	848·7	847·9	847·0	846·1
846·8	846·0	845·1	844·3	843·4	842·5
843·2	842·4	841·5	840·7	839·8	839·0
839·7	838·8	838·0	837·1	836·3	835·4

					NITRATE OF
Weight of Assay in Milligrs.	0.	1.	2.	3.	4.
1190	840·3	849·5	838·7	837·8	837·0
1195	836·8	836·0	835·1	834·3	833·5
1200	833·3	832·5	831·7	830·8	830·0
1205	829·9	829·0	828·2	827·4	826·6
1210	826·4	825·6	824·8	824·0	823·1
1215	823·0	822·2	821·4	820·6	819·7
1220	819·7	818·8	818·0	817·2	816·4
1225	816·3	815·5	814·7	813·9	813·1
1230	813·0	812·2	811·4	810·6	809·8
1235	809·7	808·9	808·1	807·3	806·5
1240	806·5	805·6	804·8	804·0	803·2
1245	803·2	802·4	801·6	800·8	800·0
1250	800·0	799·2	798·4	797·6	796·8
1255	796·8	796·0	795·2	794·4	793·6
1260	793·6	792·9	792·1	791·3	790·5
1265	790·5	789·7	788·9	788·1	787·3
1270	787·4	786·6	785·8	785·0	784·2
1275	784·3	783·5	782·7	782·0	781·2
1280	781·2	780·5	779·7	778·9	778·1
1285	778·2	777·4	776·6	775·9	775·1
1290	775·2	774·4	773·6	772·9	772·1
1295	772·2	771·4	770·7	769·9	769·1
1300	769·2	768·5	767·7	766·9	766·1
1305	766·3	765·5	764·7	764·0	763·2
1310	763·4	762·6	761·8	761·1	760·3
1315	760·5	759·7	758·9	758·2	757·4
1320	757·6	756·8	756·1	755·3	754·5
1325	754·7	754·0	753·2	752·4	751·7
1330	751·9	751·1	750·4	749·6	748·9
1335	749·1	748·3	747·6	746·8	746·1
1340	746·3	745·5	744·8	744·0	743·3
1345	743·5	742·7	742·0	741·3	740·5
1350	740·7	740·0	739·3	738·5	737·8
1355	738·0	737·3	736·5	735·8	735·1
1360	735·3	734·6	733·8	733·1	732·4
1365	732·6	731·9	731·1	730·4	729·7
1370	729·9	729·2	728·5	727·7	727·0
1375	727·3	726·5	725·8	725·1	724·4
1380	724·6	723·9	723·2	722·5	721·7
1385	722·0	721·3	720·6	719·9	719·1
1390	719·4	718·7	718·0	717·3	716·5
1395	716·8	716·1	715·4	714·7	714·0
1400	714·3	713·6	712·9	712·1	711·4

SILVER—*continued.*

5.	6.	7.	8.	9.	10.
836·1	835·3	834·5	833·6	832·8	831·9
832·6	831·8	831·0	830·1	829·3	828·4
829·2	828·3	827·5	826·7	825·8	825·0
825·7	824·9	824·1	823·2	822·4	821·6
822·3	821·5	820·7	819·8	819·0	818·2
818·9	818·1	817·3	816·5	815·6	814·8
815·6	814·7	813·9	813·1	812·3	811·5
812·2	811·4	810·6	809·8	809·0	808·2
808·9	808·1	807·3	806·5	805·7	804·9
805·7	804·9	804·0	803·2	802·4	801·6
802·4	801·6	800·8	800·0	799·2	798·4
799·2	798·4	797·6	796·8	796·0	795·2
796·0	795·2	794·4	793·6	792·8	792·0
792·8	792·0	791·2	790·4	789·6	788·8
789·7	788·9	788·1	787·3	786·5	785·7
786·6	785·8	785·0	784·2	783·4	782·6
783·5	782·7	781·9	781·1	780·3	779·5
780·4	779·6	778·8	778·0	777·3	776·5
777·3	776·6	775·8	775·0	774·2	773·4
774·3	773·5	772·8	772·0	771·2	770·4
771·3	770·5	769·8	769·0	768·2	767·4
768·3	767·6	766·8	766·0	765·2	764·5
765·4	764·6	763·8	763·1	762·3	761·5
762·4	761·7	760·9	760·1	759·4	758·6
759·5	758·8	758·0	757·2	756·5	755·7
756·6	755·9	755·1	754·4	753·6	752·8
753·8	753·0	752·3	751·5	750·8	750·0
750·9	750·2	749·4	748·7	747·9	747·2
748·1	747·4	746·6	745·9	745·1	744·4
745·3	744·6	743·8	743·1	742·3	741·6
742·5	741·8	741·0	740·3	739·5	738·8
739·8	739·0	738·3	737·5	736·8	736·1
737·0	736·3	735·6	734·8	734·1	733·3
734·3	733·6	732·8	732·1	731·4	730·6
731·6	730·9	730·1	729·4	728·7	727·9
728·9	728·2	727·5	726·7	726·0	725·3
726·3	725·5	724·8	724·1	723·4	722·6
723·6	722·9	722·2	721·4	720·7	720·0
721·0	720·3	719·6	718·8	718·1	717·4
718·4	717·7	717·0	716·2	715·5	714·8
715·8	715·1	714·4	713·7	712·9	712·2
713·3	712·5	711·8	711·1	710·4	709·7
710·7	710·0	709·3	708·6	707·9	707·1

					NITRATE OF
Weight of Assay in Milligrs.	0.	1.	2.	3.	4.
1405	711·7	711·0	710·3	709·6	708·9
1410	709·2	708·5	707·8	707·1	706·4
1415	706·7	706·0	705·3	704·6	703·9
1420	704·2	703·5	702·8	702·1	701·4
1425	701·8	701·0	700·3	699·6	698·9
1430	699·3	698·6	697·9	697·2	696·5
1435	696·9	696·2	695·5	694·8	694·1
1440	694·4	693·7	693·1	692·4	691·7
1445	692·0	691·3	690·7	690·0	689·3
1450	689·7	689·0	688·3	687·6	686·9
1455	687·3	686·6	685·9	685·2	684·5
1460	684·9	684·2	683·6	682·9	682·2
1465	682·6	681·9	681·2	680·6	679·9
1470	680·3	679·6	678·9	678·2	677·5
1475	678·0	677·3	676·6	675·9	675·2
1480	675·7	675·0	674·3	673·6	673·0
1485	673·4	672·7	672·0	671·4	670·7
1490	671·1	670·5	669·8	669·1	668·5
1495	668·9	668·2	667·6	666·9	666·2
1500	666·7	666·0	665·3	664·7	664·0
1505	664·5	663·8	663·1	662·5	661·8
1510	662·3	661·6	660·9	660·3	659·6
1515	660·1	659·4	658·7	658·1	657·4
1520	657·9	657·2	656·6	655·9	655·3
1525	655·7	655·1	654·4	653·8	653·1
1530	653·6	652·9	652·3	651·6	651·0
1535	651·5	650·8	650·2	649·5	648·9
1540	649·4	648·7	648·0	647·4	646·7
1545	647·2	646·6	645·9	645·3	644·7
1550	645·2	644·5	643·9	643·2	642·6
1555	643·1	642·4	641·8	641·2	640·5
1560	641·0	640·4	639·7	639·1	638·5
1565	639·0	638·3	637·7	637·1	636·4
1570	636·9	636·3	635·7	635·0	634·4
1575	634·9	634·3	633·6	633·0	632·4
1580	632·9	632·3	631·6	631·0	630·4
1585	630·9	630·3	629·6	629·0	628·4
1590	628·9	623·3	627·7	627·0	626·4
1595	627·0	626·3	625·7	625·1	624·4
1600	625·0	624·4	623·7	623·1	622·5
1605	623·1	622·4	621·8	621·2	620·6
1610	621·1	620·5	619·9	619·2	618·6
1615	619·2	618·6	618·0	617·3	616·7

SILVER—*continued.*

5.	6.	7.	8.	9.	10.
708·2	707·5	706·8	706·0	705·3	704·6
705·7	705·0	704·3	703·5	702·8	702·1
703·2	702·5	701·8	701·1	700·3	699·6
700·7	700·0	699·3	698·6	697·9	697·2
698·2	697·5	696·8	696·1	695·4	694·7
695·8	695·1	694·4	693·7	693·0	692·3
693·4	692·7	692·0	691·3	690·6	689·9
691·0	690·3	689·6	688·9	688·2	687·5
688·6	687·9	687·2	686·5	685·8	685·1
686·2	685·5	684·8	684·1	683·4	682·8
683·8	683·2	682·5	681·8	681·1	680·4
681·5	680·8	680·1	679 4	678·8	678·1
679·2	678·5	677·8	677·1	676·4	675·8
676·9	676·2	675·5	674·8	674·1	673·5
674·6	673·9	673·2	672·5	671·9	671·2
672·3	671·6	670·9	670·3	669·6	668·9
670·0	669·4	668·7	668·0	667·3	666·7
667·8	667·1	666·4	665·8	665·1	664·4
665·5	664·9	664·2	663·5	662·9	662·2
663·3	662·7	662·0	661·3	660·7	660·0
661·1	660·5	659·8	659·1	658·5	657·8
658·9	658·3	657·6	656·9	656·3	655·6
656·8	656·1	655·4	654·8	654·1	653·5
654·6	653·9	653·3	652·6	652·0	651·3
652·5	651·8	651·1	650·5	649·8	649·2
650·3	649·7	649·0	648·4	647·7	647·1
648·2	647·6	646·9	646·2	645·6	644·9
646·1	645·4	644·8	644·2	643·5	642·9
644·0	643·4	642·7	642·1	641·4	640·8
641·9	641·3	640·6	640·0	639·3	638·7
639·9	639·2	638·6	637·9	637·3	636·7
637·8	637·2	636·5	635·9	635·3	634·6
635·8	635·1	634·5	633·9	633·2	632·6
633·8	633·1	632·5	631·8	631·2	630·6
631·7	631·1	630·5	629·8	629·2	628·6
629·7	629·1	628·5	627·8	627·2	626·6
627·8	627·1	626·5	625·9	625·2	624·6
625·8	625·2	624·5	623·9	623·3	622·6
623·8	623·2	622·6	621·9	621·3	620·7
621·9	621·2	620·6	620·0	619·4	618·7
619·9	619·3	618·7	618·1	617·4	616·1
618·0	617·4	616·8	616·1	615·5	614·9
616·1	615·5	614·9	614·2	613·6	613·0

					NITRATE OF
Weight of Assay in Milligrs.	0.	1.	2.	3.	4.
1620	617·3	616·7	616·0	615·4	614·8
1625	615·4	614·8	614·1	613·5	612·9
1630	613·5	612·9	612·3	611·7	611·0
1635	611·6	611·0	610·4	609·8	609·2
1640	609·8	609·1	608·5	607·9	607·3
1645	607·9	607·3	606·7	606·1	605·5
1650	606·1	605·4	604·8	604·2	603·6
1655	604·2	603·6	603·0	602·4	601·8
1660	602·4	601·8	601·2	600·6	600·0
1665	600·6	600·0	599·4	598·8	598·2
1670	598·8	598·2	597·6	597·0	596·4
1675	597·0	596·4	595·8	595·2	594·6
1680	595·2	594·6	594·0	593·4	592·9
1685	593·5	592·9	592·3	591·7	591·1
1690	591·7	591·1	590·5	589·9	589·3
1695	590·0	589·4	588·8	588·2	587·6
1700	588·2	587·6	587·1	586·5	585·9
1705	586·5	585·9	585·3	584·7	584·2
1710	584·8	584·2	583·6	583·0	582·5
1715	583·1	582·5	581·9	581·3	580·8
1720	581·4	580·8	580·2	579·6	579·1
1725	579·7	579·1	578·5	578·0	577·4
1730	578·0	577·5	576·9	576·3	575·7
1735	576·4	575·8	575·2	574·6	574·1
1740	574·7	574·1	573·6	573·0	572·4
1745	573·1	572·5	571·9	571·3	570·8
1750	571·4	570·9	570·3	569·7	569·1
1755	569·8	569·2	568·7	568·1	567·5
1760	568·2	567·6	567·0	566·5	565·9
1765	566·6	566·0	565·4	564·9	564·3
1770	565·0	564·4	563·8	563·3	562·7
1775	563·4	562·8	562·2	561·7	561·1
1780	561·8	561·2	560·7	560·1	559·5
1785	560·2	559·7	559·1	558·5	558·0
1790	558·7	558·1	557·5	557·0	556·4
1795	557·1	556·5	556·0	555·4	554·9
1800	555·6	555·0	554·4	553·9	553·3
1805	554·0	553·5	552·9	552·3	551·8
1810	552·5	551·9	551·4	550·8	550·3
1815	551·0	550·4	549·9	549·3	548·8
1820	549·4	548·9	548·3	547·8	547·2
1825	547·9	547·4	546·8	546·3	545·7
1830	546·4	545·9	545·4	544·8	544·3

SILVER—*continued.*

5.	6.	7.	8.	9.	10.
614·2	613·6	613·0	612·3	611·7	611·1
612·3	611·7	611·1	610·5	609·8	609·2
610·4	609·8	609·2	608·6	608·0	607·4
608·6	607·9	607·3	606·7	606·1	605·5
606·7	606·1	605·5	604·9	604·3	603·7
604·9	604·3	603·6	603·0	602·4	601·8
603·0	602·4	601·8	601·2	600·6	600·0
601·2	600·6	600·0	599·4	598·8	598·2
599·4	598·8	598·2	597·6	597·0	596·4
597·6	597·0	596·4	595·8	595·2	594·6
595·8	595·2	594·6	594·0	593·4	592·8
594·0	593·4	592·8	592·2	591·6	591·0
592·3	591·7	591·1	590·5	589·9	589·3
590·5	589·9	589·3	588·7	588·1	587·5
588·8	588·2	587·6	587·0	586·4	585·8
587·0	586·4	585·8	585·2	584·7	584·1
585·3	584·7	584·1	583·5	582·9	582·3
583·6	583·0	582·4	581·8	581·2	580·6
581·9	581·3	580·7	580·1	579·5	578·9
580·2	579·6	579·0	578·4	577·8	577·3
578·5	577·9	577·3	576·7	576·2	575·6
576·8	576·2	575·6	575·1	574·5	573·9
575·1	574·6	574·0	573·4	572·8	572·2
573·5	572·9	572·3	571·8	571·2	570·6
571·8	571·3	570·7	570·1	569·5	569·0
570·2	569·6	569·0	568·5	567·9	567·3
568·6	568·0	567·4	566·9	566·3	565·7
566·9	566·4	565·8	565·2	564·7	564·1
565·3	564·8	564·2	563·6	563·1	562·5
563·7	563·2	562·6	562·0	561·5	560·9
562·1	561·6	561·0	560·4	559·9	559·3
560·6	560·0	559·4	558·9	558·3	557·7
559·0	558·4	557·9	557·3	556·7	556·2
557·4	556·9	556·3	555·7	555·2	554·6
555·9	555·3	554·7	554·2	553·6	553·1
554·3	553·8	553·2	552·6	552·1	551·5
552·8	552·2	551·7	551·1	550·6	550·0
551·2	550·7	550·1	549·6	549·0	548·5
549·7	549·2	548·6	548·1	547·5	547·0
548·2	547·7	547·1	546·6	546·0	545·5
546·7	546·2	545·6	545·1	544·5	544·0
545·2	544·7	544·1	543·6	543·0	542·5
543·7	543·2	542·6	542·1	541·5	541·0

					NITRATE OF
Weight of Assay in Milligrs.	0.	1.	2.	3.	4.
1835	545·0	544·4	543·9	543·3	542·8
1840	543·5	542·9	542·4	541·8	541·3
1845	542·0	541·5	540·9	540·4	539·8
1850	540·5	540·0	539·5	538·9	538·4
1855	539·1	538·5	538·0	537·5	536·9
1860	537·6	537·1	536·6	536·0	535·5
1865	536·2	535·7	535·1	534·6	534·0
1870	534·8	534·2	533·7	533·2	532·6
1875	533·3	532·8	532·3	531·7	531·2
1880	531·9	531·4	530·8	530·3	529·8
1885	530·5	530·0	529·4	528·9	528·4
1890	529·1	528·6	528·0	527·5	527·0
1895	527·7	527·2	526·6	526·1	525·6
1900	526·3	525·8	525·3	524·7	524·2
1905	524·9	524·4	523·9	523·4	522·8
1910	523·6	523·0	522·5	522·0	521·5
1915	522·2	521·7	521·1	520·6	520·1
1920	520·8	520·3	519·8	519·3	518·7
1925	519·5	519·0	518·4	517·9	517·4
1930	518·1	517·6	517·1	516·6	516·1
1935	516·8	516·3	515·8	515·2	514·7
1940	515·5	514·9	514·4	513·9	513·4
1945	514·1	513·6	513·1	512·6	512·1
1950	512·8	512·3	511·8	511·3	510·8
1955	511·5	511·0	510·5	510·0	509·5
1960	510·2	509·7	509·2	508·7	508·2
1965	508·9	508·4	507·9	507·4	506·9
1970	507·6	507·1	506·6	506·1	505·6
1975	506·3	505·8	505·3	504·8	504·3
1980	505·0	504·5	504·0	503·5	503·0
1985	503·8	503·3	502·8	502·3	501·8
1990	502·5	502·0	501·5	501·0	500·5
1995	501·3	500·7	500·2	499·7	499·2
2000	500·0	499·5	499·0	498·5	498·0

SILVER—*continued.*

5.	6.	7.	8.	9.	10.
542·2	541·7	541·1	540·6	540·0	539·5
540·8	540·2	539·7	539·1	538·6	538·0
539·3	538·7	538·2	537·7	537·1	536·6
537·8	537·3	536·8	536·2	535·7	535·1
536·4	535·8	535·3	534·8	534·2	533·7
534·9	534·4	533·9	533·3	532·8	532·3
533·5	533·0	532·4	531·9	531·4	530·8
532·1	531·5	531·0	530·5	529·9	529·4
530·7	530·1	529·6	529·1	528·5	528·0
529·3	528·7	528·2	527·7	527·1	526·6
527·8	527·3	526·8	526·3	525·7	525·2
526·5	525·9	525·4	524·9	524·3	523·8
525·1	524·5	524·0	523·5	523·0	522·4
523·7	523·2	522·6	522·1	521·6	521·0
522·3	521·8	521·3	520·7	520·2	519·7
520·9	520·4	519·9	519·4	518·8	518·3
519·6	519·1	518·5	518·0	517·5	517·0
518·2	517·7	517·2	516·7	516·1	515·6
516·9	516·4	515·8	515·3	514·8	514·3
515·5	515·0	514·5	514·0	513·5	512·9
514·2	513·7	513·2	512·7	512·1	511·6
512·9	512·4	511·9	511·3	510·8	510·3
511·6	511·0	510·5	510·0	509·5	509·0
510·3	509·7	509·2	508·7	508·2	507·7
508·9	508·4	507·9	507·4	506·9	506·4
507·6	507·1	506·6	506·1	505·6	505·1
506·4	505·8	505·3	504·8	504·3	503·8
505·1	504·6	504·1	503·5	503·0	502·5
503·8	503·3	502·8	502·3	501·8	501·3
502·5	502·0	501·5	501·0	500·5	500·0
501·3	500·8	500·2	499·7	499·2	498·7
500·0	499·5	499·0	498·5	498·0	497·5
498·7	498·2	497·7	497·2	496·7	496·2
497·5	497·0	496·5	496·0	495·5	495·0

Tables for Determining the Standard of any Silver approximatively containing

					COMMON
Weight of Assay in Milligrs.	0.	1.	2.	3.	4.
1000	1000·0				
1005	995·0	996·0	997·0	998·0	999·0
1010	990·1	991·1	992·1	993·1	994·1
1015	985·2	986·2	987·2	988·2	989·2
1020	980·4	981·4	982·4	983·3	984·3
1025	975·6	976·6	977·6	978·5	979·5
1030	970·9	971·8	972·8	973·8	974·8
1035	966·2	967·1	968·1	969·1	970·0
1040	961·5	962·5	963·5	964·4	965·4
1045	956·9	957·9	958·8	959·8	960·8
1050	952·4	953·3	954·3	955·2	956·2
1055	947·9	948·8	949·8	950·7	951·7
1060	943·4	944·3	945·3	946·2	947·2
1065	939·0	939·9	940·8	941·8	942·7
1070	934·6	935·5	936·4	937·4	938·3
1075	930·2	931·2	932·1	933·0	933·9
1080	925·9	926·8	927·8	928·7	929·6
1085	921·7	922·6	923·5	924·4	925·3
1090	917·4	918·3	919·3	920·2	921·1
1095	913·2	914·2	915·1	916·0	917·0
1100	909·1	910·0	910·9	911·8	912·7
1105	905·0	905·9	906·8	907·7	908·6
1110	900·9	901·8	902·7	903·6	904·5
1115	896·9	897·8	898·6	899·5	900·4
1120	892·9	893·7	894·6	895·5	896·4
1125	888·9	889·8	890·7	891·6	892·4
1130	885·0	885·8	886·7	887·6	888·5
1135	881·1	881·9	882·8	883·7	884·6
1140	877·2	878·1	878·9	879·8	880·7
1145	873·4	874·2	875·1	876·0	876·9
1150	869·6	870·4	871·3	872·2	873·0
1155	865·8	866·7	867·5	868·4	869·3
1160	862·1	862·9	863·8	864·7	865·5
1165	858·4	859·2	860·1	860·9	861·8
1170	854·7	855·6	856·4	857·3	858·1
1175	851·1	851·9	852·8	853·6	854·5
1180	847·5	848·3	849·2	850·0	850·8
1185	843·9	844·7	845·6	846·4	847·3

Alloy by employing an Amount of Alloy always the same Amount of Silver.

SALT.					
5.	6.	7.	8.	9.	10.
1000·0					
995·0	996·0	997·0	998·0	999·0	1000·0
990·1	991·1	992·1	993·1	994·1	995·1
985·3	986·3	987·2	988·2	989·2	990·2
980·5	981·5	982·4	983·4	984·4	985·4
975·7	976·7	977·7	978·6	979·6	980·6
971·0	972·0	972·9	973·9	974·9	975·8
966·3	967·3	968·3	969·2	970·2	971·1
961·7	962·7	963·6	964·6	965·5	966·5
957·1	958·1	959·0	960·0	960·9	961·9
952·6	953·5	954·5	955·4	956·4	957·3
948·1	949·1	950·0	950·9	951·9	952·8
943·7	944·6	945·5	946·5	947·4	948·4
939·3	940·2	941·1	942·1	943·0	943·9
934·9	935·8	936·7	937·7	938·6	939·5
930·6	931·5	932·4	933·3	934·3	935·2
926·3	927·2	928·1	929·0	930·0	930·9
922·0	922·9	923·8	924·8	925·7	926·6
917·8	918·7	919·6	920·5	921·5	922·4
913·6	914·5	915·4	916·4	917·3	918·2
909·5	910·4	911·3	912·2	913·1	914·0
905·4	906·3	907·2	908·1	909·0	909·9
901·3	902·2	903·1	904·0	904·9	905·8
897·3	898·2	899·1	900·0	900·9	901·8
893·3	894·2	895·1	896·0	896·9	897·8
889·4	890·3	891·1	892·0	892·9	893·8
885·5	886·3	887·2	888·1	889·0	889·9
881·6	882·5	883·3	884·2	885·1	886·0
877·7	878·6	879·5	880·3	881·2	882·1
873·9	874·8	875·7	876·5	877·4	878·3
870·1	871·0	871·9	872·7	873·6	874·5
866·4	867·2	868·1	869·0	869·8	870·7
862·7	863·5	864·4	865·2	866·1	866·9
859·0	859·8	860·7	861·5	862·4	863·2
855·3	856·2	857·0	857·9	858·7	859·6
851·7	852·5	853·4	854·2	855·1	855·9
848·1	848·9	849·8	850·6	851·5	852·3

					COMMON
Weight of Assay in Milligrs.	0.	1.	2.	3.	4.
1190	840·3	841·2	842·0	842·9	843·7
1195	836·8	837·7	838·5	839·3	840·2
1200	833·3	834·2	835·0	835·8	836·7
1205	829·9	830·7	831·5	832·4	833·2
1210	826·4	827·3	828·1	828·9	829·7
1215	823·0	823·9	824·7	825·5	826·3
1220	819·7	820·5	821·3	822·1	822·9
1225	816·3	817·1	818·0	818·8	819·6
1230	813·0	813·8	814·6	815·4	816·3
1235	809·7	810·5	811·3	812·1	813·0
1240	806·5	807·3	808·1	808·9	809·7
1245	803·2	804·0	804·8	805·6	806·4
1250	800·0	800·8	801·6	802·4	803·2
1255	796·8	797·6	798·4	799·2	800·0
1260	793·6	794·4	795·2	796·0	796·8
1265	790·5	791·3	792·1	792·9	793·7
1270	787·4	788·2	789·0	789·8	790·5
1275	784·3	785·1	785·9	786·7	787·4
1280	781·2	782·0	782·8	783·6	784·4
1285	778·2	779·0	779·8	780·5	781·3
1290	775·2	776·0	776·7	777·5	778·3
1295	772·2	773·0	773·7	774·5	775·3
1300	769·2	770·0	770·8	771·5	772·3
1305	766·3	767·0	767·8	768·6	769·3
1310	763·4	764·1	764·9	765·6	766·4
1315	760·5	761·2	762·0	762·7	763·5
1320	757·6	758·3	759·1	759·8	760·6
1325	754·7	755·5	756·2	757·0	757·7
1330	751·9	752·6	753·4	754·1	754·9
1335	749·1	749·8	750·6	751·3	752·1
1340	746·3	747·0	747·8	748·5	749·2
1345	743·5	744·2	745·0	745·7	746·5
1350	740·7	741·5	742·2	743·0	743·7
1355	738·0	738·7	739·5	740·2	741·0
1360	735·3	736·0	736·8	737·5	738·2
1365	732·6	733·3	734·1	734·8	735·5
1370	729·9	730·7	731·4	732·1	732·8
1375	727·3	728·0	728·7	729·4	730·2
1380	724·6	725·4	726·1	726·8	727·5
1385	722·0	722·7	723·5	724·2	724·9
1390	719·4	720·1	720·9	721·6	722·3
1395	716·8	717·6	718·3	719·0	719·7
1400	714·3	715·0	715·7	716·4	717·1

SALT—*continued.*

5.	6.	7.	8.	9.	10.
844·5	845·4	846·2	847·1	847·9	848·7
841·0	841·8	842·7	843·5	844·3	845·2
837·5	838·3	839·2	840·0	840·8	841·7
834·0	834·8	835·7	836·5	837·3	838·2
830.6	831·4	832·2	833·1	833·9	834·7
827·2	828·0	828·8	829·6	830·4	831·3
823·8	824·6	825·4	826·2	827·0	827·9
820·4	821·2	822·0	822·9	823·7	824·5
817·1	817·9	818·7	819·5	820·3	821·1
813·8	814·6	815·4	816·2	817·0	817·8
810·5	811·3	812·1	812·9	813·7	814·5
807·2	808·0	808·8	809·6	810·4	811·2
804·0	804·8	805·6	806·4	807·2	808·0
800·8	801·6	802·4	803·2	804·0	804·8
797·6	798·4	799·2	800·0	800·8	801·6
794·5	795·3	796·0	796·8	797·6	798·4
791·3	792·1	792·9	793·7	794·5	795·3
788·2	789·0	789·8	790·6	791·4	792·2
785·2	786·0	786·7	787·5	788·3	789·1
782·1	782·9	783·7	784·4	785·2	786·0
779·1	779·8	780·6	781·4	782·2	782·9
776·1	776·8	777·6	778·4	779·1	779·9
773·1	773·8	774·6	775·4	776·1	776·9
770·1	770·9	771·6	772·4	773·2	773·9
767·2	767·9	768·7	769·5	770·2	771·0
764·3	765·0	765·8	766·5	767·3	768·1
761·4	762·1	762·9	763·6	764·4	765·2
758·5	759·2	760·0	760·7	761·5	762·3
755·6	756·4	757·1	757·9	758·6	759·4
752·8	753·6	754·3	755·1	755·8	756·6
750·0	750·7	751·5	752·2	753·0	753·7
747·2	748·0	748·7	749·4	750·2	750·9
744·4	745·2	745·9	746·7	747·4	748·1
741·7	742·4	743·2	743·9	744·6	745·4
739·0	739·7	740·4	741·2	741·9	742·6
736·3	737·0	737·7	738·5	739·2	739·9
733·6	734·3	735·0	735·8	736·5	737·2
730·9	731·6	732·4	733·2	733·8	734·5
728·3	729·0	729·7	730·4	731·2	731·9
725·6	726·3	727·1	727·8	728·5	729·2
723·0	723·7	724·5	725·2	725·9	726·6
720·4	721·1	721·9	722·6	723·3	724·0
717·9	718·6	719·3	720·0	720·7	721·4

					COMMON
Weight of Assay in Milligrs.	0.	1.	2.	3.	4.
1405	711·7	712·5	713·2	713·9	714·6
1410	709·2	709·9	710·6	711·3	712·1
1415	706·7	707·4	708·1	708·8	709·5
1420	704·2	704·9	705·6	706·3	707·0
1425	701·8	702·5	703·2	703·9	704·6
1430	699·3	700·0	700·7	701·4	702·1
1435	696·9	697·6	698·3	698·9	699·6
1440	694·4	695·1	695·8	696·5	697·2
1445	692·0	692·7	693·4	694·1	694·8
1450	689·7	690·3	691·0	691·7	692·4
1455	687·3	688·0	688·7	689·3	690·0
1460	684·9	685·6	686·3	687·0	687·7
1465	682·6	683·3	684·0	684·6	685·3
1470	680·3	680·9	681·6	682·3	683·0
1475	678·0	678·6	679·3	680·0	680·7
1480	675·7	676·3	677·0	677·7	678·4
1485	673·4	674·1	674·7	675·4	676·1
1490	671·1	671·8	672·5	673·1	673·8
1495	668·9	669·6	670·2	670·9	671·6
1500	666·7	667·3	668·0	668·7	669·3
1505	664·5	665·1	665·8	666·4	667·1
1510	662·3	662·9	663·6	664·2	664·9
1515	660·1	660·7	661·4	662·0	662·7
1520	657·9	658·5	659·2	659·9	660·5
1525	655·7	656·4	657·0	657·7	658·4
1530	653·6	654·2	654·9	655·6	656·2
1535	651·5	652·1	652·8	653·4	654·1
1540	649·4	650·0	650·6	651·3	651·9
1545	647·2	647·9	648·5	649·2	649·8
1550	645·2	645·8	646·4	647·1	647·7
1555	643·1	643·7	644·4	645·0	645·7
1560	641·0	641·7	642·3	642·9	643·6
1565	639·0	639·6	640·3	640·9	641·5
1570	636·9	637·6	638·2	638·8	639·5
1575	634·9	635·6	636·2	636·8	637·5
1580	632·9	633·5	634·2	634·8	635·4
1585	630·9	631·5	632·2	632·8	633·4
1590	628·9	629·6	630·2	630·8	631·4
1595	627·0	627·6	628·2	628·8	629·5
1600	625·0	625·6	626·2	626·9	627·5
1605	623·1	623·7	624·3	624·9	625·5
1610	621·1	621·7	622·4	623·0	623·6
1615	619·2	619·8	620·4	621·0	621·7

SALT—*continued.*

5.	6.	7.	8.	9.	10.
715·3	716·0	716·7	717·4	718·1	718·9
712·8	713·5	714·2	714·9	715·6	716·3
710·2	710·9	711·7	712·4	713·1	713·8
707·7	708·4	709·2	709·9	710·6	711·3
705·3	706·0	706·7	707·4	708·1	708·8
702·8	703·5	704·2	704·9	705·6	706·3
700·3	701·0	701·7	702·4	703·1	703·8
697·9	698·6	699·3	700·0	700·7	701·4
695·5	696·2	696·9	697·6	698·3	699·0
693·1	693·8	694·5	695·2	695·9	696·6
690·7	691·4	692·1	692·8	693·5	694·2
688·4	689·0	689·7	690·4	691·1	691·8
686·0	686·7	687·4	688·0	688·7	689·4
683·7	684·3	685·0	685·7	686·4	687·1
681·4	682·0	682·7	683·4	684·1	684·7
679·1	679·7	680·4	681·1	681·8	682·4
676·8	677·4	678·1	678·8	679·5	680·1
674·5	675·2	675·8	676·5	677·2	677·8
672·2	672·9	673·6	674·2	674·9	675·6
670·0	670·7	671·3	672·0	672·7	673·3
667·8	668·4	669·1	669·8	670·4	671·1
665·6	666·2	666·9	667·5	668·2	668·9
663·4	664·0	664·7	665·3	666·0	666·7
661·2	661·8	662·5	663·2	663·8	664·5
659·0	659·7	660·3	661·0	661·6	662·3
656·9	657·5	658·2	658·8	659·5	660·1
654·7	655·4	656·0	656·7	657·3	658·0
652·6	653·2	653·9	654·5	655·2	655·8
650·5	651·1	651·8	652·4	653·1	653·7
648·4	649·0	649·7	650·3	651·0	651·6
646·3	646·9	647·6	648·2	648·9	649·5
644·2	644·9	645·5	646·1	646·8	647·4
642·2	642·8	643·4	644·1	644·7	645·4
640·1	640·8	641·4	642·0	642·7	643·3
638·1	638·7	639·4	640·0	640·6	641·3
636·1	636·7	637·3	638·0	638·6	639·2
634·1	634·7	635·3	636·0	636·6	637·2
632·1	632·7	633·3	634·0	634·6	635·2
630·1	630·7	631·3	632·0	632·6	633·2
628·1	628·7	629·4	630·0	630·6	631·2
626·2	626·8	627·4	628·0	628·7	629·3
624·2	624·8	625·5	626·1	626·7	627·3
622·3	622·9	623·5	624·1	624·8	625·4

