GOLD ASSAYING

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A PRACTICAL HANDBOOK

GIVING THE *MODUS OPERANDI* FOR THE ACCURATE ASSAY
OF AURIFEROUS ORES AND BULLION
AND THE CHEMICAL TESTS REQUIRED IN
THE PROCESSES OF EXTRACTION BY AMALGAMATION
CYANIDATION AND CHLORINATION

WITH

AN APPENDIX OF TABLES AND STATISTICS

BY

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WITH NUMEROUS ILLUSTRATIONS

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PREFACE.

THE number of workers interested in gold mining, metallurgy, and assaying has been largely increased in recent years by the exploitation and development of gold-bearing deposits in various parts of the world, consequent upon the perfection of scientific metallurgical processes for the extraction of the precious metal from poor and complex ores. There are excellent works published on Mining and Metallurgy, in which a chapter or so is devoted to Gold Assaying, but in many cases the subject is not treated in sufficient detail, or the volume is too expensive for a great number of the persons interested in the subject. The writer has no doubt, therefore, that the publication of a small work, exclusively dealing with the subject of Gold Assaying, is warranted. This view is borne out by his experience of the requirements of the numerous prospectors, mining engineers, and students with whom he has come in contact, more especially in a recent professional visit to the Western Australian gold-fields. He trusts that this little book will meet those requirements and earn for itself the approbation of those for whom it has been compiled.

The writer begs to acknowledge his obligations to various standard works, including the two books of Rose and Eissler on the "Metallurgy of Gold," and the two manuals of Beringer and Mitchell dealing with "Assaying," to which the reader who desires to follow up the subject may be referred. He is indebted also for various matters of information to the Journal of the Board of Trade and the Reports of the Deputy-Master of the Mint. Thanks are due to Messrs. Oertling, Townson and Mercer, John J. Griffin and Sons, and the Morgan Crucible Company, of London, for kindly allowing the use of electros for illustrations.

The tabular and statistical matter given in the Appendix has been compiled from various sources, and mention may be made here of "The Encyclopædia Britannica," "West Australian Geological Survey Bulletins," "Journal of the Board of Trade," "Reports of the Deputy Master of the Mint, 1902," and the writer's own work on "Engineering Chemistry."

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CONTENTS.

APPENDIX.

LIST OF ILLUSTRATIONS.

GOLD ASSAYING.

INTRODUCTION.

By *assaying* is generally meant the scientific determination of one or more elements in a given substance by means of dry reagents and heat, in contradistinction to *analysis*, which process determines, by chemical wet methods, the proportion of any desired substance contained in a sample; although the determination of certain metals by wet methods, notably iron and copper, are characterized as *wet assays*, as opposed to *dry* or *fire assays*. In this little work—which, however, only concerns itself with gold, and incidentally silver—both systems are dealt with. The intrinsic value of a gold-bearing mineral or alloy (*bullion*) of course depends upon the amount of the noble metal it contains, and a means of its accurate determination is an indispensable essential in the metallurgy of gold, and in trade dealings in the metal.

The amount of gold determined in minerals is expressed in England in terms of ounces, pennyweights, and grains (troy) per ton of 2240 lbs. (*long ton*), and in America per ton of 2000 lbs. (*short ton*).

Jewellers in this country express the proportion of gold in an alloy in *carats*, i.e. so many parts of gold in twenty-four parts. The French decimal system is now also much in vogue: this expresses the proportion of fine gold in 1000 parts of alloy.

Before entering upon the actual *modus operandi* of gold assays, some account of the mode of occurrence and of the physical and chemical characteristics of the precious metal will be given.

The attractive lustre, beautiful colour, and sparse distribution of gold have from remote ages to the present time made the metal highly prized and much sought after by all nations of the world. The word *gold* is doubtless associated with the Sanscrit *jvalita*, derived from the verb *jval*, "to shine." Gold as an element is the only metal which has a yellow colour when in mass, although under various conditions the colour is modified; for instance, gold leaf is translucent, and by transmitted light appears green, but maintains its natural yellow colour by reflected light.

Menes, who reigned in Egypt B.C. 3600, alludes in his codes to the intrinsic value of the precious metal, and, doubtless long before his time, in prehistoric ages, the natives of India and China were acquainted with its virtues. Prior to the discovery of America by Columbus, practically all the gold was derived from India. Doubtless from the fact that gold occurs in the metallic state in alluvial sands, it was the first element and metal that was isolated and used as such.

NATURAL OCCURRENCE AND FORMS OF GOLD.

GOLD, as found in nature, is generally in the metallic state, and occurs in various parts of the globe: (1) in siliceous or quartz *veins*, filling up *fissures* of the earth's crust; and (2) in *placers* or *alluvial* deposits left by streams that have disintegrated rocks containing the auriferous veins.

Gold is rarely found absolutely pure in nature, silver being the most common impurity, while it is also associated, either in a fine state of mechanical mixture, or in some instances in chemical combination, in *iron pyrites*, *copper pyrites*, *nagyagite* (telluride combination), *magnetite*, *iridosmine*, *galena*, *blende*, *tetradymite*, *zircon*, *garnets*, *rutile* and *barytes*, *wolfram*, and *scheelite*. In Western Australia it occurs free and in combination with tellurium and lead and iron pyrites in a matrix of quartz, and the carbonates of lime and magnesia and kaolin. There are numerous other minerals in which gold occurs in small quantities, and the ores of silver, antimony, and bismuth appear to always contain the metal. Gold also occurs in sea water in combination with chlorine, bromine, or iodine, to the extent of $\frac{1}{4}$ grain to 1 grain per ton.

There are several terms given to native gold, depending upon the outward form in which it is naturally found; thus—

Flake Gold.—This variety is generally found on the faces of foliation and cleavage planes of the mineral in which it is contained, generally in kaolin and diabase schists. It is exceedingly thin, and floats on water, and very little of it can be extracted from its matrix by ordinary battery treatment.

Mustard Gold is a form of the noble metal in an extremely fine yellow powder, contained in microscopic fissures of its matrix, and doubtless produced by the decomposition of highly auriferous sulphides and tellurides.

Rough, or Coarse, Gold.—This is the usual form in which gold occurs in reefs, being irregular in form and having no specific dimensions.

Dendritic Gold is a beautiful fern-like form of the metal, incipiently crystallized in cleavages.

Crystalline Gold.—Crystals, in the form of single octahedrons, have been found in *asbolite*—a double oxide of manganese and cobalt—in a kaolin clay locally known as "pug," in Kanowna, Western Australia.

Sponge Gold.—This form of gold has been found in beautiful masses on the oxidized zones of the Kalgoorlie Mines, where at certain depths tellurides of the noble metal are found. In structure it is very much akin to the ordinary marine sponge, consisting of irregular strings and cellular masses of brilliant gold, which form has doubtless been produced by the oxidation and removal of the tellurium with which it was originally combined. In March, 1897, one piece of sponge gold weighing 60 ozs. was taken from the 200-feet level of the Great Boulder Mine, West Australia.

Rhodic Gold.—This combination is found in Mexico, and has a golden colour, and contains from 34 to 43 per cent. of rhodium.

Free, or Visible, Gold.—In quartzose rock and alluvial sands gold may either be disseminated in a finely divided state throughout the matrix, or in small grains or scales, or in pieces of substantial weight unevenly distributed. These pieces are usually termed *nuggets*, and occasionally are found of such a size as to be worth thousands of pounds sterling; as, for instance, the "Welcome" nugget, found in the Colony of Victoria, which weighed no less than 2195 ozs., or 183 lbs., and which, after refining, was worth £8376 10*s.* 6*d.* In 1842 a lump of gold was discovered at Miask, Russia, weighing 96 lbs.; and the "Blanch Barkley" nugget found in South Australia weighed 146 lbs.

As previously stated, the free or metallic gold is always associated with impurities, the nature and extent of which will be seen from the following analyses of native gold from various parts of the world. The purest gold as yet found occurs in the Mount Morgan Mine, Queensland, Australia, and contains 99·7 per cent. of the metal.

According to the Report of the United States Census, 1880, the average composition of *placer* gold obtained from the chief producing States of America was—

State.	Gold.	Silver.	Base metals.
	Per cent.	Per cent.	Per cent.
California	88·36	11·24	0·40
Idaho	78·06	21·34	0·60
Montana	89·51	10·09	0·40
Oregon	87·27	12·33	0·40

Gold from Siberia (Rose).

	Schobrowski, near Katherinenburg.	Katherinenburg.	Perroc Powlowsk.
	Per cent.	Per cent.	Per cent.
Gold	98·76	93·34	92·60
Silver	0·16	6·28	7·08
Copper	0·35	0·06	0·18
Iron	0·05	0·32	0·06

NATIVE GOLD FROM CENTRAL AMERICA.

	Malapso.	Trinidad.	Guano.	Santa Rosa.
	Per cent.	Per cent.	Per cent.	Per cent.
Gold . .	88·24	82·40	73·68	64·93
Silver . .	11·76	17·60	26·32	35·07
	100·00	100·00	100·00	100·00

GOLD FROM WALES.

	Mawdoc River.	St. David's.	Dolgelly.
	Per cent.	Per cent.	Per cent.
Gold	89·85	90·85	95·55
Silver	10·15	9·15	4·45
	100·00	100·00	100·00

The following table shows the composition of native gold found in the West Australian gold-fields :*—

No.	Nature of gold.	Locality.	Sp. gr.	Gold.	Silver.	Copper and iron.
				Per cent.	Per cent.	Per cent.
1	Small alluvial nuggets	Hall's Creek, Kimberley	16·62	93·30	6·60	0·10
2	3-oz. alluvial nugget	Ditto	16·80	88·39	11·61	—
3	"Bobby Dazzler" nugget	Shark's Gully, Pilbarra	14·66	76·81	23·04	0·15
4	From quartz boulders	Talga, Pilbarra	16·20	84·46	15·54	—
5	Gold from conglomerate	Nullagine, Pilbarra	—	91·21	8·79	—
6	Gold from quartz reef	Bamboo Creek, Pilbarra	—	94·00	6·00	—
7	,, ,, ,,	Towranna, Pilbarra	—	94·53	5·47	—
8	,, ,, ,,	Peak Hill	17·16	96·54	3·46	—
9	,, ,, ,,	Nannine Murchison	15·75	89·45	10·50	—
10	Sponge gold from lode	Kalgoorlie	—	99·91	0·c9	—
11	Coarse gold from ironstone pebbles	Block 50, Coolgardie	18·91	99·46	0·64	Trace
12	Crystalline gold from calcite vein	Red Hill, Coolgardie	18·00	93·21	6·72	—
13	Alluvial . . .	Preston River	—	92·90	7·10	—
14	Quartz reef electrum	Donnybrook	—	49·29	50·71	—

* *Vide* Western Australian Geological Survey Bulletin, No. 6, 1902.

The average value of gold won in Western Australia for 1900 was £3·741 per ounce.

Gold in Iron and Copper Pyrites.—There appears to be a difference of opinion as to whether the gold is in actual combination with the sulphur or iron contained in pyrites, or in a state of fine mechanical comminuted condition in the mineral; but from recent researches on very finely divided auriferous pyrites, by the action of cyanide of potassium and microscopic observations, it is generally held that the gold is not actually combined with the sulphur, but merely locked up in the crystals in the metallic state.

The amount of gold in pyritic ore varies considerably from a few grains to many ounces per ton; a good average working ore containing about 1 oz. of the precious metal per ton.

Telluride Ores of Gold.—In these ores the gold is in actual chemical combination—occurring for the most part in Colorado, California, West Australia, and Hungary.

Calaverite is found in Colorado, and the pure mineral contains 44·5 per cent. of gold and 55·5 per cent. of tellurium, corresponding to the formula $AuTe_2$.

Graphic tellurium, or *sylvanite*, is a mineral found to correspond to the formula $(AuAg)Te_3$, found also in various parts of America.

Nagyagite, or *foliated tellurium*, found in Transylvania, contains—

Gold	9·0 to 13·0 per cent.
Lead	54·0 per cent.
Tellurium	32·2 ,,

and also occasionally contains, in addition, silver, sulphur, and copper.

In recent years a number of telluride lodes have been discovered in the West Australian gold-fields, which have greatly added to the mineral wealth of that colony. The following is an analysis, by the writer, of such an ore found in the mines of the Lake View Consols, in Kalgoorlie—

	Per cent.
Iron	15·65
Sulphur	4·50
Silica	42·50
Alumina	6·12
Lime	8·35
Magnesia	5·25
Lead	0·06
Copper	0·12
Arsenic	0·05
Carbonic acid, oxygen, gold, silver, and tellurium	17·40
	100·00

	Per ton. ozs.	dwts.	grs.
Gold	4	11	2
Silver	0	14	10
Tellurium	32	10	2

Adolphe Carnot * has made a complete analysis of the telluride ore from Lake View Consols and the Great Boulder Proprietary mines in West Australia, and in addition to the presence of *calaverite* and *sylvanite*, he has isolated two compounds of telluride containing mercury, the one he terms *kalgoorlite*, having the formula $(AuAgHg)_2Te$, and a sesqui-telluride, *coolgardite* $(AuAgHg)_2Te_3$.

The following are analyses of some typical gold-telluride compounds found in the Kalgoorlie mines :—

	Sylvanite (Krusch).	Petzite (Carnot).	Coolgardite (Phillips).	Kalgoorlite (Mingaye).	Kalgoorlite (Carnot).
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Gold	28·55	24·16	38·11	20·72	26·10
Silver	9·76	41·22	3·95	30·98	30·43
Mercury	—	2·00	3·80	10·86	0·70
Copper	0·32	0·10	0·95	0·05	0·60
Iron	0·06	—	0·85	—	0·40
Nickel	0·10	—	—	—	—
Tellurium	60·83	32·33	50·75	37·26	41·11
Selenium	0·20	—	—	—	—
Antimony	—	—	1·50	—	0·80
Sulphur	0·09	—	—	0·13	—
	99·91	99·81	99·91	100·00	100·14

* *Vide Compt. Rend.*, 1901, 132, 1298–1302.

The following is also an analysis of a complex gold-bearing compound found in Kalgoorlie, and termed *enargite* (Krusch):—

	Per cent.
Gangue	0·26
Gold	0·12
Silver	0·22
Copper	41·69
Iron	4·76
Nickel	0·15
Zinc	2·68
Lead	0·10
Arsenic	16·87
Antimony	4·30
Tellurium	0·05
Sulphur	28·43
	99·63

Origin of Gold Deposits.—Geologists differ somewhat as to the origin of the lodes or veins in which gold is found, but the theory now generally accepted is that the fissures produced upon the gradual cooling down of the earth in prehistoric times were filled with the mineral they now contain by precipitation from aqueous solution. How gold came to be present in such mineral is somewhat hypothetical. Professor Whitney is of opinion that it was deposited simultaneously from the solutions from which the lodes or veins were precipitated; and this appears the more evident from the presence of the precious metal in pyrites enclosed in siliceous incrustations. The invariable presence of gold in the iron pyrites contained in lodes has naturally suggested the idea that the sulphide of iron is an essential factor as to the presence of gold in its association with silica, and when it is considered that iron pyrites have been found to be produced from a solution of iron sulphate by reducing agents, and consequently if during such reduction gold was present in solution, it would doubtless be co-precipitated with the crystals. This is a very probable theory.

At a recent meeting of the Institution of Mining and Metallurgy held in London, Mr. B. H. Bennetts read a paper, in which he described a curious occurrence of gold at the Mount Lyell mine, Tasmania, singularly demonstrating the manner in which gold migrates in solution, and hence is deposited as metal, maybe far removed from its original source. "A piece of wrought-iron was picked up by the foreman of the mine (it originally formed a part of a mine truck) from the gutter that carried away the water from the mine tunnel. It displayed a deposit of copper, but on removing this, the iron in places displayed a deposit of metallic gold. The gold was not uniformly distributed, but appeared in plates especially near three bolt-holes. The deposit, of a beautiful yellow colour, responded to the usual tests for gold. Here is, doubtless, an instance in which an aqueous acid solution, containing a minute proportion of gold in solution, in addition to copper, coming into contact with a reducing agent (iron), precipitated copper, and this copper-iron couple, generating sufficient electricity in the acid solution, precipitated the gold in a bright metallic form."

PHYSICAL CHARACTERS OF GOLD.

GOLD has a beautiful rich yellow *colour* and a high metallic lustre. When pure it is nearly as *soft* as lead, and on this account it is *hardened* with silver, copper, etc., when required to be used for coinage and jewellery.

The metal has remarkable degrees of *malleability* and *ductility;* more than those possessed by other metals and at all temperatures. A single grain of gold can be drawn into a wire over 500 feet long, and can be beaten out to $\frac{1}{300,000}$ of an inch in thickness, which may be further reduced by treatment with a dilute solution of cyanide of potassium. Thus 300,000 of such leaves laid upon each other would be only one inch thick, yet each leaf may be beaten so perfect and free from holes that one of them laid upon any surface gives the appearance of solid gold. They are so thin that if formed into a book 1500 would only occupy the space of a single leaf of common paper, and an octavo volume of an inch thick would have as many pages as the books of a well-stocked library of 1500 volumes of 200 pages each. Pure gold has a *tenacity* of 7 tons per square inch, with an *elongation* of 30·8 per cent. The presence, however, of minute quantities of other elements, such as tellurium, bismuth, and lead, materially affects its physical properties. The *specific gravity* of cast gold varies from 19·29 to 19·37, and pure precipitated gold has a density of 20·72. Its *melting point*, as determined by various observers, varies from 1037° to 1072° C., and it *boils* at about 2240° C.

At temperatures below its melting point gold can be welded like iron, and precipitated gold can be consolidated under pressure. It cannot be well employed for castings, since the metal contracts materially upon solidification. The *coefficient* of *lineal expansion* of gold is 0·0000144 between 0° and 100° C. As compared with silver at 100, its *electrical* and *thermal conductivities* are 76·7 and 60 respectively. The *atomic weight* of gold is 196·85 compared with hydrogen, while its *atomic volume* is 10·2, the *latent heat* being 16·3. Taking iron as 100, the *specific magnetism* of gold is 3·47. Gold crystallizes in the cubic system.

OCCLUSION OF GAS BY GOLD.

Gold is capable of occluding 0·48 of its volume of hydrogen, and 0·20 of its volume of nitrogen. "Cornets" from the assay of gold may retain gas if they are not strongly heated.

CHEMICAL PROPERTIES OF GOLD.

Gold undergoes no change by the action of the atmosphere and moisture at any temperature, and, with the exception of selenic acid, no single acid has practically any effect upon it. It dissolves, however, in aqua regia—a mixture of hydrochloric and nitric acids—forming gold trichloride ($AuCl_3$), and also in solutions containing free chlorine and bromine and alkaline cyanides. Strong sulphuric acid, and polysulphides of the alkaline metals, also dissolve finely divided gold.