					COMMON
Weight of Assay in Milligrs.	0.	1.	2.	3.	4.
1620	617·3	617·9	618·5	619·1	619·7
1625	615·4	616·0	616·6	617·2	617·8
1630	613·5	614·1	614·7	615·3	615·9
1635	611·6	612·2	612·8	613·5	614·1
1640	609·8	610·4	611·0	611·6	612·2
1645	607·9	608·5	609·1	609·7	610·3
1650	606·1	606·7	607·3	607·9	608·5
1655	604·2	604·8	605·4	606·0	606·6
1660	602·4	603·0	603·6	604·2	604·8
1665	600·6	601·2	601·8	602·4	603·0
1670	598·8	599·4	600·0	600·6	601·2
1675	597·0	597·6	598·2	598·8	599·4
1680	595·2	595·8	596·4	597·0	597·6
1685	593·5	594·1	594·7	595·2	595·8
1690	591·7	592·3	592·9	593·5	594·1
1695	590·0	590·6	591·1	591·7	592·3
1700	588·2	588·8	589·4	590·0	590·6
1705	586·5	587·1	587·7	588·3	588·9
1710	584·8	585·4	586·0	586·5	587·1
1715	583·1	583·7	584·3	584·8	585·4
1720	581·4	582·0	582·6	583·1	583·7
1725	579·7	580·3	580·9	581·4	582·0
1730	578·0	578·6	579·2	579·8	580·3
1735	576·4	576·9	577·5	578·1	578·7
1740	574·7	575·3	575·9	576·4	577·0
1745	573·1	573·6	574·2	574·8	575·4
1750	571·4	572·0	572·6	573·1	573·7
1755	569·8	570·4	570·9	571·5	572·1
1760	568·2	568·7	569·3	569·9	570·4
1765	566·6	567·1	567·7	568·3	568·8
1770	565·0	565·5	566·1	566·7	567·2
1775	563·4	563·9	564·5	565·1	565·6
1780	561·8	562·4	562·9	563·5	564·0
1785	560·2	560·8	561·3	561·9	562·5
1790	558·7	559·2	559·8	560·3	560·9
1795	557·1	557·7	558·2	558·8	559·3
1800	555·6	556·1	556·7	557·2	557·8
1805	554·0	554·6	555·1	555·7	556·2
1810	552·5	553·0	553·6	554·1	554·7
1815	551·0	551·5	552·1	552·6	553·2
1820	549·4	550·0	550·5	551·1	551·6
1825	547·9	548·5	549·0	549·6	550·1
1830	546·4	547·0	547·5	548·1	548·6

SALT—*continued.*

5.	6.	7.	8.	9.	10.
620·4	621·0	621·6	622·2	622·8	623·5
618·5	619·1	619·7	620·3	620·9	621·5
616·6	617·2	617·8	618·4	619·0	619·6
614·7	615·3	615·9	616·5	617·1	617·7
612·8	613·4	614·0	614·6	615·2	615·8
610·9	611·5	612·2	612·8	613·4	614·0
609·1	609·7	610·3	610·9	611·5	612·1
607·2	607·8	608·5	609·1	609·7	610·3
605·4	606·0	606·6	607·2	607·8	608·4
603·6	604·2	604·8	605·4	606·0	606·6
601·8	602·4	603·0	603·6	604·2	604·8
600·0	600·6	601·2	601·8	602·4	603·0
598·2	598·8	599·4	600·0	600·6	601·2
596·4	597·0	597·6	598·2	598·8	599·4
594·7	595·3	595·9	596·4	597·0	597·6
592·9	593·5	594·1	594·7	595·3	595·9
591·2	591·8	592·3	592·9	593·5	594·1
589·4	590·0	590·6	591·2	591·8	592·4
587·7	588·3	588·9	589·5	590·1	590·6
586·0	586·6	587·2	587·8	588·3	588·9
584·3	584·9	585·5	586·0	586·6	587·2
582·6	583·2	583·8	584·3	584·9	585·5
580·9	581·5	582·1	582·7	583·2	583·8
579·2	579·8	580·4	581·0	581·6	582·1
577·6	578·2	578·7	579·3	579·9	580·5
575·9	576·5	577·1	577·6	578·2	578·8
574·3	574·9	575·4	576·0	576·6	577·1
572·6	573·2	573·8	574·4	574·9	575·5
571·0	571·6	572·2	572·7	573·3	573·9
569·4	570·0	570·5	571·1	571·7	572·2
567·8	568·4	568·9	569·5	570·1	570·6
566·2	566·8	567·3	567·9	568·4	569·0
564·6	565·2	565·7	566·3	566·8	567·4
563·0	563·6	564·1	564·7	565·3	565·8
561·4	562·0	562·6	563·1	563·7	564·2
559·9	560·4	561·0	561·6	562·1	562·7
558·3	558·9	559·4	560·0	560·6	561·1
556·8	557·3	557·9	558·4	559·0	559·6
555·2	555·8	556·3	556·9	557·5	558·0
553·7	554·3	554·8	555·4	555·9	556·5
552·2	552·7	553·3	553·8	554·4	554·9
550·7	551·2	551·8	552·3	552·9	553·4
549·2	549·7	550·3	550·8	551·4	551·9

					COMMON
Weight of Assay in Milligrs.	0.	1.	2.	3.	4.
1835	545·0	545·5	546·0	546·6	547·1
1840	543·5	544·0	544·6	545·1	545·6
1845	542·0	542·5	543·1	543·6	544·2
1850	540·5	541·1	541·6	542·2	542·7
1855	539·1	539·6	540·2	540·7	541·2
1860	537·6	538·2	538·7	539·2	539·8
1865	536·2	536·7	537·3	537·8	538·3
1870	534·8	535·3	535·8	536·4	536·9
1875	533·3	533·9	534·4	534·9	535·5
1880	531·9	532·4	533·0	533·5	534·0
1885	530·5	531·0	531·6	532·1	532·6
1890	529·1	529·6	530·2	530·7	531·2
1895	527·7	528·2	528·8	529·3	529·8
1900	526·3	526·8	527·4	527·9	528·4
1905	524·9	525·4	526·0	526·5	527·0
1910	523·6	524·1	524·6	525·1	525·6
1915	522·2	522·7	523·2	523·8	524·3
1920	520·8	521·3	521·9	522·4	522·9
1925	519·5	520·0	520·5	521·0	521·6
1930	518·1	518·6	519·2	519·7	520·2
1935	516·8	517·3	517·8	518·3	518·9
1940	515·5	516·0	516·5	517·0	517·5
1945	514·1	514·6	515·2	515·7	516·2
1950	512·8	513·3	513·8	514·4	514·9
1955	511·5	512·0	512·5	513·0	513·5
1960	510·2	510·7	511·2	511·7	512·2
1965	508·9	509·4	509·9	510·4	510·9
1970	507·6	508·1	508·6	509·1	509·6
1975	506·3	506·8	507·3	507·8	508·3
1980	505·0	505·6	506·1	506·6	507·1
1985	503·8	504·3	504·8	505·3	505·8
1990	502·5	503·0	503·5	504·0	504·5
1995	501·3	501·8	502·3	502·8	503·3
2000	500·0	500·5	501·0	501·5	502·0

SALT—*continued.*

5.	6.	7.	8.	9.	10.
547·7	548·2	548·8	549·3	549·9	550·4
546·2	546·7	547·3	547·8	548·4	548·9
544·7	545·3	545·8	546·3	546·9	547·4
543·2	543·8	544·3	544·9	545·4	545·9
541·8	542·3	542·9	543·4	543·9	544·5
540·3	540·9	541·4	541·9	542·5	543·0
538·9	539·4	539·9	540·5	541·0	541·5
537·4	538·0	538·5	539·0	539·6	540·1
536·0	536·5	537·1	537·6	538·1	538·7
534·6	535·1	535·6	536·2	536·7	537·2
533·2	533·7	534·2	534·7	535·3	535·8
531·7	532·3	532·8	533·3	533·9	534·4
530·3	530·9	531·4	531·9	532·4	533·0
528·9	529·5	530·0	530·5	531·0	531·6
527·6	528·1	528·6	529·1	529·7	530·2
526·2	526·7	527·2	527·7	528·3	528·8
524·8	525·3	525·8	526·4	526·9	527·4
523·4	524·0	524·5	525·0	525·5	526·0
522·1	522·6	523·1	523·6	524·2	524·7
520·7	521·2	521·8	522·3	522·8	523·3
519·4	519·9	520·4	520·9	521·4	522·0
518·0	518·6	519·1	519·6	520·1	520·6
516·7	517·2	517·7	518·2	518·8	519·3
515·4	515·9	516·4	516·9	517·4	517·9
514·1	514·6	515·1	515·6	516·1	516·6
512·8	513·3	513·8	514·3	514·8	515·3
511·4	512·0	512·5	513·0	513·5	514·0
510·1	510·7	511·2	511·7	512·2	512·7
508·9	509·4	509·9	510·4	510·9	511·4
507·6	508·1	508·6	509·1	509·6	510·1
506·3	506·8	507·3	507·8	508·3	508·8
505·0	505·5	506·0	506·5	507·0	507·5
503·8	504·3	504·8	505·3	505·8	506·3
502·5	503·0	503·5	504·0	504·5	505·0

APPLICATION.

Assay of Pure, or nearly Pure, Silver, the Temperature of the Normal Solution of Salt being that at which it was standardised.

First Example.—Let the ingot of silver have an approximative standard of from 995 to 1000 thousandths. Take one gramme; dissolve it in ten grammes of nitric acid, in the bottle fig. 247. Then pour into the bottle an exact measure of the normal solution of salt, and brighten by agitation. The silver not being supposed to be quite pure, the standard is not further sought for by the decime solution of salt, but that of nitrate of silver is employed.

One thousandth of this latter solution is poured into the bottle; it becomes cloudy, and is well agitated. A second and a third thousandth also give a precipitate, but not so a fourth. From these data the following is the method of ascertaining the standard of the alloy:—

The last thousandth of the decime solution of silver, having produced no cloudiness, is not to be counted. The third was necessary, but only partially so; consequently the number of thousandths of silver necessary to decompose the excess of salt is more than 2 and less than 3; in other words, it is equal to the mean, $2\frac{1}{2}$; but since $2\frac{1}{2}$ thousandths of silver have been required to complete the precipitation of salt representing 1000 thousandths of silver, it is evident that the silver submitted to assay contained $2\frac{1}{2}$ thousandths of alloy, and that its standard, to within nearly half a thousandth, is but $997\frac{1}{2}$.

If it be considered necessary to arrive nearer the true standard, the following proofs must be employed:—Pour into the solution $1\frac{1}{2}$ thousandths of salt, which will decompose a like number of thousandths of silver.* After due agitation, add half a thousandth of nitrate of silver. Supposing a cloudiness is produced, no further addition must be made, for it is already known that above the third thousandth no precipitate is formed in the liquid by nitrate of silver, and consequently only half of the last half thousandth must be calculated, as only a portion of it was necessary. From which, the

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* It has already been stated how a thousandth of the decime solution may be subdivided by the number of drops furnished by the pipette. If, for instance, it contains 20 drops, 10 will give the half, 5 the quarter, &c. Half a thousandth may also be obtained by diluting the solution with its volume of water, and using a whole pipetteful. This latter plan has been found the best in practice.

entire number of thousandths of nitrate of silver being $4\frac{1}{4}$, and those of salt $1\frac{1}{2}$, there remains $2\frac{3}{4}$ for the number of thousandths of nitrate of silver added to the normal solution; and consequently the standard of the alloy is $1000-2\frac{3}{4}=997\frac{1}{4}$. If, on the other hand, the last half thousandth of nitrate of silver had produced no cloudiness, it would not have to be reckoned, and only half of the preceding half thousandth would have been taken. Thus from the 4 thousandths of nitrate of silver employed a quarter of a thousandth is deducted; and from the difference, $3\frac{3}{4}$, is yet deducted $1\frac{1}{2}$ of salt, the final remainder being $2\frac{1}{4}$ thousandths of nitrate of silver which have been added to the normal solution: the standard of the alloy would be $1000-2\frac{1}{4}=997\frac{3}{4}$.

Although the above-described operation is very simple, yet it is desirable, in order to avoid all confusion, to note in writing such thousandths of salt or nitrate of silver as are added. The thousandths of salt indicating an increase of standard should be preceded by the sign +; and the thousandths of nitrate of silver announcing a diminution of standard, by the sign −.

Second Example.—Suppose the ingot has a presumed standard of 895 thousandths, and the temperature of the normal solution supposed invariable.

Find in the table of standards (Salt Table), first column, that which approaches the nearest to 895; it will be found to be 896·9, corresponding to the weight of 1115 milligrammes. This weight of the alloy is taken and dissolved in nitric acid, a measure of normal solution of salt added, and the whole well agitated. The operator is, however, doubtful whether the assay must be proceeded with by the decime salt solution, or the nitrate of silver decime solution. If the former produces a precipitate, it is gone on with; but if it does not precipitate, that already added is decomposed by a similar addition of the second, and the solution rendered bright by agitation. A starting point has now been arrived at for the continuance of the assay, for it is known that the nitrate of silver solution must be employed.

Suppose, then, that the alloy, after the addition of the measure of normal solution, yet gives a precipitate with the decime solution of salt. The first five thousandths produce a precipitate, but not the sixth, which consequently is not counted. The fifth has only been partially required, so that it is more than 4 thousandths, and less than 5, or the mean, $4\frac{1}{2}$, is the quantity required to entirely precipitate the excess of silver in the alloy submitted to assay. But by neglecting at first the fraction 0·5, seek in the Salt Table of standards the number found on the longitudinal line of the weight 1115, under column 4; it is 900·4, and on adding 0·5 to this number, we have 900·9, or 901, for the required standard.

Supposing, however, that the same alloy, after the addition of the normal measure of salt, gives a precipitate with nitrate of silver, and that the three first thousandths produce a cloudiness, but not the fourth. The number of thousandths of nitrate of silver really necessary for complete precipitation will be very nearly 2½. To ascertain the real standard of the alloy of which 1115 thousandths were supposed to contain about 1000 thousandths of silver, take the number found in the horizontal line 1115, and in the column 2 of the Nitrate of Silver Table. This number, which is 895·1, diminished by the fraction 0 5, gives 894·6 for the standard of the alloy to within half a thousandth.

Third Example.—The actual temperature of the normal solution of salt being 18° when it was standardised at 15°.

The ingot of silver submitted to assay has an approximative standard of 795 thousandths. Find in the Salt Table of Standards, first column, that which is nearest to it; it is 793·7, corresponding to the weight 1260. This weight of the alloy is taken, and the operation proceeded with as already described. Supposing it had required 6·5 thousandths of salt to precipitate the whole of the silver contained in the alloy to within half a thousandth, the required standard, without correction for temperature, will be $798{\cdot}4 + 0{\cdot}4 = 798{\cdot}8$. But, making this correction, recourse must be had to the table, page 405, column 15: the number 0·3, which will be found in the horizontal line 18 and the column 15, possesses the — sign; consequently it must be deducted from 798·8, and the remainder, 798·5, will be the standard weight. If the temperature of the solution, instead of being 3° higher than at the time it was standardised, was 3° lower, or 12°, the correction must be added, and would be equal to $+0{\cdot}2$. The standard of the alloy would consequently be $798{\cdot}8 + 0{\cdot}2 = 799$.

Graduation of the Normal Solution of Salt, the Temperature being different to that at which it is wished to be graduated.

Two equally ready processes can be employed. The one consists in reducing the temperature of the solution to the desired degree before standardising; the other, in determining its standard without regard to the temperature of the solution, and then correcting its influence by the aid of the tables of correction already given.

First Process.—Place the liquid to be graduated in a bottle, *F*, fig. 262. Introduce a thermometer, and heat to a determinate degree, say 20° for instance. This done, place the jet of the pipette in the bottle; raise the liquid by aspiration by means of the conical tube, *T*, fig. 256, which is adapted to the opening of the air-cock, *R*. As soon as the liquid is raised a little above the mark *a b*, which determines the capacity of the pipette, close the stop-cock, and complete the measurement as usual. This same means of filling the pipette by aspiration may be employed to fill it either with caustic alkali or nitric acid, as the case may be, to cleanse it instead of taking it to pieces.

Fig. 262.

Second Method.—The solution of salt being supposed at a temperature of 16°, and it is desired to graduate it at that of 20°. Proceed with the standardising without regard to temperature; but when it is obtained in each trial assay, it is necessary to make the correction required by the temperature.

If, for example, in an approximative assay the standard of the solution was expressed by 1001·5, this standard would not only be too weak by 1·5 thousandth, but, according to the table of temperatures, by yet another 0·5, for the solution is weakened by this quantity by passing from 16° to 20°. The standard, if taken at this last temperature, would be too low by two thousandths, and must consequently be corrected.

If, on the other hand, the standard of the solution were too high instead of too low, and expressed by 998·5 at the temperature of 16°; at that of 20°, the solution being weakened by 0·5, the standard would only be but one thousandth too high, and it must be corrected by that quantity.

Approximative Determination of the Standard of an Unknown Alloy.

It has always been supposed, in the experiments already detailed, that the approximative standard of the alloy submitted to assay was known; and this, indeed, is nearly always the case. If, however, this be unknown, two means are available for obtaining the necessary knowledge. A decigramme of the alloy is cupelled with one gramme of lead; or, if it be desirable not to use the cupel, it may be ascertained by the humid method, in the following manner:—

The assayer supposes the standard of the alloy known to about a twentieth, and it can always be found nearer than that by touch, density, &c. A weight relative to its supposed standard is taken, and its standard sought by adding the decime liquid by 10 thousandths at a time, by means of pipettes of this capacity (see fig. 263). The term of complete precipitation is soon passed, and the standard of the alloy to about 5 thousandths is thus ascertained. The approximative standard to 2½ thousandths may be obtained by adding only 5 thousandths of solution at a time.

FIG. 263.

Suppose the alloy 840 thousandths. Take the weight 1190, corresponding to this standard, and proceed as in an ordinary assay, adding each time, for example, a pipette of 10 thousandths of salt solution. It is found the fifth pipette gives no precipitate, and consequently the number of thousandths of salt for the precipitate of the silver to within 5 thousandths is 35. The 1199 of alloy will therefore contain $1000 + 35 = 1035$ of silver; and the approximative standard will be obtained by the proportion—

$$1120 : 1035 :: 1000 : x = 869{\cdot}7.$$

Modes of Abridging Manipulation.

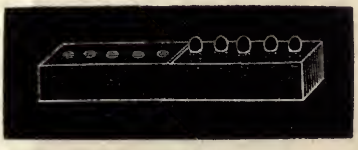
In the statement already given of the mode of conducting the assay by the wet-method, only such instructions have been given as were necessary for its full comprehension, and everything that might call away or fatigue the attention has been omitted. Nevertheless, here it will be convenient to describe some methods of abridging the necessary manipulations, supposing that ten, or at least five, assays are made at once.

Bottles.—It is necessary to have these all as nearly as possible of the same height and diameter. They are marked progressively on the shoulder, as are also their stoppers (fig. 264), thus—1, 2, 3, 4, &c. They are taken successively by tens, in the natural order.

The stoppers are placed on a support, numbered in the same manner (fig. 265). The support is pierced with ten holes, distinguished in precedence by a mark between the fifth and sixth.

FIG. 264.

FIG. 265.



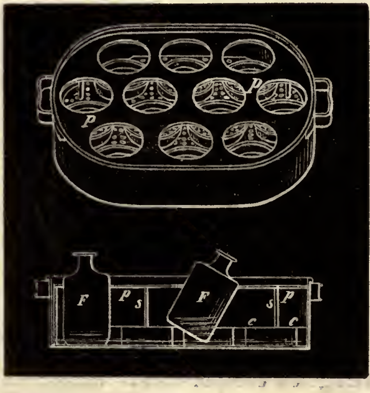
Stand.—Each ten flasks are in turn placed in a case or stand of japanned tin plate (fig. 266), having ten compartments numbered from 1 to 10. Each of these compartments is cut out anteriorly to about half their length, so as to allow the numbers of the bottles to be seen. The same stand serves for all the series, by making the same units correspond: thus No. 23 of the third series is placed in stand No. 3, &c. When each flask is charged with the alloy, about 10 grammes of nitric acid, 32° Reaumur, are measured by a pipette fig. 251, introduced into the bottles by means of a funnel with a large neck (fig. 267). The whole are then exposed to the heat of a water bath, to facilitate the solution of the alloy.

FIG. 266.

FIG. 267.

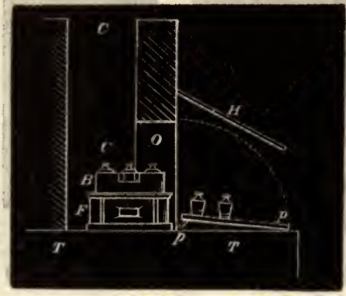
Water-bath.—This is an oblong tin-plate vessel, calculated to receive 10 bottles (fig. 268). It has a moveable double bottom, pierced with small holes, the principal object of which is to prevent the fracture of the bottles by isolating them from the bottom of the vessel, which is immediately exposed to the heat. On the moveable bottom are soldered the cylinders *c c*, three or four centimeters in height, and above which, at the distance of eight centimeters, is a sheet of tin-plate, *p p*, pierced with ten holes, corresponding to the cylinders, and connected with the moveable bottom by the supports, *s s*. These cylinders, and the sheet of tin-plate, are destined to isolate the bottles *F F* one from the other in the bath, and to keep them some time suspended over it, when the water is boiling, before complete immersion. The water-bath may be replaced by a steam bath; the bottles will then be supported by a grating above the surface of the water. The solution of the alloy in the nitric acid takes place rapidly, and as it gives rise to an abundant evolution of nitrous vapour, it must be made under a flue having a good draught.

FIG. 268.



Flue.—This is represented at Fig. 269. *C C* is a flue resting on a table or support, *T T*, about 90 centimeters high. The anterior side in the figure is removed to show the waterbath *B*, and the furnace *F*. The opening *O* of the flue is closed by the wooden door, *p*, moveable on two excentric pivots, which keep it up during the solution, and allow it to fall so that the flasks may be placed upon it. The nitrous vapour is removed from the bottles with the blower, fig. 252. The hood, *H*, prevents the diffusion of the nitrous vapour in the laboratory.

FIG. 269.



Agitator.—Figure 270 gives a sufficiently exact idea of this apparatus, and dispenses with a long description. It has ten cylindrical compartments, numbered from 1 to 10. The bottles, after solution of the alloy, are placed in it in the order of their numbers. The agitator is then placed by the side of the pipette, by which is measured the normal solution of salt, and into each flask is poured a pipetteful of the solution. The bottles are fitted with their stoppers, previously moistened with distilled water (fig. 271); they are then fixed in order with wooden wedges (fig. 272). The agitator is suspended to a spring *R*, and a rapid alternating movement given to it with both hands, by which the solution is agitated, and in less than a minute rendered as clear as water.

This movement is assisted by a spiral spring, *B*, fixed to the agitator and its stand. The agitation finished, the wedges are removed, and

Fig. 270.

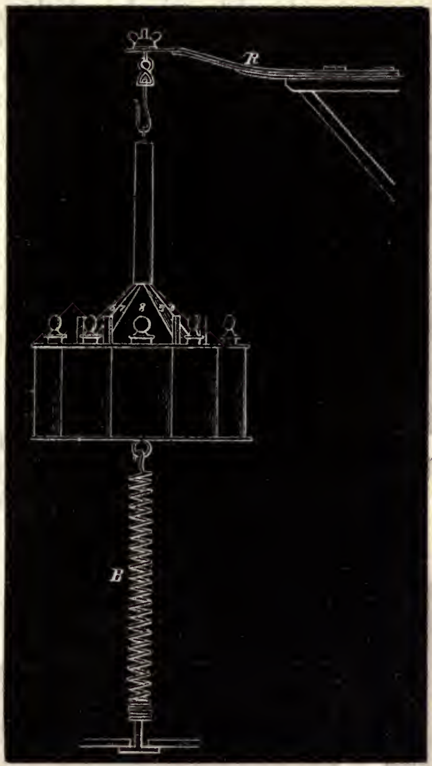


Fig. 271.

Fig. 272.

placed in the vacant spaces between the compartments. The agitator is taken from the spring, and the bottles placed in order on a table prepared to receive them.

Table.—This table (fig. 273) has a double bottom; the upper is pierced with ten holes, a little larger than the diameter of the bottles, and of such a distance from the lower portion, or false bottom, that the flasks do not rise above its edge, or at least but little. This disposition is to protect the chloride of silver from the light, for it decomposes in contact with water, and a little hydrochloric acid is produced, which requires for its precipitation a certain quantity of nitrate of silver, and so lowers the standard of the alloy. This cause of error is however not very great, at least when the light does not fall directly on the chloride; but it is easy to avoid, and should not be neglected. The disposition already pointed out does not at all complicate the process, and is moreover useful, as it prevents the fracture or upsetting of the bottles. When but one bottle is operated on, it is placed for agitation in a japanned tin-plate cylinder, which is held as shewn at fig. 273. On placing the bottles in their respective places on the table, a brisk circular movement is given to them, so as to remove any chloride of silver adhering to the sides; their stoppers are removed and suspended by spring pincers, *a a*. These are formed of sheet iron wire, see fig. 274. A thousandth of the decime solution is then poured into each bottle, and before this has been completed there will have formed in the first bottles where there is any precipitate, a well marked nebular layer about a centimeter in thickness,

FIG. 273.

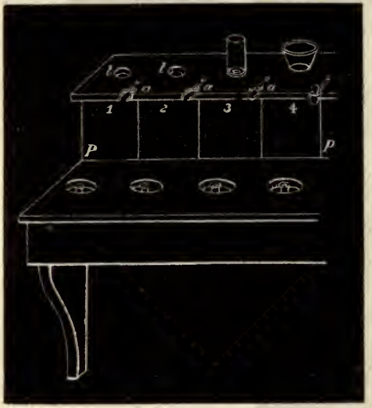


FIG. 274.

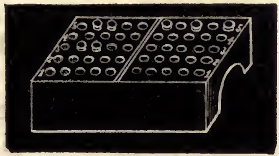
FIG. 275.

At the back of the table is a black board, *P P*, divided into compartments numbered from 1 to 10, on each of which is marked with chalk the number of thousandths of decime liquid added to the contents of the corresponding bottle. The thousandths of salt announcing augmentation of standard are preceded by the sign +, those of nitrate of silver by the sign —.

Lastly, the black board carries a small shelf pierced with holes *t t*, and these receive the funnels or drain the bottles; on this shelf also are fastened the pincers for sustaining the stoppers.

Cleansing the bottles.—The assays terminated, the liquid from each flask is poured into a large vessel in which there is always a slight excess of common salt, and when it is full the clear supernatant fluid is removed by means of a syphon. Immediately will be given the means of reducing the chloride of silver so collected to the metallic state. The bottles, to the number of ten, are first rinsed with the same water passed from one to the other, then a second and then a third time with fresh water. They are then placed to drain on the board just mentioned, and the stoppers are placed in a stand by series of tens (see figs. 276 and 265). It is important to remark, that when a glass has been rinsed with distilled water, care must be taken not to rub it with the fingers, for water poured in such a vessel would always be clouded on the addition of nitrate of silver. This effect is due to the chlorides contained in the perspiration, and is of course more to be guarded against in summer.

FIG. 276.



Reduction of Chloride of Silver obtained in the Assay of Alloys by the Humid Method.

Chloride of silver can be reduced without sensible loss, after having been well washed, by plunging into it scraps of iron or zinc, and adding dilute sulphuric acid in sufficient quantity to set up a slight disengagement of hydrogen gas. The whole can be left to itself, and in the course of a few days the silver is completely reduced. This point can be easily determined by the colour and nature of the product, but better still by treating a small quantity by ammonia, which if the chloride is perfectly reduced will give no precipitate or cloudiness on treatment with an acid. The chlorine remains in solution in the water combined with zinc or iron. The residue must now be washed; the first washings are made with acidulated water, to dissolve oxide of iron which might have formed, and the following with ordinary water: after having completed the washing, as much water as may be left is decanted, the mass dried, and a little powdered borax added. Nothing now remains but to fuse it. The powdered silver being voluminous, it is placed by separate portions into the crucible, in proportion as it sinks. The heat should be at first moderate, but towards the end of the operation should be sufficiently high to reduce the silver and slag to a state of complete liquidity. If it be found that not quite all the chloride was reduced by the iron or zinc, a little carbonate of potash or soda may be added to the powdered silver. The standard of silver thus obtained is from 999 to 1000 thousandths.

Preparation of Perfectly Pure Silver.

Take the silver prepared as above, dissolve it in nitric acid, and leave the solution some time in perfect rest in water, to deposit any gold it might contain. Decant the solution, and precipitate with common salt, well wash the precipitate, and reduce it, when the resulting silver will be perfectly pure.

M. Gay Lussac here gives a description of a process for the precipitation of chlorine from nitric acid for use in the mode of assay already described; but as that acid in a state of purity forms an ordinary article of commerce, and can be obtained at Messrs. Simpson and Maule's, of Kennington Road, and elsewhere, the process will not be here reproduced.

Modifications required in the Assay of Silver Alloys containing Mercury.

Whenever mercury is present in solution with silver, it is thrown down as insoluble chloride, and the assay rendered inaccurate. The presence of mercury in silver can be readily detected by the remarkable change which occurs in chloride of silver on exposure to light (viz. blackening) when free from mercury; but if the smallest quantity of the latter metal be present, no blackening will ensue, This source of error was removed by M. Levol in the following manner:—The sample being dissolved, as usual, in nitric acid, it was supersaturated with 25 cubic centimeters of caustic ammonia; then add the pipetteful of normal solution, and supersaturate the excess of ammonia with 20 cubic centimeters of acetic acid, and the operation continued in the usual way.

It may not be superfluous to state, that it is very easy to obtain an excellent result of an assay of silver containing mercury, made in the ordinary way, and in which the presence of the mercury is rendered manifest by the non-colouration of the precipitate under the influence of light. It suffices for this purpose to dissolve the precipitate in concentrated ammonia, and to supersaturate with acetic acid.

The ordinary acetic acid of commerce is employed, and the ammonia diluted with its volume of water, to avoid the too violent reaction. Both agents must be free from chlorides.

Some little time after the publication of this, M. Gay Lussac examined the above process himself, and very considerably simplified it. He says, "after having confirmed by several experiments the accuracy of M. Levol's process, I thought it might be simplified by adding to the nitric solution of silver the ammonia and acetic acid at one and the same time, but in sufficient quantity to saturate the whole of the nitric acid, both that in combination with the silver and that in the free state. Ten grammes of acetate of ammonia were added, with a little water, to the silver dissolved in nitric acid, and the assay finished in the ordinary manner. The quantity indicated by synthesis was found very accurately, although 100 thousandths of mercury had been added." Finally, M. Gay Lussac found that 10 grammes of acetate of soda, in crystals, also fully answered the purpose; and as that is a very cheap commercial salt, it is the best adapted for overcoming the difficulty in this class of assay, as regards the presence of mercury.

APPENDIX.

In the foregone description of the method of assay by the humid method, it has been the object of the writer not to distract the attention by too numerous details. Here, however, will be given the processes to which personal experience has given the preference.

Apparatus for Weighing the Normal Solution of Salt.

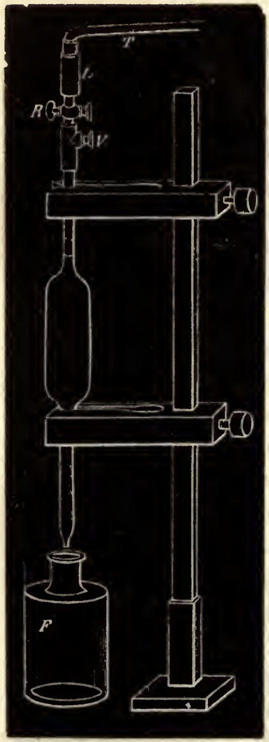
FIG. 277.

The apparatus about to be described enables the operator to weigh the normal solution of salt more rapidly than by means of the burette, (fig. 240). It is a pipette, *P* (fig. 277), capable of furnishing in a continuous jet very nearly 100 grammes of solution, when filled up to the mark *a b*, at the ordinary temperature. As this weight changes its volume with the temperature, some marks are traced on the neck of the pipette, so as to regulate approximatively the volume to be taken. The pipette is terminated below by a three-footed stop-cock, *R*, having a narrow outlet, *p* (about two millimeters). It is filled with solution by means of a small silver funnel (fig. 278), or better still by the suction-tube, *T*, of the apparatus fig. 261, making an addition similar to that represented by fig. 276. The pipette is adjusted by absorbing the excess of liquid with a small roll of filtering or other absorbent paper, or by allowing its exit by the stop-cock. The following is the method of proceeding:—

FIG. 278.

The pipette being approximatively adjusted to nearly 1 or 3 thousandths, it is placed in the balance described fig. 245, with a constant equivalent weight, and the equilibrium effected by means of the rider. It is then placed over the bottle in which the assay was dissolved, the stop-cock opened, and the liquid run out. The stop-cock must be shut as soon as the jet stops. The pipette is again placed in the balance with a weight of 100 grains, and the equilibrium effected by aid of the rider. This process is certainly more rapid than weighing with the burette. The weighing can be made even more rapidly by suspending the burette from the beam of the balance.

FIG. 279.



Apparatus for Filling the Pipette with Normal Solution by Aspiration, and for convenient adjustment.

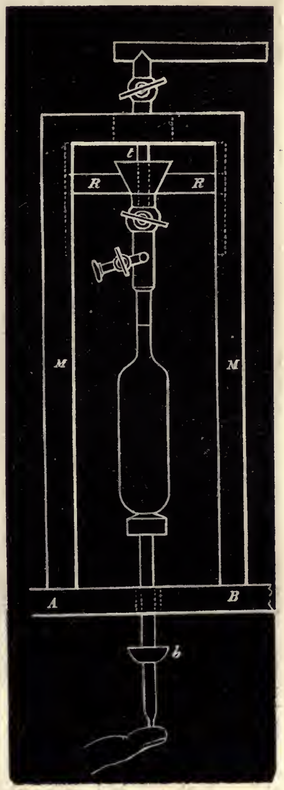
This apparatus was the first employed, and has been in use for a considerable time. It is here described, because it appears extremely suitable for such persons as may be very little used to manipulation. It is sufficiently delineated in fig. 279. To fill the pipette, the jet or beak is plunged into a bottle containing the normal solution of salt, and the liquid is raised by the glass tube *T*, fixed to the socket *D* by means of a cork. The stop-cock, *R*, is then closed whilst the tube is yet in the mouth, and the pipette is placed on its support in the following manner:—Take hold of its neck with the left hand, and place its beak or jet in the lower arm; then its neck in the upper arm, the blades of which are opened by means of the fingers. The pipette thus placed, so that its jet cannot be injured by the bottle, *F,* which is destined to receive the solution, it is adjusted by aid of the screw, *V,* whilst the "handkerchief," *M,* is applied to the jet; and as soon as it is adjusted, the handkerchief is removed with one hand, and the bottle placed under it with the other. The fluid is then allowed to run.

Another Apparatus for filling the Pipette with Normal Salt Solution.