Alloys of Gold.—Gold can be made to combine with most other metals, the more important combinations being those with silver and copper, and with these elements it unites in all proportions.

The **gold-silver** alloys are characterized by being more fusible, elastic, and harder than either free metal, while the colour of gold is materially lightened by the addition of silver. There have been several true crystallizable compounds of silver and gold isolated, corresponding to the formulæ $AuAg$, $AuAg_2$, Au_8Ag, Au_6Ag, and Au_2Ag. Silver-gold alloys used by jewellers are: *green gold*, containing 25 per cent. silver and 75 per cent. gold; *dead-leaf gold*, containing 30 per cent. silver and 70 per cent. gold. *Electrum* is a term used to designate the pale yellow alloys containing from 15 to 35 per cent. of silver. Triple compounds of silver, copper, and gold are mostly used by British jewellers, containing gold parts in every 24 (carats): 22, 18, 15, 12, and 9 respectively.

Sulphuric and nitric acids act upon silver-gold alloys, dissolving out the silver, and leaving the gold, if the silver present is over 60 per cent.; but if under this amount, some silver will remain undissolved.

Gold and Copper.—Like silver, copper unites with gold in all proportions, forming alloys of a reddish colour, which are less malleable, more elastic and fusible, and harder than gold. British standard gold is a gold-copper alloy, which has been used for our coinage since 1526, and contains eleven-twelfths gold and one-twelfth copper, or, in other words, 916·6 *fine* (*i.e.* parts gold per 1000), or 22 carats (*i.e.* gold in twenty-four parts); or copper 8·33 per cent. and gold 91·67 per cent. The English standard is also that used by India, Russia, Portugal, and Turkey. France and America and many other civilized countries use the 900 standard (*i.e.* 900 parts gold per 1000, and thus containing 10 per cent. copper). This standard originated in France in the year 1794. In addition to the copper, most gold coinage contains from 0·8 to 1·2 per cent. of silver.

Sulphuric and nitric acids dissolve out the copper from the alloys if the copper present be more than 6 per cent.; otherwise some of the latter remains undissolved. Aqua regia completely dissolves the copper-gold alloys.

Amalgams.—Mercury combines with metals in various proportions, and these are termed *amalgams*, and as mercury is extensively employed in the extraction of gold from its ores, gold amalgam becomes an important commercial commodity. Gold is dissolved by mercury at the ordinary temperature, forming amalgams which are solid, liquid, or pasty, according to the proportion of mercury used. The amalgam containing 85 per cent. of mercury is solid, and crystallizes in yellowish-white prisms; that containing 87 per cent. of mercury is pasty; and 90 per cent. of mercury produces a liquid amalgam. Gold amalgam is soluble in excess of mercury, and if the liquid amalgam thus produced is subjected to slight pressure in a filter of chamois leather, mercury filters through, leaving behind a pasty white amalgam containing about one-third its weight in gold. Gold amalgam is dissociated below a bright red heat, the mercury distilling and leaving the gold.

Oxides of Gold.—There are two oxides of gold known—the suboxide (Au_2O) and a sesquioxide (Au_2O_3), otherwise known as aurous oxide and auric oxide. *Aurous oxide* is a dark-green powder, produced by adding a dilute solution of potassic hydrate to aurous chloride ($AuCl$). It is somewhat soluble in excess of alkali. Treatment with hydrochloric acid converts it into auric chloride ($AuCl_3$) and metallic gold. The *auric oxide* is produced by decomposing a solution of auric chloride by means of magnesia, a combination of the oxide and magnesia is precipitated, and on removing the latter with diluted nitric acid, a yellow hydrate or brown anhydrous powder of the oxide is produced, depending upon the degree of dilution of the acid. The oxide is decomposed by sunlight, and, when subjected to a temperature of about 245° C., it is dissociated into metallic gold and oxygen gas. Auric oxide is dissolved by hydrochloric acid, forming the trichloride; and is also dissolved without decomposition by nitric and sulphuric acids. The hydrated oxide forms soluble compounds with alkalies, called *aurates*, and, with the alkaline earths, *insoluble aurates*.

Chlorides of Gold.—The chlorides of gold are the most important compounds of the metal. It is in the form of chloride that gold is extracted from many of its ores by what is known as the *chlorination process*. There are two chlorides of gold—the *aurous chloride* ($AuCl$) and the *auric chloride* ($AuCl_3$).

The *aurous chloride* is produced by heating auric chloride to about 175° C.; chlorine is expelled, and a pale yellow powder of AuCl is left, and if the temperature be increased beyond 200° C., the whole of the chlorine is given off and metallic gold left. It is decomposed by sunlight, and, when deposited with a solution of potassic hydrate, it yields hydrated aurous oxide and potassic chloride.

Auric chloride, or *perchloride of gold*, is produced by dissolving gold in aqua regia (1 of nitric acid to 2 of hydrochloric acid) and evaporating to dryness at a temperature below 120° C.; otherwise it decomposes. The $AuCl_3$ remains as a red deliquescent mass, containing more or less of the protochloride ($AuCl$). It is freely soluble in water, alcohol, and ether. It is decomposed by light, and at 288° C. it melts and decomposes into gold and chlorine gas. Many proto-salts, such as ferrous sulphate, decompose the chloride and precipitate fine metallic gold. Organic matter and metals act in like manner. If a solution of $AuCl_3$ be filtered through charcoal, it is decomposed, and the gold remains in the charcoal, which can be obtained when the latter is burnt off. This method is often adopted in the chlorination process of gold extraction. A current of sulphurous acid gas completely decomposes a solution of $AuCl_3$, precipitating the gold as a fine brown powder. Alkaline chlorides form double salts with the compound, as $2(KCl,AuCl_3)5H_2O$. It also forms double salts with the chlorides of most of the organic bases.

Bromides of Gold.—There being now a bromide process in vogue for gold extraction, these compounds are of importance. There are two bromides of gold—the *protobromide* ($AuBr$) and the *tribromide* ($AuBr_3$). The protobromide is a yellowish-green powder, and is produced by heating the tribromide to 140° C. It is decomposed by water into metallic gold and the tribromide. Heat resolves it into gold and bromine, which is eliminated as vapour. The tribromide is produced by the action of bromine and water on gold at a gentle heat. Its properties are similar to those of the trichloride. It is a crystalline salt, deliquescent and soluble in water, forming a highly coloured solution of a brownish red colour. The salt is decomposed in a similar manner to the trichloride.

Cyanides of Gold.—What is known as the cyanide process of gold extraction has made the cyanides of gold and their double combinations objects of much interest. There are two cyanides of gold—the *aurous* ($AuCy$) and the *auric* ($AuCy_3$): the latter has not yet been isolated in a free state, but is known to exist in combination with other cyanides. The aurous cyanide is produced by heating the double cyanide of gold and potassium ($KAuCy_2$) with nitric or hydrochloric acid. It is a lemon-yellow crystalline powder, unacted upon by the atmosphere, and is insoluble in water, but soluble in ammonia, alkaline cyanides, and sodic hyposulphite. It is dissolved by aqua regia, but not by the single acids. On heating with potassic hydrate, it is decomposed, metallic gold being precipitated as a fine powder. Heating decomposes it, with the production of cyanogen gas and metallic gold.

The most important double combination of auric cyanide is the aurocyanide of potassium, which can be prepared by dissolving fine gold and auric oxide or aurous cyanide in an aqueous solution of potassic cyanide, from which it may be obtained by crystallization. This compound is slightly soluble in water, and articles of copper and silver suspended in the hot solution are gilded. Unless potassic cyanide be in excess, a precipitate of gold is obtained when zinc or the alkali metals are added to the solution.

Purple of Cassius.—This purple compound, discovered by Cassius in 1683, is prepared by adding a dilute solution of a mixture of stannous and stannic chloride to a dilute solution of chloride of gold. It is also formed by digesting metallic tin in a neutral solution of chloride of gold, metallic gold and purple of Cassius being formed. It is this compound which gives the beautiful red colour to Bohemian glass. Purple of Cassius, when mixed with borax or fusible glass, gives to the surface of china a beautiful rose or purple colour.

Fulminate of Gold.—This violently explosive compound of oxide of gold and ammonia ($Au_2O_3(NH_3)_4$) is prepared by adding ammonium hydrate to a solution of chloride of gold, when the grey precipitate of the fulminate is produced. It explodes on being struck or by being heated to 145° C. It is soluble in potassic cyanide, but is insoluble in water. It is decomposed by protochloride of tin and sulphuretted hydrogen.

There are many other less important compounds of gold, such as the silicates, hyposulphides, sulphides, etc., for particulars of which the reader is referred to the larger chemical treatises.

Preparation of Pure Gold.—Pure gold—or "fine" gold, as it is known in the bullion and money markets—which is required as a standard in the assay of bullion, is prepared in the Royal Mint for the testing of the British gold coinage as follows:* Gold cornets, obtained by the usual gold assays, are dissolved in nitro-hydrochloric acid (aqua regia); the excess of acid is evaporated off by gentle heat, and a mixture of alcohol and potassium chloride added to precipitate any trace of the metal platinum that may be present. The whole is now diluted with distilled water in the proportion of about $\frac{1}{2}$ oz. of gold to 1 gallon of water; the solution is stirred, and allowed to stand for 3 weeks. At the end of this time all traces of silver present will have subsided as a precipitate of insoluble chloride (AgCl). The clear yellow solution of gold chloride is then carefully syphoned off into a glass vessel. Crystals of pure oxalic acid are now added from time to time, and the liquid warmed and allowed to stand for 2 or 3 days, at the end of which time the whole of the gold will be precipitated in the form of spongy scales. The gold precipitate is then washed by decantation repeatedly with hydrochloric acid, pure water, and ammonia alternately, and finally with distilled water, until no reaction is obtained for silver or chlorine. The now pure gold is carefully drained and dried and melted in a clay crucible with bisulphate of potash and borax, and poured into a stone mould. On removal of slag on cooling, and treating with hot distilled water, pure cast gold is obtained.

Chemical Tests for Gold.—Many auriferous minerals, such as iron, copper, and arsenical pyrites and tellurides, contain gold in such a finely divided condition disseminated throughout the mass, that it cannot be detected by the eye or by "panning." Chemists and assayers, however, are armed with very delicate tests for gold in minerals of this kind, so that when the precious metal has been rendered soluble, a quantity so minute as one part of gold in 100,000 parts of solution can be detected with certainty.

The two principal reagents used in testing for gold are protosulphate of iron, or green vitriol ($FeSO_4$) and bichloride

* *Vide* Fourth Annual Report of the Mint (1873).

of tin, or stannous chloride ($SnCl_2$). If the substance under examination be a mineral, it is first ground to fine powder in an iron mortar; if an alloy, filings or turnings are obtained. In either case, the substance is heated with nitro-hydrochloric acid until all that is soluble is dissolved. After evaporating off excess of acid, the mass is diluted with water, and any insoluble matter, such as quartz, etc., filtered off. If any gold is present, it is now in solution as gold chloride ($AuCl_3$). The liquid is then divided into two portions. To one portion is added a solution of protosulphate of iron in excess. If gold is present, an immediate precipitate of the metal is obtained as a dark-brown powder; but if present in minute quantities, only a brownish coloration is produced which, after standing for some time, is precipitated, the reaction being $2AuCl_3 + 6FeSO_4 = 2Au + 2Fe_2(SO_4)_3 + Fe_2Cl_6$.

To the second portion a dilute solution of tin bichloride ($SnCl_2$), containing a small quantity of tin tetrachloride, or stannic chloride ($SnCl_4$), is added. If gold is present, a beautiful purple precipitate is produced, purple of Cassius; if present only in minute quantities, a purple solution is the result. Any brown precipitate obtained by $FeSO_4$ in the first portion of the original solution can be filtered off, dissolved in aqua regia, and the gold present confirmed by adding the chloride of tin to the liquid, when the purple precipitate or solution will be obtained.

Another delicate test for gold, which will detect the metal if present only to the extent of a few grains to the ton of mineral, consists in treating 100 grams of the finely divided and roasted ore with 100 c.c. of an alcoholic solution of iodine, and allowing it to stand for an hour, with occasional stirring. On allowing it to settle, a piece of Swedish filter paper is soaked with the clear solution. This is then dried and ignited. If gold is present, the remaining ash will be coloured purple, and this can be confirmed by treating the ash with bromine water, and, on adding some tin chloride solution, the purple of Cassius is obtained.

SAMPLING OF GOLD ORE.

CONSEQUENT upon the very uneven and sparse distribution of gold in the "veins" and "placers," the obtaining of an average sample is attended with some difficulty; but in ascertaining the intrinsic value of auriferous ores, it is very necessary that great care should be exercised in obtaining an average sample, and none but experienced and competent persons should be entrusted in obtaining it, many thousands of pounds having been wasted by capitalists through fraudulent and incompetent sampling, it being so easy to pick out lumps of ore from a mass that will contain an amount of gold far exceeding that which would be obtained in actual extraction on a commercial scale.

The assayer may be called upon to ascertain the amount of gold contained in a "lode" or "reef" at various depths from the surface, and he must use his judgment as to the certainty of obtaining a sample that will give an average of the amount of gold contained in the ore at the various depths.

Of a given weight of crushed ore, it is generally assumed that 5 per cent. ($\frac{1}{20}$) of the mass taken at regular intervals, and of equal weight, will give an average representation of the amount of gold contained in the whole bulk. The amount of work attending the accurate sampling of a mass of ore will depend upon its amount, hardness, and whether it is in lumps or in powder, since it is necessary that the actual average sample taken for assay should be finely divided.

Suppose we have a parcel of lump-gold ore, which we will call A. Out of every twentieth scoop-, spade-, bag-, barrow-, or truck-load of ore, according to the amount thereof, we extract one such load, and make a second heap of ore—call this B—which will now contain one-twentieth of the bulk of A. We now crush B until it contains twenty times as many stones or particles as A, then mix and abstract one-twentieth as before, making a third heap, C. This is again reduced in fineness by grinding as before, and the process continued until a degree of fineness, by sieving, is obtained that will fit the sample for

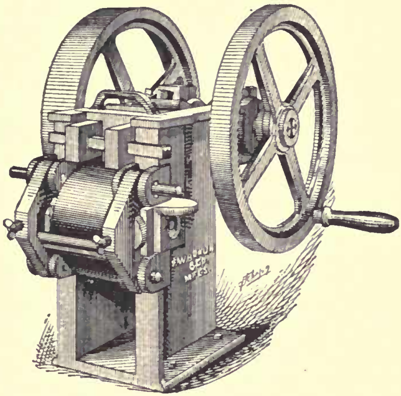


FIG. 1.—BRAUN ORE-SAMPLE CRUSHER AND PULVERIZER.

assaying. The general reduction of the original parcel to the small average sample may be illustrated thus :—

A =	1000	tons of rock and lumpy ore.	
B =	50	,,	rough stones, one-twentieth of A.
C =	2·5	,,	small stones, one-twentieth of B.
D =	0·125	,,	coarse powder, one-twentieth of C.

etc., etc.

Crushing and grinding the Sample.—There are various forms of pulverizing implements for obtaining an average sample for testing and assaying. At gold-mines, where thousands of tons of ore are crushed monthly, the stamp battery and heavy ball and roll mills are in vogue; but we shall describe here only those appliances generally in use by assayers.

The following is a description of the Braun ore-sample crusher, which reduces the lump ore to rough powder, and which may be operated by either hand or power :—

The important and novel feature of this machine is a combination of a jaw and a roll pulverizer working together. The part called the stationary jaw in other types of rock-crushers is in the Braun crusher and pulverizer composed of an upper stationary jaw, A (Fig. 2), against which the heavy breaking takes place, and a lower part, B, which is a roll revolving toward the discharge outlet only (backward rotation being prevented by means of roller stops or chokes, C).

The lower portion of the vibratory jaw D is shaped to

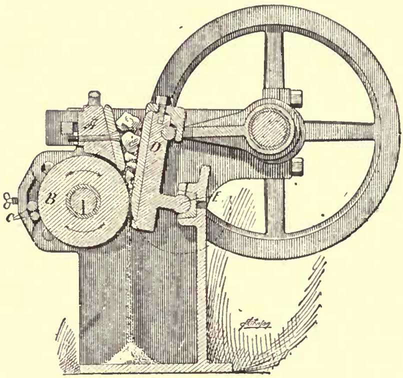


FIG. 2.—BRAUN ORE-SAMPLE CRUSHER, IN SECTION.

describe, when in operation, a segment of a circle from the axial point E, as indicated by the dotted lines in Fig. 2. Thus the discharge outlet is always the same size, and permits the operator to regulate the maximum size of the crushed product. The size of the discharge outlet can be changed in a moment by means of a simple screw adjustment.

A glance at the illustration (Fig. 2) will show that a downward motion is imparted to the material being crushed by the forward or closing movement of the vibratory jaw, D, and that this motion is compelled and continued by the one-way motion of the roll, which is towards the discharge outlet.

When the vibratory jaw recedes or opens, the upward motion of the lower portion of it raises the material being crushed, thus presenting new surfaces to be crushed each time the jaws come together.

The entire jaw A may be removed by loosening a wedge with one blow of a hammer. This simple operation exposes the crushing surfaces of the machine in shape to be easily cleaned. Provision is also made for readily removing the roll portion B; this gives access to the entire interior and all parts

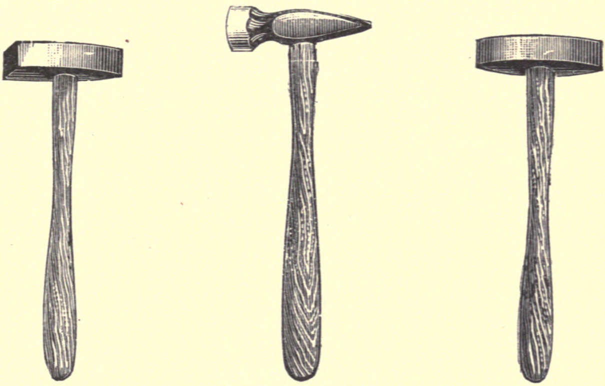


FIG. 3.—GEOLOGIST'S HAMMERS.

of the machine. The possibility of "salting" subsequent samples is entirely obviated.

The crushing plates are tempered cast steel and are reversible, and, when both ends are worn out, may be replaced at a small expense. The pulverizing roller has a chilled surface. This machine is very light running, all bearings being brass.

The weight of the machine is 225 lbs. net, and when crated for shipment, 285 lbs. The jaws are $3\frac{1}{2}$ inches wide, and the roll 6 inches in diameter.

Large lumps are broken by geologists' hammers (Fig. 3) to the desired size for further reduction by the machine.

Mortars.—For the reduction of coarse grains of small quantities of ore to powder of requisite fineness, usually of a degree that will pass through a sieve containing sixty to eighty meshes to the lineal inch, iron mortars and pestles, of the forms shown in Fig. 4, are much used; and for grinding very small quantities of ore to an impalpable powder, the agate mortar and pestle shown in Fig. 5 is used.

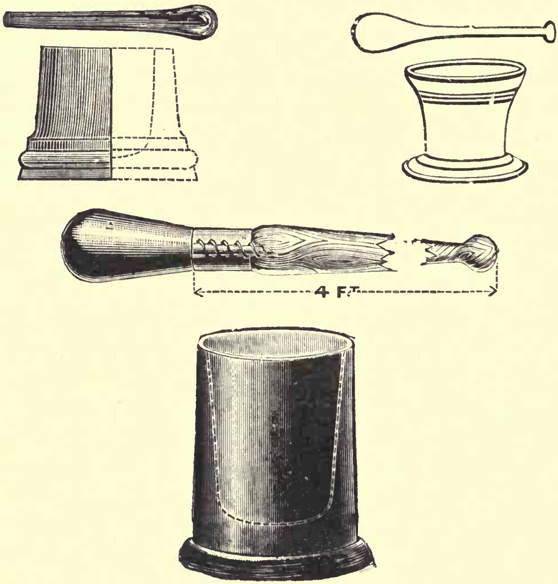


FIG. 4.—IRON MORTARS AND PESTLES.

A new form of mortar, which is not so laborious to use as the foregoing, is Calkins' gyratory mortar (Fig. 6).

This gyratory mortar is designed to pulverize small ore samples to any desired degree of fineness, such samples having previously been crushed in a rock-breaker or ore-crusher.

It consists of an iron mortar having an opening or discharge outlet in the bottom, and a round iron ball or pestle, the contour of which conforms exactly to the entire bottom of the mortar. About one-sixth ($\frac{1}{6}$) of the area of the ball comes in actual contact with the bottom of the mortar when no substance intervenes; this construction gives the maximum amount of grinding surface.

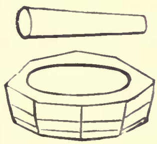


FIG. 5. — AGATE MORTAR AND PESTLE.

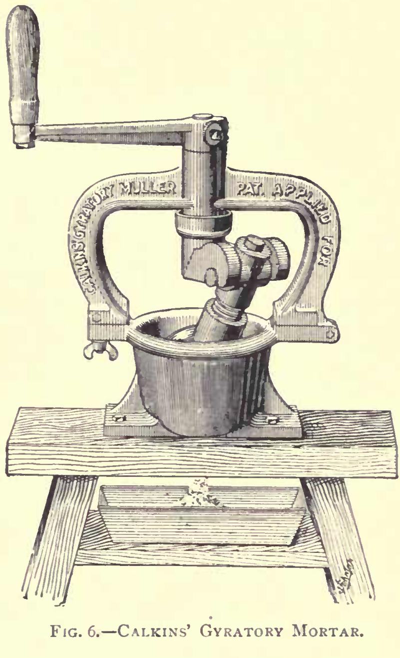


FIG. 6.—CALKINS' GYRATORY MORTAR.

The machine is operated by turning a handle, which is supported by a bale or arch over the mortar. A right-angled clutch extension attached to the shaft of the handle imparts a gyratory and rotary motion to the ball. The right-angled extension of the rotary shaft clutches a box fitted to the shaft in the ball, which forces a gyratory motion, yet allows the metal being crushed to produce, by attrition, a revolution of the ball in an opposite direction to the way it is being gyrated. This peculiar motion effects a twisting, crushing and grinding, and prevents the material being pulverized from being thrown ahead of the ball by centrifugal force. This is the most important feature of the appliance. A disruptive movement is obtained, and the material forced to discharge through the opening in the bottom.

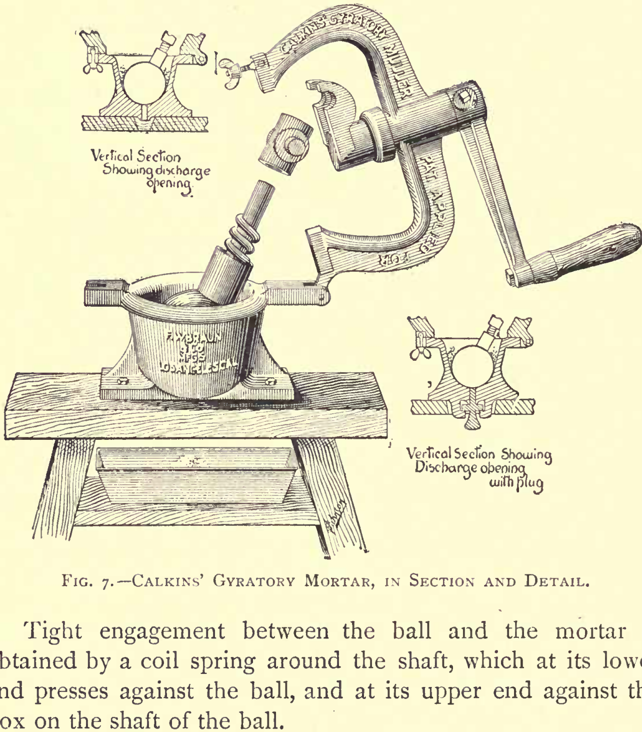


FIG. 7.—CALKINS' GYRATORY MORTAR, IN SECTION AND DETAIL.

Tight engagement between the ball and the mortar is obtained by a coil spring around the shaft, which at its lower end presses against the ball, and at its upper end against the box on the shaft of the ball.

The pestle being a true sphere, and the lower portion of the mortar which comes in contact with it being an arc of a true circle, the parts wear to place, and never become ineffective by use.

The bale or arch is hinged at one side and secured by a thumb-screw at the opposite side, which permits the entire inside to be easily accessible for cleaning by swinging the bale over as shown in Fig. 7, which allows the ball to be readily lifted out.

Bucking-plate and Hammer.—A desirable form of pulverizer in use is the bucking-plate and hammer shown in Fig. 8. It consists of a smooth iron plate about 2 feet square, surrounded with a rim about 1 inch high around three sides, and a hammer having a smooth curved surface weighing about 8 lbs., and a handle 30 inches long.

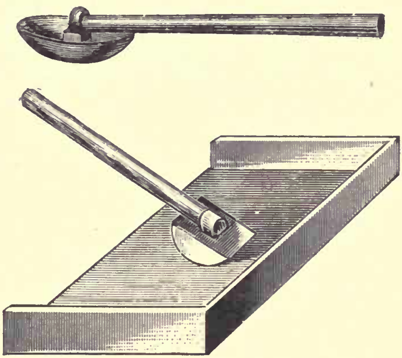


FIG. 8.—BUCKING-PLATE AND HAMMER.

The ore, in coarse grains, is spread over the surface of the plate, and the hammer manipulated upon it with both hands, one holding the handle and the other pressing the head downwards, and rubbed with an oscillatory movement of the handle until the ore is reduced to the desired state of fineness. An improved form of the implement is Calkins' radial bucking-plate, shown in the woodcuts (Figs. 9 and 10).

Calkins' Combined Radial Bucking-plate and Hammer.—This machine will quickly reduce crushed ore samples to a pulp of any desired fineness with the expenditure of but a fraction of the energy and time required for the same work on the old-style bucking-plate.

It consists of a circular plate, to the sides of which is journaled an axle carrying the shoe or muller. The tight engagement between shoe and plate is effected by two spiral

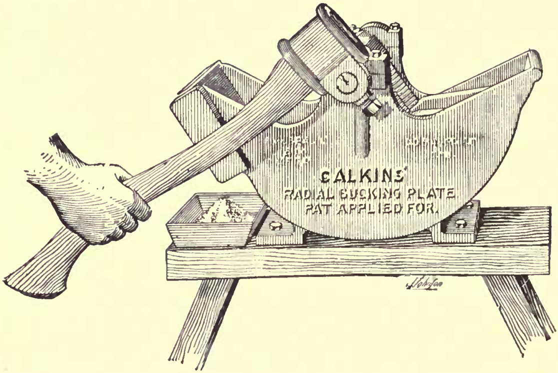


FIG. 9.—CALKINS' COMBINED RADIAL BUCKING-PLATE AND HAMMER.

springs, which admit of a much lighter shoe than would otherwise be required, and at the same time gives a more lively action to the shoe.

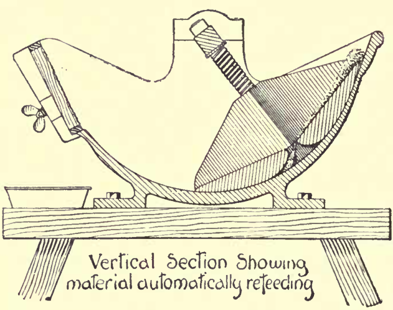


FIG. 10.—CALKINS' COMBINED RADIAL BUCKING-PLATE AND HAMMER, IN SECTION.

Heavier or lighter engagement between shoe and plate may be had by compressing or relaxing the spiral springs. The shoe is actuated by means of a handle connected to its shaft.

The grinding surfaces of the shoe and plate conform in shape exactly to each other.

Both ends of the plate depart somewhat tangentially from the true radial line of the grinding surface; this prevents the sample from being thrown out of the plate accidentally while in operation. One end of the plate does not so radically depart from the radial line as the other, and at this point it is provided with a metal screen of any desired mesh, so that, in operating, such of the material being crushed as may be fine enough will be thrown against and will fall through into a receptacle.

From time to time the muller may be swung clear of the plate, and the material in the plate may be brushed against the screen, thus liberating the product that is ground to the requisite fineness.

Both ends of the shoe terminate in a sharp edge, which as it works gathers up the coarse particles of the ore, and as the shoe approaches the extremity of the plate, these particles roll or slide over the top surface of the muller and enter a cross-wise aperture on the centre of the shoe, and are thus automatically replaced between the grinding surface of the plate and muller, as shown in sectional drawing in Fig. 10.

The importance of this construction of the shoe will be readily apparent, as by gathering up the coarser particles it prevents them from being surrounded and protected by the finer particles, which would be the case were not the coarser particles scraped up and replaced between the grinding surface of shoe and muller at each stroke.

The screen is held in place by a thumb-screw, which permits of ready removal, in case it is necessary to clean or to insert screen.

This plate never becomes ineffective through wear, as the grinding surfaces wear to each other.

Length	18 inches
Width	6 ,,
Net weight	75 lbs.
Weight, packed for shipment	100 ,,

Quartering.—An important operation in the reduction of the amount of powdered ore is quartering. The whole of the mixed ore is heaped up into a cone, and then by means of a wooden stirrer is stirred circuitously, gradually from the centre until it becomes flattened out into a low frustum of a cone. Two diameters at right angles to each other are now lined out on the surface with a straight-edge, any two alternate quarters are mixed together and reserved, and the others rejected. This process, with or without further grinding, as may be required, may be repeated with the reserved portion until the requisite quantity is obtained for assay.

An ingenious apparatus on the cone principle is the laboratory divider of Mr. Clarkson, illustrated in Fig. 11, which will

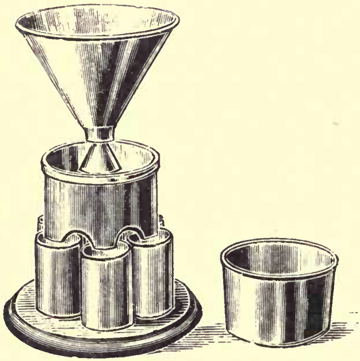


FIG. 11.—CLARKSON'S LABORATORY DIVIDER.

divide up a sample into six equal and exactly similar portions in less than the same number of seconds, ensuring agreements in the assay from any of the portions.

Preparing the Powdered Sample for Assay.—It is essential that the *whole* of the average sample obtained by whatever mode of pulverizing is adopted should pass through a 60- to 80-mesh sieve. Should there be any particles of metallic gold that could not pass through, owing to their malleability, these must be cupelled separately, and their value calculated per ton of ore on the quantity they were sifted from, independently of the result obtained by the true assay, to which amount it may be afterwards added. The sieves usually used are the tin-box sieves, which contain several of various degrees of mesh (Fig. 12), and the ordinary wooden-frame sieve, with brass gauze of specific mesh (Fig. 13).

The prepared sample should be stored in labelled tin boxes or glass bottles; bags are somewhat objectionable, owing to fine particles of gold finding their way into the fibre from the ore.

Prior to the subjection of the ore to the various assay operations, a definite weight should be decided upon to be

FIGS. 12, 13.—SIEVES.

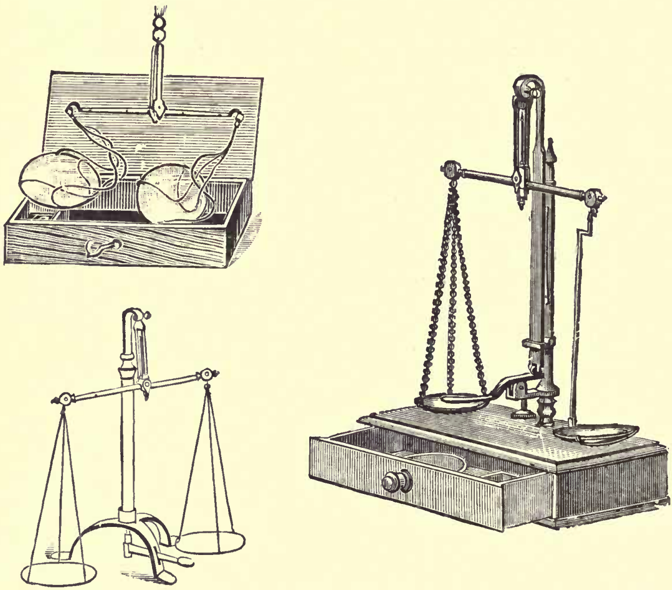
taken, depending upon the approximate amount of gold and silver found by preliminary assay.

The amount of gold found present in auriferous ores is expressed in this country and in Australia in terms of ounces, pennyweights, and grains per English "long ton" of 2240 lbs. = 32,666 troy ounces; while in America and South Africa the amount is expressed in terms of ounces, pennyweights, and grains per "short ton" of 2000 lbs. = 29,166 ozs. troy. Much inconvenience would be prevented if the French metric system of weights and measures were universally used. It will be used for weighing operations throughout this little work, while tables will be given for conversion into the English and American terms of expression.

Before weighing out the sample (pulp) for assay, the whole of it should be spread out on a sheet of glazed paper by means of a steel spatula (Fig. 14), and by its means small quantities are taken up from all over the mass, and conveyed to the left-hand pan of the pulp balance until the requisite weight—generally either 25, 50, or 100 grams—is obtained. There are

FIG. 14.—SPATULA.

various types of balances used for this purpose, Figs. 15, 16, and 17, being convenient forms. They are sensitive to about 1 centigram with a load of 500 grams. The weights (Fig. 18)



FIGS. 15, 16, 17.—PULP BALANCES.

from 500 grams to 0·01 gram are contained in a wooden box, being manipulated therefrom by means of a forceps (Fig. 19).

The amount decided upon having been weighed out, the next operations consist of—

(1) **Fusion.**—A process in which the whole of the gold and silver is dissolved by molten lead produced by reduction of its oxide by reducing and fluxing agents in a fire-clay crucible at a bright-red heat.

(2) **Scorification.**—Not an absolutely necessary operation, but a convenience, and consists in the reducing of the bulk of the lead produced by fusion by converting the bulk of it into oxide or slag, and thus concentrating the silver and gold in a small lead button for subsequent cupellation. Scorification can also be applied to sulphide ores in assaying for gold without previous roasting.

(3) **Cupellation.**—This is a process in which the lead button contained in a receptacle of bone ash is subjected to

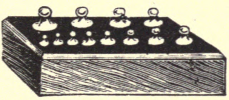


FIG. 18.—WEIGHTS.

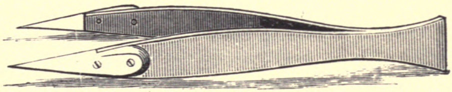


FIG. 19.—FORCEPS.

heat in a current of air in a muffle, whereby the lead is converted into oxide and absorbed by the cupel, leaving a "pril" or "button" of silver and gold behind.

(4) **Parting.**—This process consists of dissolving out the silver by nitric acid, leaving the gold in a pure state for weighing.

FUSION.

In order to effect the solution of gold in the ore with lead, the ore is mixed with fluxes, the amount and nature of which depend upon the nature and amount of ore taken. The operation is carried out in a fire-clay crucible (Fig. 20). The crucibles made by the Morgan Crucible Company are the best for the purpose; they should be of such size that when the ore and fluxes are introduced they should not be more than two-thirds full. The materials necessary for mixing with the

FIG. 20.—FIRE-CLAY CRUCIBLE.

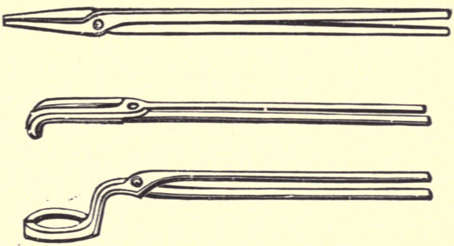
FIG. 21.—FIRE-CLAY ROASTING DISH.

powdered ore under assay are powdered borax, carbonate of soda, oxide of lead free from silver, flour or carbon, and occasionally nitre. Should the ore under examination be refractory—that is, contain such elements as sulphur, arsenic, antimony, tellurium, etc.—the weighed sample should be first carefully roasted with occasional stirring in a roasting dish (Fig. 21), this operation being conducted in a muffle furnace (Fig. 36). Care should be taken to heat the ore gradually, and not heat it suddenly to a high temperature, otherwise there will be a loss of gold. With "free milling" or quartz ore free from iron pyrites or mundic, previous roasting will be unnecessary.

The weighed quantity of the ore—a most convenient quantity to take being 50 grams, or 100 grams when very low grade—is mixed on a sheet of glazed paper by means of a spatula. The following are the charges for different types of ore :—

	Quartz.	50 per cent. quartz. 50 per cent. oxides.	All oxides.	Calcareous ores.
	Grms.	Grms.	Grms.	Grms.
Ore	50	50	50	50
Flour . . .	5	5	5	5
Litharge . . .	40	40	40	40
Soda carbonate .	60	50	25	10
Borax . . .	15	25	50	50
Silica . . .	—	—	—	25

The crucible having been previously gradually heated to a dull red heat—sudden heating may cause the crucible to crack—



FIGS. 22, 23, 24.—CRUCIBLE TONGS.

the well-mixed charge is run into it, and carefully conveyed, by means of crucible tongs (Figs. 22, 23, and 24 are convenient types), to the assay furnace already heated to redness.