In this apparatus (fig. 280) the pipette is moveable from below, above, to receive the tube *t,* through which the salt solution passes, and which fits the neck of the pipette like a funnel. To obtain this ascensional movement without lateral deviation, the jet of the pipette passes into a hole pierced in the cross piece *A B,* and the stop-cock, fitted to its upper part, carries two wings, *R R,* working in slots cut in the supports, *M M.* The extent of movement is regulated by two corks, *B b,* cemented on to the lower part of the pipette. To fill it, the forefinger of the left hand is placed against the lower orifice, and the whole raised until the cork, *b,* touches the cross piece. By this ascensional movement the tube, *t,* enters the neck of the pipette: immediately the stop-cock of the reservoir must be opened. When the pipette is filled it is allowed to fall again, the stop-cock shut, the finger removed, and finally adjusted.

The reservoir containing the solution is, for the sake of convenience, moveable.

Fig. 280.

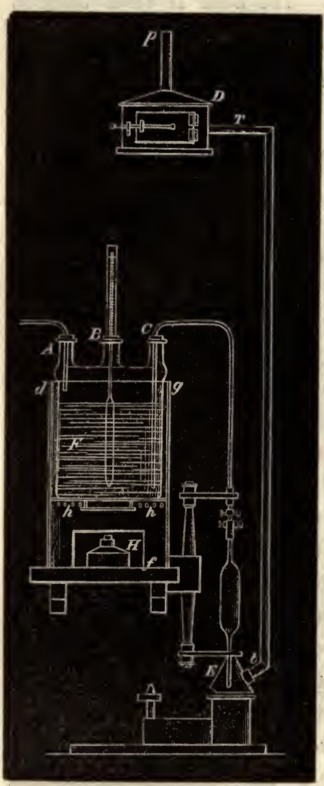


Apparatus for Preserving the Normal Solution of Salt at a constant Temperature.

The bulk of the normal solution of salt is too great to allow of its temperature being readily changed and reduced to any determinate degree. This, indeed, would be useless, for it suffices that the quantity of solution to be employed in the day should possess the desired temperature.

The solution, before entering the pipette from its reservoir, traverses an intermediate bottle, *F* (fig. 281), in which its temperature is suitably varied. The flask has three tubulures, *A. B, C.* To the tubulure *A* is adapted a tube with a stop-cock; this carries the solution into the bottle. To the tubulure *B* is fixed a centigrade thermometer, which indicates the temperature of the solution; and through the tubulure *C* passes a syphon, which conveys the liquid to the pipette. The bottle is enveloped in a sheet-iron casing, *d e f g*, whose diameter is from three to four centimeters greater. The intermediate space is closed above by a border on the envelope, and by strips of paper cemented with glue. The bottle stands on a plate of sheet-iron of its own diameter, fixed to the casing by three supports; but it is separated by a thick sheet of card-board, employed as a bad conductor of heat. Below this plate, at the distance of from 12 to 15 millimetres, is another of smaller diameter, the object of which is to deaden and spread the too powerful heat of a spirit-lamp, *H*, which is employed to raise the temperature of the salt solution. [A gas flame is still better.—J. M.] The heated air rises into the annular chimney, between the bottle and its casing, and escapes by the small circular openings, *h h*, &c. This apparatus only serves to heat the solution; it is very difficult to cool it.

FIG. 281.



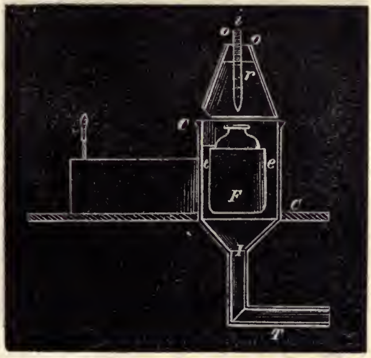
Means of Protection from the Nitrous Vapour disengaged from the Bottles during the Process of Assay by the Humid Method.

After the solution of the silver in nitric acid, it has been recommended that the nitrous vapour be expelled from the flasks by the introduction of air by the blower, fig. 252. But the solution yet remains impregnated with nitrous vapour, which continues to pass off; and it is only when it is completely cold that its disengagement is scarcely sensible. It therefore becomes necessary to find protection from this whilst the solution is yet very hot, and the vapour abundant. To the jet of the pipette, fig. 281, is adapted a funnel having a lateral tubulure, *t*, or simply an opening, by means of which it is placed in communication with a tube, *T*, *T*, of three or four centimeters in diameter, entering into the case *D*, in which is a lamp, or a chauffer with live coals. The air necessary to support this combustion can only enter the box by passing through the funnel, and carries off the nitrous vapour displaced by the normal solution at the moment it is run into the bottle. From the case the nitrous vapour escapes with the air, by the tube *p*, either into a chimney or outside the laboratory. The funnel has a small portion cut off, so as to allow the free passage of the "handkerchief" to the pipette.

This apparatus is very handy, and answers its purpose remarkably well; but, if the locality will allow, the following is preferable:—

The jet of the pipette also has a funnel (see fig. 282), but the draught is determined from below by means of the tube *T I*, which passes under the floor, and then enters the chimney or flue under which the alloys are dissolved. The cylinder, *e e*, in which the bottle, *F*, is placed, is enveloped in another cylinder, *C C*, two centimeters greater in diameter. It is through this intermediate space that the nitrous vapour is carried off. But, so that none may remain in the funnel, air also passes in by four openings, *o o*, pierced through the cork by which the funnel is fixed to the pipette. Lastly, in order to render the funnel easy of ascent and descent, a ferrule, *i r*, furnished exteriorly with a screw thread, is cemented to the beak of the pipette; and it is on this ferule that the funnel turns. The interior cylinder is connected with the exterior by three small pieces of metal soldered to either cylinder, so as to leave the intermediate space as free as possible.*

Fig. 282.



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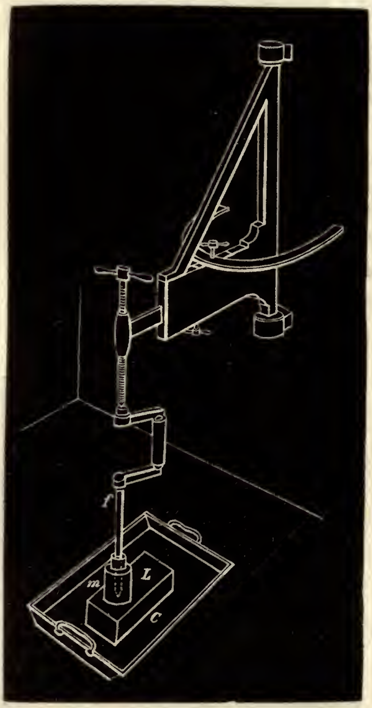
* A case built against the laboratory wall, having moveable glazed windows in front, and connected above with a flue, is the most simple mode of preventing the escape of noxious vapours.

Method of Taking the Assay from the Ingot.

The ingots are so rarely perfectly homogeneous, even taking as a starting point the standard 950 thousandths, that the differences remarked between the assays of samples made in different places should rather be attributed to the above cause than to the assay itself. It is important, therefore, to take a sample in a uniform manner, and from the same depth, on the upper surface of the ingot as on the lower. This condition is perfectly fulfilled by boring the ingots with a kind of drill, similar to that employed by the smith, and which is represented at fig. 283. The ingot, *L*, is placed in a copper tray, *C*; and in order to retain the borings, which might otherwise be thrown out, the drill, *f*, is surrounded by a casing, *m*, which does not impede its motion, and stands freely on the ingot. After a few turns of the drill, the first borings, which are not pure, are removed by means of a feather, and only those following are collected and reserved for assay. If it be desirable to try the lateral faces, it is necessary to employ a pressure screw, to keep the ingot in the position that may be deemed necessary.

Fig. 283.



The following is a slight modification of the process as already described, and the necessary apparatus are to be found in every laboratory. I employ in this class of assay very simple apparatus, (similar to those used in alkalimetry) to determine the weight of the standard solution of salt added: and the results so obtained always correspond.

The apparatus I employ are as follows:—A small flask for the solution of the silver to be assayed, a stoppered bottle (containing from three to four fluid ounces), in which the decomposition of the silver solution is made, and two small alkalimeters, known by the name of Schuster's. The alkalimeter is a light glass bottle, with two openings, one of which is drawn out, and extends over the side of the flask, parallel to its bottom; this aperture is for the purpose of allowing the fluid contained in the bottle to pass out in single drops, which it does most effectually. The other aperture just mentioned is furnished with a small stopper, and is used for the introduction of the fluid. An accurate balance and weights, with a few stirring rods, complete the set.

The standard solution of salt is made as follows:—It is absolutely necessary to employ pure salt. It is better to manufacture this, which may be accomplished by accurately neutralising pure hydrochloric acid with bicarbonate of soda, evaporating the solution to dryness, and fusing the dry residue, taking care to place it, whilst warm, in a well-stopped bottle, to preserve it perfectly free from moisture.

Distilled water must also be employed, of which 94·573 parts must have added to them 5·427 parts of the salt, as above prepared. The solution so formed must be kept in glass stoppered bottles, and exposed as little as possible to the air during manipulation, otherwise it will become sensibly stronger by evaporation, and cause fallacious results; 100 grains, by weight, of this solution, precipitate exactly 10 grains of silver.

I also employ another solution, the use of which will be pointed out hereafter. This solution is made by dissolving 10 grains of pure silver in a small quantity of nitric acid, and adding pure water (distilled) to the solution, until its weight amounts to 10,000 grains. This is the *verifying* solution.

This solution must be preserved with the same precautions as to exposure to air, &c., as the last; in addition to which it must be kept in a dark place.

The assay is thus made: 10 grains of the alloy are dissolved in nitric acid; when the solution is effected, water (distilled) must be added, and the whole poured into the assay bottle before mentioned. The flask in which the solution was made must be carefully washed out, and the rinsings added to that already in the assay bottle. A quantity (any amount) of the solution of salt must be placed in one of the alkalimeters, which, with it, must be carefully weighed, and the weight noted. The standard solution is now to be added, drop by drop, to the solution of the alloy in the bottle, replacing the stopper (taking care to hold it in the hand whilst dropping in the solution of salt) after each addition, and shaking the bottle well, to clarify its contents; repeating the above routine until the last drop occasions no turbidity in the liquid.

The weight of the alkalimeter and contents must now be again taken, and the amount of grains of salt solution employed noted.

There is most likely now in the bottle a little excess of salt, the amount of which must be estimated by the verifying solution just mentioned, in the following manner. Place in the other alkalimeter a certain amount (any quantity) of the verifying solution, and ascertain its weight with that of the alkalimeter, taking care to note it. Now add the solution, drop by drop, to the assay in the bottle, observing all the precautions as to agitation, &c., already pointed out, until the last drop causes no turbidity; then weigh the alkalimeter, and note the loss of weight, and from the amounts of solution used calculate the standard of the silver alloy in thousandths. This will be rendered perfectly clear by an example: 10 grains of alloy require for complete precipitation 60·7 grains of the salt solution; and as 10 grains of the solution are equal to 1 grain of silver, 60·7 is equal to 6·07 of silver; but a slight excess of solution has been added, which has increased the amount of silver above its true quantity; therefore 52 grains of the verifying solution were added; and as each 100 grains of such solution contains ·1 of a grain of silver, the 52 grains will contain ·052 of silver, which, deducted from 6·07 = 6·018 of silver, which gives 601·8 thousandths as the true standard of the alloy operated upon.

CHAPTER XI.

ASSAY OF GOLD.

For the purposes of assay, all substances containing gold may be divided into two classes, as in the case of silver.

The *First Class* comprises all substances containing gold in a minute state of division; such, for instance, as those which, suitably pulverised, completely pass through a sieve of 80 holes to the linear inch. It often happens, however, that these substances contain fragments of gold of such magnitude as will not allow them to pass through the sieve: in such cases, that which passes *through* belongs to the first class, and that which remains *on* the sieve to the second class.

The *Second Class* comprises all alloys of gold, native or otherwise.

Substances of Class First.

The name of substances belonging to this class is legion, for an extended examination shews that nearly every mineral substance contains more or less gold. The most common are—gold quartz, auriferous gossans, sulphurets of iron (mundic), blendes, copper pyrites, many antimonial minerals, galenas, and nearly all the primitive rocks. All auriferous slags, amalgamation residues, and tailings, belong to this class.*

Assay of Substances of the First Class.—This assay is conducted in precisely the same manner as that of the corresponding silver class, which see. In case, however, the amount of gold present in the sample is small, as much as 2000 grains, with flux suitably increased, may be employed. In case any metallic gold is left in the sieve, its amount is to be calculated as that of silver (see pages 366 and 367).

It may here be mentioned, that if silver or platinum coexist with the gold in the mineral subjected to assay, it will be found combined with the gold obtained by cupellation; and all gold so obtained must be submitted to the "parting process," which see under the head "Assay of Auriferous Substances of the Second Class." It may here be mentioned, that the metallic gold left on the sieve must be thus operated on, as well as that obtained by fusion of the sieved ore and consequent cupellation, before the calculation given at pages 366 and 367 be entered into.

When gold is associated in quantity with quartz, its per centage can be approximatively ascertained in the same manner as that of pure tin-stone when mixed with quartz (see pages 304 and 305). If possible a fragment of the gold must be detached from the quartz, and its specific gravity taken: if this be not possible, and the gold is nearly fine, the number 19 may be adopted. It is better, however, to determine experimentally the specific gravity of both quartz and gold.

Substances of the Second Class.

Native Gold.
Aururets of Silver (Native).
Gold and Rhodium.
Gold and Palladium.
Argentiferous Telluret of Gold.
Plumbo-argentiferous Telluret of Gold.
Sulpho-plumbiferous Telluret of Gold.
Artificial Alloys of Gold.

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* This matter, as well as all others connected with gold, as its Production, Distribution, &c. will be fully treated in a volume the author is now preparing.

Native Gold and Aururets of Silver (*Native*) Au and $AuAg^n$, are found in variously contorted and branched filaments, in scales, in plates, in small irregular masses, in the crevices or on the surface of common ferruginous and other quartz. In Devonshire, at the Britannia Mine, it has occurred in pipes or veins, and disseminated in a compact hard gossan, one specimen of which I found to contain 27½ per cent. of fine gold; or, as in Wales, it largely accompanies blende and galena: it also occurs in a pyritous quartz; and it has been found in Scotland and Ireland. In the latter locality it occurred in the beds of streams as small scales and rolled masses, and nearly up to the present time this has been the most frequent mode of occurrence; but now, however, by the aid of improved machinery, rocks and minerals containing a comparatively small quantity can be profitably worked; and from this source, doubtless, will the greatest part of the gold to be poured into commerce be extracted. The following are some of its crystalline forms (see figs. 283, 284, 285, 286, 287, 288, 289.)

Fig. 284.

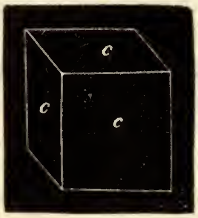


Fig. 285

Fig. 286.

Fig. 287.

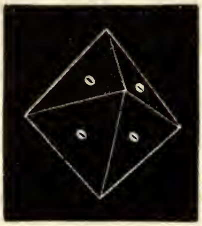


Fig. 288.

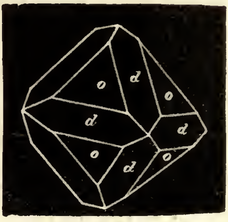
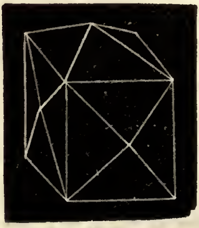


Fig. 28.).

Fig. 290.



Composition of several Varieties of Native Gold, by Boussingault, the chief part from Central America.

	Malpaso.	Llano.	La Baja.	Rio-Sucio.
Gold	88·24	88·58	88·15	87·94
Silver	11·76	11·42	11·85	12·06
	100·00	100·00	100·00	100·00

	Ojas Anchas.	Trinidad.	Guano.	Otramina.
Gold	84·50	82·40	73·68	73·60
Silver	15·50	17·60	26·32	26·60
	100·00	100·00	100·00	100·00

	Titiribi.	Marmato.	Transylvania.	Santa Rosa.
Gold	74·00	73·45	64·52	64·93
Silver	26·00	26·55	35·48	35·07
	100·00	100·00	100·00	100·00

Specimens of Gold from Siberia, by Rose.

	Schabrowski, near Katherinenburg.	Borushka, near Nischen-Tagil.
Gold	98·76	94·41
Silver	00·16	05·23
Copper	00·35	00·39
Iron	00·05	00·04
	99·32	100·07

	Berescoff.	Katherinenburg.
Gold	93·78	93·34
Silver	5·94	6·28
Copper	·08	·06
Iron	·00	·32
	99·80	100·00

	Crascewo Nicolajeusk, near Miask.	Perroc Powlowsk, near Berescoff.
Gold	92·47	92·60
Silver	7·27	7·08
Copper	·06	·18
Iron	·08	·06
	99·88	99·92

	Borushklei.	Alexander Andrejensk, near Miask.
Gold	90·76	87·40
Silver	9·02	12·07
Copper	·09	·09
	99·87	99·56

Gold from Senegal, by D'Arcet.

Gold	86·97
Silver	10·53
	97·50

Gold from Brazil, by D'Arcet.

Gold	94·00
Silver	5·85
	99·85

Gold from Anamaboe, Africa, by Henry.

Gold	98·06
Silver	1·39
Iron	·15
	99·60

Gold from California, by Henry.

	1.	2.
Gold	86·87	88·75
Silver	12·33	8·88
Copper	·29	·85
Iron	·54	traces
Silica	·00	1·40
	100·03	99·88

Gold from California, by Teschemacher.

Gold	90·33
Silver	6·80
Oxide of iron	1·10
Sand	·66
	98·89

Gold from Australia, by Henry.

Gold	95·68	
Silver	3·92	
Iron	·16	
		99·76

Gold from Devonshire and Wales, by the Author.

The author has received two specimens of gold, one from Wales, and the other from the Britannia Mine, Devon; and found both to be absolutely fine gold.

Gold and Rhodium.—This compound was discovered by M. André del Rio among some gold ores in Mexico. It has a gold colour, and contains variable proportions of rhodium; the mean, however, is 34 per cent.

Gold and Palladium.—The following is the composition of this alloy:—

Gold	85·98	
Palladium	9.85	
Silver	4·17	
		100·00

Argentiferous Telluret of Gold ($AgTe_2+3AuTe_6$).—This mineral has a steel grey colour and metallic appearance. It crystallizes in small rhomboidal prisms.

Composition:—

Gold	30	
Silver	10	
Tellurium	16	
		56

Plumbo-argentiferous Telluret of Gold (probable formula, $AgTe_2+3AuTe_3+2PbTe_2$).—Colour silver white, passing to brass yellow; semi-ductile; fracture lamellar in one direction, granular in the other. It is sometimes found crystallised in small four-faced rectangular prisms, but more often in thin plates.

Composition:—

Gold	26·75	
Silver	8·50	
Lead	19·50	
Tellurium	44·75	
Sulphur	·50	
		100·00

Sulpho-plumbiferous Telluret of Gold (probable formula $AuTe_3+4PbTe_2+2PbS$).—Colour deep lead grey, very brilliant;

crystallises in slightly elongated hexahedral tables. Its fracture is lamellar; it is soft, and stains slightly.

Composition:—

Gold	9·0
Silver	·5
Lead	54·0
Copper	1·3
Tellurium	32·2
Sulphur	3·0
	100·0

Artificial Alloys of Gold.—The only one of these alloys which will be specially noticed here, is the standard gold of this realm. It is composed of 22 parts of fine gold and 2 parts of alloy (copper), constituting 22 carat or standard gold.

General Observations on the Assay of Gold Alloys.

Cupellation, Gold and Lead.—The cupellation of the alloys of gold and lead is conducted in a similar manner to those of silver and lead. It presents even less difficulty, and requires less precaution, because it is not so volatile, and because it has a less tendency than silver to penetrate into the cupel, and the button is less subject to throw pieces out of the cupel. These cupellations take place at a higher temperature than those of silver, and we need not be afraid of giving a good heat at the moment of brightening: the gold is but the purer.

Gold and Copper, Proportion of Lead.—The alloys of gold and copper are cupelled like the alloys of gold and silver; but as copper has a very great affinity for gold, it is necessary to use a larger proportion of lead to ensure its oxidation when combined with gold than when united with silver. This proportion varies according to the standard and the temperature. It is admitted that for the same standard there must, under similar circumstances, be twice as much lead used in the cupellation of gold as for that of silver. Thus, 14 parts, at least, ought to be employed in common furnaces for an assay of gold coin which contains 0·100 of copper. There is no inconvenience in employing a little more, as it does not increase the loss of gold. However great the proportion of lead may be that is added to the cupreous gold for the purpose of cupellation, the button retains always a very small quantity of copper, which a fresh cupellation does not free it from, and which occasions what is termed the surcharge. This surcharge being very slight, can be neglected in assays of minerals; but it is necessary to take notice of it in the assay of alloys. But it is known that the presence of silver much facilitates the separation of copper from gold, and it is rare that an alloy of cupreous gold does not contain a little silver, which must be separated: and when that is not the case, a small quantity of that metal can be introduced into the alloy, so as to be in about the proportion of 3 parts to 1 of gold. When an assay is to be made of an alloy of gold and copper, a sufficient quantity of silver is to be added to fulfil this condition according to the presumed standard, which is determined approximatively by a preliminary assay, and then cupelled with lead.

TABLE FOR PROPORTION OF LEAD TO BE EMPLOYED IN THE CUPELLATION OF GOLD AND COPPER.

Gold in Alloy.	Lead required.
1000 thousandths	1 part.
900 „	10 parts.
800 „	16 „
700 „	22 „
600 „	24 „
500 „	26 „
400 „	34 „
300	
200	
100	
50	

Touchstone.—It is often sufficient in commerce to determine approximatively the standard of alloys of gold and copper by the proof of the touchstone. The following is the mode of operation:—Make on the touchstone a trace with the alloy; then rub this trace with the feather of a pen, moistened in the acid liquid composed as described further on. This acid dissolves the copper; the effect is then examined; after which wipe it slightly to take away the liquid, and examine afresh that which remains of the trace. When in the habit, the standard of the alloy can be ascertained very nearly, according to the more or less green tint the acid assumes, and the thickness of the trace of pure gold which remains on the stone. In order to accustom oneself to this proof, we must make comparative assays with different known alloys, moulded into the form of strong needles, known by the name of touch needles; and it can be noticed with which of these needles the alloy is identical.

The Acid Liquid.—The liquid which is used to act on the metallic streak is composed of 98 parts of nitric acid of the density of

1·340, two parts of muriatic acid of a density of 1·173, and 25 parts of distilled water. The composition of this liquid has been determined by trial; and at the temperature of 50° to 54°, at which we ought always to operate, it is without action on alloys of the standard of 0·750, and above. The alloys of an inferior standard are attacked by this acid liquid; they become brown, and the liquid becomes green, and when the liquid is removed there remains a metallic trace, smaller in proportion to the quantity of copper contained in the alloy. If we operate at a temperature lower than 50° the acid does not attack all the alloys of a lower standard than 0·750; on the contrary, if the temperature were more elevated, the acid would attack the alloys of 0·750, and a little above. When assays are made in unknown circumstances, we commence by trying the effect of the acid on the traces left by needles of a known standard.

Gold, Silver, Platinum, and Copper.—The presence of platinum in an alloy renders the separation of the oxidisable metals, more especially copper, very difficult by cupellation. It appears, indeed, that it would be almost impossible to arrive at it, if the alloy of copper contained nothing but gold and platinum. It is necessary that silver be present at the same time. When this metal is absent, it is requisite to add a quantity of it, which ought to be equivalent to double the weight of the gold and platinum united, and cupel at the strongest heat which can be obtained in a good muffle with a suitable proportion of lead. This proportion varies much, according to the composition of the alloy, and the temperature at which the operation is carried on.

Experience has shown that the copper can be more completely separated, and less silver lost, by cupelling at a high temperature, with the least possible quantity of lead, than by employing more lead, and working at a lower temperature. M. Chaudet has made several assays, in order to determine the proportion of lead required for the cupellation of the three following alloys:—

	1.	2.	3,
Gold . .	0·100	0·020	0·005
Platinum .	0·100	0·200	0·300
Sliver . .	0·250	0·580	0·595
Copper . .	0·550	0·200	0·100

And has found for the first, that by employing 20 parts of lead the separation is very nearly complete; but that at a higher temperature there is a loss of silver; and in order to render the assay correct, it must be cupelled at the latter temperature, with only 14 of lead; for the second, 8 of lead, at a high temperature; and for the third 30 parts of lead are necessary, at the same high temperature of the muffle; but it is almost impossible to separate all the copper, and no advantage can be obtained by increasing the quantity of lead. When almost the last traces of the copper are separated, the button must be cupelled afresh, with a small quantity of lead; but a small quantity of silver is nearly always lost. In all cases, in order that no lead shall remain, it is necessary to leave the assay button some few minutes in the muffle, after the cupellation is finished,

The alloys of gold and silver which contain platinum, show, either by cupellation or parting, certain characters which prove the presence of that metal. If the assay be not heated very strongly, it does not pass, and the button becomes flat: this effect becomes very sensible when the platinum is to the gold as the proportion of 2 to 100. Under the same circumstances, the nitric acid solution proceeding from the parting is coloured straw-yellow. At the moment an assay of an alloy containing platinum terminates, the motion is slower, and the coloured bands are less numerous, more obscure, and remain a much longer time, than when there is no platinum; the button does not uncover, and the surface does not become as brilliant as that of an alloy of gold or silver, but it remains dull and tarnished. When the assay is well made, it is to be remarked that the edges of the button are thicker and more rounded than in ordinary assays, and it is of a dull white, approaching a little to the yellow; and lastly, its surface is wholly or in part crystalline. These effects are sensible even when the gold does not contain more than 0·01 of platinum. When the alloy contains more than 10 parts of platinum to 90 of gold, the annealed cornet produced in the parting process is of a pale yellow, or tarnished silver colour.

Gold alloyed with Silver.—The separation of gold from silver is termed *parting.* Parting is not only used to separate silver from gold, but for the separation of other metals, such as copper, when cupellation does not separate it entirely. Parting by the wet process is carried on by the means of nitric acid, aqua regia, or sulphuric acid.

When an alloy of gold and silver has been reduced by a flatting mill to very thin plates, it is sufficient that it contains 2½ of silver to 1 of gold in order that the parting may be effected completely by nitric acid, and takes place much less easily when the silver in the alloy is in larger proportion: but when this proportion exceeds 3 parts of silver for 1 of gold, then the latter is obtained in leaves so fine, that there is risk incurred of losing some in the subsequent manipulation, and even by the act of boiling the acid liquid.

We must always, therefore, when a very exact assay is required, contrive that the alloy shall contain a little less than 3 parts of silver to 1 of gold; a proportion which long experience has demonstrated to be the best. If the alloy contain less than 2½ of silver to 1 of gold, the silver does not wholly dissolve, because there is a part of it so enveloped in the gold that the strongest acid does not act on it.*

Inquartation.—The operation by which the alloy is brought to this standard is termed *quartation,* or *inquartation.* It consists in fusing the alloy in a cupel, with 2 parts of lead and the quantity of fine silver, or fine gold, necessary to bring it to the desired composition. This quantity is estimated according to the approximative determination of the standard of the alloy, which ought to be made either by means of a preliminary assay, as hereafter described, or by means of the touchstone. In order to make assays by the touchstone, touch-needles of various well-known standards must be provided. When an alloy is to be assayed it must be rubbed on the stone, and a needle employed which shall leave a trace of the same colour. If we do not employ the whole of the alloy the assay will not be exact, because the gold and silver are not always found distributed in an uniform manner; at least, every time it is not poured into a cold ingot mould.

Operation.—The cupelled and quartated button is flattened on an anvil and annealed, in order to soften it. It is laminated to give it a certain thickness, and is then annealed afresh, and rolled into a cornet or spiral around the quill of a pen. It is necessary that the alloy should be reduced to a suitable thickness, on the one hand, in order that the silver may be dissolved completely; and, on the other, that the plate of gold may remain whole after the operation. The following is that which experience has proved best. The quantity of matter operated upon, or taken for the assay, should be about 12 grains; and the alloy resulting from these 12 grains, and the silver, employed in the inquartation into a plate of from 18 to 20 lines in length, and 4 or 5 in breadth.

The cornet for assay is placed in a glass matrass, capable of containing about three ounces of water; pure nitric acid is added at different times, and heat applied. When all the silver is dissolved, it is washed by decantation with water; the matrass is reversed into a small crucible, the cornet falls out and is dried. In this state the cornet is very fragile, and of a dull red colour; it is annealed

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* Later experiments by Pettenkoffer have shown that under certain circumstances a little less than two parts of silver will suffice; the author, however, prefers to use nearly three parts, as in the text.

in a muffle, and heated gradually without fusion. It becomes thereby much contracted, and acquires a metallic lustre, and so much solidity that it can be weighed without fear of breaking it. Its weight can be ascertained in the assay balance.

There are many ways of employing nitric acid. Formerly 2½ ounces (thirty-five times the weight of the alloy) of nitric acid (1·15 sp. gr.) was poured upon the inquartated cornet, and boiled gently for fifteen or twenty minutes, the liquid decanted and replaced by 1½ of acid (1·24 or 1·26), twenty-four times the weight of the alloy, boiling for twelve minutes, then decanting and washing, &c. Vauquelain pointed out in his "Manuel de l'Essayeur," to pour on the quartated cornet—the weight of the assay being 7·7 grains—554 to 770 grains of nitric acid (1·16 sp. gr.), which ought to fill the matrass half or two-thirds, and boil gently for twenty, or twenty-two minutes at most, to decant and replace the liquid by 500 to 800 grains of acid (1·26 sp. gr.), and to boil for eight or ten minutes. The assay is to be acted on always twice, because, if we employ at once very strong acid, the action will be too brisk, and the cornet might be broken or carried out of the matrass, and, on the other side, the acid of 1·16 sp. gr. cannot dissolve the last portions of silver, which are very difficult to separate from the gold.

Surcharge.—It is remarked that by following this method the cornet always retains a small quantity of silver, so that fine gold submitted to quartation and parting always weighs more after than before the operation. The augmentation of weight which it undergoes is termed the *surcharge;* this surcharge is commonly from 0·001 to 0·002. M. Chaudet has found means to avoid it. In order to do so, pour on to the quartated cornet nitric acid of 1·16 sp. gr., and heat for three or four minutes only; replace this acid by acid at 1·26 sp. gr., and boil during ten minutes; decant and make a second boiling with acid at 1·26 sp. gr., which boil for eight or ten minutes. The assay requires but from twenty to twenty-three minutes, and, according to M. Chaudet, gives perfectly pure gold.

Argentiferous and Auriferous Ores.—In the assay of auriferous ores, the button produced by cupellation commonly contains silver. When the proportion of this metal surpasses that of inquartation, the button is flattened between two pieces of paper, and treated by pure nitric acid. The gold remains under the form of a yellowish-brown powder, which is weighed immediately, or fused in the cupel enveloped in a sheet of lead. When the quantity is extremely small and imponderable, we can assure ourselves at least of its presence by treating the residue left by nitric acid with aqua regia; if it contain gold, it dissolves and gives a yellowish liquid, in which a drop of solution of chloride of tin or the crystallised chloride forms a deposit of purple of Cassius of a violet colour: this character proves the presence of the smallest traces of gold. When the gold predominates in the button, it is necessary to re-fuse it with three times or less its weight of silver, and recommence the assay with the addition of this preparation of silver.

Sea-salt.—We can, according to M. Gay-Lussac, make assays of the alloys of gold, silver, and copper, with great exactitude, by means of the standard solution of sea-salt. When the alloy contains five or six times more of silver and copper than of gold, a known weight of the alloy is taken, containing nearly 1 gramme of silver; it is dissolved in a matrass (fig. 291) capable of containing about 200 grammes of water, with 462 grs. of nitric acid, at 1·26 sp. gr., and boiled for ten minutes. The assay is finished as usual; but in order to leave the gold and separate the silver, supersaturate the solution with ammonia, which dissolves the chloride; wash the residue twice in succession with ammonia, then place in a crucible to anneal. If the gold were alloyed with silver and copper in a larger proportion than 1 to 6, a known quantity of fine silver should be added, and then deducted from the assay. In order to avoid all loss, the bottom of the crucible is lined with paper, and the alloy placed thereon, and the latter covered with fused borax.

FIG. 291.

Aqua Regia.—When gold is the largest portion of the alloy, and when there are reasons for not adding silver, the parting can be made by aqua regia. In this case, all the gold is dissolved, and the silver converted into chloride; the chloride is washed, dried perfectly, and weighed. When the gold is precipitated by proto-sulphate of iron, it is washed with a little muriatic acid, and annealed strongly before weighing or even carrying the annealing so far as to fuse it, and then cupelling it with lead.

If an alloy, containing much silver, be treated by this process, it sometimes happens that the excess of chloride of silver prevents the complete solution of the gold. In this case it is necessary to reduce the alloy to an excessively thin plate, to dissolve the chloride in ammonia, and to treat afresh with aqua regia. This process can rarely be made use of in the large scale, because the precipitation of gold by sulphate of iron is long and troublesome.

Method of M. Rose.—M. G. Rose fuses the alloy with lead, over a spirit-lamp, in a porcelain crucible, acts on it with nitric acid, which dissolves the silver and lead, precipitates the silver by a solution of chloride of lead; lastly, the auriferous residue is dissolved by aqua regia, and the gold precipitated by protochloride of iron.

Standard of the alloys of gold.—The real standard of the alloys of gold is expressed in fractions of unity as in the case of alloys of silver. We suppose 24 carats in unity, and 32 32nds in the carat; the unity contains then 768 32nds. After these data the following Table has been formed, which expresses the relation of 32nds and carats to decimal fractions of the unity.

32nds.	Decimals.	Carats.	Decimals.
1	0·001302	1	0·041667
2	0·002604	2	0·083334
3	0·003906	3	0·125001
4	0·005208	4	0·166667
5	0·006510	5	0·208333
6	0·007912	6	0·250000
7	0·009115	7	0·291666
8	0·010415	8	0·333333
9	0·011718	9	0·374999
10	0·013021	10	0·416667
11	0·014323	11	0·458630
12	0·015625	12	0·500000
13	0·016927	13	0·541667
14	0·018230	14	0·583333
15	0·019531	15	0·624555
16	0·020833	16	0·666667
17	0·022135	17	0·707333
18	0·023436	18	0·750000
19	0·024740	19	0·791666
20	0·026042	20	0·833333
21	0·027343	21	0·874999
22	0·028644	22	0·916666
23	0·029948	23	0·958333
24	0·031250	24	1·000000
25	0·032552		
26	0·033854		
27	0·035156		
28	0·036460		
29	0·037760		
30	0·039062		
31	0·040364		
32	0·041667		

Assay of the Alloys of Gold and Copper, or Gold, Silver, and Copper.