The Assay Furnace.—There are various forms. At large mines a permanent brickwork furnace, which also contains one or more muffles, is used and heated by means of coke or charcoal. The most convenient form of furnace for single assays, where gas is available, is Fletcher's gas assay furnace

(Fig. 25), consisting of an iron burner arranged to admit air

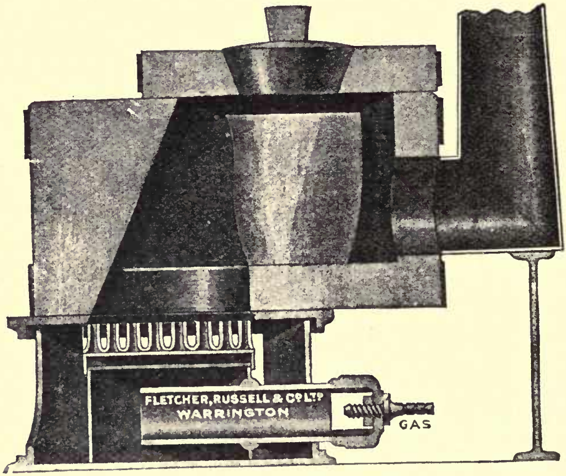


FIG. 25.—ASSAY FURNACE (GAS).

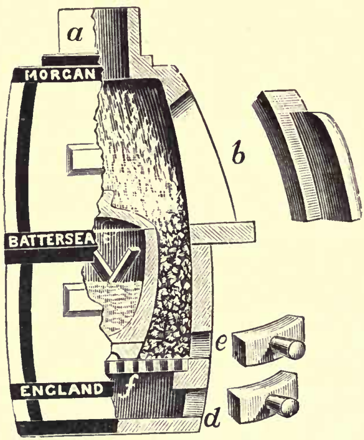


FIG. 26.—ASSAY FURNACE (CHARCOAL).

with the gas before ignition, as in the Bunsen burner; the heating chamber is of fire-brick, and an iron chimney creates the draught, and carries away the products of combustion.

A form of furnace much used in gold-mines is Morgan's charcoal furnace (Fig. 26). This consists of fire-brick bound together with hoop-iron. Its construction will be readily seen from the sketch. The draught is produced by a chimney 20 to 30 feet high. A small charcoal fire is first kindled, the hot

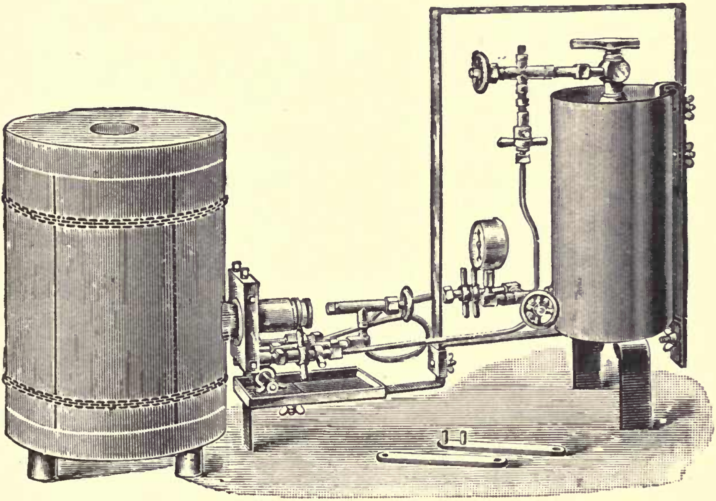


FIG. 27.—ASSAY FURNACE (OIL).

crucible and its charge placed in it, and covered around and over with small lumps of charcoal; the cover having been placed on, a white heat is soon obtained.

Where gas, charcoal, or coke is not available, Nelson's portable oil furnace is useful (Fig. 27).

In this furnace a mixture of oil vapour and air is the source of heat. The light petroleum is contained in a strong steel cylinder, supplied with an air-pump, pressure gauge, etc. The compressed air forces the oil from the cylinder in a fine stream; it is mixed with air, and burnt in a specially constructed burner, the flame from which enters the aperture of the fire-brick furnace, as seen in the sketch.

The crucible and its contents are kept in the furnace at a bright-red heat until complete fusion has occurred and effervescence subsided, which generally takes place in about half an hour. The crucible is now taken out of the furnace with

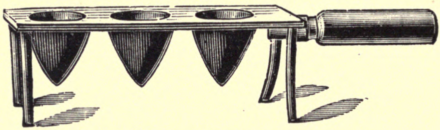


FIG. 28.—INGOT MOULD.

the tongs, and its contents carefully poured into an ingot mould (Fig. 28) as quickly as possible. The slag is allowed to overflow, the reduced lead containing the gold and silver collecting in the bottom of the mould. When cold, the mould is turned upside down, and the button of lead detached from the slag by tapping with a hammer on an anvil. The lead button is now flattened out, and is next subjected to the process of *cupellation*.

CUPELLATION.

This operation is carried out in small cup-shaped receptacles made of compressed bone ash. Fig. 29 shows elevation and section of one; it will be observed that they have a slight taper. The cupels produced in the Royal Mint are made in special steel cupel moulds.

There are two types in use, illustrated by Figs. 30 and 31. Fig. 30 shows a mould for making single cupels, and Fig. 31 a mould that produces four cupels at one time. They consist of a plunger C, a guide B, and the mould A. Bone ash which has been slightly damped with a dilute solution of carbonate of potash, is placed in the mould A, just a little more than will completely fill it; the guide B is then placed over it; the plunger C introduced, which is then subjected to pressure under a lever press. On dismantling, the bone ash will have assumed the form shown in Fig. 29. Before use, the cupels should be very carefully dried and stored in a dry place, otherwise they are very liable to crack and form fissures during cupellation, which would render the assay worthless.

A recent American invention is Calkins' automatic cupel machine, illustrated in Fig. 32, for which it is claimed that it will turn out six hundred cupels of perfect shape, uniform in size and density, in one hour. The machine, as seen in sketch, consists of a compound lever of ingenious construction, a plunger or die, and two discs. The top disc contains the holes in which the cupel is compressed, and the bottom disc is a plane plate with one hole somewhat larger than in the disc above. A hopper is attached to the machine, in which the bone ash properly moistened is placed. A strong wheel in the hopper bears on the top disc, and rotates as the machine is worked, thus preventing the moist bone ash from bridging in the hopper, and ensures a perfect automatic and uniform feed. The machine is manufactured by F. W. Braun and Co., of Los Angeles, California.

Now, the object of cupellation is to separate the lead which

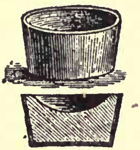


FIG. 29.—CUPEL.

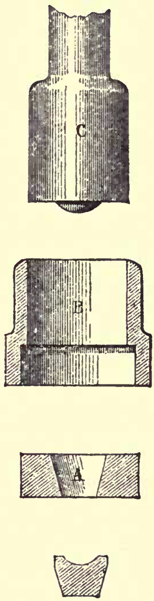


FIG 30.—CUPEL MOULD (MINT).

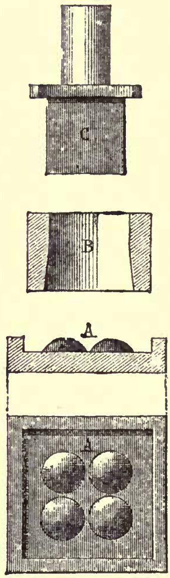


FIG. 31.—QUADRUPLE MOULD USED AT ROYAL MINT.

has been used to dissolve gold and silver, in the case of gold ores, and in the case of bullion, to separate the added lead and the oxidizable metals originally present in the bullion. Bone ash, at a bright-red heat, owing to its porosity, has the property of absorbing oxide of lead and other oxides, such as those of copper, bismuth, zinc, etc., which are soluble in oxide of lead; while metals which do not oxidize in the atmosphere, such as gold, silver, platinum, etc., are not absorbed. This property, then, is the principle upon which cupellation is based. The cupel must be large enough to absorb the whole of the oxidizable metals associated with the precious metals, and the absorptive power of the cupel depends upon its texture, porosity, etc. A cupel of average porosity will absorb the fused oxide produced from about its own weight of lead. In the assay of bullion, the amount of lead necessary to add will depend upon the amount of oxidizable metal present; the more the latter, the more lead is required.

The following table shows the proportion of lead necessary for the elimination of varying amounts of copper in bullion :—

Gold in alloy.	Lead required for 1 part alloy.
1000 thousandths	1 part
900 ,,	10 parts
800 ,,	16 ,,
700 ,,	22 ,,
600 ,,	24 ,,
500 ,,	26 ,,
400, 300, 200, 100, 50 thousandths	34 ,,

The actual operation of cupellation is carried on in a fire-clay muffle (Fig. 33) heated by coke, charcoal, oil, or gas in

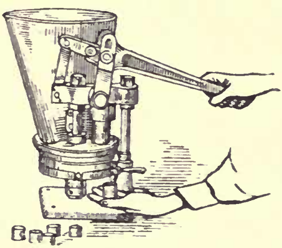


FIG. 32.—CALKINS' AUTOMATIC CUPEL MACHINE.

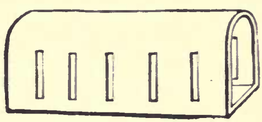
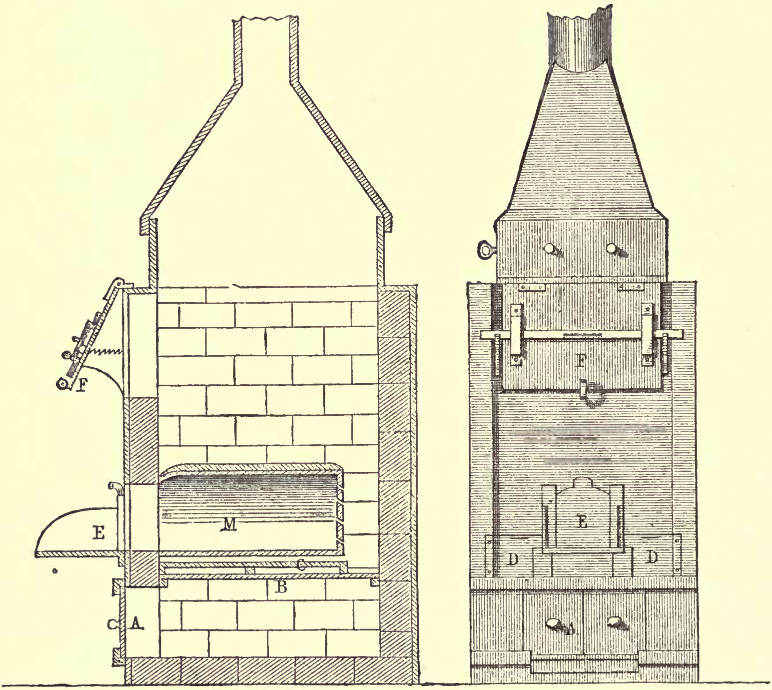


FIG. 33.—FIRE-CLAY MUFFLE.

furnaces to suit various conditions. The muffle has slits in the sides and back to admit air, which is essential to cupellation.

There are numerous forms of furnace in use. The form used in the Royal Mint is illustrated by Figs. 34 and 35, showing front elevation and vertical section. The muffle M rests on a bed of fire-clay, supported on an iron girder plate, C, resting upon the fire-bars B. The external portion of the furnace is made of wrought-iron about $\frac{1}{8}$ inch thick, the whole being lined with fire-bricks.

There are five openings to the furnace. The bottom one,



FIGS. 34, 35.—MUFFLE FURNACE (MINT).

A, is a convenience for clearing the ash-pit; the two side ones, DD, to remove two fire-bars so as to admit of the fuel being dropped into the ash-pit when necessary; F is an opening through which fuel—a mixture of coke and coal is most suitable—is charged; E is the snaffle opening into which are introduced the cupels, crucibles, or scorifiers.

The chimney is supplied with a damper, and with this, in conjunction with the various openings, the requisite degree of draught can be regulated to suit the various degrees of heat that may be required.

A convenient form of furnace for prospecting and laboratory work is seen by the illustration (Fig. 36), and can be used for

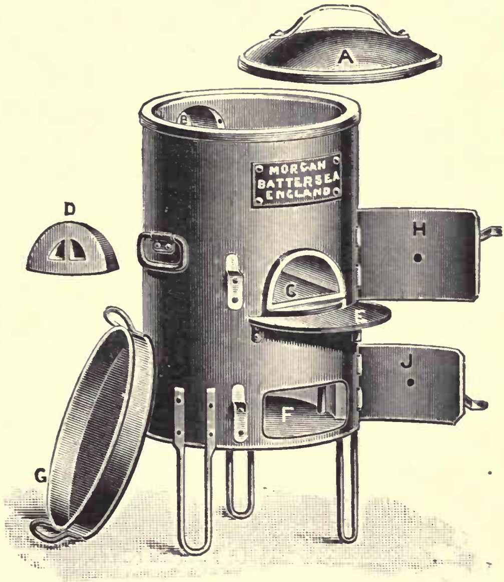


FIG. 36.—PROSPECTOR'S MUFFLE FURNACE.

muffles up to $8 \times 4\frac{3}{4} \times 3$ inches, or four Battersea round crucibles G, three ditto F, or two ditto G, and adapted for fusing, melting, and cupellation, and constructed of wrought-iron lined with fire-clay. The sketch shows the furnace for cupellation. If required for melting or fusing, remove the muffle C and close aperture with the fire-clay plug D. It is supplied with a sand-bath, G, most useful for drying cupels, evaporations, etc. Coke, charcoal, or coal is used as fuel, or mixtures of them.

Another useful form of portable muffle furnace is seen illustrated in Fig. 37 for use with coke and charcoal. It is made in sections of fire-clay bound with iron bands. The working of the furnace will be readily understood from the sketch. *a* is the socket on which a long iron chimney is fitted; *b*, the opening, provided with a plug, for charging the fuel;

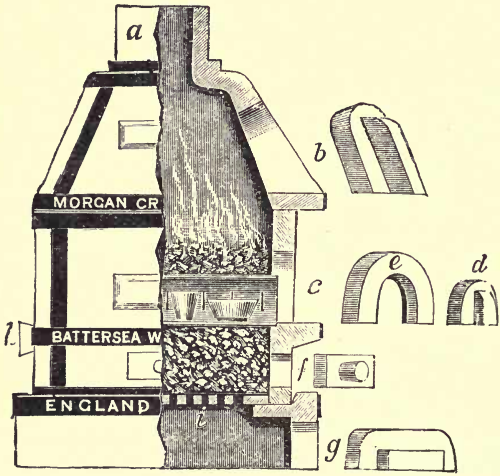


FIG. 37.—MORGAN'S MUFFLE FURNACE (CHARCOAL).

c, the muffle; *d*, the door for muffle; *e*, muffle arch; *f*, door for stirring fire; *g*, the door for regulating draught; *h*, support for muffle; and *i*, iron grating. The chimney is provided with a damper to regulate draught for desired temperature.

A most convenient and useful form of muffle furnace is shown in section sketch (Fig. 38), for use where gas is available. All the inconveniences of coke and charcoal furnaces due to attention to stirring, to ash, clinkers, dust, etc., are here avoided, and an even temperature can be maintained for any length of time by regulating gas and air supply, without further trouble. The furnace is constructed of fire-clay bound with iron bands, and adapted for various-sized muffles. It rests on a large draught Bunsen burner, and is provided with an iron chimney.

Another form of muffle furnace is Nelson's, in which benzoline oil is used as fuel. Its construction will be understood from the illustration seen in Fig. 39.

It consists of the muffle furnace A, constructed of sheet-iron lined with fire-clay; an oil reservoir, B, provided with air-

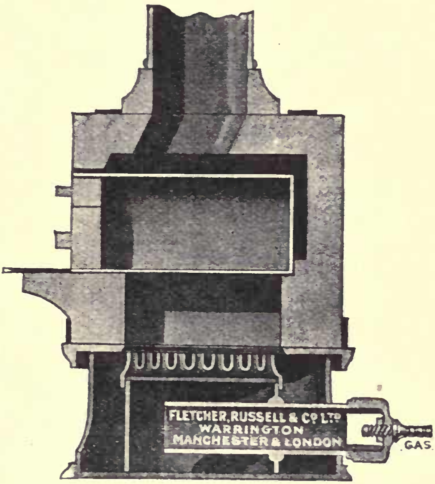


FIG. 38.—FLETCHER'S MUFFLE FURNACE (GAS).

pump, valves, and gauge, connected with the vaporizer; and burner, D, at which the mixture of oil-vapour and air burns, and the flame, entering the back of the furnace, surrounds the muffle. This furnace will be found useful in localities where coal, coke, or charcoal is unavailable.

A compact and portable necessary apparatus for prospectors, etc., is illustrated in Fig. 40, and is neatly packed for transport

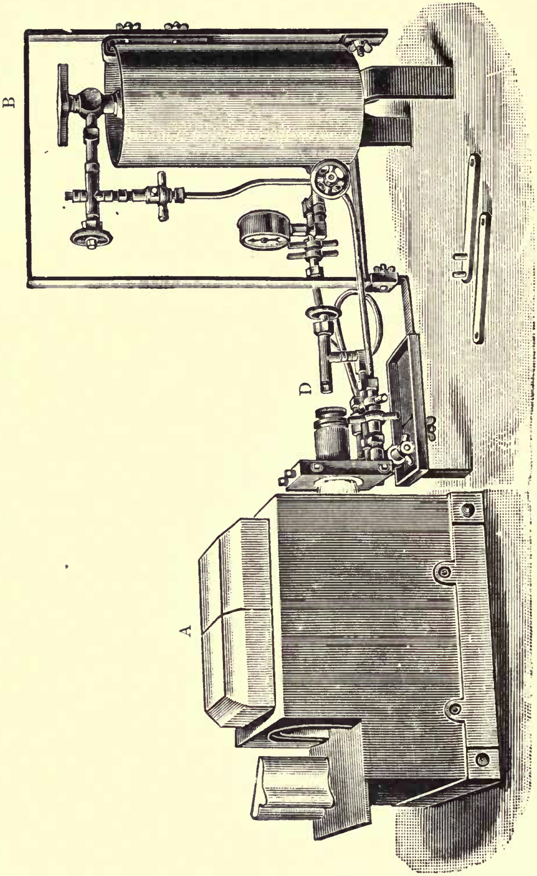


Fig. 39.—Nelson's Muffle Furnace (Oil).

purposes. It is supplied by Messrs. Fletcher, Russell, and Co., Limited, of Warrington, and comprises—

No. 4 muffle furnace,
No. 3 crucible furnace, } modified for oil.
Four spare muffles,
Two spare crucibles.
One spare burner coil.
Bow and plain tongs.
Oil storage tank.
Size of case, 29 × 27 × 19 ins.
Weight, packed, 146 lbs.

Having now described cupels and cupellation, and the furnaces necessary for carrying out the process, we will proceed

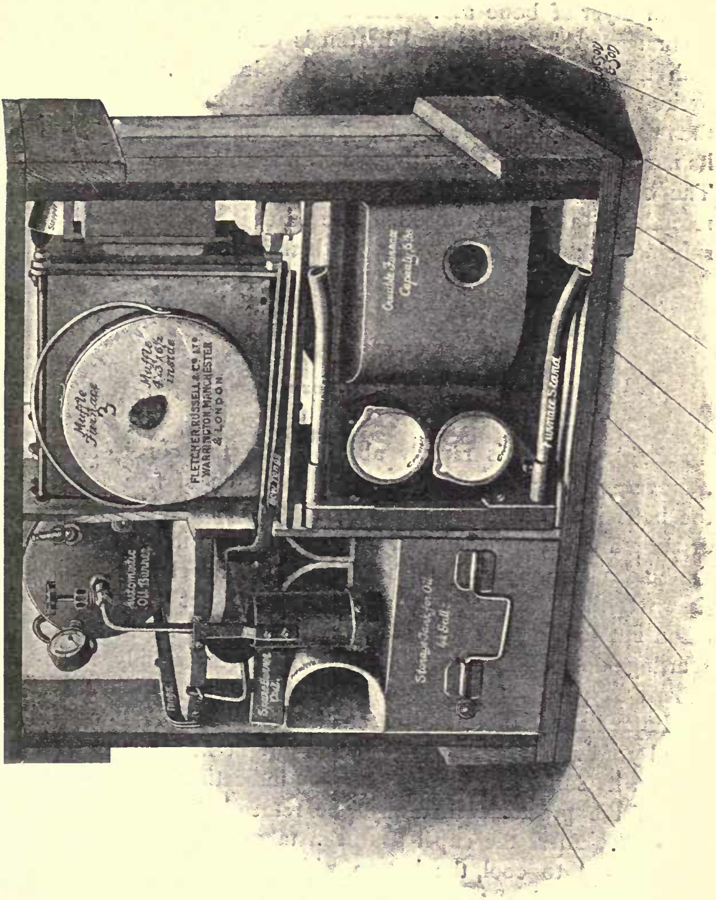


FIG. 40.—PROSPECTOR'S SET OF APPARATUS.

to describe the methods of extraction of gold from the lead button obtained as described on p. 38.

Cupellation of the Lead Button.—The muffle furnace having been charged with fuel, and the fire started, the cupels are introduced into the muffle by means of cupel tongs (Fig. 41), the bottom of the muffle being previously covered with a thin layer of bone ash. The muffle having been raised to an orange-red heat, the lead button is conveyed to the cupel with the tongs. Should the muffle be already raised to the desired temperature prior to the introduction of the cupels, then the latter should be gradually pushed into the muffle from its mouth, since sudden heating would be liable to cause cracks. The button immediately melts, and assumes a convex form, resembling a globule of oil. The lead is rapidly oxidized superficially; the molten oxide, in which is dissolved any other

FIG. 41.—CUPEL TONGS.

oxidizable metals, is rapidly absorbed by the cupel—some, however, escaping from the muffle in the form of fumes—and the button gradually diminishes in size, until but a small bead or bullion containing the gold remains. When it is seen that the button no longer diminishes in size, the cupel is gradually drawn to the mouth of the muffle. It must not be suddenly taken out to the cool air, otherwise there may be loss from spurting due to sudden liberation of gases, mainly atmospheric oxygen.

Immediately before the button sets it emits a flash of light called *fulguration* or *coruscation*, and bright iridescent bands play on its surface; this phenomenon, indicating the termination of the process, will always be remembered when once observed. After the cupel has been taken out of the muffle and allowed to cool, the button, which should have a clean convex surface, is detached by means of the end of a penknife, brushed, and conveyed to the left-hand pan of the assay balance with a forceps, for weighing.

Weighing the Button.—This important operation is performed by means of the assay balance. There are numerous types of this delicate instrument in use. A description of the one illustrated in Fig. 42 will suffice to explain the principle upon which they are constructed and manipulated. The weights are made of platinum and aluminium, the set containing from 1 gram (= 1000 milligrams) to 1 milligram, with

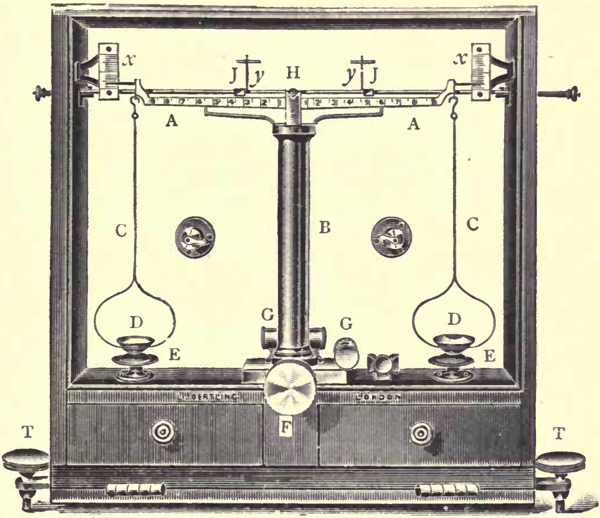


FIG. 42.—OERTLING'S ASSAY BALANCE. (Beam 6 inches long.)

milligram riders for manipulation on graduated scales on the arms of the beam AA. The balance can thus be made to indicate $\frac{1}{10}$ milligram in weight. The weights are contained in compartments in a small box (Fig. 43), so as to keep them from getting astray and from dust. They are conveyed to and from the balance by means of the forceps (Fig. 19, p. 33).

The mechanism of the balance is fixed in a glass case with sliding door, so as to keep away dust and also air-currents during weighing. The graduated beam AA, which is 6 inches long, is made of brass, and when oscillating the central steel knife-edge is supported on an agate plane. The stirrups C, C, made of German silver, are suspended from the ends of the arms by means of hooks. The pans D, D, resting on the stirrups, are made of silver; the pan supports E, E have a screw adjustment; the agate support for the beam at H is manipulated by the milled head F, which is connected with an eccentric at foot of pillar B. When at rest, the central steel knife-edge

FIG. 43.—ASSAY WEIGHTS.

of the beam is raised just clear of the agate plane at H by the supports at top of the pillar. On turning F to the left, a rod running through B and carrying the agate plane is raised, bringing the agate plane into contact with the steel knife-edge, thus setting the balance in action.

It will be observed that there are pointers protruding from the ends of the beam; these oscillate immediately in front of the divisions engraved on the ivory plates x, x, and indicate when the balance is in equilibrium, and also the correct weight obtained. The final adjustment of the necessary weight is obtained by manipulating a "rider"—these are seen in the centre of the weight-box (Fig. 43)—suspended at *y*, by means of the sliding-rods J, J, to the correct part of the graduated beam AA, each division of which represents $\frac{1}{10}$ milligram.

It is necessary that the balance should be perfectly level, and for this purpose it is provided with spirit-levels, G, G, the levelling being adjusted by the levelling-screws T, T. In order to keep the atmosphere inside the balance dry, to minimize

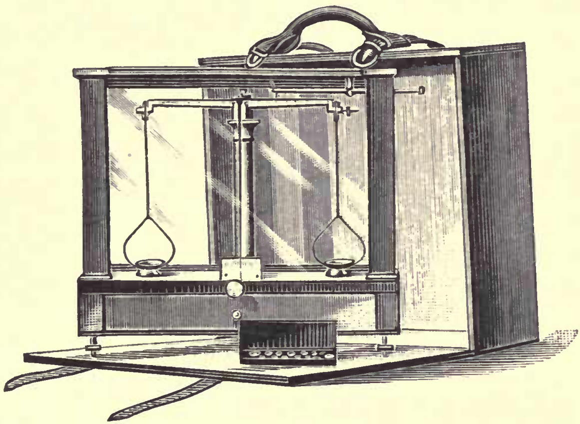


FIG. 44.—PORTABLE ASSAY BALANCE FOR PROSPECTORS.

rusting, hygroscopic substances—such as calcium chloride, recently burnt quicklime, or anhydrous sulphuric acid—should be kept inside in a shallow dish or beaker.

The button having been deposited in the left-hand pan, weights should be placed in the right-hand pan until short of about 5 milligrams. The case is then closed, and the rider moved on the beam until it is placed on a point that allows the beam to oscillate the same number of divisions above and below the centre of the ivory scales x, x. The correct weight of the button is then noted.

A handy form of portable assay balance for use by prospectors is illustrated in Fig. 44. It is sensitive to $\frac{1}{10}$ milligram, and can be packed in a light flat case, which can be strapped and carried by hand.

PARTING.

THE button of gold obtained from ores by the methods described almost invariably contains some silver, and it therefore becomes necessary to separate this from the gold in order to get an accurate result. To separate silver from gold, advantage is taken of the fact that silver is soluble in nitric acid, forming nitrate of silver, while gold is insoluble. It is necessary, however, that the silver should be present to the extent of at least two and a half times the proportion of gold present; if not, the silver is only partly dissolved, as a consequence of the excess gold cloaking as it were the action of the acid on the silver. By having the latter in excess, the solvent action of the acid upon it converts the metal into a porous mass, and thus the large surface exposed allows of the complete extraction of the silver.

To the weighed button is added two and a half times its weight of chips of silver-foil or wire, and the whole is wrapped up in a piece of lead-foil free from silver, weighing about 1½ gram, and this is conveyed by tongs to a red-hot cupel in a muffle, and subjected to cupellation in the manner described on p. 39. The resulting button of gold and silver is now placed on a polished steel block or anvil (Fig. 45), and flattened into a thin disc by carefully tapping with the flat surface of a metallurgical hammer (Fig. 46).

The flattened metal is now conveyed with the forceps to a porcelain crucible (Fig. 47). 10 c.c. of nitric acid (2 of strong acid to 1 of water) are poured upon it, and a watch-glass placed over the top. The whole is now transferred to a sand-bath or hot plate, and heated to boiling. It will be seen that the acid rapidly attacks the silver, which in the course of 10 minutes will have all gone into solution, leaving pure gold as a spongy mass in the original form of the disc if the silver was under three parts to one part of gold present; but if more than three parts of silver be present, then the gold will have fallen to powder, and settled on the bottom of the crucible as such. The

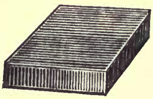


FIG. 45.—STEEL ANVIL.

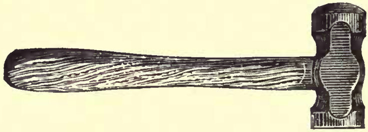


FIG. 46.—METALLURGICAL HAMMER.

crucible is now filled with distilled water by aid of a wash-bottle (Fig. 48), and the contents stirred with a glass rod; the gold rapidly settles at the bottom. The clear solution is now decanted from the sediment very carefully, and the crucible again filled with distilled water, stirred and decanted as before, until the washings show no turbidity, when a few drops of

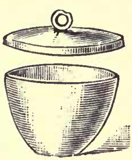


FIG. 47.—PORCELAIN CRUCIBLE.

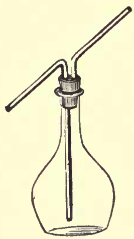


FIG. 48.—WASH-BOTTLE.

hydrochloric acid or solution of salt are added to it, showing that all nitrate of silver has been washed out of the gold. Generally four or five washings are sufficient.

The final washing and draining having been accomplished, the crucible and contents are very carefully dried in a water oven, and finally brought to a dull-red heat over a spirit-lamp.

When cool, the gold, in the form of powder or in one spongy piece, is transferred by the combined aid of the end of a pen-knife and camel-hair brush to the left-hand pan of the assay balance, and the weight observed. The difference between this weight and the original weight prior to the elimination of silver will represent the quantity of silver present in the sample taken.

The following table facilitates the calculation of the result per "long" and "short" ton and the French ton of 1000 kilogs.:—

ASSAY TABLE.

50 grams taken.

Milligrams of gold or silver obtained.	Yield per ton of 2000 lbs.			Yield per ton of 2240 lbs.			Yield per ton of 1000 kilogs.
	ozs.	dwts.	grs.	ozs.	dwts.	grs.	grms.
10	5	16	16	6	10	16	200
9	5	5	0	5	17	14	180
8	4	13	8	5	4	13	160
7	4	1	16	4	11	12	140
6	3	10	0	3	18	10	120
5	2	18	8	3	5	8	100
4	2	6	16	2	12	6	80
3	1	15	0	1	19	5	60
2	1	3	8	1	6	3	40
1	0	11	16	0	13	2	20
0·9	0	10	12	0	11	19	18
0·8	0	9	8	0	10	11	16
0·7	0	8	4	0	9	3·5	14
0·6	0	7	0	0	7	20	12
0·5	0	5	20	0	6	13	10
0·4	0	4	16	0	5	5·5	8
0·3	0	3	12	0	3	22	6
0·2	0	2	8	0	2	14·75	4
0·1	0	1	4	0	1	7·5	2
0·05	0	0	14	0	0	16	1

SCORIFICATION.

Assay of Concentrates, Sulphides, Arsenides, and Tellurides, by Scorification.—This method is in vogue for the assay of rich refractory ores without previous roasting, the principle of which is to convert the silica and other constituents of the ore into scoria or slag, brought about by oxidation of metallic lead by the atmosphere, instead of using oxide of lead as in the ordinary assay. The excess of lead used contains all the gold and silver contained in the ore, while any sulphur, tellurium, arsenic, are oxidized partly by the oxide of lead produced, and partly by direct oxidation in the atmosphere.

FIG. 49.—SCORIFIER.

FIG. 50.—SCORIFYING TONGS.

The process is carried on at a bright-red heat in a muffle in a scorifer (Fig. 49). This is a cup-shaped receptacle made of compact refractory fire-clay to withstand the corrosive action of the molten lead oxide; it is manipulated to and from the muffle by means of the scorifying tongs (Fig. 50).

The process is carried out as follows: 4 grams of the powdered ore are first intimately mixed with three to five times its weight of granulated lead free from silver, and about half a gram of borax. This mixture is run into the scorifier, and covered over with about 12 grams of granulated lead, and introduced into the muffle at a bright-red heat. The door of the muffle is closed for about a quarter of an hour so as to melt the charge, and then opened so as to let in a current of air through the muffle. The lead is now rapidly oxidized, and attacks the oxidizable metals present—most of the arsenic, sulphur, and tellurium escaping as oxide fumes—and converts them into a fluid slag. It is desirable to occasionally introduce about 1 gram of powdered charcoal on to the charge, by which means a portion of the lead oxide is reduced to the metallic state, which, in passing as small globules through the mass of molten scoria, carries with it to the bottom of the scorifier any traces of gold or silver that may still exist in it. The process is known to have terminated when a small iron rod, previously heated to redness, is introduced into the fluid mass, and on its withdrawal the adhering film of scoria runs off clean.

The scorifier is now taken out of the muffle, and its contents rapidly poured into an ingot mould (Fig. 28). The button containing the gold and silver settles in the metallic state in the bottom of the mould, by reason of its greater gravity, and the litharge and other metallic oxides settle as a brittle mass on the top. When cold, the adhering slag is separated from the lead button by tapping with a hammer, and the latter is then cupelled as described on p. 39, parted, and weighed. If the ore be low grade, several weighed portions of the ore can be subjected to the process, and the several lead buttons obtained, melted together, further scorified, and finally cupelled.

Assays of pyritic ores and concentrates can also be made, without previous roasting, in an ordinary crucible by using excess of litharge and also nitre; but it is necessary to know by preliminary assay what proportion of sulphides, etc., are present, in order to ascertain the necessary proportion of fluxes, etc.

The following table shows the charges for ores containing 10, 50, and 80–90 per cent. sulphides :—

	10 per cent. sulphides.	50 per cent. sulphides.	80–90 per cent. sulphides.
	grms.	grms.	grms.
Ore	25	25	25
Glass . . .	12	12	—
Flour . . .	1	—	—
Litharge . . .	60	60	100
Soda . . .	40	40	34
Borax . . .	—	—	30
Nitre . . .	—	—	40
Salt . . .	—	—	35
Iron . . .	—	4·5	—

Should there be any iron matt formed, more nitre should be added in a repeat assay. If too large a button of lead is produced, this should be reduced by scorification. The salt is added as a covering.

ASSAY OF BULLION.

Expressing the Gold Value.—The intrinsic value of bullion being directly proportional to the amount of pure gold it contains, its accurate assay for the noble metal becomes a matter of great importance. Unrefined bullion, as received at the Mint from the reduction works and cyanide plants, invariably contains silver, and often more or less quantities of copper, lead, antimony, zinc, tin, and iron. Silver is present as a consequence of its being present in the original ore; the copper may be present owing to a little finding its way into the gold amalgam scraped from the amalgamated copper plates of the gold-mills, and also from the accidental introduction of old cartridge-cases, etc., with the ore into the stamp battery. The introduction of metallic oddments into mills with the ore, such as pieces of tin plate, solder, galvanized iron, nails, etc., is occasionally the cause of a base bar.

There are two systems in use for expressing the value of bullion.

(1) The amount of gold present is expressed in terms of "carats," absolutely pure gold being expressed as being 24 carats; each carat is divided into four imaginary grains, and these again are subdivided into eighths and "excess grains," one carat grain representing 60 excess grains; so that the unit weight or "assay pound" being taken, its divisions may be understood from the following table:—

Assay pound.	Carats.	Carat grains	Eighths.	Excess grains.	Decimal equivalent.
					Per cent.
				1	0·017
			1	7·5	0·130
		1	8	60	1·042
	1	4	32	240	4·167
1	24	96	768	5760	100·000

It will be seen that the excess grain is the $\frac{1}{5700}$ part of the metal taken for assay, the ratio being the same as that of the grain to 1 lb. troy.

The English standard gold coinage is 22 carats, that is, in every twenty-four parts of the coin there are twenty-two parts of gold and two parts of copper, or it contains 91·667 per cent. of pure gold. The "trade system" of reporting the value of alloy does not generally give the amount of gold present, but states the results as being so much better or worse than the standard, indicated by prefixing the letter B or W, as the assay demands. Thus, if an assay be returned as B 1 ct. 3 grs. 5 eighths + 3·5 excess grains, it means that this amount added to 22 carats gives the actual amount in carats or twenty-four parts of alloy.

(2) The decimal system as used in France and America, is far more simple and sensible than the carat system. In it the amount of gold present is expressed in thousandths, or parts of gold in 1000 parts of bullion. Thus in France and America the standard gold coin is expressed as being 900 thousandths fine, that is, in every 1000 parts there are 900 parts of gold and 100 parts of copper, or 90 per cent. of gold and 10 per cent. of copper. The English standard, 22 carats, is represented in the decimal system as being 916·667 thousandths fine.