Preliminary Assay.—As in the case of silver assaying the quantity of lead to be employed is of importance, a preliminary assay must be made when the standard of the alloy to be examined is not approximatively known. It is thus effected:—To 2 grains of the alloy add 6 grains of fine silver and 50 grains of pure lead. The lead must be introduced into a hot cupel, and when fused, and its surface fully uncovered, the alloy and silver may be added, wrapped either in thin paper or a small quantity of lead foil. The cupellation finished, and the cupel cold, the button of gold and silver must be removed from the cupel by aid of the pliers, and if necessary cleansed. Hammer it to a thin plate on the anvil, place it in a small evaporating basin, and treat it with half an ounce of nitric acid. (It may be here mentioned, that the nitric acid employed in the assay of gold must be chemically pure, and special care must be taken that it contains no trace of chlorine.) The evaporating basin is gently heated until all action ceases. The brownish residue is repeatedly washed with hot water, dried, ignited, and weighed; and from its weight the amount of lead and silver to be added in the actual assay may be determined. The presence of copper in the alloy is indicated by the blackness of the cupel where it is saturated with oxide.

Assay Proper.—In this case it will be supposed that standard gold is the alloy operated on, and that preliminary assay has given about 91½ per cent. of gold. On referring to the table (page 453), it will be found that between 27 and 30 parts of lead are required for such a per-centage of gold, and that, according to the general observations on this class of assay, three times its weight (that is, the weight of fine or water silver) will be required to so dilute the gold that nitric acid can attack and dissolve out the whole of the silver combined with it.

Place the weight representing 24 carats in the pan of the balance, and exactly counterpoise it with the gold to be assayed; two portions should be thus weighed. Two portions of fine silver must now be weighed; 33 grains will be required for each 24 carats of gold, as 22 carats, or 11 grains, of fine gold exist in the 24 carats, and three times the quantity of silver is necessary. 300 grains of lead must be placed in a hot cupel (two being thus prepared), and, as in the preliminary assay, when the surface is fully uncovered, the gold and silver are added, and the cupellation proceeded with, taking all the precautions already fully pointed out elsewhere.

The button so obtained is cleansed, hammered on the anvil, then annealed and passed between the rollers of a small flatting-mill; being occasionally annealed, in order to prevent the laminated button cracking at the edges. When reduced to the desired degree of thinness it is again annealed, and rolled round a quill or glass rod into a spiral, termed a cornet. This cornet is placed in a parting flask with 1½ oz. of nitric acid, sp. gr. 1·16, very gently heated to the boiling point, and at that maintained for ten minutes. The acid is then to be poured off, and 2 oz. of nitric acid, sp. gr. 1·26, added, and again boiled for ten minutes. This second acid is also poured off, and a third quantity of like specific gravity added and boiled. The cornet is then well washed with distilled water, and the flask, filled with distilled water, is inverted, having its mouth closed with the thumb. The cornet will fall through the water without breaking, and can be introduced, together with some of the water, into a small crucible (cornet crucible), the water poured off, the crucible and gold gradually dried, and then heated to redness. When cold, the final operation of weighing may be performed, thus:—The weight representing 22 carats is placed in one pan of the balance, and the cornet in the other: as the gold employed was supposed to be standard, it ought to weigh exactly 22 carats. If, however, gold of greater or less fineness had been submitted to assay—say of 23 and 21 carats respectively—1 carat weight would have been required in the pan containing the 22 carat weight, to counterbalance the gold carat: in this case the gold would be 23 carats fine, or, in the usual mode of reporting, "one carat better." If, on the other hand, the 1 carat weight had been found necessary in the pan containing the cornet, the gold would be 21 carats fine, or "one carat worse."

In cases where it is known that the gold under examination contains no silver, the only alloy being copper, its fineness can be determined by cupelling 24 carats with its proper portion of lead, and weighing the resulting button, which should represent the amount of fine gold in the alloy assayed.

Parting Assays.—Parting assays are those assays by which the amount of fine gold and fine silver in any alloy is determined. When the amount of gold exceeds that of the silver, it is called "gold parting;" when the amount of silver exceeds that of the gold, "silver parting."

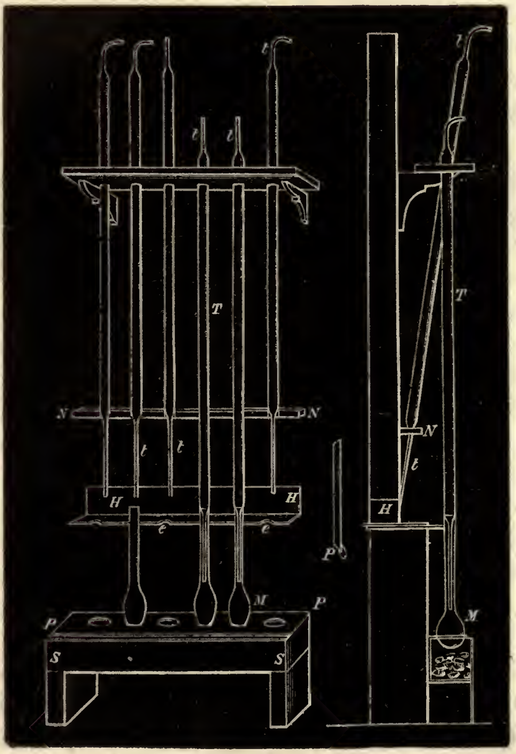
In this assay the weights employed in the silver assay are employed, as the report is made in ounces of fine metal per pound Troy.

12 grains (representing 1 lb. Troy) of the alloy are weighed off, cupelled with 300 grains of lead, and the resulting button, contain-

ing only gold and silver, is weighed. Suppose it weigh 10 grains, then 2 grains, = 2 ounces in the pound of alloy, is copper or some other metal, which has been oxidised and carried into the cupel with the litharge. A preliminary assay must be made of the alloy, to ascertain the approximative quantity of silver and gold, so as to apportion the amount of silver in the assay proper: this amount being found, it is to be weighed off, added to the button of fine gold and silver obtained as above, and the whole cupelled with 200 grains of lead; the cupelled mass of gold and silver laminated and treated with nitric acid, as already described, and the resulting gold weighed. Suppose the weight to be 8 grains, = 8 ounces, the result would stand thus:—

Copper or other base metal . . .	2 oz.
Gold	8 oz.
Silver	2 oz.
	12 oz.

Fig. 292.



The above apparatus is very convenient for accomplishing gold assays, and is the one employed in the assay office of the French Mint. The annexed cut (fig. 292) represents this apparatus:—

The assay flask, *M*, being charged with the cornet, a constant amount of acid is added with a pipette. On the addition of the second acid a small piece of charcoal is placed in the flask: this serves to prevent bumping during ebullition. The flasks are supported on a plate of sheet iron, *P*, pierced with holes, or by a grating, and the acid vapours, before escaping by the flue, pass into glass tubes, *T T*, about half an inch in diameter, and four feet long: at each end a narrower tube, *t*, is fused. The lower tube freely enters the neck of the flask; and as the space between is so small that a layer of acid remains suspended and obstructs the passage of the acid vapours, they are thus forced to pass into the large tube, where, for the greater part, they condense and fall into the flasks. By this means the quantity of acid employed in the assay can be diminished, as there is no loss by evaporation, and the results are found to be more constant In order that the passage to the large tube for the acid vapours may always remain free, the end of the narrow tube passing into the flask must be cut at an angle (see *P*). The drops of acid collect at this part, and never close the tube.

For the assay of gold and silver alloys by Gay-Lussac's normal solution, see page 458.

Assay of Tellurets and other Native Mineralised Substances containing Gold.—These assays are made in the scorifier, in precisely the same manner as for silver substances of a like kind. The button resulting from cupellation is treated by quartation if necessary, and by nitric acid, as already described.

CHAPTER XXII.

DISCRIMINATION OF GEMS AND PRECIOUS STONES.

As the present work is intended especially for the use of those who may be exploring, or, to use a more modern though less refined term, "*prospecting*" in this or other countries, it has been thought advisable not only to give the mode of ascertaining the richness of mineral matters, or, in other words, the mode of assay, but to give such instruction in crystallography, and elementary analytical, and general chemistry, that the discrimination of all the more ordinarily occurring, and even some of the more rarely occurring, minerals, when they are valuable, may be rendered a matter of comparative ease even to the uninitiated, if ordinary attention only be paid to the rules laid down. Having premised thus much, the author may state, by way of explanation as to the introduction of the present chapter into this work, that as many of the precious stones are found in connection with gold, and as the alluvial and other sources of that metal have of late been so wonderfully multiplied, and as diamonds, rubies, emeralds, &c., have by careful examination and research been discriminated in Australia and elsewhere, he thought it advisable to devote a chapter to the elucidation of this important subject, in the hope that, with the instruction here given, those who may cast their lots, either temporarily or permanently, in positions geologically likely to furnish the subjects to be treated under the present heading, may find themselves materially assisted in the discovery of minerals, in the discrimination of which but little has been popularly written.

The principal sources of recognition are colour, crystalline form, specific gravity, and hardness. Chapter II. will give all necessary information as to crystallographic form, its modifications, &c.; and in the present chapter will be introduced all the most constantly occurring natural forms of all the gems and precious stones mentioned. At pages 203 and 204 the means of taking specific gravities are given, and here will be given copious tables showing the comparative weights of many precious stones in air and water. A scale of degrees of hardness is given at page 202. The tendency of various stones to exhibit under certain influences an amount of electrical disturbance will be noticed where necessary.

COLOURLESS STONES.

The Diamond.—Specific gravity, 3·48 to 3·52; hardness, 10. The diamond is the hardest of all known substances; it scratches all, and hence is the utmost term of hardness. When cut and polished it is the most brilliant gem. The greater part of diamonds are limpid and colourless, but many coloured specimens are found; as rose, yellow, orange, blue, green, brown, or even black. It sometimes occurs in regular crystals, octahedrons, dodecahedrons, and more complex forms: see figs. 293, 294, 295, 296.

FIG. 293.

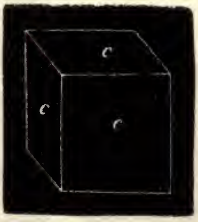


FIG. 294.

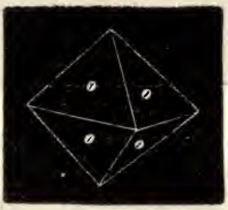


FIG. 295.

FIG. 296.

The crystalline faces are often curved. The cleavage is octahedral and highly perfect: hence, although diamonds are so exceedingly hard, they are very brittle, owing to their tendency to facile cleavage. Like most gems it becomes electrical by friction; but it has been remarked that other gems do not, unless they have been previously polished.

Composition (C):—Pure carbon.

Quartz.—Specific gravity, 2·55 to 2·7; hardness, 7. Quartz occurs in many forms, and has often by inexperienced persons been mistaken for the diamond, owing to the lustre of its crystals and its considerable hardness. It, however, can always be distinguished from the diamond by its crystalline faces, hardness, and specific gravity (see example in Table I.)

It usually occurs in six-sided prisms more or less modified, terminated with six-sided pyramids. Traces of cleavage are seldom or ever apparent. The following are some of its salient forms (figs 297, 298, 299, 300, 301, 302, 303) :—

Fig. 297.

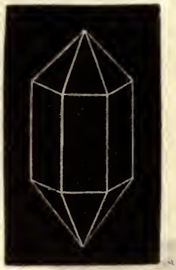


Fig. 298.

Fig. 299.

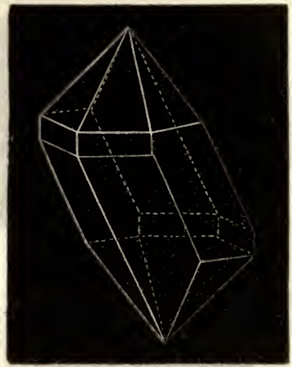


Fig. 300.

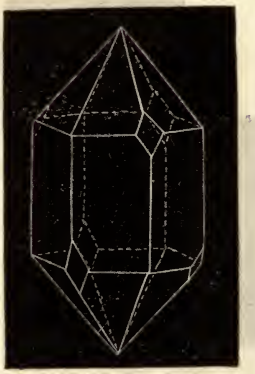


Fig. 301.

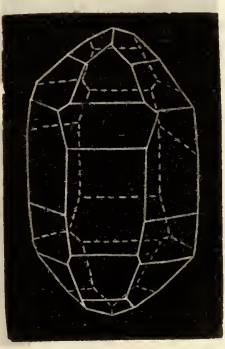


Fig. 302.

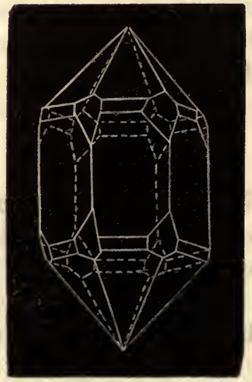
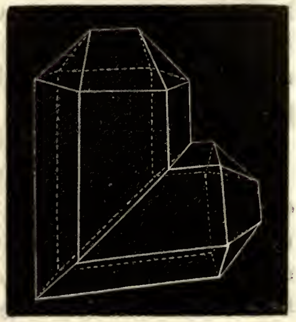


Fig. 303.



Some crystals are as pellucid as glass; others, however, assume all the shades of colour mentioned in the case of the diamond.

Composition (SiO_3) :—Pure silica or silicic acid.

White Zircon.—Specific gravity, 4·44 to 4·8; hardness, 7·5. This stone is often found crystallised in nature in four-sided prisms, terminated by four-sided or rhomboidal or triangular pyramids, and other forms: see figs. 304, 305, 306, 307, 308, and 309.

FIG. 304.

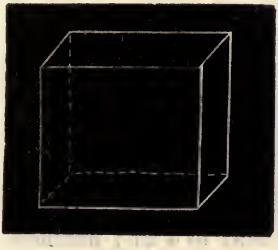


FIG. 305.

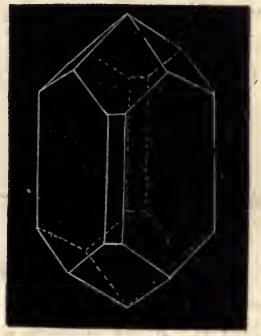


FIG. 306.

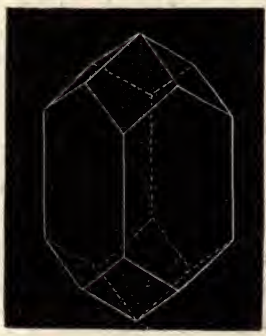


FIG. 307.

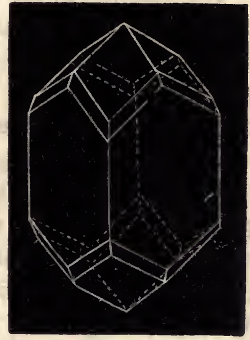


FIG. 308

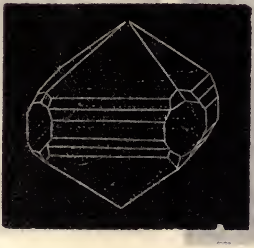
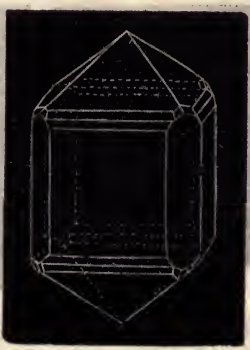


FIG. 309.



These stones are often employed in jewellery under the name of "rough diamonds." It often occurs brownish-red and brown, red, yellow, and grey: these varieties will be treated under their appropriate heads. It can be readily distinguished from the diamond and quartz by hardness and specific gravity; also from the former by the action of strong hydrochloric acid, which, if dropped on a diamond and allowed to remain for a little time, produces no change, but if a zircon be so treated, the spot on which the acid was placed remains dull.

Composition (Zr_2O_3,SiO_3):—

Zirconia	67·2
Silicic acid	33·5
	100·7

White Sapphire.—Specific gravity, 3·97 to 4·27; hardness, 9. This stone, in hardness, is next to the diamond. It occurs variously coloured; other colours will be discussed under their appropriate heads. It crystallises in the rhombohedric system, usually in six-sided prisms, but often so very rough as not to be readily distinguishable. May be distinguished by gravity and hardness from all the preceding.

Composition (Al_2O_3):—Pure alumina.

White Topaz.—Specific gravity, 3·54; hardness, 9. This variety of topaz, known for its limpidity by the term "gouttes d'eau," when polished has nearly the same lustre as the diamond: the topaz, however, occurs of many colours—see hereafter. It crystallises in the right rectangular prismatic system. The following are some of its natural forms: figs. 310, 311, 312, 313, 314, 315:—

FIG. 310.

FIG. 311.

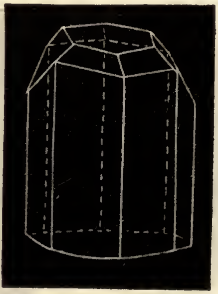
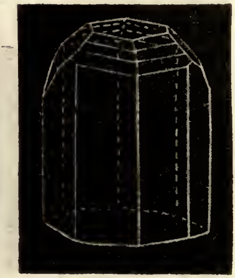


FIG. 312.



It is readily rendered electric, and retains its electricity for a very considerable time; it is also pyro-electric, or becomes electric when heated,—a property by which it is distinguished from the diamond its specific gravity being so similar that it cannot be made available as a means of discriminating between the two stones. From the other stones in this group, with the exception of the sapphire, it is readily distinguished by its hardness and gravity, and from the latter by its gravity and pyro-electricity.

Fig. 313.

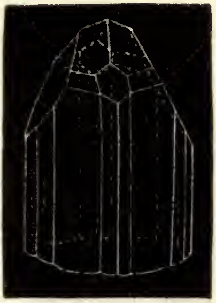


Fig. 314.

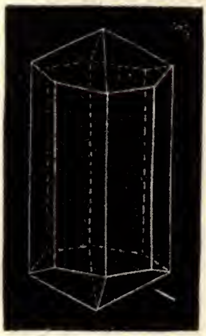
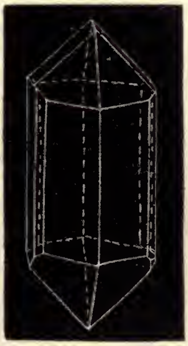


Fig. 315.



Composition :—

Silica	34·2
Alumina	57·5
Fluorine	7·8
	98·5

*Example of the Use of Table I.**—A colourless stone, weighing 40 grains in air, is reduced to 24·43 in water. Look in the first column to 40, and then trace along its horizontal line until a number very nearly approaching 24·43 is found; refer then to the heading of the table, above the number found, and the name there expressed will be that of the stone examined. Supposing, however, the weight of the stone be 41 grains, still the number 24·43 will be the nearest in the table, and ·611 must be added to it, as that sum would be the weight of 41 grains of quartz or water. From the numbers obtained by calculation, also, can the specific gravity be determined. If this course be pursued, refer to the bottom line of the table for corresponding number, and to the heading of table for name of stone. When the weight is any even number of grains (that is, without fractions), the readiest way is to refer to the table (first column), for the number of grains, and then to the horizontal line to corresponding number obtained, which is the weight in water.

---

* The Tables of Comparative Weights were calculated by Brard.

Table I.

COMPARATIVE TABLE OF THE WEIGHTS OF COLOURLESS STONES WEIGHED IN AIR AND WATER.

WEIGHT IN AIR GRAINS.	WEIGHT IN WATER.				
	WHITE ZIRCON.	WHITE SAPPHIRE.	WHITE TOPAZ.	WHITE DIAMOND.	WHITE QUARTZ.
1	0·775	0·766	0·716	0·715	0·611
4	3·10	3·06	2·86	2·86	2·42
8	6·20	6·12	5·72	5·72	4·86
12	9·30	9·18	8·58	8·58	7·31
16	12·40	12·25	11·55	11·45	9·75
20	15·50	15·31	14·42	14·31	12·19
24	18·60	18·37	17.28	17·17	14·64
28	21·70	21·44	20·15	20·13	17·08
32	24·80	24·51	23·01	22·90	19·53
36	27·90	27·57	25·88	25·76	11·98
40	31·00	30·64	28·75	28·63	24·43
44	34·10	33·71	31·61	31·49	26·88
48	37·20	36·76	34·47	34·35	29·32
52	40·30	39·82	37·34	37·21	31·77
56	43·40	42·89	40·20	40·17	34·21
60	46·50	45·95	43·06	42·94	36·66
64	49·60	49·01	45·93	45·80	39·11
68	52·70	52·07	48·90	48·66	41·56
72	55·80	55·14	51·77	51·52	44·00
76	58·90	58·21	54·63	54·38	46·44
80	62·00	61·28	57·49	57·24	48·88
84	65·10	64·34	60·35	60·12	51·32
88	68·20	67·41	63·22	62·97	53·76
92	71·30	70·47	66·08	65·33	56·21
96	74·40	73·54	68·94	68·69	58·65
100	77·50	76·60	71·80	71·55	61·09
Specific Gravity	4·44	4·27	3·54	3·52	2·55

Diamond and topaz, however, have very nearly equal density, and a second characteristic must be had recourse to, in order to determine the nature of two stones which have an equal weight in water. This auxiliary character is the development of electricity by heat, a phenomenon exhibited by the topaz but not by the diamond. The test of hardness may be also resorted to.

YELLOW STONES.

Yellow Zircon (*Jargon*).—The crystalline form, characteristics, and composition of this stone have been described under the head "White Zircon."

Yellow Sapphire.—Characteristics, &c. described under "White Sapphire."

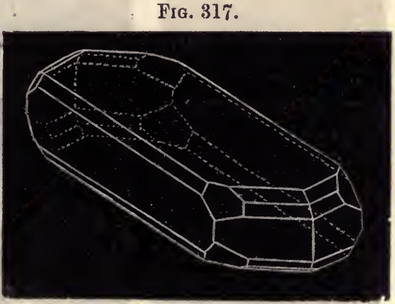
Cymophane (*Chrysoberyl*).—Specific gravity, 3·65 to 3·89; hardness, 8·5. The cymophane is nearly as hard as the sapphire, harder than the topaz and the emerald; it readily scratches quartz. Its colour is greenish yellow, and has been placed in the list of yellow stones rather than green, because usually the yellowish tint is most decided. This tint, which is very agreeable in itself, is often relieved by a small spot of light of a bluish white tinge, which moves from point to point of the stone as the position of the latter is varied. It is rarely found in regular crystals, but more generally occurs in rolled and rounded masses. For some of its forms, however, see figs. 316, 317, 318, and 319.

Composition:—No. 1 is a sample from the Brazils; No. 2, from Siberia.

	1.	2.
Alumina	78·10	78·92
Glucina	17·94	18·02
Oxide of Iron	4·46	3·12
Oxide of Chromium	—	0·36
Oxides of Copper and Lead	—	0·29
	100·50	100·71

Fig. 316.

Fig. 317.



Yellow Topaz.—The general characteristics of this stone are described under "White Topaz."

Yellow Tourmaline.—Specific gravity, 3·00—3·22; hardness, 7—7·5. The tourmaline becomes electrical by heat: one portion of a crystal attracts light bodies, the other repels them. Its colour

FIG 318.

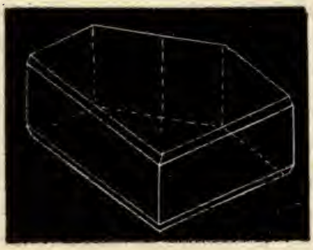
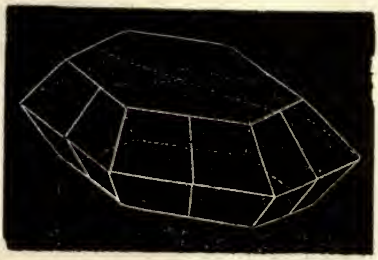


FIG. 319.



is very varied. The tourmaline has a vitreous fracture. It occurs in semicrystalline prisms of irregular form, generally deeply striated, and in prisms of six or more sides, variously terminated, one end usually differing from the other.

Figs. 320, 321, 322, 323, 324, and 325, represent some of the forms of this mineral.

FIG. 320.

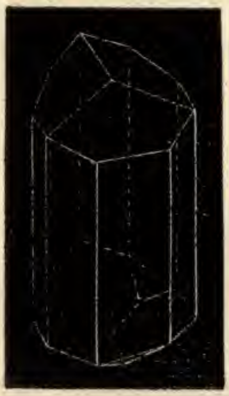


FIG. 321.

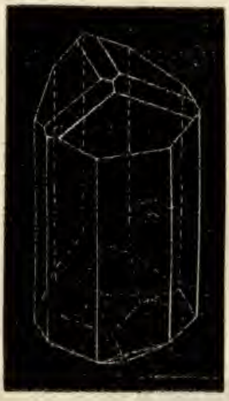


FIG. 322.

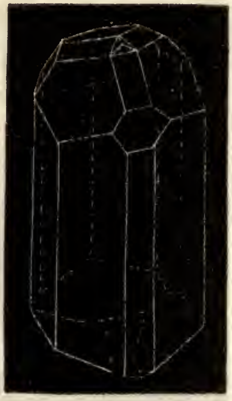


FIG. 323.

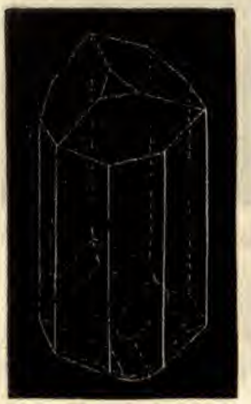


FIG. 324.

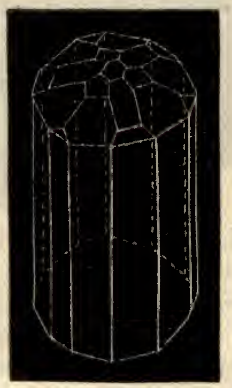
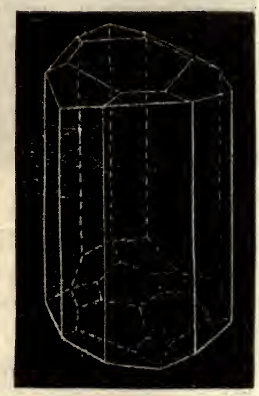


FIG. 325.



Yellow Emerald. — Specific gravity, 2·73—2·76; hardness, 7·5—8. The emerald occurs of many colours; its tint *par excellence* is green; but there are many varieties tinged more or less yellow or blue, and they even occur white. Its fracture is vitreous, brilliant, and undulating. Its common form is the hexahedral prism, sometimes deeply striated longitudinally. It readily cleaves parallel to all the planes of its primary form—the hexahedral prism.

FIG. 326.

FIG. 327.

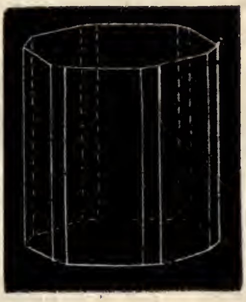


FIG. 328.

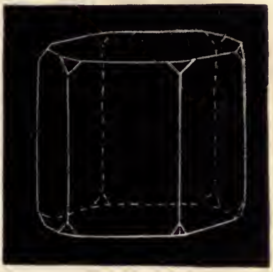


FIG. 329.

FIG. 330.

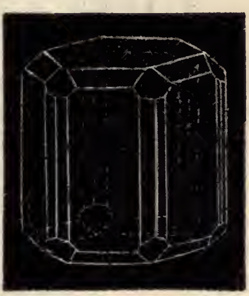


FIG. 331.

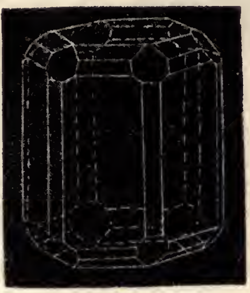


FIG. 332.

The above are some of the forms it assumes: figs. 326, 327, 328, 329, 330, 331, and 332.

Composition:—

Glucina	15·50
Silica	66·45
Alumina	16·75
Oxide of Iron	·60
	90·30

The green varieties contain a small quantity of oxide of chromium.

Yellow Quartz.—For the characteristics, hardness, &c. of this mineral, see "White Quartz."

COMPARATIVE TABLE OF THE WEIGHTS OF YELLOW STONES WEIGHED IN AIR AND WATER.

WEIGHT IN AIR GRAINS.	WEIGHTS IN WATER.						
	YELLOW ZIRCON.	YELLOW SAPPHIRE	YELLOW CYMOPHANE.	YELLOW TOPAZ.	YELLOW TOURMALINE	YELLOW EMERALD	YELLOW QUARTZ.
1	0·775	0·766	9·738	0·716	0·690	0·633	0·611
4	3·10	3·06	2·95	2·86	2·76	2·53	2·42
8	6·20	6·12	5·90	5·72	5·52	5·06	4·86
12	9·30	9·18	8·85	8·58	8·28	7·59	7·31
16	12·40	12·25	11·80	11·55	11·04	10·12	9·75
20	15·50	15·31	14·75	14·42	13·80	12·65	12·19
24	18·60	18·07	17·70	17·28	16·56	15·19	14·04
28	21·70	21·44	20·65	20·15	19·32	17·72	17·08
32	24·80	24·51	23·60	23·01	20·08	20·25	19·53
36	27·90	27·57	26·55	25·88	24·84	22·77	21·98
40	31·00	30·64	29·50	29·75	27·60	25·30	24·43
44	34·10	33·71	32·45	31·61	30·36	27·83	26·88
48	37·20	36·76	35·40	34·47	33·12	30·36	29·32
52	40·30	39·82	38·35	37·34	35·88	32·89	31·77
56	43·40	42·89	41·30	40·20	38·64	35·43	34·21
60	46·50	45·95	44·25	43·06	41·40	37·94	36·66
64	49·60	49·01	47·20	45·93	44·16	40·47	39·11
68	52·70	52·08	50·15	48·90	46·92	43·00	41·56
72	55·80	55·14	53·10	51·77	49·68	45·53	44·00
76	58·90	58·21	56·05	54·63	52·44	48·07	46·44
80	62·00	61·28	59·00	57·49	55·20	50·60	48·88
84	65·10	64·34	61·95	60·35	57·96	53·13	51·32
88	68·20	67·41	64·90	63·22	60·72	55·66	53·76
92	71·30	70·47	67·85	66·08	63·48	58·19	56·21
96	74·40	73·54	70·80	68·94	66·24	60·72	58·65
100	77·50	76·60	73·75	71·80	69·00	63·25	61·09
Specific Gravity	4·44	4·27	3·89	3.53	3·22	2·72	2·55

BROWN AND FLAME-COLOURED STONES.

Zircon (*Hyacinth*).—For characteristics, &c. see "White Zircon."

Vermeil Garnet, Noble Garnet, Almandine.—Specific gravity, 4—4·2; hardness, 6·5—7·5. There are very many varieties of garnet, variously coloured; but their crystalline form—a rhombic dodecahedron more or less modified—is a distinguishing characteristic. The colouring matter of the garnet is iron. The following are some of its crystalline forms: figs. 333, 334, 335, 336, and 337:—

FIG. 333.

Fig. 334.

FIG. 335.

FIG. 336.

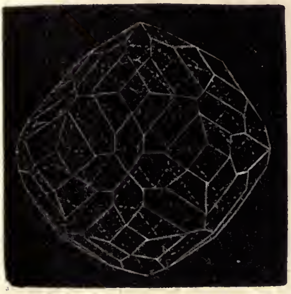
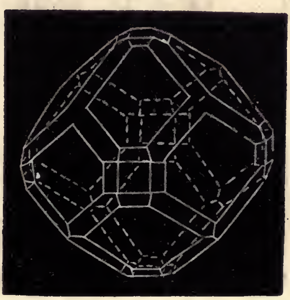


FIG. 337.



Composition :—

Silica	33·75
Alumina	27·25
Oxide of Iron	36·00
Oxide of Manganese	·25
	97·25

COMPARATIVE TABLE OF THE WEIGHTS OF BROWNISH AND FLAME-COLOURED STONES WEIGHED IN AIR AND WATER.

WEIGHT IN AIR GRAINS.	WEIGHT IN WATER.			
	HYACINTHINE ZIRCON.	VERMEIL GARNET.	ESSONITE.	TOURMALINE.
1	0·775	0·750	0·710	0·690
4	3·10	3·00	2·87	2·76
8	6·20	6·00	5·74	5·52
12	9·30	9·00	8·61	8·28
16	12·40	12·00	11·48	11·04
20	15·50	15·00	14·35	13·80
24	18·60	18·00	17·22	16·56
28	21·70	21·00	20·09	19·32
32	24·80	24·00	22·96	22·08
36	27·90	27·00	25·83	24·84
40	31·30	30·00	28·70	27·60
44	34·10	33·00	31·57	30·36
48	37·20	36·00	34·44	33·12
52	40·30	39·00	37·31	35·88
56	43·40	42·00	40·18	38·64
60	46·50	45·00	43·05	41·40
64	49·60	48·00	45·92	44·16
68	52·70	51·00	48·79	46·92
72	55·80	54·00	51·66	49·68
76	58·90	57·00	54·53	52·44
80	61·00	60·00	57·40	55·20
84	65·10	63·00	60·27	57·96
88	68·20	66·00	63·14	60·72
92	71·30	69·00	66·01	63·48
96	74·40	72·00	68·88	66·24
100	77·50	75·00	71·75	69·00
Specific Gravity	4·44	4·00	3·54	3·22

Essonite, Cinnamon Stone.—Specific gravity, 3·5 to 3·6. This stone has an agreeable orange yellow tinge, which becomes a warm and brilliant tint when the mass is large. This stone is not usually found crystalline, but in irregular forms and masses, which are characterised by fissures in all directions.

Composition:—

Silica	38·80
Alumina	21·20
Lime	31·25
Oxide of Iron	6·50
with small quantities of Potash and Magnesia	——
	97·75

Tourmaline.—For the characteristics of this mineral see "Yellow Tourmaline."

RED AND ROSE-COLOURED STONES.

Red Sapphire.—For characteristics, crystalline form, &c., see "White Sapphire."

Deep Red Garnet, Noble Garnet.—For characteristics, &c., see "Vermeil Garnet."

Ruby (*Spinel*).—Specific gravity, 3·5—3·6; hardness, 8. The ruby readily scratches quartz, but is scratched by the sapphire. Its special colour is red, approaching a rose tint; this tinge, however, undergoes various modifications, such as scarlet, red, rose, yellowish red, and reddish purple: it is also found blue and black. Its fracture is flattish conchoidal, with a splendent vitreous lustre. It occurs crystallised in regular octahedrons, sometimes having their edges replaced as in macles; sometimes it assumes the globular form. The ruby may be distinguished from the red sapphire and the garnet by hardness and specific gravity; and from reddish topaz, which possesses nearly the same specific gravity, by its electric properties.