From the following table results can be calculated from one system into the other :—

Carat.	Decimal equivalent.	Carat grains.	Decimal equivalent.
1	41·667	1	10·417
2	83·333	2	20·833
3	125·000	3	31·250
4	166·667	4	41·667
5	208·333	**Eighths.**	**Decimal equivalent.**
6	250·000	1	1·302
7	291·667	2	2·604
8	333·333	3	3·906
9	375·000	4	5·208
10	416·667	5	6·510
11	458·222	6	7·812
12	500·000	7	9·115
13	541·667	8	10·417
14	583·333	**Excess grains.**	**Decimal equivalent.**
15	625·000	1	0·174
16	666·667	2	0·347
17	708·333	3	0·521
18	750·000	4	0·694
19	791·667	5	0·868
20	833·333	6	1·072
21	875·000	7	1·215
22	916·667	7·5	1·302
23	958·222		
24	1000·000		

Process of Assay.—The method described will be that in vogue at the Royal Mint, and consists of—

(1) The accurate weighing and preparation of the assay piece or sample. In the case of ingots, two corners, one from the top and one from the bottom, are chipped off with a cold chisel.

(2) Cupellation, or removal of copper or other oxidizable metals by oxidation and absorption in bone ash.

(3) Parting by inquartation, or separation of silver from the gold by nitric acid.

(4) Final weighing of the gold "cornet," and applying necessary corrections as a result of assaying the same weight of pure gold under the same conditions.

Preparation and Weighing of Assay Piece.—In the Mint, when a gold bar is to be assayed, two chips are cut off with a chisel, one from the top corner and the other from the bottom corner. These are rolled out into thin strips by means of the "cornet" rolls. Fig. 51 illustrates the latest design of

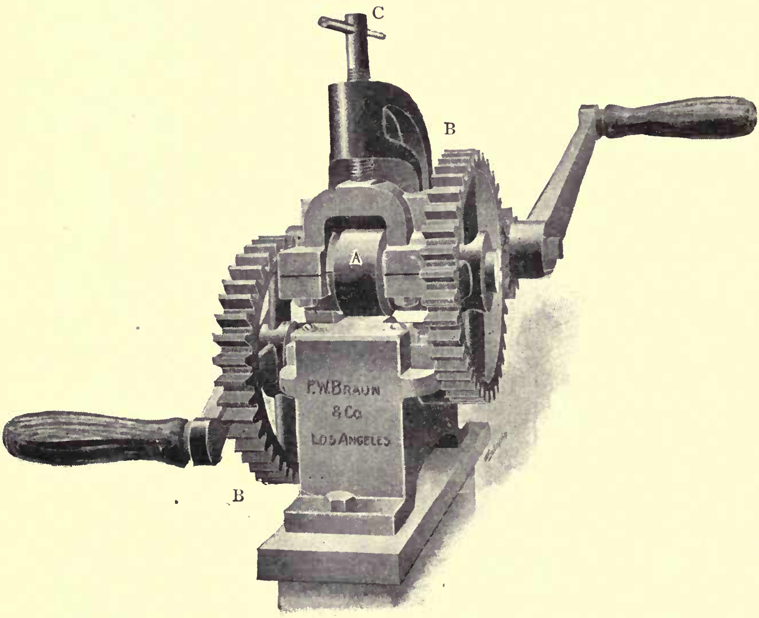


FIG. 51.—CORNET ROLLS.

rolls essential to gold assaying. The top roll will be observed at A, the bottom one being immediately underneath. They are revolved by hand by means of the double pair of cogs B, B, any desired pressure being obtained by manipulating the screw C. A feed-plate that is tangent to the contact point of both rolls obviates the difficulty of inserting a small piece of bullion between the rolls—a common source of trouble in ordinary rolls. The button to be rolled is placed on the feed-plate, and may be easily pushed with a pair of pincers between the rolls. Opposite the feed-plate, where the metallic strip emerges, there is another plate that closely wipes the bottom roll, and conducts it away from the rolls. This prevents the strip from dropping on to the floor or becoming lost.

The two chips are rolled into thin plates, and cut up into very small pieces by means of shears (Fig. 52), and then mixed. 1 gram of this—if the metal is very base bullion—is now accurately weighed, or, if nearly pure gold, 0·5 gram is weighed for assay.

In many assay offices, about 1 dwt. of drillings are bored out of the top and bottom of the bar and mixed, any bits of steel that may have been rubbed off the drill being extracted by means of a magnet.

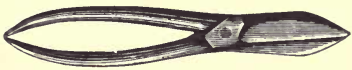


FIG. 52.—SHEARS.

As it is necessary to add silver to about two and a half times the weight of gold present, it is essential to know about how much already exists in the bullion. An experienced assayer can approximately tell, by the colour, the amount present—the lighter the colour, the more the silver. Copper gives a more or less coppery colour to the bar. Frequent handling and assaying of bullion of various values soon gives one a rough idea of its approximate value, by observation of colour, hardness, etc.

To ascertain approximately the amount of silver, and also of the oxidizable metals present, such as copper, lead, etc., weigh 1 gram of the clippings or drillings of the bullion, and wrap up in 30 grams of lead-foil, and cupel and weigh the button of gold and silver; the difference in weight from the gram taken will equal the amount of copper, etc., present. Now wrap this button, together with 3 grams of silver, in 30 grams of sheet lead and cupel. The button thus obtained is hammered into a disc, and the silver dissolved out by nitric acid in a porcelain crucible. As there is in this case an excess of silver, the gold will be left in the form of a brown powder. This is washed and filtered, and estimated as described on p. 55. The difference in the weight of gold thus obtained, plus the weight of copper, etc., found, from the original gram taken, gives the amount of silver present.

Now, having made an approximate determination of the gold, silver, and base metals present, the accurate assay can be proceeded with. 0·5 gram, or 1 gram, as the case demands, of the prepared sample is accurately weighed on the assay balance, and mixed with silver to two and a half times the

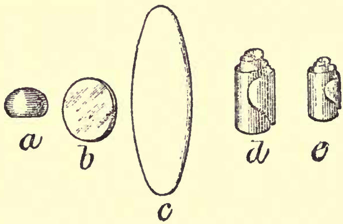


FIG. 53.—GOLD BUTTONS AND CORNETS.

weight of gold contained in it, as found by preliminary assay. The two metals are then wrapped up in 30 grams of lead-foil, and subjected to cupellation as described on p. 39. (It may here be remarked that, to ensure accuracy, a duplicate assay should be simultaneously made.) The button of gold and silver thus obtained is next prepared for treatment with nitric acid in order to dissolve out the silver; and for this purpose the button is rolled into a thin strip, and curled up into a shape known as a "cornet." Fig. 53 illustrates the transition from the button to the cornet.

a is the original button; it is hammered into shape *b*, as described on p. 53; it is then rolled into shape *c* by means of the cornet rolls (Fig. 51), and this is coiled into the cornet *d*, which still retains its shape as pure gold after the silver has been eliminated, but diminished in size as seen in *e*.

The cornet *d* is now introduced into a parting flask, C (the illustration (Fig. 54) shows half a dozen of them in one stand, in which six partings can be simultaneously carried on), and about 80 c.c. of nitric acid of specific gravity 1·26 poured into it. It will be observed that long glass tubes D are inserted into the necks of the flasks, which rest on "rose" Bunsen

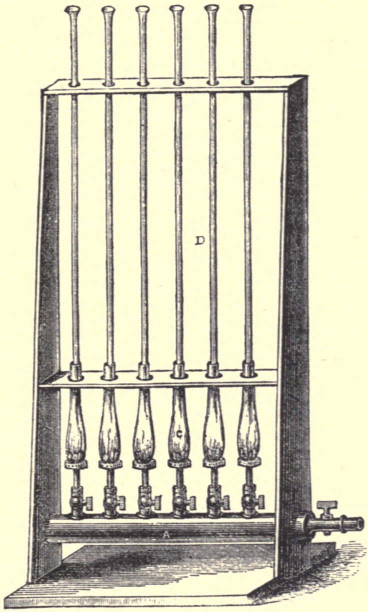


FIG. 54.—ASSAY FLASKS.

burners, from which the necessary heat required to effect the solution of the silver is obtained by means of coal-gas. The tubes condense most of the acid vapours evolved during the solution of the silver, while the gaseous oxides of nitrogen escape. Here it is necessary to remark that the irritating fumes of the oxides of nitrogen should be conveyed beyond the pale of the operator.

The cornet and acid being introduced into the flask, heat is carefully applied until the acid boils, and it is kept boiling from 3 to 5 minutes, after which the liquid is drained off and the cornet washed with distilled water. The cornet is now boiled for 15 or 20 minutes with about 50 c.c. of nitric acid of specific gravity 1·30. To prevent "bumping," consequent from the necessity of the freedom of vapour at the bottom of the flask, a few pieces of broken porcelain about the size of peas are introduced. This prevents violent and sudden ebullition. The acid is now poured off, and washed three or four times with 20 c.c. of distilled water, to free the cornets from nitrate of silver. After the last washing has taken place, judged as described on p. 54, a porcelain crucible is placed upside down on the tube, and, both held tight, it is then inverted; the liquid flows away, and the cornet and pieces of porcelain are retained in the crucible. The latter are taken out by means of forceps, and the cornet of the now pure gold is dried in the crucible, first in a water-bath, and then heated over a spirit-lamp (*vide* p. 54) and weighed, the calculation of the weight into carats or thousandths being determined by reference to the table on p. 61.

Now, while the weight of the pure gold in bullion thus ascertained will be sufficiently accurate for ordinary purposes, in cases where thousands of ounces of bullion are to be accurately assayed, the determination of the absolute amount of gold present will be obvious. There are certain errors that may take place, which may be *plus* or *minus* the result obtained, depending upon a variety of circumstances, including amounts of oxidizable metals present, temperature of cupellation, etc.; and although this amount may not vary more than 0·2 to 0·5 in 1000, this can be accurately determined by subjecting two or three check assays upon pure gold—prepared in the manner described on p. 17—precisely under the circumstances as the sample as regards the amount taken for assays, amount of silver and lead used, temperature, etc. The amount found may be *plus* or *minus* the amount originally taken, and this must be added or subtracted from the result of the assays of the samples and those duplicately conducted at the same time and in a similar manner.

The correction to be applied to a gold assay will be evident from the following formula :—

Let 1000 be the weight of alloy taken ;

p = the weight of the piece of gold finally obtained ;

x = the actual amount of gold in the alloy expressed in thousandths ;

a = the weight of gold (supposed to be absolutely pure) taken as a check, which approximately equals x ;

b = the loss or gain in weight experienced by a during the process of assay, expressed in thousandths ;

k = the variation of "check gold" from absolute purity, expressed in thousandths ;

Then the actual amount of fine gold in the check piece $= a\left(1 - \frac{k}{1000}\right)$, and x, the corrected weight of the assay will $= p - \frac{ak}{1000} \pm b$; b being added or subtracted according as it is loss or gain.

If a be assumed to be equal to x, the equation becomes

$$x = \frac{p \pm b}{1 + \frac{k}{1000}}.$$

Example—

Let p = 901·1 thousandths
a = 920·0 ,,
b = 0·3 ,, (gain in weight)
k = 0·1 ,,

Then, by the first formula—

$$x = 901{\cdot}1 - \frac{920 + 0{\cdot}1}{1000} - 0{\cdot}3$$

For, as b is a gain in weight, it must be deducted ; hence—

$$x = 901{\cdot}1 - 0{\cdot}092 - 0{\cdot}3$$
$$= 900{\cdot}708$$

and by the second formula—

$$x = \frac{901{\cdot}1 - 0{\cdot}3}{1 + \frac{0{\cdot}1}{1000}}$$
$$= 900{\cdot}708$$

Determination of Gold by Wet Assay.—Advantage is taken of the solubility of gold in aqua regia (2 parts of hydrochloric acid to 1 part nitric acid) as perchloride ($AuCl_3$), and its subsequent precipitation therefrom by reducing agents in the pure metallic state, as a basis of estimating gold in the wet way.

The method adopted is as follows: 1 gram of the bullion in turnings or drillings, or, if a rich ore in fine powder, a quantity that would contain about 0·5 gram gold, is weighed and introduced into a 100 c.c. beaker; about 20 c.c. of strong hydrochloric acid is added, and the beaker covered over with a clock-glass, and placed on a hot-plate or sand-bath. Strong nitric acid is now gradually added—about 12 c.c. will be found sufficient—and the whole kept near the boiling point until all that is soluble is dissolved. The cover is now removed and the liquid evaporated to dryness with 10 c.c. of strong hydrochloric acid. When cold, 5 c.c. of HCl are added and warmed, and then 50 c.c. of distilled water, and the whole heated until all that is soluble is dissolved. If ore was operated on there would doubtless be an insoluble residue of siliceous matter, while in the case of bullion containing only, say, lead and copper, there would be no residue. Silver would be rendered insoluble as chloride.

Should there be any residue, this is filtered off, and the filtrate of chloride of gold, etc., received in a porcelain basin of 150 c.c. capacity; the residue is washed with hot distilled water till free from soluble salts, and the solution diluted to 100 c.c. It now becomes necessary to precipitate the gold. To effect this a clear solution of ferrous sulphate ($FeSO_4$) is added in excess, and the whole stirred and allowed to stand in a warm place for a few hours until the whole of the gold present has subsided as a fine brown powder. The gold is now filtered through a Swedish filter paper, and the solution tested to ensure complete precipitation of gold by the addition of more $FeSO_4$. The amorphous gold, thoroughly washed from soluble salts with hot water, is now transferred to a weighed porcelain crucible with the filter, and dried at the mouth of a hot muffle, after which it is gradually inserted into the red-hot interior until the paper has all completely burnt off. The crucible is now withdrawn, cooled in a desiccator, and weighed; the increase in weight of the crucible equals the weight of the gold in the sample taken, which can be expressed in percentage, thousandths or carats.

Valuation of Gold sent to the Mint.—To find the value per ounce of gold sent from a mine to the Mint, divide the standard gold by the weight before melting, and multiply the result by £3 17*s*. 10½*d*.

For instance, supposing the Mint return to show—

	ozs.
Weight before melting	47·41
Standard gold	38·19

the calculation would be as follows:—

4741)3819·0(0·805	0·805 × £3 17*s*. 10½*d*.
3792·8	= 0·805 × £3·894
———	·805
26200	———
23705	19470
———	311520
2495	———
	£3·134(670)
	20
	———
	s. 2·680
	12
	———
	d. 8·160 = £3 2*s*. 8*d*., value per ounce of gold as produced from the mine.

Assay of Minute Quantities of Gold by the Microscope.*—The aid of the microscope for ascertaining the weight of very small "prills" of gold is now often resorted to, especially when the assay balance available is not sufficiently sensitive. For quantities of gold from 0·5 to 0·005 milligram

* *Vide* Dr. Tate's Paper to Liverpool Polytechnic Society, November, 1889.

a microscope with $\frac{1}{2}$-inch objective and B eye-piece is suitable. The measurements are made with the help of a scale engraved or photographed on a circular piece of glass, which rests on the diaphragm of the eye-piece. This scale and the object upon the stage can be easily brought into focus at the same time. The button of gold obtained by cupelling is loosened from the cupel by gently touching it with the moistened point of a knife; it generally adheres to the knife, and is then transferred to a glass slide. The slide is placed on the stage of the microscope, illuminated from below, and the bottom is brought into focus, and so placed that it apparently coincides with the scale. The diameters in two or three directions (avoiding the flattened surface) are then read off: the different directions got by rotating the eye-piece. The mean diameter is taken.

The weight of the button is arrived at by comparing with the mean diameter of a *standard prill* of gold of known weight. The weights are in the proportion of the cubes of the diameters. For example, suppose a prill has been obtained which measures 12·5 divisions of the scale, and that a standard prill, weighing 0·1 mg., measures 11·1 divisions. The weight will be calculated as follows:—

$$11{\cdot}1^3 : 12{\cdot}5^3 :: 0{\cdot}1 : x$$

$$x = \frac{0{\cdot}1 \times 12{\cdot}5 \times 12{\cdot}5 \times 12{\cdot}5}{11{\cdot}1 \times 11{\cdot}1 \times 11{\cdot}1} = 0{\cdot}143 \text{ mg.}$$

The calculations are simplified by the use of a table of cubes. The standard prills used in the comparison should not differ much in size from the prills to be determined. They are prepared by alloying known weights of gold and lead, so as to get an alloy of known composition, say 1 per cent. gold. Portions of the alloy containing the weight of gold required (say 0·1 mg.) are then weighed off and cupelled on small smooth cupels, made with the finest bone ash. Care must be taken to remove the cupels as soon as cupellation has finished. Several standard prills of the same size should be made at the same time, and their mean diameters calculated. The lead for making the gold-lead alloy is prepared from litharge purified by reducing from it about 10 per cent. of its lead by fusion with a suitable proportion of flour; the purified litharge is powdered, mixed with sufficient flour, and reduced to metal.

In determining the gold contained in small buttons of silver-gold alloy obtained in assaying (and in which the silver is almost sure to be in excess of that required for parting), transfer the button from the cupel to a small, clean, porcelain crucible; pour on to it a few drops of dilute nitric acid (50 per cent. in water), and heat carefully until action has ceased.

If the residual gold is broken up, move the crucible in a manner that the particles may cohere. Wash three or four times with distilled water, half filling the crucible each time, and decanting off against the finger. Dry the crucible in a warm place, and when dry, take the gold up on a small piece of pure lead. Half a grain of lead is sufficient, and it is best to hold it on the point of a blunt penknife, and press it on the gold in the crucible. The latter generally adheres. Transfer to a small, smooth cupel, and place in the muffle. When the cupellation has finished, the button of gold is measured as already described.

Estimation of Proportion of Gold in Quartz from the Specific Gravity.—Should it be desired to determine the amount of gold present in a rich piece of quartz (provided no other mineral is present in quantity), this can be calculated with tolerable accuracy from an estimation of the specific gravity of the sample, consequent upon the great difference in the specific gravity of gold and silica—19·2 and 2·6 respectively.

A handy machine for this purpose is Walker's specific gravity balance (Fig. 55).

The specimen is attached to a piece of horsehair, and suspended on to the graduated arm of the balance, and its weight first ascertained in air; it is then weighed in water at 15·5° C., as in the sketch. Its weight in water will, of course, be less than its weight in air, and by dividing the difference into the latter the specific gravity is obtained.

We will now illustrate how the proportion of gold is calculated.

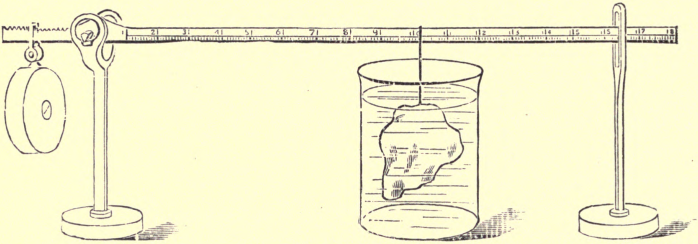


FIG. 55.—WALKER'S SPECIFIC GRAVITY BALANCE.