Composition of red ruby:—

Silica	2·02
Alumina	69·01
Magnesia	26·21
Protoxide of Iron	0·71
Oxide of Chromium	1·11
	99·05

Reddish Topaz.—For characteristics, &c., see "White Topaz."

Red Tourmaline.—For characteristics, &c., see "Yellow Tourmaline."

COMPARATIVE TABLE OF THE WEIGHTS OF RED OR ROSE COLOURED STONES WEIGHED IN AIR AND WATER.

WEIGHT IN AIR GRAINS.	WEIGHT IN WATER.				
	RED SAPPHIRE.	DEEP GARNETS.	RUBIES.	SMOKE OR RED TOPAZ.	RED TOURMALINE.
1	0·766	0·750	0·722	0·716	0·690
4	3·060	3·000	2·880	2·860	2·760
8	6·120	6·000	5·770	5·720	5·520
12	9·180	9·000	8·660	8·585	8·280
16	12·250	12·000	11·550	11·550	11·040
20	15·310	15·000	14·440	14·420	13·800
24	18·370	18·000	17·330	17·280	16·560
28	21·440	21·000	20·220	20·150	19·320
32	24·510	24·000	23·110	23·010	22·080
36	27·570	27·000	26·000	25·880	24·840
40	30·640	30·000	28·880	28·750	27·600
44	33·710	33·000	31·770	31·610	30·360
48	36·760	36·000	34·660	34·470	33·120
52	39·820	39·000	37·550	37·340	35·880
56	42·890	42·000	40·440	40·200	38·640
60	44·950	45·000	43·300	43·060	41·400
64	49·010	48·000	46·220	45·930	44·160
68	52·080	51·000	49·110	48·900	46·920
72	55·140	54·000	51·990	51·770	49·680
76	58·210	57·000	54·880	54·630	52·440
80	61·280	60·000	57·770	57·490	55·200
84	64 340	63·000	60·660	60·350	57·960
88	67·410	66·000	63·550	63·220	60·720
92	70·470	69·000	66·440	66·080	63·480
96	73·540	72·000	69·330	68·940	66·240
100	76·600	75·000	72·220	71·800	69·000
Specific Gravity	4·270	4·000	3·600	3·530	3·220

BLUE STONES.

Blue Sapphire.—For characteristics, &c., see "White Sapphire."

Disthene, Cyanite.—Specific gravity, 3·5—3·7; hardness, 5—7. Fine specimens of disthene possess a bright blue colour, which passes insensibly into a deep sky blue. Its transparency is nearly perfect, and it presents small pearly reflections, which add to the beauty of its colour. The primary form of its crystals is a doubly oblique prism, and they cleave very readily in the direction of their length. It can be readily distinguished from the sapphire by its being less hard, as also by its specific gravity. Figs. 338, 339, and 340, represent some of its crystalline forms.

FIG. 338.

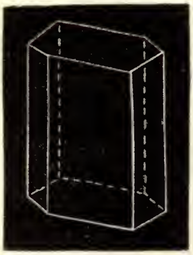


FIG. 339.

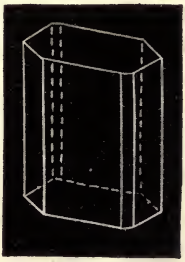
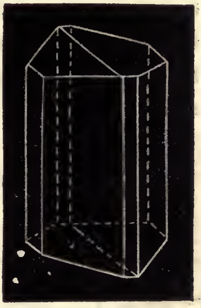


FIG. 340.



Composition of a specimen from St. Gothard:—

Silica	43·0
Alumina	55·0
Oxide of Iron	·5—98·5

Blue Topaz.—For characteristics, &c., see "White Topaz." Blue topaz and disthene having the same specific gravity, may by that test alone be confounded with each other; but the appearance of each is so different, that they can be rarely confounded. If, however, the electrical test be applied, no fear of mistaking one for the other need be entertained, as only the topaz becomes electrical.

Blue Tourmaline.—For characteristics, &c., see "Yellow Tourmaline."

Blue Beryl.—For characteristics, &c. see "Emerald." The tint and appearance of this stone and that of the blue topaz are so similar that they cannot be distinguished by that test; their specific gravities, however, are so different, that they may, by this simple means, be readily discriminated.

Dichroite, "Water Sapphire."—Specific gravity, 2·56—2·65; hardness, 7—7·5. The chief characteristic of this stone is, that it possesses a double colour; that is, it is a fine blue or a normal yellow, as it is viewed in the direction of its base, or the planes of a hexahedral prism, which is its crystalline form. It can be thus readily distinguished, as also by its having nearly the same specific gravity of quartz, and thus being the lightest of the blue stones. Composition:—

Silica	48·35
Alumina	31·71
Magnesia	10·16
Protoxide of Iron	8·12
Protoxide of Manganese	·33
Loss in fire (Water?)	·60—90·47

Turquoise.—Specific gravity, 2·8—3; hardness, 5—6. This stone has not been placed in the list of specific gravities, as it can be so readily detected by its appearance. It is bright or greenish blue in colour; its aspect is earthy or compact. It scratches apartite, and even glass; but is scratched by quartz. It occurs filling fissures, or forming concretions in siliceous and argillo-ferruginous rocks.

COMPARATIVE TABLE OF THE WEIGHTS OF BLUE STONES WEIGHED IN AIR AND WATER.

Weight in Air Grains.	Weight in Water.					
	Blue Sapphire.	Disthene, Cyanite.	Blue Topaz.	Tourmaline.	Blue Beryl.	Dichroite, Water Sapphire.
1	0·766	0·717	0·716	0·690	0·633	0·622
4	3·06	2.87	2·86	2·16	2·53	2·49
8	6·12	5·74	5·72	5·52	5·06	4·98
12	9·18	8·61	8·58	8·28	7·59	7·47
16	12·25	11·48	11·45	11·04	10·12	9·96
20	15·31	14·35	14·42	13·80	12·65	12·45
24	18·37	17·22	17·18	16·56	15·19	14·94
28	21·44	20·09	20·05	19·32	17·72	17·43
32	24·51	22·96	22·91	20·08	20·25	19·92
36	27·57	25·83	25·78	24·84	22·77	22·41
40	30·64	28·70	28·65	27·60	25·30	24·90
44	33·71	31·57	31·51	30·36	27·83	27·39
48	36·76	34·44	34·37	33·12	30·36	29·88
52	39·82	37·31	37·24	35·88	32·89	32·37
56	42·89	40·18	40·10	38·64	35·43	34·86
60	45·95	43·05	42·96	41·40	37·94	37·35
64	49·01	45·92	45·83	44·16	40·47	39·84
68	52·08	48·79	48·80	46·92	43·00	42·33
72	55·14	51·66	51·67	49·68	45·53	44·82
76	58·21	54·53	54·53	52·44	48·07	47·31
80	61·28	57·40	57·49	55·20	50·60	49·80
84	64·34	60·27	60·25	57·96	53·13	52·29
88	67·41	63·14	63·12	60·72	55·66	54·78
92	70·47	66·01	65·98	63·48	58·19	57·27
96	73·54	68·88	68·84	66·24	60·72	59·76
100	76·60	71·75	71·70	69·00	63·25	62·25
Specific Gravity	4·27	3·54	3·53	3·22	2·72	2·65

Composition :—

Phosphoric acid	17·86
Alumina	10·01
Silica	8·90
Peroxide of Iron	36·82
Lime	0·15
Water and Fluoric Acid . . .	25·95—99·69

VIOLET STONES.

Violet Sapphire.—For characteristics, &c. see " White Sapphire."

COMPARATIVE TABLE OF THE WEIGHTS OF VIOLET STONES WEIGHED IN AIR AND WATER.

Weight in Air Grains.	Weight in Water.		
	Violet Sapphire.	Violet Tourmaline.	Amethystine Quartz. (Amethyst.)
1	0·766	0·690	0·611
4	3·06	2·76	2·42
8	6·12	5·52	4·86
12	9·18	8·28	7·31
16	12·25	11·04	9·75
20	15·31	13·80	12·19
24	18·37	16·56	14·64
28	21·44	19·32	17·08
32	24·51	20·08	19·53
36	27·57	24·84	21·98
40	30·64	27·60	24·43
44	33·71	30·36	26·88
48	36·76	33·12	29·32
52	39·82	35·88	31·77
56	42·89	38·64	34·21
60	45·95	41·40	36·66
64	49·01	44·16	39·11
68	52·02	46·92	41·56
72	55·14	49·68	44·00
76	58·21	52·44	46·44
80	61·28	55·20	48·88
84	64·34	57·96	51·32
88	67·41	60·72	53·76
92	70·47	63·48	56·21
96	73·54	66·24	58·65
100	76·60	69·00	61·09
Specific Gravity	.... 4·27	3·22	2·55

Violet Tourmaline. — For characteristics, &c., see "Yellow Tourmaline."

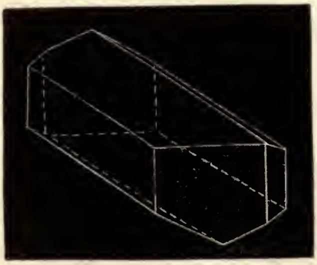
Violet Quartz, Amethyst.—For characteristics, &c., see "White Quartz."

GREEN STONES.

Green Sapphire.—For characteristics, &c., see "Yellow Emerald."

Peridot, Crysolite.—Specific gravity, 3·3—3·5; hardness, 6·5—7. This stone has a more or less deep olive or yellowish green colour. It is more generally found in rolled grains than in regular prismatic crystals. It is possessed in a very high degree of double refraction. Figs. 341, 342, 343, and 344, represent some of its crystalline forms.

FIG. 341.



G. 342.

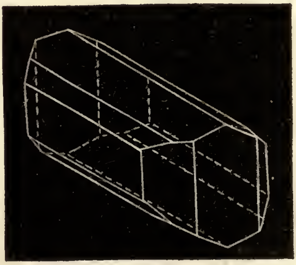


FIG. 343.

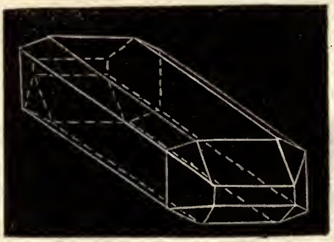
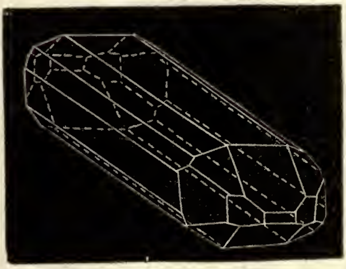


FIG. 344.



Green Tourmaline. — For characteristics, see "Yellow Tourmaline."

Emerald.—For characteristics, see "Yellow Emerald."

Aqua-marine.—This stone possesses a very pale green tinge. For other characteristics, see "Yellow Emerald."

Chrysoprase.—This mineral is a green-coloured quartz, and can be readily recognised by referring to the characteristics of quartz.

COMPARATIVE TABLE OF THE WEIGHTS OF GREEN STONES WEIGHED IN AIR AND WATER.

Weight in Air Grains.	Weight in Water.					
	Green Sapphire.	Peridot.	Green Tourmaline	Emerald.	Aqua Marine.	Chryso-prase.
1	0·766	0·708	0·690	0·633	0·633	0·611
4	3·06	2·83	2·76	2·53	2·53	2·42
8	6·12	5·66	5·52	5·06	5·06	4·86
12	9·18	8·49	8·28	7·59	7·59	7·31
16	12·25	11·32	11·04	10·12	10·12	9·75
20	15·31	14·16	13·80	12·65	12·65	12·19
24	18·37	16·99	16·56	15·19	15·19	14·64
28	21·44	19·82	19·32	17·72	17·72	17·08
32	24·51	22·65	22·08	20·25	20·25	19·53
36	27·57	25·48	24·84	22·77	27·77	21·98
40	30·64	28·32	27·60	25·30	25·30	24·43
44	33·71	31·15	30·36	27·83	27·83	36·88
48	36·76	33·98	33·12	30·36	30·36	29·32
52	39·82	36·81	35·88	32·89	32·89	31·77
56	42·89	39·64	38·64	35·43	35·43	34·21
60	45·95	42·48	41·40	37·94	37·94	36·66
64	49·01	45·31	44·16	40·47	40·47	39·11
68	52·08	48·14	46·92	43·00	43·00	41·56
72	55·14	50·97	49·68	45·53	45·53	44·00
76	58·21	53·80	52·44	48·07	48·07	46·44
80	61·28	56·64	55·20	50·60	50·60	48·88
84	64·34	59·47	57·96	53·13	53·13	51·32
88	67·41	62·30	60·72	55·66	55·66	53·76
92	70·47	65·13	63·48	58·19	58·19	56·21
96	73·54	67·96	66·24	60·72	60·72	58·65
100	76·60	70·80	69·00	63·25	63·25	61·09
Specific Gravity	4.27	3·42	3·22	2·72	2·72	2·56

STONES POSSESSING A PLAY OF COLOURS (CHATOYANT).

In the following list of stones no regard has been paid to absolute colours, but only to the play of colours the stones exhibit. This play or reflection is of two kinds: in some, as the sapphires, it appears as a white star with six rays, on a blue, red, or yellow ground; or on a purple ground in the garnet. In others it is but a point or mass of pearly light, which sometimes appears to occupy the whole of the stone, and varies according to the inclination given to the stone

The cymophane, crysolite quartz, Egyptian emerald, felspar, and cat's-eye, belong to this class.

The specific gravities of such stones as the opal, &c., have not been given, as the appearance sufficiently characterises them.

Sapphire.—For characteristics, &c., see "White Sapphire."

Garnet.—For characteristics, &c., see "Vermeil Garnet."

Cymophane.—See "Cymophane."

Antique Emerald.—For characteristics, &c., see "Yellow Emerald."

Quartz.—See "White Quartz."

Felspar, Nacreous Felspar, Fish-eye, &c.—Specific gravity, 2·3—2·5; hardness, 4·5—5. This species of felspar has a lamellar texture. It will be seen by the lowness of its specific gravity that it cannot be readily confounded with other stones. In appearance its transparency is nebulous, and it presents pearly white reflections, which float about and vacillate in proportion as its position changes. The following are some of the forms of felspar: see figs. 345, 346, 347, 348, 349, and 350:—

Fig. 345.

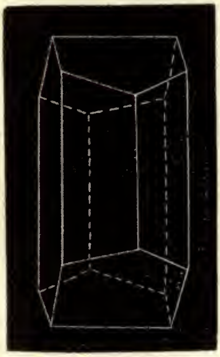


Fig. 346.

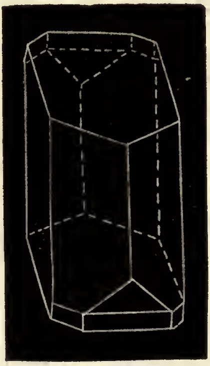


Fig. 347.

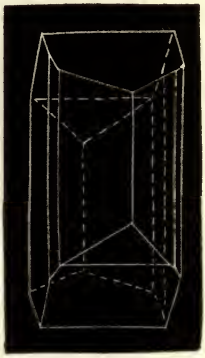


Fig. 348.

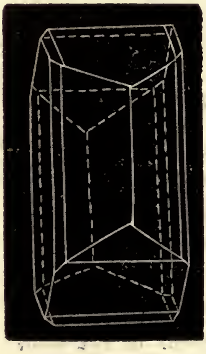


Fig. 349.

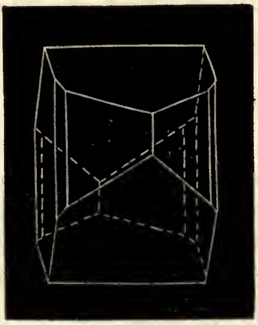
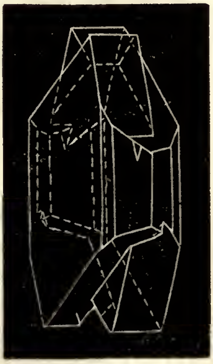


Fig. 350.



Composition:—

Potash	5·26
Silica	52·90
Lime	25·20
Water	16·00
Fluoric Acid	0·82
	100·18

COMPARATIVE TABLE OF THE WEIGHTS OF STONES POSSESSING A PLAY OF COLOURS (CHATOYANT).

WEIGHT IN AIR GRAINS.	WEIGHT IN WATER.					
	SAPPHIRES.	GARNETS.	CYMOPHANE.	ANTIQUE EMERALD.	QUARTZ.	FELSPAR.
1	0·766	0·750	0·738	0·633	0·611	0·592
4	3·06	3·00	2·95	2·53	2·42	2·37
8	6·12	6·00	5·90	5·06	4·86	4·74
12	9·18	9·00	8·85	7·59	7·31	7·11
16	12·25	12·00	11·80	10·12	9·75	9·47
20	15·31	15·00	14·75	12·65	12·19	11·84
24	18·37	18·00	17·70	15·19	14·64	14·20
28	21·44	21·00	20·65	17·72	17·08	16·57
32	24·51	24·00	23·60	20·25	19·53	18·94
36	27·57	27·00	26·55	22·77	21·98	21·31
40	30·64	30·00	29·50	25·30	24·43	23·68
44	33·71	33·00	32·46	27·83	26·88	26·05
48	36·76	36·00	35·40	30·36	29·32	28·42
52	39·84	39·00	38·35	32·89	31·77	30·79
56	42·89	42·00	41·30	35·43	34·21	33·15
60	45·95	45·00	44·25	37·94	36·66	35·52
64	49·01	48·00	47·20	40·47	39·11	37·88
68	52·07	51·00	50·15	43·00	41·56	40·25
72	55·14	54·00	53·10	45·53	44·00	42·62
76	58·21	57·00	56·05	48·07	46·44	44·99
80	61·28	60·00	59·00	50·60	48·88	47·36
84	64·34	63·00	61·95	53·13	51·32	49·73
88	67·47	66·00	64·90	55·66	53·76	52·10
92	70·47	69·00	67·85	58·19	56·21	54·47
96	73·54	72·00	70·80	60·72	58·65	56·84
100	76·60	75·00	73·75	63·25	61·09	59·21
Specific Gravity	4·27	4·00	3·89	2.72	2·55	2·45

CHAPTER XXIII.

ASSAY AND ANALYSIS OF FUEL.

THE substances generally employed as fuel, are wood, wood-charcoal, turf, turf-charcoal, coal, and its coke.

The essential elements of combustible matters are carbon, oxygen, and hydrogen; nitrogen being present sometimes, but only in small proportions. These constitute the organic part; various salts and silica constitute the inorganic part, or ash.

Gaseous products.—In order to estimate the amount of gas given off from any particular sample of coal, proceed in the following manner. Place a given weight, say 200 grs., of the coal in a red hot iron tube, closed at one end, to the other end of which adapt, by means of a cork, a glass or other tube, which must be conducted into an inverted jar, full of water, and standing in the pneumatic trough. Continue the red heat until no more gas is given off, then ascertain its quantity in cubic inches with due correction for temperature and pressure.

Amount of Coke.—The residue of the last operation is the amount of coke which that particular sample of coal produces; and its weight divided by two, gives the per centage of coke.

Amount of Ash.—Fully ignite about 50 grs. of coal in a platinum capsule, until nothing but ash is left. Its amount may then be ascertained by weighing.

Amount of Sulphur.—This is a most important operation in the assay; as a coal containing sulphur cannot be employed for particular purposes, and, indeed, those which contain much sulphur ought only to be used for the commonest purposes. This assay is most important to steam-boat and other companies who consume fuel under steam-boilers; and the coal they purchase should always be subjected to this particular test, as sulphur has a most corroding and destroying action on iron and copper. Where sulphur coals are continually burnt under boilers, the metal of the latter becomes so speedily deteriorated, that the boiler is rapidly rendered useless.

Process.—1 part of the coal, finely pulverized, is mixed with 7 or 8 parts of nitrate of potash and 16 parts of common salt, and 4 parts of carbonate of potash, all of which saline matters must be perfectly pure; the mixture is then placed in a platinum crucible and gently heated. At a certain temperature, the whole ignites and burns quietly; the operation is finished when the mass is white. It must, when cold, be dissolved in water, the solution slightly acidulated by means of hydrochloric acid, and chloride of barium added to it as long as a white precipitate forms. This precipitate is sulphate of baryta, which must be collected on a filter, washed, dried, ignited, and weighed: every 116 parts of it indicate 16 of sulphur.

Heating power of Coal.—Equal weights of different combustibles give off, when burned, very unequal quantities of heat. Their heating or calorific power is equal to these quantities. Sometimes these quantities are ascertained by the quantity of water evaporated, and sometimes by the amount of ice melted, and at others by the quantity of water raised 1° of the thermometer.

According to Berthier, however, the most convenient method for ascertaining the comparative calorific powers of any combustible matters is by means of litharge. He says: "It has been proved by the experiments of many philosophers, that the quantities of heat emitted by combustible substances are exactly proportioned to the amounts of oxygen required for their complete combustion. From whence, after the elementary constitution of any combustible is known, its calorific power is easily determined by calculation. For instance, it is only necessary to ascertain the quantity of oxygen absorbed in the conversion of all its carbon into carbonic acid, and all its hydrogen into water, and compare that quantity with that which is consumed in burning a fuel whose calorific power is well ascertained. Such a substance is charcoal."

By adopting the principle just pointed out, it may be conceived that, without knowing the composition of a fuel, its heating power may be ascertained by determining the amount of oxygen it absorbs in burning. This can be done in a very simple and expeditious manner, if not exactly, at least with sufficient exactitude to afford very useful results in practice. It is as follows:—Many metallic oxides are reduced with such facility, that when heated with a combustible body, the latter burns completely, without any of its elements escaping the action of the oxygen of the oxide, if the operation be suitably performed. The composition of the oxide being well known, if the weight of the part reduced to the metallic state be taken, the quantity of oxygen employed in the combustion can be ascertained. In order to collect the metal, and separate it from the non-reduced mass, it must be fusible as well as its oxide. Litharge fulfils these conditions, and experiment has proved that it completely burns the greater part of all ordinary fuels; the only exceptions are some very bituminous matters, which, containing a large proportion of volatile elements, a portion escapes before the temperature is sufficiently high to allow the reduction to take place. The experiment is made as follows :—

One part, say 10 grs., of the finely powdered or otherwise divided fuel, is mixed with about 400 grs. of litharge. The mixture is carefully placed in an earthen crucible, and covered with 200 grs. more litharge. The crucible is then placed in the fire, and gradually heated. When the fusion is perfect, the heat is urged for about ten minutes, in order that all the lead may collect into a single button. The crucible is then taken from the fire, cooled, broken, and the button of lead weighed. Sometimes the button of lead is livid, leafy, and only slightly ductile; in which case it has absorbed a little litharge. This I find can be partially prevented by fusing slowly, and adding a little borax.

Two assays, at least, ought to be made; and those results which differ more than a grain or two ought not to be relied on. The purer the litharge, the better the result; it ought to contain as little minium as possible. It is an excellent plan to mix up the litharge of commerce with one or two thousandths of its weight of charcoal, and fuse the whole in a pot: when cold, pulverize the fused litharge, which will now be deprived of minium.

Pure carbon produces with pure litharge thirty-four times its weight of lead, and hydrogen 103·7 times its weight of lead; that is to say, a little more than three times as much as carbon. We can, therefore, from these data, find the equivalent of any fuel, either in carbon or hydrogen.

When a fuel contains volatile matters, the quantity can be ascertained, as before pointed out, by ignition in a close tube or crucible. If, further, we ascertain the proportion of lead it gives with litharge, it is easy to calculate the equivalent in carbon of the volatile matters, and, in consequence, to ascertain its calorific value.

Supposing that a substance gives by distillation C of coke, or carbon, having deducted the weight of the ash and V of volatile substances, and that it produces P of lead with litharge. The quantity C of carbon would give $34 \times C$ of lead; the quantity of volatile matter would give but $P—34 \times C$; it would be equivalent then to $\frac{P—34 \times C}{34}$ of carbon; from whence it follows, that the quantity of heat developed by the charcoal, the volatile matter, and the unaltered combustible, will be to each other as the numbers $34 \times C$, $P - 34 \times C$ and P, which represents the quantities of lead; or as the numbers $C, \frac{P - 34 \times C}{34}\ \frac{P}{34}$ which represents the quantities of carbon.

Dr. Ure* says, speaking of the above method of assay: "On subjecting this theory to the touchstone of experiment, I have found it to be entirely fallacious. Having mixed, very intimately, 10 grains of recently calcined charcoal with 1000 parts of litharge, both in fine powder, I placed the mixture in a crucible, which was so carefully covered as to be protected from all fuliginous fumes, and exposed it to distinct ignition.

"No less than 603 grains of lead were obtained; whereas, by Berthier's rule, only 340 or 346·6 were possible. On igniting a mixture of 10 grains of pulverised anthracite, from Merthyr Tydfill, with 500 grs. of pure litharge, previously fused and pulverised, I obtained 380 grains of metallic lead. In a second experiment, with the same anthracite and the same litharge, I obtained 450 grains of lead; and in a third only 350 grains. It is, therefore, obvious that this method of Berthier's is altogether nugatory for ascertaining the quantity of carbon in coals, and is worse than useless in judging of the calorific qualities of different kinds of fuel."

This discrepancy in the results obtained by Dr. Ure is very perplexing, and does not at all accord with Berthier's experience, as shown by his experiments, or by my own on the subject. I have never had a difference of more than 50 grains, and in general only 2 or 3, which latter result is satisfactory. The only precaution I have found necessary is to heat very gradually until the mixture be fully fused, and then to increase the fire to bright redness for a few minutes. I shall, however, make a more extended series of experiments on this subject, with the view of perfecting the process, as it is at once easy, expeditious, and would be exceedingly valuable could it be rendered certain.

Since writing the above, I have made many experiments on this subject, and succeed most perfectly in estimating the value of a fuel. With the litharge of commerce, which contains much minium, the process is never exact; I have obtained results differing as much as 40 or 50 grains, when I have not purified the litharge employed, and to purify it completely is a troublesome process. This difficulty I have completely obviated, however, by substituting for litharge the

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* Supplement to the Dictionary of Arts, Mines, and Manufactures.

tube prepared for use). The protruding part of the cork is cut off, and the cut surface covered with sealing wax.

A small *Caoutchouc Tube* is necessary to connect the chloride of calcium tube with the potash apparatus (see fig. 359, p. 694). This tube may be made from sheet caoutchouc, as directed at p. 104.

Silk Cord.—This should be thick silk, and the same kind as employed for the suspension of ordinary balance pans. It must be cut into lengths of about eight or ten inches, and knotted at each end.

Corks.—These must be of the best quality, soft, and free from fractures or crevices. A perfectly smooth and round hole, of the same diameter as the end *b a* of the chloride of calcium tube, is bored throughout the length of a cork by means of a fine round file, and into this hole the end *b a* must fit perfectly air-tight. It is as well to keep a few of these corks ready prepared: before use they must be thoroughly dried in the water-bath, fig. 219, p. 243.

Mortar.—A shallow porcelain-ware mortar and pestle is required for mixing the coal and chromate of lead; it must be perfectly dry before the trituration is attempted.

A Suction Tube.—Fig. 355 represents the best form of this apparatus. The aperture *a* is fitted with a perforated cork, through which the tube *b* of the potash apparatus is fitted.

FIG. 355.

A long glass tube, about two feet long and open at both ends, is required; and some finely glazed paper, with carefully cut edges.

FIG. 356.

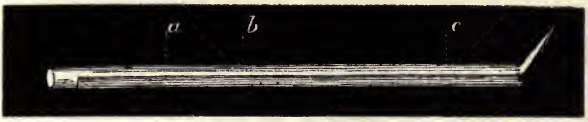
Liebig's Combustion Furnace is a long sheet iron box, open at top and behind. A top view is represented at fig. 356. It is about two feet long and four inches deep. The bottom serves as a grating, having small holes punched out; it has a width of about three inches. A few pieces of strong sheet iron (see *B*, fig. 357) are rivetted to the bottom, at a distance of about two inches from each other. The object of these is to support the tube. There is an aperture in front of the furnace, to allow the passage of the combustion tube. Two screens, see *a* and right hand corner engraving, fig. 357; they also are provided with openings large enough to allow the combustion tube to pass readily. When in use, the furnace is placed on two bricks, see fig. 359, p. 494.

FIG. 357.

Chromate of Lead, Dried Chloride of Calcium, and *Solution of Caustic Potash,* had better be bought in readiness for use at a manufacturing chemist's.

Analysis of Coal, &c.—Weigh the potash apparatus and chloride of calcium tube, and carefully note their weights. Pulverise as finely as possible the fuel to be examined, and carefully dry it in the water-bath. Weigh out from 6 to 7 grains in a small tube, closed with a sound cork. Introduce a small quantity of the fuel to be analysed (6 or 7 grains as nearly as may be guessed, rather less than more), and carefully cork; weigh the whole, and note its contents. A combustion tube (see fig. 358) is now to be filled to *b* with chromate of lead. A portion is to be shaken into the mortar (previously made gently warm), and then as much as possible of the fuel shaken from the tube in which it was weighed into the mortar with the chromate of lead, and the tube carefully closed with its cork and set aside.

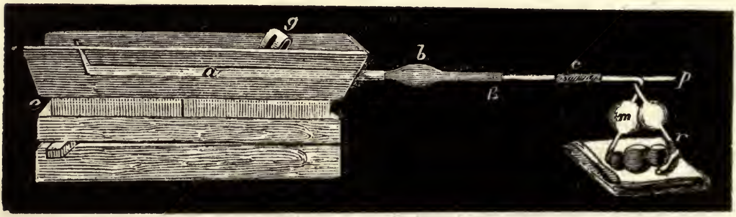
FIG. 358.



The chromate of lead and fuel must now be carefully mixed; after which all but about an inch and a half of the chromate added from the tube, and all again well mixed. The mixture is now transferred to the tube, by introducing its open end into the mortar, and scooping, as it were, the contents into itself by a semicircular motion, alternately raising and depressing the end so as to allow that portion of the mixture which has already entered the tube to descend to the closed end. A small portion will remain in the mortar, which cannot be thus removed; it must be carefully poured upon a small card or glazed paper, and transferred to the tube. A little fresh chromate of lead is now placed in the mortar, and the latter carefully rinsed with it, and the rinsings added to the mixture already in the tube. The tube is now filled to within an inch and a half of the mouth with pure chromate of lead, and temporarily stopped with a cork.

The combustion tube is now placed in the furnace, the cork removed, and the chloride of calcium tube with its perforated cork carefully and securely fixed in the mouth of the combustion tube. The end *B*, fig. 359, of the chloride of calcium tube is now connected, by means of the caoutchouc tube, with the end *m* of the potash apparatus, and secured on both sides with silk cord. The potash apparatus is rested on a folded cloth.

FIG. 359.



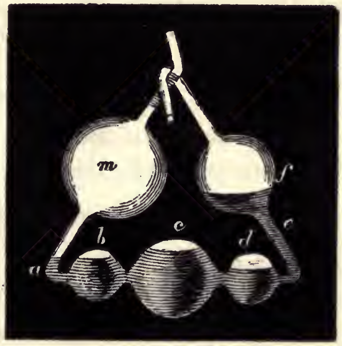
The whole apparatus must now be examined as to the tightness of the joints. A small cork, about the size of the finger, is placed under the bulb *r*, fig. 359, of the potash apparatus, so as to raise the bulb slightly. A live coal is then held near the bulb *m*, until a certain portion of air is expelled through the apparatus; the piece of wood is removed, and the bulb *m* allowed to cool. The potash solution will now rise in the bulb *m*, and fill it more or less. If the liquid in *m* preserves for a few minutes the same level which it has been found to have acquired after the perfect cooling of the bulb, the junctions may be considered perfect; if not, they must be remade.

Suppose them perfect, the combustion tube must be made to project a full inch from the front of the furnace, and the simple screen *A*, fig. 357, suspended over it, so as to shield the cork. The other screen is now placed over the combustion tube, at a distance of about two inches from the front of the furnace, see fig. 359. The cork is again placed under the bulb *r* of the potash apparatus, and live coals (charcoal) are placed under and around that part of the tube enclosed by the screen. When this portion has been completely surrounded, and is red hot, the screen is moved backwards about an inch, and fresh coals placed upon that portion of the tube so uncovered. In this manner the fire is slowly and gradually extended to the further end of the tube, taking care to wait until the last exposed portion of the tube is red hot, and taking care to maintain the whole length, as proceeded with, in complete ignition. The process generally requires about half to three-quarters of an hour.

The first effect of the heat is the gradual displacement of the liquid in the potash apparatus from the bulb, *m*; this is due to the expansion of the heated air in the combustion tube. As soon, however, as the heat reaches that portion of chromate of lead which has been employed in rinsing out the mortar, carbonic acid and aqueous vapour begin to be evolved, which drive the air present in the apparatus before them, and force it in large bubbles through the potash apparatus. The evolution of carbonic acid and aqueous vapour becomes brisker as the heat is applied to that portion of the tube containing the mixture of fuel and chromate; and as soon as the whole of the air has been expelled, the bubbles of carbonic acid which then pass over are nearly entirely absorbed by the potash, so that only an occasional bubble of air passes through. The process should be conducted in such a manner that the gas bubbles follow each other from intervals of one half to one second.

Fig. 360 shews how an air-bubble, entering at *a*, first passes into the bulb *b*; then from *b* to *c*, from *c* to *d*, and finally escapes through the tube *e* into the bulb *f*.

FIG. 360.



When the tube has been thoroughly covered throughout its whole length with burning charcoal, and all evolution of gas has ceased, the charcoal is removed from the curved end of the combustion tube, and the screen placed between it and the remainder of the burning charcoal. The cork support must now be removed from the potash apparatus, so that it stands level, and in the course of a few moments the liquid will commence ascending into the tube *m*, owing to the cooling of the combustion tube, and consequent condensation of its gaseous contents. When the liquid about half fills the bulb *m*, the part of the curved end of the combustion tube is cut off by a small pair of nippers, when the fluid in the potash apparatus will regain its equilibrium. The potash apparatus is now again placed in its oblique position by means of the cork support. The long tube, open at both ends, placed over the curved portion of the combustion tube (a portion of which has just been removed by the pliers), and rested against a retort stand or other suitable support, the suction tube is now applied to the end *f* of the potash apparatus, and air gently drawn through, in order to remove all the carbonic acid remaining in the combustion tube, and draw it over into the potash apparatus, where it may be absorbed. This suction is continued until the bubbles passing through cease to diminish in size. The operation is now finished. The potash apparatus and chloride of calcium tube are disconnected, and set aside to cool. When cold, or in about half an hour, both are weighed, and their weights noted. The increase in weight in the chloride of calcium tube over the former weighing represents the amount of water formed by the combustion of the hydrogen in the quantity of fuel submitted to analysis; the increase of weight in the potash apparatus, that of the carbonic acid furnished by the carbon.

The tube in which the fuel was weighed is now again weighed, and the loss of weight represents the quantity of fuel submitted to analysis. The amount of carbon is thus calculated: suppose the substance gave of carbonic 16·46; then—

Equivalent of Carbonic Acid.		Amount of Carbonic Acid.		Equivalent of Carbon.		
22	:	16·46	::	6	:	x

x = 4·48 amount of carbon.

To find amount of hydrogen, supposing 3·336 grains of water to have been produced; then—

Equivalent of Water.		Amount of Water.		Equivalent of Hydrogen.		
9	:	3.336	::	1	:	x

x = ·37 amount of hydrogen.

Now, supposing 6 grains of coal had been employed in the analysis, the per centage amount of carbon and hydrogen would be thus calculated:—

Amount of Coal employed in Analysis.		Coal.		Amount of Carbon found on Analysis.		
6	:	100	::	4·48	:	x

x = 74·66 per centage of carbon.

For hydrogen:—

Amount of Coal employed in Analysis.		Coal.		Amount of Hydrogen. obtained on Analysis.		
6	:	100	::	·37	:	x

x = 6·13 per centage of hydrogen.

From the amounts of carbon and hydrogen thus obtained, the heating power of any fuel may be readily calculated.

The following is the method of ascertaining the calorific power of fuel, employed by Dr. Ure, and described in his Supplement.

"The following calorimeter, founded upon the same principle as that of Count Rumford, but with certain improvements, may be considered as an equally correct instrument for measuring heat with any of the preceding (Lavoisier, Meyers, and others), but one of much more general application, since it can determine the quantity of heat disengaged in combustion, as well as the latent heat of steam and other vapours.

"It consists of a large copper bath, capable of holding 100 gallons of water. It is traversed four times backwards and forwards, in four different levels, by a zig-zag horizontal flue, or flat pipe, 9 inches broad and 1 deep, ending below in a round pipe, which passes through the bottom of the bath, and receives there into it the top of a small black-lead furnace, the innermost crucible of which contains the fuel. It is surrounded, at the distance of an inch, by a second crucible, which is enclosed, at the same time, by the sides of the outermost furnace, the strata of stagnant air between the crucibles serving to prevent the heat being dissipated into the atmosphere by the body of the furnace. A pipe from a double pair of bellows enters the ash-pit of the furnace at one side, and supplies a steady but gentle heat to carry on the combustion kindled at first by half an ounce of burning charcoal. So completely is the heat which is disengaged by the burning fuel absorbed by the water in the bath, that the air discharged at the top pipe is generally of the same temperature as the atmosphere. The vessel is made of copper, weighing 2 lbs. per square foot; it is 5½ feet long, 1½ wide, 2 deep, with a bottom 5½ feet long, and 1¾ broad upon an average. Including the zig-zag tin-plate flue, and a rim of wrought iron, it weighs altogether 85 lbs. Since the specific heat of copper is to that of water as 94 to 1000, the specific heat of the vessel is equal to that of 8 lbs. of water; for which, therefore, the exact correction is made by leaving 8 lbs. of water out of the 600 or 1000 lbs. used in each experiment.

"In the experiments made with former calorimeters of this kind, the combustion was maintained by the current or draught of a chimney open at bottom, which carried off at the top orifice of the flue a variable quantity of heat, very difficult to estimate.

"The heating power of the fuel is measured by the number of degrees of temperature which the combustion of 1 lb. of it raises

600 or 1000 lbs. of water in the bath, the copper substance of the vessel being taken into account. One pound of dry wood charcoal, by its combustion, causes 6000 lbs. of water to become 20° hotter. For the sake of brevity, we shall call this calorific energy 12,000 unities. In like circumstance, 1 lb. of Llangennock coal will yield by combustion 11,500 unities of caloric."

This form of calorimeter of Dr. Ure's seems to possess many advantages over Laplace's and others; and is, no doubt, very convenient in use, although rather bulky.

APPENDIX.

TABLE I.

Showing the Quantity of Fine Gold in 1 oz. of any Alloy to $\frac{1}{8}$ of a Carat Grain, and the Mint Value of 1 oz. of each Alloy.

Fine Gold, Per Ounce.			Carat Gold, Per Ounce.			Sterling Value, Per Ounce.		
Oz.	*Dwts.*	*Grs.*	*Carats.*	*Grs.*	*Eighths.*	£	*s.*	*d.*
1	0	0·000	24	0	0	4	4	11·4545
0	19	23·375	23	3	7	4	4	10·1271
0	19	22·750	23	3	6	4	4	8·7997
0	19	22·125	23	3	5	4	4	7·4723
0	19	21·500	23	3	4	4	4	6·1448
0	19	20·875	23	3	3	4	4	4·8174
0	19	20·250	23	3	2	4	4	3·4900
0	19	19·625	23	3	1	4	4	2·1626
0	19	19·000	23	3	0	4	4	0·8352
0	19	18·375	23	2	7	4	3	11·5078
0	19	17·750	23	2	6	4	3	10·1804
0	19	17·125	23	2	5	4	3	8·8529
0	19	16·500	23	2	4	4	3	7·5255
0	19	15·875	23	2	3	4	3	6·1981
0	19	15·250	23	2	2	4	3	4·8707
0	19	14·625	23	2	1	4	3	3·5433
0	19	14·000	23	2	0	4	3	2·2159
0	19	13·375	23	1	7	4	3	0·8885
0	19	12·750	23	1	6	4	2	11·5610
0	19	12·125	23	1	5	4	2	10·2336
0	19	11·500	23	1	4	4	2	8·9062
0	19	10·875	23	1	3	4	2	7·5788
0	19	10·250	23	1	2	4	2	6·2514
0	19	9·625	23	1	1	4	2	4·9240
0	19	9·000	23	1	0	4	2	3·5965
0	19	8·375	23	0	7	4	2	2·2691
0	19	7·750	23	0	6	4	2	0·9417
0	19	7·125	23	0	5	4	1	11·6143
0	19	6·500	23	0	4	4	1	10·2869
0	19	5·875	23	0	3	4	1	8·9595
0	19	5·250	23	0	2	4	1	7·6321
0	19	4·625	23	0	1	4	1	6·3047
0	19	4·000	23	0	0	4	1	4·9772
0	19	3·375	22	3	7	4	1	3·6498
0	19	2·750	22	3	6	4	1	2·3224

Fine Gold, Per Ounce.			Carat Gold, Per Ounce.			Sterling Value, Per Ounce.		
Oz.	*Dwts.*	*Grs.*	*Carats.*	*Grs.*	*Eighths.*	£	*s.*	*d.*
0	19	2·125	22	3	5	4	1	0·9950
0	19	1·500	22	3	4	4	0	11·6676
0	19	0·875	22	3	3	4	0	10·3402
0	19	0·250	22	3	2	4	0	8·0127
0	18	23·625	22	3	1	4	0	7·6854
0	18	23·000	22	3	0	4	0	6·3579
0	18	22·375	22	2	7	4	0	4·0305
0	18	21·750	22	2	6	4	0	3·7031
0	18	21·125	22	2	5	4	0	2·3757
0	18	20·500	22	2	4	4	0	0·0482
0	18	19·875	22	2	3	3	19	11·7208
0	18	19·250	22	2	2	3	19	10·3934
0	18	18·625	22	2	1	3	19	8·0660
0	18	18·000	22	2	0	3	19	7·7386
0	18	17·375	22	1	7	3	19	6·4112
0	18	16·750	22	1	6	3	19	4·0838
0	18	16·125	22	1	5	3	19	3·7563
0	18	15·500	22	1	4	3	19	2·4289
0	18	14·875	22	1	3	3	19	0·1015
0	18	14·250	22	1	2	3	18	11·7741
0	18	13·625	22	1	1	3	18	10·4467
0	18	13·000	22	1	0	3	18	8·1193
0	18	12·375	22	0	7	3	18	7·7919
0	18	11·750	22	0	6	3	18	6·4644
0	18	11·125	22	0	5	3	18	4·1370
0	18	10·500	22	0	4	3	18	3·8096
0	18	9·875	22	0	3	3	18	2·4822
0	18	9·250	22	0	2	3	18	0·1548
0	18	8·625	22	0	1	3	17	11·8274
0	18	8·000	22	0	0	3	17	10·5000
0	18	7·375	21	3	7	3	17	8·1725
0	18	6·750	21	3	6	3	17	7·8451
0	18	6·125	21	3	5	3	17	6·5177
0	18	5·500	21	3	4	3	17	4·1903
0	18	4·875	21	3	3	3	17	3·8629
0	18	4·250	21	3	2	3	17	2·5355
0	18	3·625	21	3	1	3	17	0·2081
0	18	3·000	21	3	0	3	16	11·8806
0	18	2·375	21	2	7	3	16	10·5532
0	18	1·750	21	2	6	3	16	8·2258
0	18	1·125	21	2	5	3	16	7·8984
0	18	0·500	21	2	4	3	16	6·5710
0	17	23·875	21	2	3	3	16	4·2436
0	17	23·250	21	2	2	3	16	3·9162

Fine Gold, Per Ounce.			Carat Gold, Per Ounce.			Sterling Value, Per Ounce.		
Oz.	*Dwts.*	*Grs.*	*Carats.*	*Grs.*	*Eighths.*	£	*s.*	*d.*
0	17	22·625	21	2	1	3	16	2·5887
0	17	22·000	21	2	0	3	16	1·2613
0	17	21·375	21	1	7	3	15	11·9339
0	17	20·750	21	1	6	3	15	10·6065
0	17	20·125	21	1	5	3	15	9·2791
0	17	19·500	21	1	4	3	15	7·9517
0	17	18·875	21	1	3	3	15	6·6243
0	17	18·250	21	1	2	3	15	5·2968
0	17	17·625	21	1	1	3	15	3·9694
0	17	17·000	21	1	0	3	15	2·6420
0	17	16·375	21	0	7	3	15	1·3146
0	17	15·750	21	0	6	3	14	11·9872
0	17	15·125	21	0	5	3	14	10·6598
0	17	14·500	21	0	4	3	14	9·3324
0	17	13·875	21	0	3	3	14	8·0049
0	17	13·250	21	0	2	3	14	6·6775
0	17	12·625	21	0	1	3	14	5·3501
0	17	12·000	21	0	0	3	14	4·0227
0	17	11·375	20	3	7	3	14	2·6953
0	17	10·750	20	3	6	3	14	1·3678
0	17	10·125	20	3	5	3	14	0·0404
0	17	9·500	20	3	4	3	13	10·7130
0	17	8·875	20	3	3	3	13	9·3856
0	17	8·250	20	3	2	3	13	8·0582
0	17	7·625	20	3	1	3	13	6·7308
0	17	7·000	20	3	0	3	13	5·4034
0	17	6·375	20	2	7	3	13	4·0759
0	17	5·750	20	2	6	3	13	2·7485
0	17	5·125	20	2	5	3	13	1·4211
0	17	4·500	20	2	4	3	13	0·0937
0	17	3·875	20	2	3	3	12	10·7663
0	17	3·250	20	2	2	3	12	9·4389
0	17	2·625	20	2	1	3	12	8·1115
0	17	2·000	20	2	0	3	12	6·7840
0	17	1·375	20	1	7	3	12	5·4566
0	17	0·750	20	1	6	3	12	4·1292
0	17	0·125	20	1	5	3	12	2·8018
0	16	23·500	20	1	4	3	12	1·4744
0	16	22·875	20	1	3	3	12	0·1470
0	16	22·250	20	1	2	3	11	10·8196
0	16	21·625	20	1	1	3	11	9·4921
0	16	21·000	20	1	0	3	11	8·1647
0	16	20·375	20	0	7	3	11	6·8373
0	16	19·750	20	0	6	3	11	5·5099

Fine Gold, Per Ounce.			Carat Gold, Per Ounce.			Sterling Value, Per Ounce.		
Oz.	*Dwts.*	*Grs.*	*Carats.*	*Grs.*	*Eighths.*	£	*s.*	*d.*
0	16	19·125	20	0	5	3	11	4·1825
0	16	18·500	20	0	4	3	11	2·8551
0	16	17·875	20	0	3	3	11	1·5277
0	16	17·250	20	0	2	3	11	0·2002
0	16	16·625	20	0	1	3	10	10·8728
0	16	16·000	20	0	0	3	10	9·5454
0	16	15·375	19	3	7	3	10	8·2180
0	16	14·750	19	3	6	3	10	6·8906
0	16	14·125	19	3	5	3	10	5·5632
0	16	13·500	19	3	4	3	10	4·2357
0	16	12·875	19	3	3	3	10	2·9083
0	16	12·250	19	3	2	3	10	1·5809
0	16	11·625	19	3	1	3	10	0·2534
0	16	11·000	19	3	0	3	9	10·9260
0	16	10·375	19	2	7	3	9	9·5986
0	16	9·750	19	2	6	3	9	8·2712
0	16	9·125	19	2	5	3	9	6·9437
0	16	8·500	19	2	4	3	9	5·6163
0	16	7·875	19	2	3	3	9	4·2889
0	16	7·250	19	2	2	3	9	2·9615
0	16	6·625	19	2	1	3	9	1·6341
0	16	6·000	19	2	0	3	9	0·3067
0	16	5·375	19	1	7	3	8	10·9793
0	16	4·750	19	1	6	3	8	9·6518
0	16	4·125	19	1	5	3	8	8·3244
0	16	3·500	19	1	4	3	8	6·9970
0	16	2·875	19	1	3	3	8	5·6696
0	16	2·250	19	1	2	3	8	4·3422
0	16	1·625	19	1	1	3	8	3·0148
0	16	1·000	19	1	0	3	8	1·6874
0	16	0·375	19	0	7	3	8	0·3599
0	15	23·750	19	0	6	3	7	11·0325
0	15	23·125	19	0	5	3	7	9·7051
0	15	22·500	19	0	4	3	7	8·3777
0	15	21·875	19	0	3	3	7	7·0503
0	15	21·250	19	0	2	3	7	5·7229
0	15	20·625	19	0	1	3	7	4·3955
0	15	20·000	19	0	0	3	7	3·0681
0	15	19·375	18	3	7	3	7	1·7407
0	15	18·750	18	3	6	3	7	0·4133
0	15	18·125	18	3	5	3	6	11·0859
0	15	17·500	18	3	4	3	6	9·7585
0	15	16·875	18	3	3	3	6	8·4311
0	15	16·250	18	3	2	3	6	7·1036

Fine Gold, Per Ounce.			Carat Gold, Per Ounce.			Sterling Value, Per Ounce.		
Oz.	*Dwts.*	*Grs.*	*Carats.*	*Grs.*	*Eighths.*	£	*s.*	*d.*
0	15	15·625	18	3	1	3	6	5·7762
0	15	15·000	18	3	0	3	6	4·4488
0	15	14·375	18	2	7	3	6	3·1214
0	15	13·750	18	2	6	3	6	1·7940
0	15	13·125	18	2	5	3	6	0·4666
0	15	12·500	18	2	4	3	5	11·1392
0	15	11·875	18	2	3	3	5	9·8117
0	15	11·250	18	2	2	3	5	8·4843
0	15	10·625	18	2	1	3	5	7·1569
0	15	10·000	18	2	0	3	5	5·8295
0	15	9·375	18	1	7	3	5	4·5021
0	15	8·750	18	1	6	3	5	3·1747
0	15	8·125	18	1	5	3	5	1·8473
0	15	7·500	18	1	4	3	5	0·5198
0	15	6·875	18	1	3	3	4	11·1924
0	15	6·250	18	1	2	3	4	9·8650
0	15	5·625	18	1	1	3	4	8·5376
0	15	5·000	18	1	0	3	4	7·2102
0	15	4·375	18	0	7	3	4	5·8828
0	15	3·750	18	0	6	3	4	4·5554
0	15	3·125	18	0	5	3	4	3·2279
0	15	2·500	18	0	4	3	4	1·9005
0	15	1·875	18	0	3	3	4	0·5731
0	15	1·250	18	0	2	3	3	11·2457
0	15	0·625	18	0	1	3	3	9·9183
0	15	0·000	18	0	0	3	3	8·5909
0	14	23·375	17	3	7	3	3	7·2634
0	14	22·750	17	3	6	3	3	5·9360
0	14	22·125	17	3	5	3	3	4·6086
0	14	21·500	17	3	4	3	3	3·2812
0	14	20·875	17	3	3	3	3	1·9538
0	14	20·250	17	3	2	3	3	0·6264
0	14	19·625	17	3	1	3	2	11·2990
0	14	19·000	17	3	0	3	2	9·9715
0	14	18·375	17	2	7	3	2	8·6441
0	14	17·750	17	2	6	3	2	7·3167
0	14	17·125	17	2	5	3	2	5·9893
0	14	16·500	17	2	4	3	2	4·6619
0	14	15·875	17	2	3	3	2	3·3345
0	14	15·250	17	2	2	3	2	2·0071
0	14	14·625	17	2	1	3	2	0·6796
0	14	14·000	17	2	0	3	1	11·3522
0	14	13·375	17	1	7	3	1	10·0248
0	14	12·750	17	1	6	3	1	8·6974

Fine Gold, Per Ounce.			Carat Gold, Per Ounce.			Sterling Value, Per Ounce.		
Oz.	*Dwts.*	*Grs.*	*Carats.*	*Grs.*	*Eighths.*	£	*s.*	*d.*
0	14	12·125	17	1	5	3	1	7·3700
0	14	11·500	17	1	4	3	1	6·0426
0	14	10·875	17	1	3	3	1	4·7152
0	14	10·250	17	1	2	3	1	3·3877
0	14	9·625	17	1	1	3	1	2·0603
0	14	9·000	17	1	0	3	1	0·7329
0	14	8·375	17	0	7	3	0	11·4055
0	14	7·750	17	0	6	3	0	10·0781
0	14	7·125	17	0	5	3	0	8·7507
0	14	6·500	17	0	4	3	0	7·4233
0	14	5·875	17	0	3	3	0	6·0958
0	14	5·250	17	0	2	3	0	4·7684
0	14	4·625	17	0	1	3	0	3·4410
0	14	4·000	17	0	0	3	0	2·1136
0	14	3·375	16	3	7	3	0	0·7862
0	14	2·750	16	3	6	2	19	11·4588
0	14	2·125	16	3	5	2	19	10·1313
0	14	1·500	16	3	4	2	19	8·8039
0	14	0·875	16	3	3	2	19	7·4765
0	14	0·250	16	3	2	2	19	6·1491
0	13	23·625	16	3	1	2	19	4·8217
0	13	23·000	16	3	0	2	19	3·4943
0	13	22·375	16	2	7	2	19	2·1669
0	13	21·750	16	2	6	2	19	0·8394
0	13	21·125	16	2	5	2	18	11·5120
0	13	20·500	16	2	4	2	18	10·1846
0	13	19·875	16	2	3	2	18	8·8572
0	13	19·250	16	2	2	2	18	7·5298
0	13	18·625	16	2	1	2	18	6·2024
0	13	18·000	16	2	0	2	18	4·8750
0	13	17·375	16	1	7	2	18	3·5475
0	13	16·750	16	1	6	2	18	2·2201
0	13	16·125	16	1	5	2	18	0·8927
0	13	15·500	16	1	4	2	17	11·5653
0	13	14·875	16	1	3	2	17	10·2377
0	13	14·250	16	1	2	2	17	8·9103
0	13	13·625	16	1	1	2	17	7·5829
0	13	13·000	16	1	0	2	17	6·2554
0	13	12·375	16	0	7	2	17	4·9280
0	13	11·750	16	0	6	2	17	3·6006
0	13	11·125	16	0	5	2	17	2·2732
0	13	10·500	16	0	4	2	17	0·9458
0	13	9·875	16	0	3	2	16	11·6184
0	13	9·250	16	0	2	2	16	10·2909

Fine Gold, Per Ounce.			Carat Gold, Per Ounce.			Sterling Value, Per Ounce.		
Oz.	*Dwts.*	*Grs.*	*Carats.*	*Grs.*	*Eighths.*	£	*s.*	*d.*
0	13	8·625	16	0	1	2	16	8·9635
0	13	8·000	16	0	0	2	16	7·6363
0	13	7·375	15	3	7	2	16	6·3089
0	13	6·750	15	3	6	2	16	4·9815
0	13	6·125	15	3	5	2	16	3·6541
0	13	5·500	15	3	4	2	16	2·3267
0	13	4·875	15	3	3	2	16	0·9992
0	13	4·250	15	3	2	2	15	11·6718
0	13	3·625	15	3	1	2	15	10·3444
0	13	3·000	15	3	0	2	15	9·0170
0	13	2·373	15	2	7	2	15	7·6896
0	13	1·750	15	2	6	2	15	6·3622
0	13	1·125	15	2	5	2	15	5·0348
0	13	0·500	15	2	4	2	15	3·7073
0	12	23·875	15	2	3	2	15	2·3799
0	12	23·250	15	2	2	2	15	1·0525
0	12	22·625	15	2	1	2	14	11·7251
0	12	22·000	15	2	0	2	14	10·3976
0	12	21·375	15	1	7	2	14	9·0702
0	12	20·750	15	1	6	2	14	7·7428
0	12	20·125	15	1	5	2	14	6·4154
0	12	19·500	15	1	4	2	14	5·0880
0	12	18·875	15	1	3	2	14	3·7606
0	12	18·250	15	1	2	2	14	2·4332
0	12	17·625	15	1	1	2	14	1·1057
0	12	17·000	15	1	0	2	13	11·7783
0	12	16·375	15	0	7	2	13	10·4509
0	12	15·750	15	0	6	2	13	9·1235
0	12	15·125	15	0	5	2	13	7·7961
0	12	14·500	15	0	4	2	13	6·4687
0	12	13·875	15	0	3	2	13	5·1413
0	12	13·250	15	0	2	2	13	3·8138
0	12	12·625	15	0	1	2	13	2·4864
0	12	12·000	15	0	0	2	13	1·1591
0	12	11·375	14	3	7	2	12	11·8316
0	12	10·750	14	3	6	2	12	10·5042
0	12	10·125	14	3	5	2	12	9·1768
0	12	9·500	14	3	4	2	12	7·8494
0	12	8·875	14	3	3	2	12	6·5220
0	12	8·250	14	3	2	2	12	5·1946
0	12	7·625	14	3	1	2	12	3·8671
0	12	7·000	14	3	0	2	12	2·5397
0	12	6·375	14	2	7	2	12	1·2123
0	12	5·750	14	2	6	2	11	11·8849

FINE GOLD, Per Ounce.			CARAT GOLD, Per Ounce.			STERLING VALUE, Per Ounce.		
Oz.	*Dwts.*	*Grs.*	*Carats.*	*Grs.*	*Eighths.*	£	*s.*	*d.*
0	12	5·125	14	2	5	2	11	10·5575
0	12	4·500	14	2	4	2	11	9·2301
0	12	3·875	14	2	3	2	11	7·9027
0	12	3·250	14	2	2	2	11	6·5752
0	12	2·625	14	2	1	2	11	5·2478
0	12	2·000	14	2	0	2	11	3·9204
0	12	1·375	14	1	7	2	11	2·5930
0	12	0·750	14	1	6	2	11	1·2656
0	12	0·125	14	1	5	2	10	11·9382
0	11	23·500	14	1	4	2	10	10·6107
0	11	22·875	14	1	3	2	10	9·2833
0	11	22·250	14	1	2	2	10	7·9559
0	11	21·625	14	1	1	2	10	6·6285
0	11	21·000	14	1	0	2	10	5·3011
0	11	20·375	14	0	7	2	10	3·9737
0	11	19·750	14	0	6	2	10	2·6463
0	11	19·125	14	0	5	2	10	1·3188
0	11	18·500	14	0	4	2	9	11·9914
0	11	17·875	14	0	3	2	9	10·6640
0	11	17·250	14	0	2	2	9	9·3366
0	11	16·625	14	0	1	2	9	8·0092
0	11	16·000	14	0	0	2	9	6·6818
0	11	15·375	13	3	7	2	9	5·3544
0	11	14·750	13	3	6	2	9	4·0269
0	11	14·150	13	3	5	2	9	2·6995
0	11	13·500	13	3	4	2	9	1·3721
0	11	12·875	13	3	3	2	9	0·0447
0	11	12·250	13	3	2	2	8	10·7173
0	11	11·625	13	3	1	2	8	9·3899
0	11	11·000	13	3	0	2	8	8·0625
0	11	10·375	13	2	7	2	8	6·7350
0	11	9·750	13	2	6	2	8	5·4076
0	11	9·125	13	2	5	2	8	4·0802
0	11	8·500	13	2	4	2	8	2·7528
0	11	7·875	13	2	3	2	8	1·4254
0	11	7·250	13	2	2	2	8	0·0980
0	11	6·625	13	2	1	2	7	10·7705
0	11	6·000	13	2	0	2	7	9·4431
0	11	5·375	13	1	7	2	7	8·1157
0	11	4·750	13	1	6	2	7	6·7883
0	11	4·125	13	1	5	2	7	5·4609
0	11	3·500	13	1	4	2	7	4·1335
0	11	2·875	13	1	3	2	7	2·8061
0	11	2·250	13	1	2	2	7	1·4786

Fine Gold, Per Ounce.			Carat Gold, Per Ounce.			Sterling Value, Per Ounce.		
Oz.	*Dwts.*	*Grs.*	*Carats.*	*Grs.*	*Eighths.*	*£*	*s.*	*d.*
0	8	18·625	10	2	1	1	17	3·3387
0	8	18·000	10	2	0	1	17	2·0113
0	8	17·375	10	1	7	1	17	0·6839
0	8	16·750	10	1	6	1	16	11·3565
0	8	16·125	10	1	5	1	16	10·0291
0	8	15·500	10	1	4	1	16	8·7017
0	8	14·875	10	1	3	1	16	7·3742
0	8	14·250	10	1	2	1	16	6·0468
0	8	13·625	10	1	1	1	16	4·7194
0	8	13·000	10	1	0	1	16	3·3920
0	8	12·375	10	0	7	1	16	2·0646
0	8	11·750	10	0	6	1	16	0·7372
0	8	11·125	10	0	5	1	15	11·4098
0	8	10·500	10	0	4	1	15	10·0823
0	8	9·875	10	0	3	1	15	8·7549
0	8	9·250	10	0	2	1	15	7·4275
0	8	8·625	10	0	1	1	15	6·1001
0	8	8·000	10	0	0	1	15	4·7728
0	8	7·375	9	3	7	1	15	3·4454
0	8	6·750	9	3	6	1	15	2·1179
0	8	6·125	9	3	5	1	15	0·7905
0	8	5·500	9	3	4	1	14	11·4631
0	8	4·875	9	3	3	1	14	10·1357
0	8	4·250	9	3	2	1	14	8·8083
0	8	3·625	9	3	1	1	14	7·4809
0	8	3·000	9	3	0	1	14	6·1535
0	8	2·375	9	2	7	1	14	4·8260
0	8	1·750	9	2	6	1	14	3·4986
0	8	1·125	9	2	5	1	14	2·1712
0	8	0·500	9	2	4	1	14	0·8438
0	7	23·875	9	2	3	1	13	11·5164
0	7	23·250	9	2	2	1	13	10·1890
0	7	22·625	9	2	1	1	13	8·8616
0	7	22·000	9	2	0	1	13	7·5341
0	7	21·375	9	1	7	1	13	6·2067
0	7	20·750	9	1	6	1	13	4·8793
0	7	20·125	9	1	5	1	13	3·5519
0	7	19·500	9	1	4	1	13	2·2245
0	7	19·875	9	1	3	1	13	0·8971
0	7	18·250	9	1	2	1	12	11·5697
0	7	17·625	9	1	1	1	12	10·2422
0	7	17·000	9	1	0	1	12	8·9168
0	7	16·375	9	0	7	1	12	7·5874
0	7	15·750	9	0	6	1	12	6·2600

Fine Gold, Per Ounce.			Carat Gold, Per Ounce.			Sterling Value, Per Ounce.		
Oz.	*Dwts.*	*Grs.*	*Carats.*	*Grs.*	*Eighths.*	*£*	*s.*	*d.*
0	7	15·125	9	0	5	1	12	4·9326
0	7	14·500	9	0	4	1	12	3·6052
0	7	13·875	9	0	3	1	12	2·2778
0	7	13·250	9	0	2	1	12	0·9503
0	7	12·625	9	0	1	1	11	11·6229
0	7	12·000	9	0	0	1	11	10·2954
0	7	11·375	8	3	7	1	11	8·9680
0	7	10·750	8	3	6	1	11	7·6406
0	7	10·125	8	3	5	1	11	6·3132
0	7	9·500	8	3	4	1	11	4·9857
0	7	8·875	8	3	3	1	11	3·6583
0	7	8·250	8	3	2	1	11	2·3309
0	7	7·625	8	3	1	1	11	1·0035
0	7	7·000	8	3	0	1	10	11·6761
0	7	6·375	8	2	7	1	10	10·3487
0	7	5·750	8	2	6	1	10	9·0213
0	7	5·125	8	2	5	1	10	7·6938
0	7	4·500	8	2	4	1	10	6·3664
0	7	3·875	8	2	3	1	10	5·0390
0	7	3·250	8	2	2	1	10	3·7116
0	7	2·625	8	2	1	1	10	2·3843
0	7	2·000	8	2	0	1	10	1·0568
0	7	1·375	8	1	7	1	9	11·7294
0	7	0·750	8	1	6	1	9	10·4019
0	7	0·125	8	1	5	1	9	9·0745
0	6	23·500	8	1	4	1	9	7·7471
0	6	22·875	8	1	3	1	9	6·4197
0	6	22·250	8	1	2	1	9	5·0923
0	6	21·625	8	1	1	1	9	3·7649
0	6	21·000	8	1	0	1	9	2·4375
0	6	20·375	8	0	7	1	9	1·1100
0	6	19·750	8	0	6	1	8	11·7826
0	6	19·125	8	0	5	1	8	10·4552
0	6	18·500	8	0	4	1	8	9·1278
0	6	17·875	8	0	3	1	8	7·8004
0	6	17·250	8	0	2	1	8	6·4730
0	6	16·625	8	0	1	1	8	5·1455
0	6	16·000	8	0	0	1	8	3·8181
0	6	15·375	7	3	7	1	8	2·4907
0	6	14·750	7	3	6	1	8	1·1633
0	6	14·125	7	3	5	1	7	11·8359
0	6	13·500	7	3	4	1	7	10·5085
0	6	12·875	7	3	3	1	7	9·1811
0	6	12·250	7	3	2	1	7	7·8536

Fine Gold, Per Ounce.			Carat Gold, Per Ounce.			Sterling Value, Per Ounce.		
Oz.	*Dwts.*	*Grs.*	*Carats.*	*Grs.*	*Eighths.*	£	*s.*	*d.*
0	4	4·625	5	0	1	0	17	9·7137
0	4	4·000	5	0	0	0	17	8·3863
0	4	3·375	4	3	7	0	17	7·0589
0	4	2·750	4	3	6	0	17	5·7315
0	4	2·125	4	3	5	0	17	4·4041
0	4	1·500	4	3	4	0	17	3·0767
0	4	0·875	4	3	3	0	17	1·7492
0	4	0·250	4	3	2	0	17	0·4218
0	3	23·625	4	3	1	0	16	11·0944
0	3	23·000	4	3	0	0	16	9·7670
0	3	22·375	4	2	7	0	16	8·4396
0	3	21·750	4	2	6	0	16	7·1122
0	3	21·125	4	2	5	0	16	5·7848
0	3	20·500	4	2	4	0	16	4·4573
0	3	19·875	4	2	3	0	16	3·1299
0	3	19·250	4	2	2	0	16	1·8025
0	3	18·625	4	2	1	0	16	0·4751
0	3	18·000	4	2	0	0	15	11·1477
0	3	17·375	4	1	7	0	15	9·8203
0	3	16·750	4	1	6	0	15	8·4929
0	3	16·125	4	1	5	0	15	7·1655
0	3	15·500	4	1	4	0	15	5·8380
0	3	14·875	4	1	3	0	15	4·5106
0	3	14·250	4	1	2	0	15	3·1832
0	3	13·625	4	1	1	0	15	1·8558
0	3	13·000	4	1	0	0	15	0·5284
0	3	12·375	4	0	7	0	14	11·2009
0	3	11·750	4	0	6	0	14	9·8735
0	3	11·125	4	0	5	0	14	8·5461
0	3	10·500	4	0	4	0	14	7·2187
0	3	9·875	4	0	3	0	14	5·8913
0	3	9·250	4	0	2	0	14	4·5639
0	3	8·625	4	0	1	0	14	3·2365
0	3	8·000	4	0	0	0	14	1·9090
0	3	7·375	3	3	7	0	14	0·5816
0	3	6·750	3	3	6	0	13	11·2542
0	3	6·125	3	3	5	0	13	9·9268
0	3	5·500	3	3	4	0	13	8·5994
0	3	4·875	3	3	3	0	13	7·2720
0	3	4·250	3	3	2	0	13	5·9446
0	3	3·625	3	3	1	0	13	4·6171
0	3	3·000	3	3	0	0	13	3·2897
0	3	2·375	3	2	7	0	13	1·9623
0	3	1·750	3	2	6	0	13	0·6349