Example—

Let A = weight in grams of sample in air ;
B = weight in grams of sample in water ;
C = specific gravity of gold ;
D = specific gravity of quartz ;
X = weight of gold in sample ;

Then A − X = weight of quartz.

$\frac{X}{C}$ = weight of water displaced by the gold in the sample when weighed in water

$\frac{A - X}{D}$ = weight of water displaced by the quartz in the sample when weighed in water.

Then $\frac{X}{C} + \frac{A - X}{D} = A - B$ = total water displaced by sample.

$$\text{Then } x = \frac{DCA - DCB - AC}{-C + D}$$

$$DX + AC - CX = ACD - BCD$$

$$X = \frac{ACD - BCD - AC}{D - C} = \frac{C(AD - BD - A)}{D - C}$$

ASSAYS IN CYANIDATION, CHLORINATION, AND AMALGAMATION PROCESSES.

Cyanidation—Synopsis of Process.—The principle of this process, commercially perfected by Messrs. MacArthur and Forrest, is based upon the fact that a very dilute solution of cyanide of potassium (KCN), containing so small a quantity as from 0·1 to 0·5 per cent. of the salt in solution, dissolves finely divided gold from its association with other minerals, and that such a dilute solution has a selective or preferential solvent action on gold which a stronger solution would not have, numerous other minerals being soluble in strong but insoluble in weak solutions, the reaction taking place being—

$$2Au + 4KCy + O + H_2O = 2KAuCy_2 + 2KHO$$

the gold going into solution as double cyanide of gold and potassium.

In the ordinary cyanide process air is essential, as will be seen by the presence of oxygen in the above reaction. Of late, however, there have been improvements made which do not necessitate the presence of air, small additions of chloro- or bromo-cyanogen answering the same purpose.

The gold is precipitated from its combinations with potassium and cyanogen with metallic zinc according to the theoretical reaction—

$$2KAuCy_2 + Zn = 2Au + K_2ZnCy_4$$

and is afterwards smelted by well-known methods.

Tests necessary in Cyanidation.—These should include free sulphuric acid and other cyanicides, such as sulphates and basic sulphates of iron, and calculation of the amount of lime or caustic soda necessary to neutralize these; the consumption of cyanide per ton; the percentage of extraction; testing the strengths of cyanide solutions.

Acidity of Gold Ores.—Should iron pyrites be present in the ore, they gradually become oxidized in a damp atmosphere, forming free sulphuric acid and sulphate of iron, thus—

$$FeS_2 + H_2O + 7O = FeSO_4 + H_2SO_4$$

Other basic sulphates are also formed.

Free sulphuric acid and the sulphates of iron decompose potassium cyanide, and unless they should have been washed out or neutralized with lime or caustic soda prior to leaching with the cyanide solution, serious consequences would accrue —there would be an undue amount of cyanide used up, and the extraction would also be low.

Should the ore be acid, stirring it with distilled water, applying a blue litmus, the latter would be turned red.

Should it be found necessary to determine the amount of acid present and the amount of caustic soda or lime necessary to neutralize it prior to cyanidation, the following is a convenient method to adopt:—

200 grams of the ore are weighed and transferred to a beaker, and 200 c.c. of water poured on and well stirred. In the mean time, 10 grams of commercial caustic soda are dissolved in water and diluted in a graduated vessel (Fig. 57) to 1 litre (= 1000 c.c.) and well mixed. A burette (Fig. 59) graduated in $\frac{1}{10}$ c.c. is now filled with this solution, and is gradually run into the beaker containing the ore and water, stirring until a drop taken out with the stirrer just turns red litmus paper blue. Each cubic centimetre required corresponds to $\frac{1}{10}$ lb. of the same strength of caustic soda necessary to neutralize the acid and acid salts contained in 1 ton of the ore. If the consumption be more than 3 lbs. per ton, it will then be found more economic to give the ore a water wash

prior to running on a weak alkaline wash and the cyanide solution on the large scale.

Extraction Tests.—First make an accurate assay of a portion of the powdered sample. Weigh out 200 grams of the sample—should it be acid, it is previously treated with water and alkali in the proportion that it is proposed to use on the large scale—and transfer to the funnel of the apparatus shown n Fig. 56.

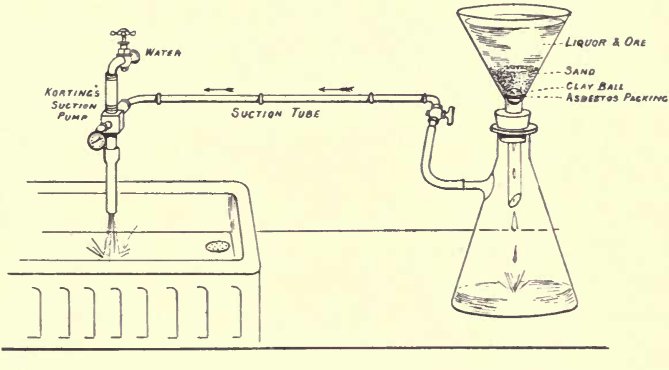


FIG. 56.—CYANIDE ASSAY APPARATUS.

The sketch will be readily understood. The apparatus consists of a funnel so arranged as to imitate the cyanide process on a small scale. The tube passes through a cork fitted into a flask which is connected with a vacuum apparatus. As will be observed, the funnel is packed with asbestos and sand, which acts as a filter. 150 c.c. of a 0·5 per cent. solution of potassium cyanide is poured on the sample in the funnel, and allowed to stand for a couple of days, after which a slight vacuum is produced by turning on the water sufficient to allow the solution to gently trickle into the flask. When the solution has all drained through, the flask is emptied and the funnel refitted into it, and the solution again returned and allowed to gently percolate as before.

The length of time necessary for complete extraction will depend upon the nature of the sample and the degree of fineness of the gold; the more minute the particles of gold, the sooner its solution takes place. From one to three days should be sufficient with the above amount of "strong" solution.

When it is assured that all the soluble gold is dissolved, the solution is allowed to completely drain into the flask, and the remaining solution still clinging to the ore is washed out with water. The leached ore is now taken out and dried in a water oven or on a hot plate, and 100 grams taken and the gold estimated in it, using double the amount of fluxes given on p. 35, and the result obtained by the assay table, p. 55, multiplied by 2, will give its assay value, and, subtracting this from the original assay, the amount of extraction will thus be obtained.

Determination of Gold in Solution.—It is sometimes advisable to estimate the gold that has gone into the solution direct. In order to effect this, transfer the solution to a large porcelain dish, and add to it 80 grams of litharge, and carefully evaporate to dryness. Now add to it 30 grams of borax, 120 grams of carbonate of soda, and 10 grams of flour. Thoroughly mix the whole by means of a flexible steel spatula, and transfer to an assay crucible, and proceed with the assay as described on p. 72. As 200 grams were taken, the result obtained by reference to the assay table on p. 55 should be multiplied by 4.

Another method of determining the gold in solution is to add an excess of a solution of nitrate of silver. This produces a curdy precipitate of cyanide of silver and a double cyanide of gold and silver, which rapidly settles. This is filtered and dried, and then mixed with litharge and the usual fluxing materials, and fused in the usual manner. The button of lead obtained is cupelled, the silver separated from the resulting bullion with nitric acid, and the gold weighed.

Determination of the Consumption of Potassium Cyanide.—The method adopted is a simple volumetric one, and depends upon the fact that if a solution of nitrate of silver be gradually added to a solution of potassium cyanide, there is produced a double cyanide of potassium and silver, according to the reaction—

$$2KCy + AgNO_3 = AgKCy_2 + KNO_3$$

Now, this double cyanide is a white precipitate, and is soluble in excess of potassium cyanide, so that immediately the latter is all

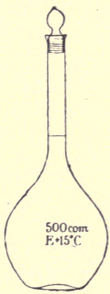


FIG. 57.—GRADUATED FLASK.

FIG. 58.—CYANIDE TEST FLASK.

FIG. 59.—GRADUATED BURETTE.

decomposed a permanent white precipitate takes place. This forms the basis of the method, which is carried out as follows: 13·05 grams of silver nitrate are dissolved in pure water and diluted to exactly 1 litre = 1000 c.c. in a graduated flask (Fig. 57) and stocked in a dark-blue bottle. The strength of this solution is thus so arranged that when 10 c.c. of the sample of cyanide solution are taken for testing, each cubic centimetre of the silver solution taken to form a permanent white precipitate represents 0·1 per cent. of pure potassium cyanide (KCN) in solution. 10 c.c. of the cyanide solution obtained in the extraction test are poured into a small flask (Fig. 58). A burette graduated in $\frac{1}{10}$ c.c. (Fig. 59) is now filled with the nitrate of silver solution, and this is gradually run into the cyanide drop by drop, gently shaking, until finally a drop produces a permanent white turbidity. The volume of silver solution consumed is now noted. Suppose 2·2 c.c. were required, and the original solution contained 0·5 per cent. KCN, then $2·2 \times 0·1 = 0·22$ per cent. in solution and $0·50 - 0·22 = 0·28$ per cent. KCN consumed.

Testing the Strength of Cyanide Solutions.—Since the cyanide solutions used in extraction of gold are used over and over again, it becomes frequently necessary to ascertain the strength of them in order to know the amount of additional cyanide necessary to add to make them up to the required strength. The method adopted is the same as that used to ascertain the consumption of cyanide, 10 c.c. of the solution being taken, and titrated with the standard nitrate of silver solution. Its strength is thus ascertained, and it is then necessary to calculate how much of a strong solution contained in the dissolving tank is necessary to add in order to increase its strength to the required degree. The following formula may be used :—

A = desired strength of stock solution per cent.
B = present strength " " "
C = the strength of dissolving tank solution per cent.
D = the quantity in tons, lbs., gallons, litres, etc., of stock.

$\frac{A - B}{C - A} \times D$ = quantity of dissolving tank solution to be added (in tons, lbs., gallons, litres, etc.).

Example.—Supposing the stock solution to consist of 100,000 gallons of 0·4 per cent. strength, and it be desired to bring this up to 0·6 per cent. by adding some 10 per cent. solution, then—

$\frac{0·6 - 0·4}{10 - 0·6} \times 100,000 = 2127·65$ gallons of the dissolving tank solution.

Tank Capacities.—To calculate the cubical contents of a circular tank, multiply the square of the radius by 3·14, and the product by the height of the tank. Supposing a tank was 20 feet in diameter and 6 feet high, then—

$$10^2 \times 3{\cdot}14 \times 6 = 1884 \text{ cubic feet}$$

1 cubic foot of water weighs 62·3 lbs., therefore—

$$1884 \times 62{\cdot}3 = 117573, \text{ and } \frac{117573}{2000} = 58{\cdot}78 \text{ tons of water}$$

If it is desired to prepare a 0·3 per cent. stock solution, then $\frac{117573 \times 0{\cdot}3}{100} = 352{\cdot}71$ lbs. of cyanide will have to be dissolved in it.

After treatment it is found that the cyanide percentage has fallen to 0·16, which equals $\frac{117573 \times 0{\cdot}16}{100} = 188{\cdot}11$ lbs. left in solution, and to make it again up to 0·3 per cent. another 164·61 lbs. of cyanide must be added.

Extraction Test for Slimes.—Since slimes that have been cyanided cannot be treated by the ordinary percolation method, owing to the difficulty in filtration, unless they are filtered under pressure, the foregoing methods are modified. The writer has found that the apparatus shown in Fig. 60 acts admirably for slimes cyanidation.

It consists of a cylindrical glass jar clamped on to a mechanical device, whereby it is made to revolve by means of a water motor or by hand. The jar is charged standing vertically, the mouth is covered with a sheet of indiarubber, the clamps are turned up vertically, and the jar tightly screwed down, after which it may be coupled to the motor horizontally as seen in the sketch. 200 grams of the slimes are introduced into the cylinder, together with 200 c.c. of 0·2 per cent. solution of cyanide, and made to revolve about thirty revolutions per minute for about 12 hours, after which the cylinder is turned up vertically and allowed to stand for a short time. When sufficient clear solution appears, 10 c.c. of this are taken, and the consumption of cyanide determined as described on p. 76.

The solution is now stirred up with about 20 c.c. of milk of lime, and allowed to settle for a few hours. The clear solution is then decanted, the residue, mixed with clean water, stirred, allowed to settle and decanted as before, this being repeated three times to ensure complete extraction. The residue may

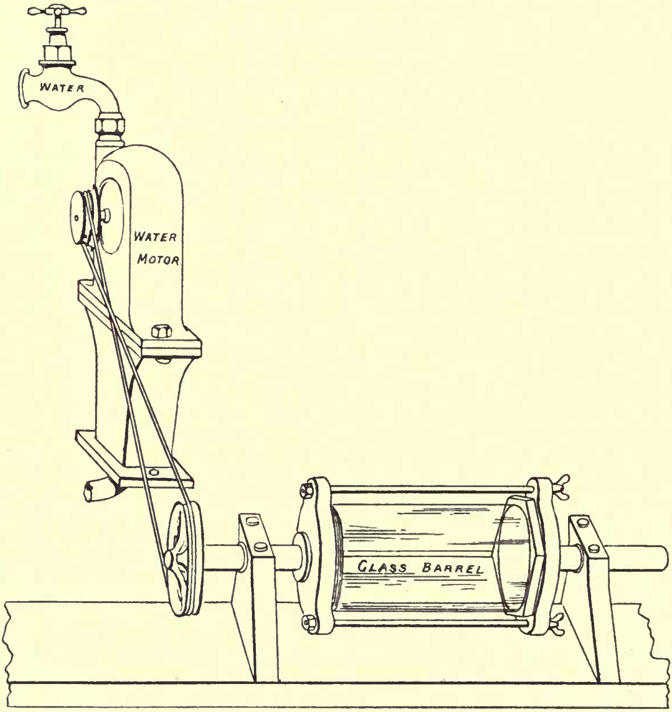


FIG. 60.—CYANIDE TEST APPARATUS FOR SLIMES.

then be dried and assayed; and the result deducted from the amount found in the original sample gives the amount extracted, which should be calculated centesimally. The gold in solution may be estimated by the methods described on p. 76.

This apparatus can also be advantageously used for the rapid cyaniding of sands and for testing the Newberry-Vautin chlorination process on small samples of ore. It can also be used for amalgamation assay.

Where such apparatus is not available, sands and slimes can be cyanided in corked bottles, giving them a shake occasionally.

Chlorination—Synopsis of Process.—The principle of this process is based on the fact that free gold is dissolved by a solution of chlorine gas, or compounds that liberate nascent chlorine, forming chloride of gold, which is soluble. Thus—

$$Au + Cl_3 = AuCl_3$$

All ores containing pyrites, mispickel, tellurides, etc., are first roasted before being subjected to the process. Quartz and oxidized ores containing fine gold and no other minerals can be treated without previous roasting.

The gold is obtained from the filtered chloride by precipitation with sulphate of iron or charcoal, or as an electrolytical deposit, from which it is smelted and refined by usual methods. There are numerous chlorination processes in vogue, all of which have for their object the conversion of the gold into chloride, and the subsequent reduction of the chloride into metallic gold. For a full description of these, the reader is referred to the large manuals on Metallurgy.

Chlorination Assay.—This can be conveniently carried out by the apparatus seen in Fig. 61, which consists of a flask, A, for generating chlorine gas; *d*, a wash-bottle containing water, which serves to wash the gas free from hydrochloric acid. C is a glass cylinder in which the ore is chlorinated; D is a cylinder containing rolls of blotting-paper or shavings moistened with alcohol, which serve to absorb the excess of chlorine that escapes. The method is conducted as follows: 20 ozs. of ore, previously roasted free from sulphides, arsenides, etc., are weighed. Into the generating flask A place a mixture of 1 oz. of peroxide of manganese in powder, 4 ozs. of hydrochloric acid, and 1 oz. of sulphuric acid previously mixed with 1 oz. of water. Into the glass cylinder C, which is 8 to 10 inches high and $2\frac{1}{2}$ inches wide, is introduced fragments of bottle glass about the size of hazel nuts, the layer being a couple of inches high. Over this is placed a thin layer of coarse clean sand, and then a layer of fine quartz sand. Over the top of this now place loosely the 20 grams of ore previously moistened with water. The whole apparatus is now coupled together with glass tubing, as seen in the sketch. The cover for the cylinder C is made of indiarubber.

A gentle heat is now applied to the flask A, when the

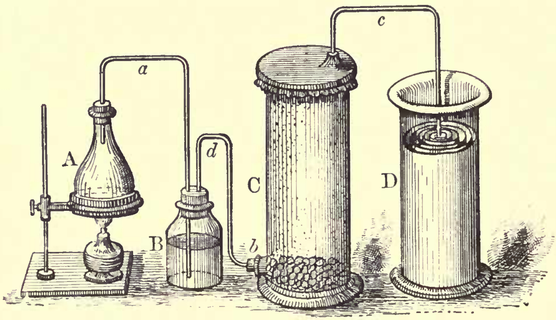


Fig. 61.—Chlorination Assay Apparatus.

greenish gas will pass through the water in B and fill the cylinder C.

The more coarse the gold, the longer should it remain in contact with the gas. If roasted pyrites are under treatment, about 1 hour would suffice, but ores containing coarse gold should remain in contact from 5 to 10 hours. The apparatus is uncoupled and water poured into the cylinder C, and the clear solution containing the chloride of gold allowed to drain through the orifice *b* into another cylinder, and after several washings, to ensure complete extraction of the gold, the solution is mixed with a few drops of hydrochloric acid, and excess of a strong solution of sulphate of iron (*ferrous sulphate*, or *copperas*), well stirred with a glass rod, and allowed to stand for some hours in a warm place until the gold is completely precipitated as a dark-brown powder and the solution above remains perfectly clear. The solution is now carefully decanted or syphoned from the precipitated gold, and the latter is stirred and collected on a small filter paper by means of a wash-bottle and a feather. The filter and its contents are now transferred to a small porcelain crucible. A gentle heat is first applied, so as to free from moisture, and then carefully heated in a muffle until all the filter paper has burnt off. The residue is then wrapped up in about ten times its weight of sheet lead, and cupelled on bone ash (*vide* p. 48), and the button of gold weighed.

Amalgamation—Synopsis of Process.—By amalgamation is meant the combination of mercury or quicksilver with the gold and silver contained in the ore. There are various machines in use on a large scale for the purpose, the principal, however, being the stamp battery. Here the ore is ground to powder, wet, and the pulp passes over inclined copper plates amalgamated with mercury, in which the gold is absorbed, and from which it is recovered by first scraping off the gold amalgam, squeezing out excess of mercury through chamois leather. The resulting gold amalgam—which contains from 30 to 40 per cent. of gold—is retorted, the mercury being distilled and the gold left in a porous mass, this being eventually smelted with fluxes in plumbago crucibles and cast into bars.

Other methods of amalgamation consist in grinding the ore wet in contact with mercury in grinding-pans, of which there is a great variety.