Fine Gold, Per Ounce.			Carat Gold, Per Ounce.			Sterling Value, Per Ounce.		
Oz.	*Dwts.*	*Grs.*	*Carats.*	*Grs.*	*Eighths.*	£	*s.*	*d.*
0	3	1·125	3	2	5	0	12	11·3075
0	3	0·500	3	2	4	0	12	9·9801
0	2	23·875	3	2	3	0	12	8·6527
0	2	23·250	3	2	2	0	12	7·3250
0	2	22·625	3	2	1	0	12	5·9978
0	2	22·000	3	2	0	0	12	4·6704
0	2	21·375	3	1	7	0	12	3·3430
0	2	20·750	3	1	6	0	12	2·0156
0	2	20·125	3	1	5	0	12	0·6882
0	2	19·500	3	1	4	0	11	11·3607
0	2	18·875	3	1	3	0	11	10·0333
0	2	18·250	3	1	2	0	11	8·7059
0	2	17·625	3	1	1	0	11	7·3785
0	2	17·000	3	1	0	0	11	6·0511
0	2	16·375	3	0	7	0	11	4·7237
0	2	15·750	3	0	6	0	11	3·3963
0	2	15·125	3	0	5	0	11	2·0688
0	2	14·500	3	0	4	0	11	0·7414
0	2	13·875	3	0	3	0	10	11·4140
0	2	13·250	3	0	2	0	10	10·0866
0	2	12·625	3	0	1	0	10	8·7592
0	2	12·000	3	0	0	0	10	7·4318
0	2	11·375	2	3	7	0	10	6·1044
0	2	10·750	2	3	6	0	10	4·7769
0	2	10·125	2	3	5	0	10	3·4495
0	2	9·500	2	3	4	0	10	2·1221
0	2	8·875	2	3	3	0	10	0·7947
0	2	8·250	2	3	2	0	9	11·4673
0	2	7·625	2	3	1	0	9	10·1399
0	2	7·000	2	3	0	0	9	8·8125
0	2	6·375	2	2	7	0	9	7·4850
0	2	5·750	2	2	6	0	9	6·1576
0	2	5·125	2	2	5	0	9	4·8302
0	2	4·500	2	2	4	0	9	3·5028
0	2	3·875	2	2	3	0	9	2·1754
0	2	3·250	2	2	2	0	9	0·8480
0	2	2·625	2	2	1	0	8	11·5205
0	2	2·000	2	2	0	0	8	10·1931
0	2	1·375	2	1	7	0	8	8·8657
0	2	0·750	2	1	6	0	8	7·5383
0	2	0·125	2	1	5	0	8	6·2109
0	1	23·500	2	1	4	0	8	4·8835
0	1	22·875	2	1	3	0	8	3·5561
0	1	22·250	2	1	2	0	8	2·2286

Fine Gold, Per Ounce.			Carat Gold, Per Ounce.			Sterling Value, Per Ounce.		
Oz.	*Dwts.*	*Grs.*	*Carats.*	*Grs.*	*Eighths.*	£	*s.*	*d.*
0	1	21·625	2	1	1	0	8	0·9012
0	1	21·000	2	1	0	0	7	11·5738
0	1	20·375	2	0	7	0	7	10·2464
0	1	19·750	2	0	6	0	7	8·9190
0	1	19·125	2	0	5	0	7	7·5916
0	1	18·500	2	0	4	0	7	6·2642
0	1	17·875	2	0	3	0	7	4·9367
0	1	17·250	2	0	2	0	7	3·6093
0	1	16·625	2	0	1	0	7	2·2819
0	1	16·000	2	0	0	0	7	0·9545
0	1	15·375	1	3	7	0	6	11·6271
0	1	14·750	1	3	6	0	6	10·2997
0	1	14·125	1	3	5	0	6	8·9723
0	1	13·500	1	3	4	0	6	7·6448
0	1	12·875	1	3	3	0	6	6·3174
0	1	12·250	1	3	2	0	6	4·9900
0	1	11·625	1	3	1	0	6	3·6626
0	1	11·000	1	3	0	0	6	2·3352
0	1	10·375	1	2	7	0	6	1·0078
0	1	9·750	1	2	6	0	5	11·6803
0	1	9·125	1	2	5	0	5	10·3529
0	1	8·500	1	2	4	0	5	9·0255
0	1	7·875	1	2	3	0	5	7·6981
0	1	7·250	1	2	2	0	5	6·3707
0	1	6·625	1	2	1	0	5	5·0433
0	1	6·000	1	2	0	0	5	3·7159
0	1	5·375	1	1	7	0	5	2·3884
0	1	4·750	1	1	6	0	5	1·0610
0	1	4·125	1	1	5	0	4	11·7336
0	1	3·500	1	1	4	0	4	10·4062
0	1	2·875	1	1	3	0	4	9·0788
0	1	2·250	1	1	2	0	4	7·7514
0	1	1·625	1	1	1	0	4	6·4240
0	1	1·000	1	1	0	0	4	5·0965
0	1	0·375	1	0	7	0	4	3·7691
0	0	23·750	1	0	6	0	4	2·4417
0	0	23·125	1	0	5	0	4	1·1143
0	0	22·500	1	0	4	0	3	11·7869
0	0	21·875	1	0	3	0	3	10·4595
0	0	21·250	1	0	2	0	3	9·1321
0	0	20·625	1	0	1	0	3	7·8046
0	0	20·000	1	0	0	0	3	6·4772
0	0	19·375	0	3	7	0	3	5·1498
0	0	18·750	0	3	6	0	3	3·8224

Fine Gold, Per Ounce.			Carat Gold, Per Ounce.			Sterling Value, Per Ounce.		
Oz.	*Dwts.*	*Grs.*	*Carats.*	*Grs.*	*Eighths.*	£	*s.*	*d.*
0	0	18·125	0	3	5	0	3	2·4950
0	0	17·500	0	3	4	0	3	1·1676
0	0	16·875	0	3	3	0	2	11·8401
0	0	16·250	0	3	2	0	2	10·5127
0	0	15·625	0	3	1	0	2	9·1853
0	0	15·000	0	3	0	0	2	7·8579
0	0	14·375	0	2	7	0	2	6·5305
0	0	13·750	0	2	6	0	2	5·2031
0	0	13·125	0	2	5	0	2	3·8757
0	0	12·500	0	2	4	0	2	2·5482
0	0	11·875	0	2	3	0	2	1·2208
0	0	11·250	0	2	2	0	1	11·8934
0	0	10·625	0	2	1	0	1	10·5660
0	0	10·000	0	2	0	0	1	9·2386
0	0	9·375	0	1	7	0	1	7·9112
0	0	8·750	0	1	6	0	1	6·5838
0	0	8·125	0	1	5	0	1	5·2563
0	0	7·500	0	1	4	0	1	3·9289
0	0	6·875	0	1	3	0	1	2·6015
0	0	6·250	0	1	2	0	1	1·2741
0	0	5·625	0	1	1	0	0	11·9467
0	0	5·000	0	1	0	0	0	10·6193
0	0	4·375	0	0	7	0	0	9·2919
0	0	3·750	0	0	6	0	0	7·9644
0	0	3·125	0	0	5	0	0	6·6370
0	0	2·500	0	0	4	0	0	5·3096
0	0	1·875	0	0	3	0	0	3·9822
0	0	1·250	0	0	2	0	0	2·6548
0	0	0·625	0	0	1	0	0	1·3274

To convert MINT VALUE into BANK VALUE when the Standard is expressed in Carats, Grains, and Eighths. This can be readily accomplished for every report by the following Tables :—

TABLE A.

Carats.	Value in Pence.	Carats.	Value in Pence.
1	·0681	13	·8863
2	·1363	14	·9545
3	·2045	15	1·0227
4	·2727	16	1·0909
5	·3409	17	1·1590
6	·4090	18	1·2272
7	·4772	19	1·2954
8	·5454	20	1·3636
9	·6136	21	1·4318
10	·6818	22	1·5000
11	·7500	23	1·5681
12	·8181	24	1·6363

TABLE B.

Carat Grains.	Value in Pence.	Carat Grains.	Value in Pence.
1	·0170	3	·0511
2	·0340	4	·0681

TABLE C.

Eighth Carat Grains.	Value in Pence.	Eighth Carat Grains.	Value in Pence.
1	·0021	5	·0106
2	·0042	6	·0127
3	·0063	7	·0149
4	·0085	8	·0170

Table A gives the difference in price between Mint and Bank value for each carat up to fine gold; Table B the same for carat grains; and Table C the same for eighths of carat grains.

Now as the Bank value of gold is £3. 17s. 9d. per oz. standard against Mint value of £3. 17s. 10½d., it follows by calculation that fine gold would fetch, Bank price, only £4. 4s. 9·8182d., instead of £4. 4s. 11·4545d., as shown by Table I. of Mint Values; and the Bank value of 1 oz. of gold, of any standard whatever, may be readily ascertained by the above Tables A, B, and C, and Table I.—the Tables A, B, and C, giving the quantities in pence to be deducted from the corresponding standard in Table I. Thus, suppose it is necessary to ascertain the Bank value of 1 oz. of gold of 14 carats 2 grains 5 eighths fine: refer to Table A, at 14 carats is found ·9545d.; at 2 grains in Table B is found ·0340d.; and at 5 eighths in Table C ·0106d. Now ·9545+·0340+·0106=·9991, which has to be deducted from £2. 11s. 10·5575d. (see Table I.), leaving £2. 11s. 9·5564d. as the Bank value of 1 oz. of gold of the above fineness.

TABLE II.

Table of relative proportions of Fine Gold and Alloy, with the respective Mint Values of 1 Oz. of each Alloy when the Standard is expressed in Thousandths.

Fine Gold.	Alloy.	Value.			Fine Gold.	Alloy.	Value.		
		£	*s.*	*d.*			£	*s.*	*d.*
1000	·000	4	4	11·4545	986	·014	4	3	9·1821
999	·001	4	4	10·4350	985	·015	4	3	8·1627
998	·002	4	4	9·4156	984	·016	4	3	7·1432
997	·003	4	4	8·3961	983	·017	4	3	6·1238
996	·004	4	4	7·3767	982	·018	4	3	5·1043
995	·005	4	4	6·3572	981	·019	4	3	4·0849
994	·006	4	4	5·3378	980	·020	4	3	3·0654
993	·007	4	4	4·3183	979	·021	4	3	2·0459
992	·008	4	4	3·2989	978	·022	4	3	1·0265
991	·009	4	4	2·2793	977	·023	4	3	0·0070
990	·010	4	4	1·2600	976	·024	4	2	10·9876
989	·011	4	4	0·2405	975	·025	4	2	9·9681
988	·012	4	3	11·2210	974	·026	4	2	8·9487
987	·013	4	3	10·2016	973	·027	4	2	7·9292

Fine Gold.	Alloy.	Value.			Fine Gold.	Alloy.	Value.		
		£	s.	d.			£	s.	d.
972	·028	4	2	6·9098	929	·071	3	18	11·0732
971	·029	4	2	5·8903	928	·072	3	18	10·0538
970	·030	4	2	4·8709	927	·073	3	18	9·0343
969	·031	4	2	3·8504	926	·074	3	18	8·0149
968	·032	4	2	2·8319	925	·075	3	18	6·9954
967	·033	4	2	1·8125	924	·076	3	18	5·9759
966	·034	4	2	0·7930	923	·077	3	18	4·9565
965	·035	4	1	11·7736	922	·078	3	18	3·9370
964	·036	4	1	10·7541	921	·079	3	18	2·9176
963	·037	4	1	9·7347	920	·080	3	18	1·8981
962	·038	4	1	8·7152	919	·081	3	18	0·8787
961	·039	4	1	7·6958	918	·082	3	17	11·8592
960	·040	4	1	6·6763	917	·083	3	17	10·8398
959	·041	4	1	5·6569	916*	·084	3	17	9·8203
958	·042	4	1	4·6374	915	·085	3	17	8·8009
957	·043	4	1	3·6179	914	·086	3	17	7·7814
956	·044	4	1	2·5985	913	·087	3	17	6·7619
955	·045	4	1	1·5790	912	·088	3	17	5·7425
954	·046	4	1	0·5596	911	·089	3	17	4·7230
953	·047	4	0	11·5401	910	·090	3	17	3·7036
952	·048	4	0	10·5207	909	·091	3	17	2·6841
951	·049	4	0	9·5012	908	·092	3	17	1·6647
950	·050	4	0	8·4818	907	·093	3	17	0·6452
949	·051	4	0	7·4623	906	·094	3	16	11·6258
948	·052	4	0	6·4429	905	·095	3	16	10·6063
947	·053	4	0	5·4234	904	·096	3	16	9·5869
946	·054	4	0	4·4039	903	·097	3	16	8·5674
945	·055	4	0	3·3835	902	·098	3	16	7·5479
944	·056	4	0	2·3650	901	·099	3	16	6·5285
943	·057	4	0	1·3456	900	·100	3	16	5·5090
942	·058	4	0	0·3261	899	·101	3	16	4·4896
941	·059	3	19	11·3067	898	·102	3	16	3·4701
940	·060	3	19	10·2872	897	·103	3	16	2·4507
939	·061	3	19	9·2678	896	·104	3	16	1·4312
938	·062	3	19	8·2483	895	·105	3	16	0·4118
937	·063	3	19	7·2289	894	·106	3	15	11·3923
936	·064	3	19	6·2094	893	·107	3	15	10·3729
935	·065	3	19	5·1899	892	·108	3	15	9·3534
934	·066	3	19	4·1705	891	·109	3	15	8·3339
933	·067	3	19	3·1510	890	·110	3	15	7·3145
932	·068	3	19	2·1316	889	·111	3	15	6·2950
931	·069	3	19	1·1121	888	·112	3	15	5·2756
930	·070	3	19	0·0927	887	·113	3	15	4·2561

* 916·666̇ Standard ·083·333̇ £3. 17*s.* 10·5000*d.*

FINE GOLD.	ALLOY.	VALUE.			FINE GOLD.	ALLOY.	VALUE.		
		£	*s.*	*d.*			£	*s.*	*d.*
886	·114	3	15	3·2367	841	·159	3	11	5·3612
885	·115	3	15	2·2172	840	·160	3	11	4·3418
884	·116	3	15	1·1978	839	·161	3	11	3·3223
883	·117	3	15	0·1783	838	·162	3	11	2·3029
882	·118	3	14	11·1589	837	·163	3	11	1·3834
881	·119	3	14	10·1394	836	·164	3	11	0·2639
880	·120	3	14	9·1199	835	·165	3	10	11·2445
879	·121	3	14	8·1005	834	·166	3	10	10·2250
878	·122	3	14	7·0810	833	·167	3	10	9·2056
877	·123	3	14	6·0616	832	·168	3	10	8·1861
876	·124	3	14	5·0421	831	·169	3	10	7·1667
875	·125	3	14	4·0227	830	·170	3	10	6·1472
874	·126	3	14	3·0032	829	·171	3	10	5·1278
873	·127	3	14	1·9838	828	·172	3	10	4·1083
872	·128	3	14	0·9643	827	·173	3	10	3·0889
871	·129	3	13	11·9449	826	·174	3	10	2·0694
870	·130	3	13	10·9254	825	·175	3	10	1·0499
869	·131	3	13	9·9059	824	·176	3	10	0·0305
868	·132	3	13	8·8865	823	·177	3	9	11·0110
867	·133	3	13	7·8670	822	·178	3	9	9·9916
866	·134	3	13	6·8476	821	·179	3	9	8·9721
865	·135	3	13	5·8281	820	·180	3	9	7·9527
864	·136	3	13	4·8087	819	·181	3	9	6·9332
863	·137	3	13	3·7892	818	·182	3	9	5·9138
862	·138	3	13	2·7698	817	·183	3	9	4·8943
861	·139	3	13	1·7503	816	·184	3	9	3·8749
860	·140	3	13	0·7309	815	·185	3	9	2·8554
859	·141	3	12	11·7114	814	·186	3	9	1·8359
858	·142	3	12	10·6919	813	·187	3	9	0·8165
857	·143	3	12	9·6725	812	·188	3	8	11·7970
856	·144	3	12	8·6530	811	·189	3	8	10·7776
855	·145	3	12	7·6336	810	·190	3	8	9·7581
854	·146	3	12	6·6141	809	·191	3	8	8·7387
853	·147	3	12	5·5947	808	·192	3	8	7·7192
852	·148	3	12	4·5752	807	·193	3	8	6·6998
851	·149	3	12	3·5558	806	·194	3	8	5·6803
850	·150	3	12	2·5363	805	·195	3	8	4·6609
849	·151	3	12	1·5169	804	·196	3	8	3·6414
848	·152	3	12	0·4974	803	·197	3	8	2·6219
847	·153	3	11	11·4779	802	·198	3	8	1·6025
846	·154	3	11	10·4585	801	·199	3	8	0·5830
845	·155	3	11	9·4390	800	·200	3	7	11·5636
844	·156	3	11	8·4196	799	·201	3	7	10·5441
843	·157	3	11	7·4001	798	·202	3	7	9·5247
842	·158	3	11	6·3807	797	·203	3	7	8·5052

Fine Gold.	Alloy.	Value.			Fine Gold.	Alloy.	Value.		
		£	s.	d.			£	s.	d.
796	·204	3	7	7·4858	751	·249	3	3	9·6103
795	·205	3	7	6·4663	750	·250	3	3	8·5909
794	·206	3	7	5·4469	749	·251	3	3	7·5714
793	·207	3	7	4·4274	748	·252	3	3	6·5519
792	·208	3	7	3·4079	747	·253	3	3	5·5325
791	·209	3	7	2·3885	746	·254	3	3	4·5130
790	·210	3	7	1·3690	745	·255	3	3	3·4936
789	·211	3	7	0·3496	744	·256	3	3	2·4741
788	·212	3	6	11·3301	743	·257	3	3	1·4547
787	·213	3	6	10·3107	742	·258	3	3	0·4352
786	·214	3	6	9·2912	741	·259	3	2	11·4158
785	·215	3	6	8·2718	740	·260	3	2	10·3963
784	·216	3	6	7·2523	739	·261	3	2	9·3769
783	·217	3	6	6·2329	738	·262	3	2	8·3574
782	·218	3	6	5·2134	737	·263	3	2	7·3379
781	·219	3	6	4·1939	736	·264	3	2	6·3185
780	·220	3	6	3·1745	735	·265	3	2	5·2990
779	·221	3	6	2·1550	734	·266	3	2	4·2796
778	·222	3	6	1·1356	733	·267	3	2	3·2601
777	·223	3	6	0·1161	732	·268	3	2	2·2407
776	·224	3	5	11·0967	731	·269	3	2	1·2212
775	·225	3	5	10·0772	730	·270	3	2	0·2018
774	·226	3	5	9·0578	729	·271	3	1	11·1823
773	·227	3	5	8·0383	728	·272	3	1	10·1629
772	·228	3	5	7·0189	727	·273	3	1	9·1434
771	·229	3	5	5·9994	726	·274	3	1	8·1239
770	·230	3	5	4·9799	725	·275	3	1	7·1045
769	·231	3	5	3·9605	724	·276	3	1	6·0850
768	·232	3	5	2·9410	723	·277	3	1	5·0656
767	·233	3	5	1·9216	722	·278	3	1	4·0461
766	·234	3	5	0·9021	721	·279	3	1	3·0267
765	·235	3	4	11·8827	720	·280	3	1	2·0072
764	·236	3	4	10·8632	719	·281	3	1	0·9878
763	·237	3	4	9·8438	718	·282	3	0	11·9683
762	·238	3	4	8·8243	717	·283	3	0	10·9489
761	·239	3	4	7·8049	716	·284	3	0	9·9294
760	·240	3	4	6·7854	715	·285	3	0	8·9099
759	·241	3	4	5·7659	714	·286	3	0	7·8905
758	·242	3	4	4·7465	713	·287	3	0	6·8710
757	·243	3	4	3·7270	712	·288	3	0	5·8516
756	·244	3	4	2·7076	711	·289	3	0	4·8321
755	·245	3	4	1·6881	710	·290	3	0	3·8127
754	·246	3	4	0·6687	709	·291	3	0	2·7932
753	·247	3	3	11·6492	708	·292	3	0	1·7738
752	·248	3	3	10·6298	707	·293	3	0	0·7543

FINE GOLD.	ALLOY.	VALUE.			FINE GOLD.	ALLOY.	VALUE.		
		£	*s.*	*d.*			£	*s.*	*d.*
706	·294	2	19	11·7349	661	·339	2	16	1·8594
705	·295	2	19	10·7154	660	·340	2	16	0·8399
704	·296	2	19	9·6959	659	·341	2	15	11·8205
703	·297	2	19	8·6765	658	·342	2	15	10·8010
702	·298	2	19	7·6570	657	·343	2	15	9·7816
701	·299	2	19	6·6376	656	·344	2	15	8·7621
700	·300	2	19	5·6181	655	·345	2	15	7·7427
699	·301	2	19	4·5987	654	·346	2	15	6·7232
698	·302	2	19	3·5792	653	·347	2	15	5·7038
697	·303	2	19	2·5598	652	·348	2	15	4·6843
696	·304	2	19	1·5403	651	·349	2	15	3·6649
695	·305	2	19	0·5209	650	·350	2	15	2·6454
694	·306	2	18	11·5014	649	·351	2	15	1·6259
693	·307	2	18	10·4820	648	·352	2	15	0·6065
692	·308	2	18	9·4625	647	·353	2	14	11·5870
691	·309	2	18	8·4430	646	·354	2	14	10·5676
690	·310	2	18	7·4236	645	·355	2	14	9 5481
689	·311	2	18	6·4041	644	·356	2	14	8·5287
688	·312	2	18	5·3847	643	·357	2	14	7·5092
687	·313	2	18	4·3652	642	·358	2	14	6·4898
686	·314	2	18	3·3458	641	·359	2	14	5·4703
685	·315	2	18	2·3263	640	·360	2	14	4.4509
684	·316	2	18	1·3069	639	·361	2	14	3·4314
683	·317	2	18	0·2874	638	·362	2	14	2·4120
682	·318	2	17	11·2680	637	·363	2	14	1·3925
681	·319	2	17	10·2485	636	·364	2	14	0·3730
680	·320	2	17	9·2290	635	·365	2	13	11·3536
679	·321	2	17	8·2096	634	·366	2	13	10·3341
678	·322	2	17	7·1901	633	·367	2	13	9·3147
677	·323	2	17	6·1707	632	·368	2	13	8·2952
676	·324	2	17	5·1512	631	·369	2	13	7·2758
675	·325	2	17	4·1318	630	·370	2	13	6·2563
674	·326	2	17	3·1123	629	·371	2	13	5·2369
673	·327	2	17	2·0929	628	·372	2	13	4·2174
672	·328	2	17	1·0734	627	·373	2	13	3·1979
671	·329	2	17	0·0540	626	·374	2	13	2·1785
670	·330	2	16	11·0345	625	·375	2	13	1·1590
669	·331	2	16	10·0151	624	·376	2	13	0·1396
668	·332	2	16	8·9956	623	·377	2	12	11·1201
667	·333	2	16	7·9761	622	·378	2	12	10·1007
666	·334	2	16	6·9567	621	·379	2	12	9·0812
665	·335	2	16	5·9372	620	·380	2	12	8·0618
664	·336	2	16	4·9178	619	·381	2	12	7·0423
663	·337	2	16	3·8983	618	·382	2	12	6·0229
662	·338	2	16	2·8789	617	·383	2	12	5·0034

FINE GOLD.	ALLOY.	VALUE.			FINE GOLD.	ALLOY.	VALUE.		
		£	*s.*	*d.*			£	*s.*	*d.*
616	·384	2	12	3·9839	571	·429	2	8	6·1085
615	·385	2	12	2·9645	570	·430	2	8	5·0890
614	·386	2	12	1·9451	569	·431	2	8	4·0696
613	·387	2	12	0·9256	568	·432	2	8	3·0501
612	·388	2	11	11·9061	567	·433	2	8	2·0307
611	·389	2	11	10·8867	566	·434	2	8	1·0112
610	·390	2	11	9·8672	565	·435	2	7	11·9918
609	·391	2	11	8·8478	564	·436	2	7	10·9723
608	·392	2	11	7·8283	563	·437	2	7	9·9529
607	·393	2	11	6·8089	562	·438	2	7	8·9334
606	·394	2	11	5·7894	561	·439	2	7	7·9140
605	·395	2	11	4·7699	560	·440	2	7	6·8945
604	·396	2	11	3·7505	559	·441	2	7	5·8751
603	·397	2	11	2·7311	558	·442	2	7	4·8556
602	·398	2	11	1·7116	557	·443	2	7	3·8361
601	·399	2	11	0·6921	556	·444	2	7	2·8167
600	·400	2	10	11·6727	555	·445	2	7	1·7972
599	·401	2	10	10·6532	554	·446	2	7	0·7778
598	·402	2	10	9·6338	553	·447	2	6	11·7583
597	·403	2	10	8·6143	552	·448	2	6	10·7389
596	·404	2	10	7·5949	551	·449	2	6	9·7194
595	·405	2	10	6·5754	550	·450	2	6	8·6999
594	·406	2	10	5·5559	549	·451	2	6	7·6805
593	·407	2	10	4·5365	548	·452	2	6	6·6611
592	·408	2	10	3·5170	547	·453	2	6	5·6416
591	·409	2	10	2·4976	546	·454	2	6	4·6221
590	·410	2	10	1·4781	545	·455	2	6	3·6027
589	·411	2	10	0·4587	544	·456	2	6	2·5832
588	·412	2	9	11·4392	543	·457	2	6	1·5638
587	·413	2	9	10·4198	542	·458	2	6	0.5443
586	·414	2	9	9·4003	541	·459	2	5	11·5249
585	·415	2	9	8·3809	540	·460	2	5	10·5054
584	·416	2	9	7.3614	539	·461	2	5	9·4859
583	·417	2	9	6.3419	538	·462	2	5	8·4665
582	·418	2	9	5.3225	537	·463	2	5	7·4470
581	·419	2	9	4 3030	536	·464	2	5	6·4276
580	·420	2	9	3·2836	535	·465	2	5	5·4081
579	·421	2	9	2·2641	534	·466	2	5	4·3887
578	·422	2	9	1·2447	533	·467	2	5	3·3692
577	·423	2	9	0·2252	532	·468	2	5	2·3498
576	·424	2	8	11·2058	531	·469	2	5	1·3303
575	·425	2	8	10·1863	530	·470	2	5	0·3109
574	·426	2	8	9·1669	529	·471	2	4	11·2914
573	·427	2	8	8·1474	528	·472	2	4	10·2719
572	·428	2	8	7·1279	527	·473	2	4	9·2525

FINE GOLD.	ALLOY.	VALUE.			FINE GOLD.	ALLOY.	VALUE.		
		£	*s.*	*d.*			£	*s.*	*d.*
526	·474	2	4	8·2330	481	·519	2	0	10·3576
525	·475	2	4	7·2136	480	·520	2	0	9·3381
524	·476	2	4	6·1941	479	·521	2	0	8·3187
523	·477	2	4	5·1747	478	·522	2	0	7·2992
522	·478	2	4	4·1552	477	·523	2	0	6·2798
521	·479	2	4	3·1358	476	·524	2	0	5·2603
520	·480	2	4	2·1163	475	·525	2	0	4·2409
519	·481	2	4	1·0969	474	·526	2	0	3·2214
518	·482	2	4	0·0774	473	·527	2	0	2·2020
517	·483	2	3	11·0579	472	·528	2	0	1·1825
516	·484	2	3	10·0385	471	·529	2	0	0·1630
515	·485	2	3	9·0190	470	·530	1	19	11·1436
514	·486	2	3	7·9996	469	·531	1	19	10·1241
513	·487	2	3	6·9801	468	·532	1	19	9·1047
512	·488	2	3	5·9607	467	·533	1	19	8·0852
511	·489	2	3	4·9412	466	·534	1	19	7·0658
510	·490	2	3	3·9218	465	·535	1	19	6·0463
509	·491	2	3	2·9023	464	·536	1	19	5·0269
508	·492	2	3	1·8829	463	·537	1	19	4·0074
507	·493	2	3	0·8634	462	·538	1	19	2·9879
506	·494	2	3	11·8439	461	·539	1	19	1·9685
505	·495	2	2	10·8245	460	·540	1	19	0·9490
504	·496	2	2	9·8051	459	·541	1	18	11·9296
503	·497	2	2	8·7856	458	·542	1	18	10·9101
502	·498	2	2	7·7661	457	·543	1	18	9·8907
501	·499	2	2	6·7467	456	·544	1	18	8·8712
500	·500	2	2	5·7272	455	·545	1	18	7·8518
499	·501	2	2	4·7078	454	·546	1	18	6·8323
498	·502	2	2	3·6883	453	·547	1	18	5·8129
497	·503	2	2	2·6689	452	·548	1	18	4·7934
496	·504	2	2	1·6494	451	·549	1	18	3·7739
495	·505	2	2	0.6300	450	·550	1	18	2·7545
494	·506	2	1	11·6105	449	·551	1	18	1·7351
493	·507	2	1	10·5911	448	·552	1	18	0·7156
492	·508	2	1	9·5716	447	·553	1	17	11·6961
491	·509	2	1	8·5521	446	·554	1	17	10·6767
490	·510	2	1	7·5327	445	·555	1	17	9·6572
489	·511	2	1	6·5132	444	·556	1	17	8·6378
488	·512	2	1	5·4938	443	·557	1	17	7·6183
487	·513	2	1	4·4743	442	·558	1	17	6·5989
486	·514	2	1	3·4549	441	·559	1	17	5.5794
485	·515	2	1	2·4354	440	·560	1	17	4.5599
484	·516	2	1	1·4159	439	·561	1	17	3·5405
483	·517	2	1	0·3965	438	·562	1	17	2·5211
482	·518	2	0	11.3770	437	·563	1	17	1·5016

Fine Gold.	Alloy.	Value.			Fine Gold.	Alloy.	Value.		
		£	s.	d.			£	s.	d.
436	·564	1	17	0·4821	391	·609	1	13	2·6067
435	·565	1	16	11·4627	390	·610	1	13	1·5872
434	·566	1	16	10·4432	389	·611	1	13	0·5678
433	·567	1	16	9·4238	388	·612	1	12	11·5483
432	·568	1	16	8·4043	387	·613	1	12	10·5289
431	·569	1	16	7·3849	386	·614	1	12	9·5094
430	·570	1	16	6·3654	385	·615	1	12	8·4899
429	·571	1	16	5·3459	384	·616	1	12	7·4705
428	·572	1	16	4·3265	383	·617	1	12	6·4511
427	·573	1	16	3·3070	382	·618	1	12	5·4316
426	·574	1	16	2·2876	381	·619	1	12	4·4121
425	·575	1	16	1·2681	380	·620	1	12	3·3927
424	·576	1	16	0·2487	379	·621	1	12	2·3732
423	·577	1	15	11·2292	378	·622	1	12	1·3538
422	·578	1	15	10·2098	377	·623	1	12	0·3343
421	·579	1	15	9·1903	376	·624	1	11	11·3142
420	·580	1	15	8·1709	375	·625	1	11	10.2954
419	·581	1	15	7.1514	374	·626	1	11	9·2759
418	·582	1	15	6·1319	373	·627	1	11	8·2565
417	·583	1	15	5·1125	372	·628	1	11	7·2370
416	·584	1	15	4·0930	371	·629	1	11	6·2176
415	·585	1	15	3·0736	370	·630	1	11	5·1981
414	·586	1	15	2·0541	269	·631	1	11	4·1787
413	·587	1	15	1·0347	368	·632	1	11	3·1592
412	·588	1	15	0·0152	367	·633	1	11	2·1398
411	·589	1	14	10·9958	366	·634	1	11	1·1203
410	·590	1	14	9·9763	365	·635	1	11	0·1009
409	·591	1	14	8·9569	364	·636	1	10	11·0814
408	·592	1	14	7·9374	363	·637	1	10	10·0620
407	·593	1	14	6·9179	362	·638	1	10	9·0425
406	·594	1	14	5·8985	361	·639	1	10	8·0230
405	·595	1	14	4·8790	360	·640	1	10	7·0036
404	·596	1	14	3·8596	359	·641	1	10	5·9841
403	·597	1	14	2·8401	358	·642	1	10	4·9647
402	·598	1	14	1·8207	357	·643	1	10	3·9452
401	·599	1	14	0·8012	356	·644	1	10	2·9258
400	·600	1	13	11·7818	355	·645	1	10	1·9063
399	·601	1	13	10·7623	354	·646	1	10	0·8869
398	·602	1	13	9·7429	353	·647	1	9	11·8674
397	·603	1	13	8·7234	352	·648	1	9	10·8479
396	·604	1	13	7·7039	351	·649	1	9	9·8285
395	·605	1	13	6·6845	350	·650	1	9	8·8090
394	·606	1	13	5·6651	349	·651	1	9	7·7896
393	·607	1	13	4·6456	348	·652	1	9	6·7701
392	·608	1	13	3·6261	347	·653	1	9	5·7507

Fine Gold.	Alloy.	Value.			Fine Gold.	Alloy.	Value.		
		£	s.	d.			£	s.	d.
346	·654	1	9	4·7312	301	·699	1	5	6·8558
345	·655	1	9	3·7118	300	·700	1	5	5·8363
344	·656	1	9	2·6923	299	·701	1	5	4·8169
343	·657	1	9	1·6729	298	·702	1	5	3·7974
342	·658	1	9	0·6534	297	·703	1	5	2·7779
341	·659	1	8	11·6339	296	·704	1	5	1·7585
340	·660	1	8	10·6145	295	·705	1	5	0·7390
339	·661	1	8	9·5951	294	·706	1	4	11·7196
338	·662	1	8	8·5756	293	·707	1	4	10·7011
337	·663	1	8	7·5561	292	·708	1	4	9·6807
336	·664	1	8	6·5367	291	·709	1	4	8·6612
335	·665	1	8	5·5172	290	·710	1	4	7·6418
334	·666	1	8	4·4978	289	·711	1	4	6·6223
333	·667	1	8	3·4783	288	·712	1	4	5·6029
332	·668	1	8	2·4589	287	·713	1	4	4·5834
331	·669	1	8	1·4394	286	·714	1	4	3.5639
330	·670	1	8	0·4199	285	·715	1	4	2·5445
329	·671	1	7	11·4005	284	·716	1	4	1.5251
328	·672	1	7	10·3811	283	·717	1	4	0·5056
327	·673	1	7	9·3616	282	·718	1	3	11·4861
326	·674	1	7	8·3421	281	·719	1	3	10·4667
325	·675	1	7	7·3227	280	·720	1	3	9·4472
324	·676	1	7	6·3032	279	·721	1	3	8·4278
323	·677	1	7	5·2838	278	·722	1	3	7·4083
322	·678	1	7	4·2643	277	·723	1	3	6·3889
321	·679	1	7	3.2449	276	·724	1	3	5·3694
320	·680	1	7	2·2254	275	·725	1	3	4·3499
319	·681	1	7	1·2059	274	·726	1	3	3·3305
318	·682	1	7	0·1865	273	·727	1	3	2·3110
317	·683	1	6	11·1670	272	·728	1	3	1·2916
316	·684	1	6	10·1476	271	·729	1	3	0·2721
315	·685	1	6	9·1281	270	·730	1	2	11·2527
314	·686	1	6	8·1087	269	·731	1	2	10·2332
313	·687	1	6	7·0892	268	·732	1	2	9·2138
312	·688	1	6	6·0698	267	·733	1	2	8·1943
311	·689	1	6	5·0503	266	·734	1	2	7·1749
310	·690	1	6	4·0309	265	·735	1	2	6·1554
309	·691	1	6	3·0114	264	·736	1	2	5·1351
308	·692	1	6	1·9919	263	·737	1	2	4·1165
307	·693	1	6	0·9725	262	·738	1	2	3·0970
306	·694	1	5	11·9530	261	·739	1	2	2·0776
305	·695	1	5	10·9336	260	·740	1	2	1·0581
304	·696	1	5	9·9141	259	·741	1	2	0·0387
303	·697	1	5	8·8947	258	·742	1	1	11·0192
302	·698	1	5	7·8752	257	·743	1	1	9·9998

Fine Gold.	Alloy.	Value.			Fine Gold.	Alloy.	Value.		
		£	s.	d.			£	s.	d.
256	·744	1	1	8·9803	211	·789	0	17	11·1049
255	·745	1	1	7·9609	210	·790	0	17	10·0854
254	·746	1	1	6·9414	209	·791	0	17	9·0659
253	·747	1	1	5·9219	208	·792	0	17	8·0465
252	·748	1	1	4·9025	207	·793	0	17	7·0270
251	·749	1	1	3·8830	206	·794	0	17	6·0076
250	·750	1	1	2·8636	205	·795	0	17	4·9881
249	·751	1	1	1·8441	205	·796	0	17	3·9687
248	·752	1	1	0·8247	203	·797	0	17	2·9492
247	·753	1	0	11·8052	202	·798	0	17	1·9298
246	·754	1	0	10·7858	201	·799	0	17	0·9103
245	·755	1	0	9·7663	200	·800	0	16	11·8909
244	·756	1	0	8·7469	199	·801	0	16	10·8714
243	·757	1	0	7·7274	198	·802	0	16	9·8519
242	·758	1	0	6·7079	197	·803	0	16	8·8325
241	·759	1	0	5·6885	196	·804	0	16	7·8130
240	·760	1	0	4·6690	195	·805	0	16	6·7936
239	·761	1	0	3·6496	194	·806	0	16	5·7741
238	·762	1	0	2·6301	193	·807	0	16	4·7547
237	·763	1	0	1·6107	192	·808	0	16	3·7352
236	·764	1	0	0·5912	191	·809	0	16	2·7158
235	·765	0	19	11·5718	190	·810	0	16	1·6963
234	·766	0	19	10·5523	189	·811	0	16	0·6769
233	·767	0	19	9·5329	188	·812	0	15	11·6574
232	·768	0	19	8.5134	187	·813	0	15	10·6379
231	·769	0	19	7·4939	186	·814	0	15	9·6185
230	·770	0	19	6·4745	185	·815	0	15	8·5990
229	·771	0	19	5·4551	184	·816	0	15	7·5796
228	·772	0	19	4·4356	183	·817	0	15	6·5601
227	773	0	19	3·4161	182	·818	0	15	5·5407
226	·774	0	19	2·3967	181	·819	0	15	4·5212
225	·775	0	19	1·3772	180	·820	0	15	3·5018
224	·776	0	19	0·3578	179	·821	0	15	2·4823
223	·777	0	18	11·3383	178	·822	0	15	1·4629
222	·778	0	18	10·3189	177	·823	0	15	0·4434
221	·779	0	18	9·2994	176	·824	0	14	11·4239
220	·780	0	18	8·2799	175	·825	0	14	10·4045
219	·781	0	18	7·2605	174	·826	0	14	9·3851
218	·782	0	18	6·2410	173	·827	0	14	8·3656
217	·783	0	18	5·2216	172	·828	0	14	7·3461
216	·784	0	18	4·2021	171	·829	0	14	6·3267
215	·785	0	18	3.1827	170	·830	0	14	5·3072
214	·786	0	18	2·1632	169	·831	0	14	4·2878
213	·787	0	18	1·1438	168	·832	0	14	3·2683
212	·788	0	18	0·1243	167	·833	0	14	2·2489

Fine Gold.	Alloy.	Value.			Fine Gold.	Alloy.	Value.		
		£	s.	d.			£	s.	d.
166	·834	0	14	1·2294	121	·879	0	10	3·3530
165	·835	0	14	0·2099	120	·880	0	10	2·3345
164	·836	0	13	11.1905	119	·881	0	10	1·3151
163	·837	0	13	10·1710	118	·882	0	10	0·2956
162	·838	0	13	9·1516	117	·883	0	9	11·2761
161	·839	0	13	8·1321	116	·884	0	9	10·2567
160	·840	0	13	7·1127	115	·885	0	9	9·2372
159	·841	0	13	6·0932	114	·886	0	9	8·2178
158	·842	0	13	5·0738	113	·887	0	9	7·1983
157	·843	0	13	4·0543	112	·888	0	9	6·1789
156	·844	0	13	3·0349	111	·889	0	9	5·1594
155	·845	0	13	2·0154	110	·890	0	9	4·1399
154	·846	0	13	0·9959	109	·891	0	9	3·1205
153	·847	0	12	11·9765	108	·892	0	9	2·1010
152	·848	0	12	10·9570	107	·893	0	9	1·0816
151	·849	0	12	9·9376	106	·894	0	9	0·0621
150	·850	0	12	8·9181	105	·895	0	8	11·0427
149	·851	0	12	7·8987	104	·896	0	8	10·0232
148	·852	0	12	6·8792	103	·897	0	8	9·0038
147	·853	0	12	5·8598	102	·898	0	8	7·9843
146	·854	0	12	4·8403	101	·899	0	8	6·9649
145	·855	0	12	3·8209	100	·900	0	8	5·9454
144	·856	0	12	2·8014	99	·901	0	8	4·9259
143	·857	0	12	1·7819	98	·902	0	8	3·9065
142	·858	0	12	0·7625	97	·903	0	8	2·8870
141	·859	0	11	11·7430	96	·904	0	8	1·8676
140	·860	0	11	10·7236	95	·905	0	8	0·8481
139	·861	0	11	9·7041	94	·906	0	7	11.8287
138	·862	0	11	8·6847	93	·907	0	7	10·8092
137	·863	0	11	7·6652	92	·908	0	7	8·7898
136	·864	0	11	6·6458	91	·909	0	7	9·7703
135	·865	0	11	5·6263	90	·910	0	7	7·7509
134	·866	0	11	4·6069	89	·911	0	7	6·7314
133	·867	0	11	3·5874	88	·912	0	7	5·7119
132	·868	0	11	2·5679	87	·913	0	7	4·6925
131	·869	0	11	1·5485	86	·914	0	7	3·6730
130	·870	0	11	0·5290	85	·915	0	7	2·6536
129	·871	0	10	11·5096	84	·916	0	7	1·6341
128	·872	0	10	10·4901	83	·917	0	7	10·6147
127	·873	0	10	9·4707	82	·918	0	6	11·5952
126	·874	0	10	8·4512	81	·919	0	6	0·5758
125	·875	0	10	7·4318	80	·920	0	6	9·5563
124	·876	0	10	6·4123	79	·921	0	6	8·5369
123	·877	0	10	5·3929	78	·922	0	6	7·5174
122	·878	0	10	4·3734	77	·923	0	6	6·4979

Fine Gold.	Alloy.	Value.			Fine Gold.	Alloy.	Value.		
		£	s.	d.			£	s.	d.
76	·924	0	6	5·4785	38	·962	0	3	2·7392
75	·925	0	6	4·4590	37	·963	0	3	1·7198
74	·926	0	6	3·4396	36	·964	0	3	0·7003
73	·927	0	6	2·4201	35	·965	0	2	11·6809
72	·928	0	6	1·4007	34	·966	0	2	10·6614
71	·929	0	6	0·3812	33	·967	0	2	9·6419
70	·930	0	5	11·3618	32	·968	0	2	8·6225
69	·931	0	5	10·3423	31	·969	0	2	7·6030
68	·932	0	5	9·3229	30	·970	0	2	6·5836
67	·933	0	5	8·3034	29	·971	0	2	5·5641
66	·934	0	5	7·2839	28	·972	0	2	4·5447
65	·935	0	5	6·2645	27	·973	0	2	3·5252
64	·936	0	5	5·2451	26	·974	0	2	2·5058
63	·937	0	5	4·2256	25	·975	0	2	1·4863
62	·938	0	5	3·2061	24	·976	0	2	0·4669
61	·939	0	5	2·1867	23	·977	0	1	11·4474
60	·940	0	5	1·1672	22	·978	0	1	10·4279
59	·941	0	5	0·1478	21	·979	0	1	9·4085
58	·942	0	4	11·1283	20	·980	0	1	8·3890
57	·943	0	4	10·1089	19	·981	0	1	7·3696
56	·944	0	4	9·0894	18	·982	0	1	6·3501
55	·945	0	4	8·0699	17	·983	0	1	5·3307
54	·946	0	4	7·0505	16	·984	0	1	4·3112
53	·947	0	4	6·0310	15	·985	0	1	3·2918
52	·948	0	4	5·0116	14	·986	0	1	2·2723
51	·949	0	4	3·9921	13	·987	0	1	1·2529
50	·950	0	4	2·9727	12	·988	0	1	0·2334
49	·951	0	4	1·9532	11	·989	0	0	11·2139
48	·952	0	4	0·9338	10	·990	0	0	10·1945
47	·953	0	3	11·9143	9	·991	0	0	9·1750
46	·954	0	3	10·8949	8	·992	0	0	8·1556
45	·955	0	3	9·8754	7	·993	0	0	7·1361
44	·956	0	3	8·8559	6	·994	0	0	6·1167
43	·957	0	3	7·8365	5	·995	0	0	5·0972
42	·958	0	3	6·8170	4	·996	0	0	4·0778
41	·959	0	3	5·7976	3	·997	0	0	3·0583
40	·960	0	3	4·7781	2	·998	0	0	2·0389
39	·961	0	3	3·7587	1	·999	0	0	1·0194

To convert Mint Value into Bank Value when the Standard is expressed in Thousandths.

Thousandths.	Value in Pence.	Thousandths.	Value in Pence.
1	·001636	6	·009816
2	·003272	7	·011352
3	·004908	8	·013088
4	·006544	9	·014724
5	·008180		

To illustrate the use of the above table, gold of $\frac{500}{1000}$ths fine may be taken. As in the Table for finding the Bank value of gold when the standard is reported in carats, &c. the amounts in pence, as above, are to be deducted from the prices attached to corresponding standards in Table No. 2. Thus, the minus value of $\frac{5}{1000}$ths is ·00818 of a penny; therefore, the minus value of $\frac{500}{1000}$th is ·818 of a penny, which amount must be deducted from the Mint price of gold at the above standard. On referring to the Table it will be found to be £2. 2s. 5·7272d. per oz. Now, if ·818 be deducted, the remainder will be £2. 2s. 4·9092d., representing the Bank value of 1 oz. of gold of the fineness just mentioned.

TABLE III.

ASSAY TABLE, showing the Amount of GOLD OR SILVER, in Ounces, Pennyweights, and Grains, contained in a Ton of Ore, &c. from the Weight of Metal obtained in an Assay of 200 Grains of Mineral.

If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE MELAL		
Gr.	*Oz.*	*Dwts.*	*Grs.*
·001	0	3	6
·002	0	6	12
·003	0	9	19
·004	0	13	1
·005	0	16	8
·006	0	19	14
·007	1	2	20
·008	1	6	3
·009	1	9	9
·010	1	12	6
·011	1	15	22
·012	1	19	4
·013	2	2	11
·014	2	5	17
·015	2	9	0
·016	2	12	6
·017	2	15	12
·018	2	18	19
·019	3	2	1
·020	3	5	8
·021	3	8	14
·022	3	11	20
·023	3	15	3
·024	3	18	9
·025	4	1	16
·026	4	4	22
·027	4	8	4
·028	4	11	11
·029	4	14	17
·030	4	18	0
·031	5	1	6
·032	5	4	12
·033	5	7	19
·034	5	11	1
·035	5	14	8
·036	5	17	14
·037	6	0	20
·038	6	4	3
·039	6	7	9
·040	6	10	16
·041	6	13	22
·042	6	17	4
·043	7	0	11
·044	7	3	17
·045	7	7	0
·046	7	10	6
·047	7	13	12
·048	7	16	19
·049	8	0	1
·050	8	3	8
·051	8	6	14
·052	8	9	20
·053	8	13	3
·054	8	16	9
·055	8	19	16
·056	9	2	22
·057	9	6	4
·058	9	9	11
·059	9	12	17
·060	9	16	0

If 200 Grains of Ore give of	One Ton of Ore will yield of		
FINE METAL	FINE METAL		
Gr.	*Oz.*	*Dwts.*	*Grs.*
·061	9	19	6
·062	10	2	12
·063	10	5	19
·064	10	9	1
·065	10	12	8
·066	10	15	14
·067	10	18	20
·068	11	2	3
·069	11	5	9
·070	11	8	16
·071	11	11	22
·072	11	15	4
·073	11	18	11
·074	12	1	17
·075	12	5	0
·076	12	8	6
·077	12	11	12
·078	12	14	19
·079	12	18	1
·080	13	1	8
·081	13	4	14
·082	13	7	20
·083	13	11	3
·084	13	14	9
·085	13	17	16
·086	14	0	22
·087	14	4	4
·088	14	7	11
·089	14	10	17
·090	14	14	0
·091	14	17	6
·092	15	0	12
·093	15	3	19
·094	15	7	1
·095	15	10	8
·096	15	13	14
·097	15	16	20
·098	16	0	3
·099	16	3	9
·100	16	6	16
·101	16	9	22
·102	16	13	4
·103	16	16	11
·104	16	19	17
·105	17	3	0
·106	17	6	6
·107	17	9	12
·108	17	12	19
·119	17	16	1
·110	17	19	8
·111	18	2	14
·112	18	5	20
·113	18	9	3
·114	18	12	9
·115	18	15	16
·116	18	18	22
·117	19	2	4
·118	19	5	11
·119	19	8	17
·120	19	12	0
·121	19	15	6
·122	19	18	12
·123	20	1	19
·124	20	5	1
·125	20	8	8
·126	20	11	14
·127	20	14	20
·128	20	18	3
·129	21	1	9
·130	21	4	16
·131	21	7	22
·132	21	11	4
·133	21	14	11
·134	21	17	17
·135	22	1	0
·136	22	4	6
·137	22	7	12
·138	22	10	19
·139	22	14	1
·140	22	17	8
·141	23	0	14
·142	23	3	20
·143	23	7	3
·144	23	10	9
·145	23	13	16
·146	23	16	22
·147	24	0	4
·148	24	3	11

If 200 Grains of Ore give of FINE METAL	One Ton of Ore of will yield FINE METAL			If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL		
Gr.	*Oz.*	*Dwts.*	*Grs.*	*Gr.*	*Oz.*	*Dwts.*	*Grs.*
·149	24	6	17	·193	31	10	11
·150	24	10	0	·194	31	13	17
·151	24	13	6	·195	31	17	0
·152	24	16	12	·196	32	0	6
·153	24	19	19	·197	32	3	12
·154	25	3	1	·198	32	6	19
·155	25	6	8	·199	32	10	1
·156	25	9	14	·200	32	13	8
·157	25	12	20	·201	32	16	14
·158	25	16	3	·202	32	19	20
·159	25	19	9	·203	33	3	3
·160	26	2	16	·204	33	6	9
·161	26	5	22	·205	33	9	16
·162	26	9	4	·206	33	12	22
·163	26	12	11	·207	33	16	4
·164	26	15	17	·208	33	19	11
·165	26	19	0	·209	34	2	17
·166	27	2	6	·210	34	6	0
·167	27	5	12	·211	34	9	6
·168	27	8	19	·212	34	12	12
·169	27	12	1	·213	34	15	19
·170	27	15	8	·214	34	19	1
·171	27	18	14	·215	35	2	8
·172	28	1	20	·216	35	5	14
·173	28	5	3	·217	35	8	20
·174	28	8	9	·218	35	12	3
·175	28	11	16	·219	35	15	9
·176	28	14	22	·220	35	18	16
·177	28	18	4	·221	36	1	22
·178	29	1	11	·222	36	5	4
·179	29	4	17	·223	36	8	11
·180	29	8	0	·224	36	11	17
·181	29	11	6	·225	36	15	0
·182	29	14	12	·226	36	18	6
·183	29	17	19	·227	37	1	12
·184	30	1	1	·228	37	4	19
·185	30	4	8	·229	37	8	1
·186	30	7	14	·230	37	11	8
·187	30	10	20	·231	37	14	14
·188	30	14	3	·232	37	17	20
·189	30	17	9	·233	38	1	3
·190	31	0	16	·234	38	4	9
·191	31	3	22	·235	38	7	16
·192	31	7	4	·236	38	10	22

If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL			If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL		
Gr.	*Oz.*	*Dwts.*	*Grs.*	*Gr.*	*Oz.*	*Dwts.*	*Grs.*
·237	38	14	4	·281	45	17	22
·238	38	17	11	·282	46	1	4
·239	39	0	17	·283	46	4	11
·240	39	4	0	·284	46	7	17
·241	39	7	6	·285	46	11	0
·242	39	10	12	·286	46	14	6
·243	39	13	18	·287	46	17	12
·244	39	17	1	·288	47	0	19
·245	40	0	8	·289	47	4	1
·246	40	3	14	·290	47	7	8
·247	40	6	20	·291	47	10	14
·248	40	10	3	·292	47	13	20
·249	40	13	9	·293	47	17	3
·250	40	16	16	·294	48	0	9
·251	40	19	22	·295	48	3	16
·252	41	3	4	·296	48	6	22
·253	41	6	11	·297	48	10	4
·254	41	9	17	·298	48	13	11
·255	41	13	0	·299	48	16	17
·256	41	16	6	·300	49	0	0
·257	41	19	12	·301	49	3	6
·258	42	2	19	·302	49	6	12
·259	42	6	1	·303	49	9	19
·260	42	9	8	·304	49	13	1
·261	42	12	14	·305	49	16	8
·262	42	15	20	·306	49	19	14
·263	42	19	3	·307	50	2	20
·264	43	2	9	·308	50	6	3
·265	43	5	16	·309	50	9	9
·266	43	8	22	·310	50	12	16
·267	43	12	4	·311	50	15	22
·268	43	15	11	·312	50	19	4
·269	43	18	17	·313	51	2	11
·270	44	2	0	·314	51	5	17
·271	44	5	6	·315	51	9	0
·272	44	8	12	·316	51	12	6
·273	44	11	19	·317	51	15	12
·274	44	15	1	·318	51	18	19
·275	44	18	8	·319	52	2	1
·276	45	1	14	·320	52	5	8
·277	45	4	20	·321	52	8	14
·278	45	8	3	·322	52	11	20
·279	45	11	9	·323	52	15	3
·280	45	14	16	·324	52	18	9

If 200 Grains of Ore give of	One Ton of Ore will yield of		
FINE METAL	FINE METAL		
Gr.	*Oz.*	*Dwts.*	*Grs.*
·325	53	1	16
·326	53	4	22
·327	53	8	4
·328	53	11	11
·329	53	14	17
·330	53	18	0
·331	54	1	6
·332	54	4	12
·333	54	7	19
·334	54	11	1
·335	54	14	8
·336	54	17	14
·337	55	0	20
·338	55	4	3
·339	55	7	9
·340	55	10	16
·341	55	13	22
·342	55	17	4
·343	56	0	11
·344	56	3	17
·345	56	7	0
·346	56	10	6
·347	56	13	12
·348	56	16	19
·349	57	0	1
·350	57	3	8
·351	57	6	14
·352	57	9	20
·353	57	13	3
·354	57	16	9
·355	57	19	16
·356	58	2	22
·357	58	6	4
·358	58	9	11
·359	58	12	17
·360	58	16	0
·361	58	19	6
·362	59	2	12
·363	59	5	19
·364	59	9	1
·365	59	12	8
·366	59	15	14
·367	59	18	20
·368	60	2	3
·369	60	5	9
·370	60	8	16
·371	60	11	22
·372	60	15	4
·373	60	18	11
·374	61	1	17
·375	61	5	0
·376	61	8	6
·377	61	11	12
·378	61	14	19
·379	61	18	1
·380	62	1	8
·381	62	4	14
·382	62	7	20
·383	62	11	3
·384	62	14	9
·385	62	17	16
·386	63	0	22
·387	63	4	4
·388	63	7	11
·389	63	10	17
·390	63	14	0
·391	63	17	6
·392	64	0	12
·393	64	3	19
·394	64	7	1
·395	64	10	8
·396	64	13	14
·397	64	16	20
·398	65	0	3
·399	65	3	9
·400	65	6	16
·401	65	9	22
·402	65	13	4
·403	65	16	11
·404	65	19	17
·405	66	3	0
·406	66	6	6
·407	66	9	12
·408	66	12	19
·409	66	16	1
·410	66	19	8
·411	67	2	14
·412	67	5	20

If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL		
Gr.	*Oz.*	*Dwts.*	*Grs.*
·413	67	9	3
·414	67	12	9
·415	67	15	16
·416	67	18	22
·417	68	2	4
·418	68	5	11
·419	68	8	17
·420	68	12	0
·421	68	15	6
·422	68	18	12
·423	69	1	19
·424	69	5	1
·425	69	8	8
·426	69	11	14
·427	69	14	20
·428	69	18	3
·429	70	1	9
·430	70	4	16
·431	70	7	22
·432	70	11	4
·433	70	14	11
·434	70	17	17
·435	71	1	0
·436	71	4	6
·437	71	7	12
·438	71	10	19
·439	71	14	1
·440	71	17	8
·441	72	0	14
·442	72	3	20
·443	72	7	3
·444	72	10	9
·445	72	13	16
·446	72	16	22
·447	73	0	4
·448	73	3	11
·449	73	6	17
·450	73	10	0
·451	73	13	6
·452	73	16	12
·453	73	19	19
·454	74	3	1
·455	74	6	8
·456	74	9	14
·457	74	12	20
·458	74	16	3
·459	74	19	9
·460	75	2	16
·461	75	5	22
·462	75	9	4
·463	75	12	11
·464	75	15	17
·465	75	19	0
·466	76	2	6
·467	76	5	12
·468	76	8	19
·469	76	12	1
·470	76	15	8
·471	76	18	14
·472	77	1	20
·473	77	5	3
·474	77	8	9
·475	77	11	16
·476	77	14	22
·477	77	18	4
·478	78	1	11
·479	78	4	17
·480	78	8	0
·481	78	11	6
·482	78	14	12
·483	78	17	19
·484	79	1	1
·485	79	4	8
·486	79	7	14
·487	79	10	20
·488	79	14	3
·489	79	17	9
·490	80	0	16
·491	80	3	22
·492	80	7	4
·493	80	10	11
·494	80	13	17
·495	80	17	0
·496	81	0	6
·497	81	3	12
·498	81	6	19
·499	81	10	1
·500	81	13	8

If 200 Grains of Ore give of	One Ton of Ore will yield of		
FINE METAL	FINE METAL		
Gr.	*Oz.*	*Dwts.*	*Grs.*
·501	81	16	14
·502	81	19	20
·503	82	3	3
·504	82	6	9
·505	82	9	16
·506	82	12	22
·507	82	16	4
·508	82	19	11
·509	83	2	17
·510	83	6	0
·511	83	9	6
·512	83	12	12
·513	83	15	19
·514	83	19	1
·515	84	2	8
·516	84	5	14
·617	84	8	20
·518	84	12	3
·519	84	15	9
·520	84	18	16
·521	85	1	22
·522	85	5	4
·523	85	8	11
·524	85	11	17
·525	85	15	0
·526	85	18	6
·527	86	1	12
·528	86	4	19
·529	86	8	1
·530	86	11	8
·531	86	14	14
·532	86	17	20
·533	87	1	3
·534	87	4	9
·535	87	7	16
·536	87	10	22
·537	87	14	4
·538	87	17	11
·539	88	0	17
·540	88	4	0
·541	88	7	6
·542	88	10	12
·543	88	13	19
·544	88	17	1
·545	89	0	8
·546	89	3	14
·547	89	6	20
·548	89	10	3
·549	89	13	9
·550	89	16	16
·551	89	19	22
·552	90	3	4
·553	90	6	11
·554	90	9	17
·555	90	13	0
·556	90	16	6
·557	90	19	12
·558	91	2	19
·559	91	6	1
·560	91	9	8
·561	91	12	14
·562	91	15	20
·563	91	19	3
·564	92	2	9
·565	92	5	16
·566	92	8	22
·567	92	12	4
·568	92	15	11
·569	92	18	17
·570	93	2	0
·571	93	5	6
·572	93	8	12
·573	93	11	19
·574	93	15	1
·575	93	18	8
·576	94	1	14
·577	94	4	20
·578	94	8	3
·579	94	11	9
·580	94	14	16
·581	94	17	22
·582	95	1	4
·583	95	4	11
·584	95	7	17
·585	95	11	0
·586	95	14	6
·587	95	17	12
·588	96	0	19

If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL			If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL		
Gr.	*Oz.*	*Dwts.*	*Grs.*	*Gr.*	*Oz.*	*Dwts.*	*Grs.*
·589	96	4	1	·633	103	7	19
·590	96	7	8	·634	103	11	1
·591	96	10	14	·635	103	14	8
·592	96	13	20	·636	103	17	14
·593	96	17	3	·637	104	0	20
·594	97	0	9	·638	104	4	3
·595	97	3	16	·639	104	7	9
·596	97	6	22	·640	104	10	16
·597	97	10	4	·641	104	13	22
·598	97	13	11	·642	104	17	4
·599	97	16	17	·643	105	0	11
·600	98	0	0	·644	105	3	17
·601	98	3	6	·645	105	7	0
·602	98	6	12	·646	105	10	6
·603	98	9	19	·647	105	13	12
·604	98	13	1	·648	105	16	19
·605	98	16	8	·649	106	0	1
·606	98	19	14	·650	106	3	8
·607	99	2	20	·651	106	6	14
·608	99	6	3	·652	106	9	20
·609	99	9	9	·653	106	13	3
·610	99	12	16	·654	106	16	9
·611	99	15	22	·655	106	19	16
·612	99	19	4	·656	107	2	22
·613	100	2	11	·657	107	6	4
·614	100	5	17	·658	107	9	11
·615	100	9	0	·659	107	12	17
·616	100	12	6	·660	107	16	0
·617	100	15	12	·661	107	19	6
·618	100	18	19	·662	108	2	12
·619	101	2	1	·663	108	5	19
·620	101	5	8	·664	108	9	1
·621	101	8	14	·665	108	12	8
·622	101	11	20	·666	108	15	14
·623	101	15	3	·667	108	18	20
·624	101	18	9	·668	109	2	3
·625	102	1	16	·669	109	5	9
·626	102	4	22	·670	109	8	16
·627	102	8	4	·671	109	11	22
·628	102	11	11	·672	109	15	4
·629	102	14	17	·673	109	18	11
·630	102	18	0	·674	110	1	17
·631	103	1	6	·675	110	5	0
·632	103	4	12	·676	110	8	6

If 200 Grains of Ore give of FINE METAL	One Ton of Ore of will yield FINE METAL			If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL		
Gr.	*Oz.*	*Dwts.*	*Grs.*	*Gr.*	*Oz.*	*Dwts.*	*Grs.*
·853	139	6	11	·897	146	10	4
·854	139	9	17	·898	146	13	11
·855	139	13	0	·899	146	16	17
·856	139	16	6	·900	147	0	0
·857	139	19	12	·901	147	3	6
·858	140	2	19	·902	147	6	12
·859	140	6	1	·903	147	9	19
·860	140	9	8	·904	147	13	1
·861	140	12	14	·905	147	16	8
·862	140	15	20	·906	147	19	14
·863	140	19	3	·907	148	2	2
·864	141	2	9	·908	148	6	3
·865	141	5	16	·909	148	9	9
·866	141	8	22	·910	148	12	16
·867	141	12	4	·911	148	15	21
·868	141	15	11	·912	148	19	4
·869	141	18	17	·913	149	2	11
·870	142	2	0	·914	149	5	17
·871	142	5	6	·915	149	9	0
·872	142	8	12	·916	149	12	6
·873	142	11	19	·917	149	15	12
·874	142	15	1	·918	149	18	19
·875	142	18	8	·919	150	2	1
·876	143	1	14	·920	150	5	8
·877	143	4	20	·921	150	8	14
·878	143	8	3	·922	150	11	20
·879	143	11	9	·923	150	15	3
·880	143	14	16	·924	150	18	9
·881	143	17	22	·925	151	1	16
·882	144	1	4	·926	151	4	22
·883	144	4	11	·927	151	8	4
·884	144	7	17	·928	151	11	11
·885	144	11	0	·929	151	14	17
·886	144	14	6	·930	151	18	0
·887	144	17	12	·931	152	1	6
·888	145	0	19	·932	152	4	12
·889	145	4	1	·933	152	7	19
·890	145	7	8	·934	152	11	1
·891	145	10	14	·935	152	14	8
·892	145	13	20	·936	152	17	14
·893	145	17	3	·937	153	0	20
·894	146	0	9	·938	153	4	3
·895	146	3	16	·939	153	7	9
·896	146	6	22	·940	153	10	16

If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL		
Gr.	Oz.	Dwts.	Grs.
·941	153	13	22
·942	153	17	4
·943	154	0	11
·944	154	3	17
·945	154	7	0
·946	154	10	6
·947	154	13	12
·948	154	16	19
·949	155	0	1
·950	155	3	8
·951	155	6	14
·952	155	9	20
·953	155	13	3
·954	155	16	9
·955	155	19	16
·956	156	2	22
·957	156	6	4
·958	156	9	11
·959	156	12	17
·960	156	16	0
·961	156	19	6
·962	157	2	12
·963	157	5	19
·964	157	9	1
·965	157	12	8
·966	157	15	14
·967	157	18	20
·968	158	2	3
·969	158	5	9
·970	158	8	16
·971	158	11	22
·972	158	15	4
·973	158	18	11
·974	159	1	17
·975	159	5	0
·976	159	8	6
·977	159	11	12
·978	159	14	19
·979	159	18	1
·980	160	1	8
·981	160	4	14
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·984	160	14	9
·985	160	17	6
·986	161	0	22
·987	161	4	4
·988	161	7	11
·989	161	10	17
·990	161	14	0
·991	161	17	6
·992	162	0	12
·993	162	3	19
·994	162	7	1
·995	162	10	8
·996	162	13	14
·997	162	16	20
·998	163	0	3
·999	163	3	9
1 grain	163	6	16
2	326	13	8
3	490	0	0
4	653	6	16
5	816	13	8
6	980	0	0
7	1143	6	16
8	1306	13	8
9	1470	0	0
10	1633	6	16
11	1796	13	8
12	1960	0	0
13	2123	6	16
14	2286	13	8
15	2450	0	0
16	2613	6	16
17	2776	13	8
18	2940	0	0
19	3103	6	16
20	3266	13	8
21	3430	0	0
22	3593	6	16
23	3756	13	8
24	3920	0	0
25	4083	6	16
26	4246	13	8
27	4410	0	0
28	4573	6	16
29	4736	13	8

If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL		
Grs.	*Oz.*	*Dwts.*	*Grs.*
30	4900	0	0
31	5063	6	16
32	5226	13	8
33	5390	0	0
34	5553	6	16
35	5716	13	8
36	5880	0	0
37	6043	6	16
38	6206	13	8
39	6370	0	0
40	6533	6	16
41	6696	13	8
42	6860	0	0
43	7023	6	16
44	7186	13	8
45	7350	0	0
46	7513	6	16
47	7676	13	8
48	7840	0	0
49	8003	6	16
50	8166	13	8
51	8330	0	0
52	8493	6	16
53	8656	13	8
54	8820	0	0
55	8983	6	16
56	9146	13	8
57	9310	0	0
58	9473	6	16
59	9636	13	8
60	9800	0	0
61	9963	6	16
62	10126	13	8
63	10290	0	0
64	10453	6	16
65	10616	13	8
66	10780	0	0
67	10943	6	16
68	11106	13	8
69	11270	0	0
70	11433	6	16
71	11596	13	8
72	11760	0	0
73	11923	6	16
74	12086	13	8
75	12250	0	0
76	12413	6	16
77	12576	13	8
78	12740	0	0
79	12903	6	16
80	13066	13	8
81	13230	0	0
82	13393	6	16
83	13556	13	8
84	13720	0	0
85	13883	6	16
86	14046	13	8
87	14210	0	0
88	14373	6	16
89	14536	13	8
90	14700	0	0
91	14863	6	16
92	15026	13	8
93	15190	0	0
94	15353	6	16
95	15516	13	8
96	15680	0	0
97	15843	6	16
98	16006	13	8
99	16170	0	0
100	16333	6	16
101	16496	13	8
102	16660	0	0
103	16823	6	16
104	16986	13	8
105	17150	0	0
106	17313	6	16
107	17476	13	8
108	17640	0	0
109	17803	6	16
110	17966	13	8
111	18130	0	0
112	18293	6	16
113	18456	13	8
114	18620	0	0
115	18783	6	16
116	18946	13	8
117	19110	0	0

If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL		
Grs.	*Oz.*	*Dwts.*	*Grs.*
118	19273	6	16
119	19436	13	8
120	19600	0	0
121	19763	6	16
122	19926	13	8
123	20090	0	0
124	20253	6	16
125	20416	13	8
126	20580	0	0
127	20743	6	16
128	20906	13	8
129	21070	0	0
130	21233	6	16
131	21396	13	8
132	21560	0	0
133	21723	6	16
134	21886	13	8
135	22050	0	0
136	22213	6	16
137	22376	13	8
138	22540	0	0
139	22703	6	16
140	22866	13	8
141	23030	0	0
142	23193	6	16
143	23356	13	8
144	23520	0	0
145	23683	6	16
146	23846	13	8
147	24010	0	0
148	24173	6	16
149	24336	13	8
150	24500	0	0
151	24663	6	16
152	24826	13	8
153	24990	0	0
154	25153	6	16
155	25316	13	8
156	25480	0	0
157	25643	6	16
158	25806	13	8
159	25970	0	0
160	26133	6	16
161	26296	13	8
162	26460	0	0
163	26623	6	16
164	26786	13	8
165	26950	0	0
166	27113	6	16
167	27276	13	8
168	27440	0	0
169	27603	6	16
170	27766	13	8
171	27930	0	0
172	28093	6	16
173	28256	13	8
174	28420	0	0
175	28583	6	16
176	28746	13	8
177	28910	0	0
178	29073	6	16
179	29236	13	8
180	29400	0	0
181	29563	6	16
182	29726	13	8
183	29890	0	0
184	30053	6	16
185	30216	13	8
186	30380	0	0
187	30543	6	16
188	30706	13	8
189	30870	0	0
190	31033	6	16
191	31196	13	8
192	31360	0	0
193	31523	6	16
194	31686	13	8
195	31850	0	0
196	32013	6	16
197	32176	13	8
198	32340	0	0
199	32503	6	16
200	32666	13	8

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