Amalgamation Assay.—When it is necessary to ascertain the amount of gold that can be extracted by mercury on a small scale, the writer has found that the apparatus shown in Fig. 62 is very suitable for the purpose. As will be observed, it consists of an amalgamator which can be driven by water-power or by hand. The mortar in which the amalgamation takes place is made of iron, as is also the grinder, which is arranged to revolve. The following is the method of conducting the assay: 1000 grams of the powdered ore, about 1500 c.c. of water made alkaline with caustic soda, and about 100 grams of redistilled mercury, are introduced into the amalgamator, the grinder of which is made to revolve by turning on water to the motor. The rate at which the apparatus revolves can be regulated by the inflow of water.

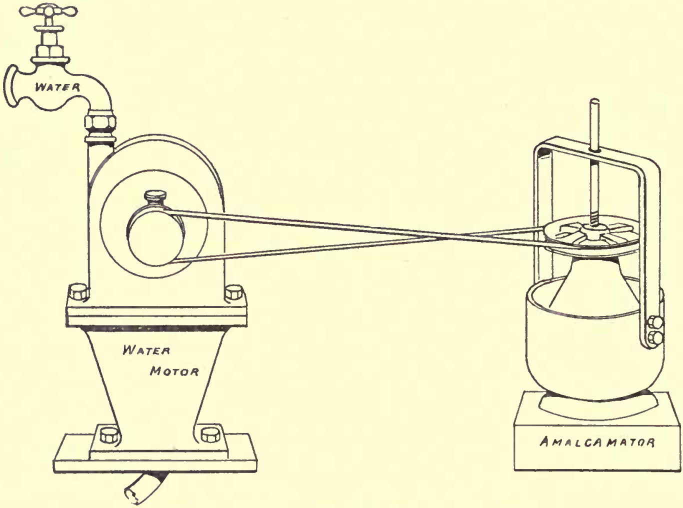


FIG. 62.—AMALGAMATION ASSAY APPARATUS.

After the apparatus has been running for a couple of hours, the motor is stopped, and the whole of the contents washed out into a shallow dish. The whole is stirred, and the pulp carefully run off, leaving the amalgam behind. Several washings with water will, of course, be required to free all the ore from the amalgam. The latter is carefully run into a piece of chamois leather held in the palm of the hand. The ends of the leather are held up together so as to form a bag, as it were. These are screwed around with the right hand, while the left is used to squeeze out the excess of mercury, leaving a hard amalgam behind. This is transferred to a piece of lead-foil about ten times the weight of the amalgam, in which it is wrapped, placed on a cupel transferred to a muffle furnace, a very low heat being first applied to evaporate off the mercury, otherwise loss would occur by spurting. It is then heated more strongly, and the rest of the process conducted as described on p. 53. The amount of gold per ton can be calculated from the table on p. 55. As there were 1000 grams taken, the result as obtained from the table must be multiplied by 20.

As a check against the result, the pulp separated from the amalgam could be evaporated to dryness and 100 grams of this taken for assay in the usual manner, and the result thus obtained deducted from the assay of the original ore should tally with that obtained from the amalgam.

APPENDIX.

COINAGE, VALUATION TABLES, MINT AND MINE STATISTICS, WEIGHTS AND MEASURES, ETC., ETC.

The Imperial Coinage.

STANDARD gold contains eleven-twelfths of fine metal, and one-twelfth of alloy. Twenty pounds troy of standard gold are coined into 934 sovereigns and one half-sovereign : 1 oz. troy is, therefore, intrinsically worth £3 17*s.* 10½*d.* On the same basis, 1 oz. of pure gold is worth £4 4*s.* 11½*d.*

Standard silver contains thirtyseven-fortieths of fine metal, and three-fortieths of alloy.

Bronze is an alloy of copper 95 parts, tin 4 parts, and zinc 1 part.

The coinage of the United Kingdom consists of the following pieces. Some of these are, however, only issued from time to time on special occasions.

The Bank of England issues notes for sums of £5, £10, £20, £50, £100, £200, £500, and £1000.

The tender of Bank of England notes is legal in England and Wales for all purposes, and by any one except by the Bank of England. No one can be compelled to give change.

Gold is a legal tender to any amount.

Silver is not a legal tender for sums over £2.

Pennies, halfpence, or farthings are not legal tender for sums over 1*s.*

MONEY TABLE.

4 farthings, or 2 halfpennies	= 1 penny (*d.*)
12 pence	= 1 shilling (*s.*)
20 shillings	= 1 pound (£)

¼*d.* = 1 farthing
½*d.* = 2 farthings
¾*d.* = 3 farthings

Proposed Decimal Coinage.

1 mil	. . . . .		= £0·001	= $\frac{24}{25}$ *q*.
10 mils =	1 cent . .		= £0·01	= 2·4*d*.
100 ,, =	10 cents =	1 florin	= £·1	= 2*s*.
1000 ,, =	100 ,, =	10 florins	= £1	

Old Coins formerly in Use.

Gold.

Joannes .	= 36*s*. 0*d*.
Moidore .	= 27*s*. 0*d*.
Jacobus .	= 25*s*. 0*d*.
Guinea .	= 21*s*. 0*d*.
Mark .	= 13*s*. 4*d*.
Half-guinea	= 10*s*. 6*d*.
Angel .	= 10*s*. 0*d*.
Noble .	= 6*s*. 8*d*.
Dollar .	= 4*s*. 6*d*.

Silver.

Tester .	= 0*s*. 6*d*.
Groat .	= 0*s*. 4*d*.

Old Scots Money.

2 pennies	= 1 bodle . .	= $\frac{1}{6}$*s*.	sterling
4 ,,	= 1 plack or groat	= $\frac{1}{3}$*s*.	,,
6 ,,	= 1 bawbee . .	= $\frac{1}{2}$*s*.	,,
12 ,,	= 1 shilling . .	= 1*s*.	,,
20 shillings	= 1 pound . .	= 20*s*.	,,
13 ,, & 4*d*.	= 1 mark . .	= 13$\frac{1}{3}$*s*.	,,

To reduce Scots money to Imperial values, divide by 12.
The Irish pound (£1) = £$\frac{12}{13}$ sterling.

British Coins in use, with their Equivalents.

	£5.	£2.	£1.	10*s*.	5*s*.	4*s*.	2*s*. 6*d*.	2*s*.	1*s*.	6*d*.	3*d*.	1*d*.	½*d*.	¼*d*.
Gold.														
£5, or £5-piece .	1													
£2, or £2-piece .	2½	1												
£1, or sovereign, or pound . .	5	2	1											
10*s*., or half-sovereign . .	10	4	2	1										
Silver.														
Crown . .	20	8	4	2	1									
Double florin .	25	10	5	2½	1¼	1								
Half-crown . .	40	16	8	4	2	1⅗	1							
Florin . . .	50	20	10	5	2½	2	1¼	1						
Shilling . .	100	40	20	10	5	4	2½	2	1					
Sixpence . .	200	80	40	20	10	8	5	4	2	1				
Threepenny-piece	400	160	80	40	20	16	10	8	4	2	1			
Copper.														
Penny . . .	1200	480	240	120	60	48	30	24	12	6	3	1		
Halfpenny . .	2400	960	480	240	120	96	60	48	24	12	6	2	1	
Farthing . .	4800	1920	960	480	240	192	120	96	48	24	12	4	2	1

Table showing the Weight of New Coins.

A sovereign, or pound, weighs		123·274	grains
A half-sovereign	,,	61·637	,,
A half-crown	,,	218·1818	,,
A shilling	,,	87·2727	,,
A sixpence	,,	43·6364	,,

Measurement and Weight of Bronze Coins.

A halfpenny measures exactly 1 inch in diameter, so that twelve of them in a row make 1 foot.

In the bronze coinage three pence, five halfpence, or ten farthings weigh 1 oz. avoirdupois.

TABLE OF VALUES OF GOLD.

Calculated from the standard at £3 17*s.* 10½*d.* per ounce.

Carats fine.	Value.			Carats fine.	Value.			Carats fine.	Value.		
	£	*s.*	*d.*		£	*s.*	*d.*		£	*s.*	*d.*
1	0	3	6½	9	1	11	10¼	17	3	0	2
2	0	7	1	10	1	15	4¾	18	3	3	8½
3	0	10	7½	11	1	18	11¼	19	3	7	3
4	0	14	2	12	2	2	5¾	20	3	10	9½
5	0	17	8¼	13	2	6	0	21	3	14	4
6	1	1	2¾	14	2	9	6½	22	3	17	10½
7	1	4	9¼	15	2	13	1	23	4	1	5
8	1	8	3¾	16	2	16	7½	24	4	4	11½

All articles manufactured of gold and silver, except watch-cases, have to be taken to the Assay Office of the district, and if found of legal quality are stamped thus—

The Hall Mark, showing the district where manufactured, or the hall where assayed, is, at *Birmingham*, an anchor ; *Chester*, three wheat-sheaves or a dagger ; *Dublin*, a harp or figure of Hibernia ; *Edinburgh*, a thistle, or castle and lion ; *Exeter*, a castle with two wings ; *Glasgow*, a tree, and a salmon with a ring in its mouth ; LONDON, a leopard's head ; *Newcastle-on-Tyne*, three castles ; *Sheffield*, a crown ; *York*, five lions and a cross.

The Standard Mark for gold of 22 carats, and silver of 11 ozs. 2 dwts., is, for England, a lion passant ; for Edinburgh, a thistle ; for Glasgow, a lion rampant ; for Ireland, a harp crowned. Gold of 18 carats fine, a crown and the figures 18. Silver of the new standard, figure of Britannia.

The Duty Mark is the head of the sovereign, and indicates that the duty has been paid.

The Date Mark is a letter of the alphabet placed in a shield. The letter is changed every year.

Gold Valuation Table.

Value per oz. £	s.	d.	Value per dwt. £	s.	d.	Value per grain. £	s.	d.
4	0	0	0	4	0	0	0	2
3	17	6	0	3	10½	0	0	1 15/16
3	15	0	0	3	9	0	0	1⅞
3	12	6	0	3	7½	0	0	1 13/16
3	10	0	0	3	6	0	0	1¾
3	7	6	0	3	4½	0	0	1 11/16
3	5	0	0	3	3	0	0	1⅝
3	2	6	0	3	1½	0	0	1 9/16
3	0	0	0	3	0	0	0	1½

Every rise or fall in the value of gold of one shilling per ounce gives a difference of ⅗ of a penny per dwt., and 1/40 of a penny per grain.

Money of Foreign Countries in which the French Metric System is in Use.

Algiers.

The French coins are in general use.
Accounts are usually kept in French money by European merchants.

Argentine Republic.

Money the same as in Spain.

Peso, or dollar of 100 centesimos, about . = 4*s*.
The par of exchange (P. of E.) = 5·04 pesos = £1
Accounts kept in dollars.

The quintal = 101·4 lbs.
The fanega = 1·5 Imperial bushels

Austria.

New monetary system since 1892.

Gold.

20-crown piece	=	16*s*. 8*d*.
10 " "	=	8*s*. 4*d*.
Ducat . .	=	8*s*. 0*d*.

Silver.

Crown .	. =	0*s*. 10*d*.
Half-crown	. =	0*s*. 5*d*.

(2 crowns or krones = 1 florin.)

Nickel.

20-heller piece	=	0*s*. 0½*d*.
1 " "	=	0*s*. 0$\frac{1}{10}$*d*.

Bronze.

2-heller piece .	=	0*s*. 0⅕*d*.
1 " " .	=	0*s*. 0$\frac{1}{10}$*d*.

The value of the florin is about 11·9 to 12·1 to the £1, and equals 100 kreutzers.

BRAZIL.

Accounts kept in milreis.

Milreis = 1000 reis .	=	2*s*. 3*d*.
10-milreis piece .	. =	22*s*. 6*d*.
P. of E. = 8·9 milreis	=	20*s*. 0*d*.

BELGIUM.

Gold.

30 francs .	=	16*s*. 0*d*.

Silver.

5 francs .	=	4*s*. 0*d*.
2 "	=	1*s*. 7*d*.
1 franc	=	0*s*. 9½*d*.
50 centimes	=	0*s*. 4¾*d*.

Nickel.

20 centimes	=	0*s*. 2*d*.
10 "	=	0*s*. 1*d*.
5 "	=	0*s*. 0½*d*.

Accounts kept in francs.

The French metric system is used, but some of the values are differently expressed, viz.—

Aune	for mètre or ell
Litron	" litre or kaunen
Livre	" kilogram or ponden

BOLIVIA.

The boliviano or dollar = 100 centavos = 1*s.* 9*d.*
With half-bolivianos in use.

CHILI.

Gold.

		£	s.	d.
20 peso = 1 condor	. =	4	3	4
10 „ = 1 doblon	. =	2	1	8
5 „ = 1 escudo .	. =	1	0	10

Silver.

Dollar, or peso (nominal)	=	0	4	2
P. of E. = 5 francs .	. =	0	3	11½
„ = 5·05 pesos	. =	1	0	0

A gold dollar is in circulation.

FRANCE.

Gold.

20 francs (the Napoleon or Louis)	=	16*s.* 0*d.*
10 „	. =	8*s.* 0*d.*
5 „	. =	4*s.* 0*d.*

Silver.

5 francs	. =	4*s.* 0*d.*
2 „	. =	1*s.* 7*d.*
1 franc = 100 centimes	. =	0*s.* 9½*d.*
50 centimes	. =	0*s.* 4¾*d.*
20 „ . . . . about	=	0*s.* 2*d.*

Bronze.

10 centimes	. =	0*s.* 1*d.*
5 „	. =	0*s.* 0½*d.*

GERMANY.

Gold.

20 marks	. =	20*s.* 0*d.*
10 „	. =	10*s.* 0*d.*
5 „	. =	5*s.* 0*d.*

Silver.

5 marks .	=	5*s.* 0*d.*
3 „ .	=	3*s.* 0*d.*
2 „ .	=	2*s.* 0*d.*
1 mark .	=	1*s.* 0*d.*
50 pfennige	=	0*s.* 6*d.*
20 „	=	0*s.* 2½*d.*

Nickel.

20 pfennige	=	0*s.* 2½*d.*
10 „	=	0*s.* 1¼*d.*
5 „	=	0*s.* 0½*d.*

Other names are used in the metric system, viz.—

Strich	for	millimètre
Neuzoll	„	centimètre
Stab	„	mètre
Kette	„	décamètre
Konne	„	litre
Schoppen	„	half-litre
Fass	„	hectolitre
Neuloth	„	décagramme
Pfund	„	half-kilogramme
Certner	=	100 lbs.
Tonne	=	1000 kilogrammes

GREECE.

Gold.

20-drachmai piece	=	14*s.* 2½*d.*
5 „ „	=	3*s.* 9*d.*

Silver.

1 drachma . .	=	0*s.* 9*d.*
½ „ . .	=	0*s.* 4½*d.*
¼ „ . .	=	0*s.* 2¼*d.*

Accounts kept in drachmai and lepti.

100 lepti = 1 drachma
P. of E. = 25·22 drachmai = 20*s.*

The weights and measures of the metric system have different names—

Gramne	for millimètre
Dactylos	,, centimètre
Palame	,, décimètre
Pecheus	,, mètre
Stadion	,, kilomètre
Skoinis	,, myriamètre
Stremma	,, are
Kybos	,, millilitre
Mystron	,, centilitre
Kotylos	,, décilitre
Litra	,, litre
Koilon	,, hectolitre
Kokkos	,, centigramme
Obolos	,, décigramme
Drachme	,, gramme
The ocque	= 2·84 lbs. (av.)
The livre	= 1·1 lb. (av.)
The quintal	= 123·2 lbs. (av.)

HOLLAND.

Gold.

10 guilders = 16*s.* 0*d.*

Silver.

2½ guilders	. =	4*s.* 2*d.*
1 ,, .	. =	1*s.* 8*d.*
50 cents .	. =	0*s.* 10*d.*
25 ,, .	. =	0*s.* 5*d.*
10 ,, .	. =	0*s.* 2*d.*
5 ,, .	. =	0*s.* 1*d.*

Copper.

5 cents = 1 stiver = 0*s.* 1*d.*

Accounts kept in florins or guilders = 100 cents

The weights and measures have different names, viz.—

Length.

Streep	for	millimètre
Duim	,,	centimètre
Palm	,,	décimètre
Ell	,,	mètre
Roede	,,	décamètre
Mijle	,,	kilomètre

Capacity.

Vingerhoed	for	centilitre
Maatje	,,	décilitre
Kan	,,	litre
Vat	,,	hectolitre

Dry Measure.

Maatje	for	décilitre
Kop	,,	litre
Schepel	,,	décalitre
Mudde, or zak	,,	hectolitre

The last = 30 mudde

Weight.

Korrel	for	décigramme
Wigtje	,,	gramme
Lood	,,	décagramme
Ons	,,	hectogramme
Pond	,,	kilogramme

The bunder = 1 hectare

Apothecaries' weights are similar to those of England.

ITALY.

The same as in France, but the money in general use is a paper currency.

20-lire piece . .	=	15*s.* 10*d.*
1 lire = 100 centimes	=	0*s.* 9½*d.*

The rate of exchange varies from 26·2 to 26·5 lires = £1.

Notes issued by local banks are only payable at those banks.

Weights and Measures.

The gramma .	= 15·43 grains troy
Chilo gramma .	= 2·2 lbs. avoirdupois
Quintale metrico	= 220 lbs. „
Tonnellata .	= 2200 lbs. „
Litro . . .	= 0·22 gallons
Metro . .	= 3·28 feet = 39·37 inches
Metro cubo .	= 35·31 cubic feet
Ettara . .	= 2·47 acres

Mexico.

Gold.

	£	s.	d.
Doubloon . . . =	3	4	8
Half-doubloon . . =	1	12	4

Silver.

Dollar, or peso, or 8 reals =	0	4	2
Half-dollar . . . =	0	2	1

Accounts kept in dollars and cents.

100 cents = 1 dollar

P. of E. = 4·64 dollars . =	1	0	0

Norway and Sweden.

Gold.

20 kroners . . =	22*s.* 3*d.*
10 „ . . =	11*s.* 1½*d.*
5 „ . . =	5*s.* 6¾*d.*

Silver.

2 kroners . . =	2*s.* 3*d.*
1 kroner . . =	1*s.* 1½*d.*
50 ores . . =	0*s.* 6¾*d.*
25 „ . . =	0*s.* 3*d.*
10 „ . . =	0*s.* 1*d.*

Copper.

5 ores . . = 0*s.* 0½*d.*

Accounts kept in crowns.

1 crown = 100 ores . = 1*s.* 1½*d.*
P. of E. = 18·2 crowns = 20*s.* 0*d.*

The coins of the two countries pass freely between them, but notes are negotiable in their own country.

Portugal.

Gold.

		£	s.	d.
Johannes d'or = 12,800 reis . .	=	3	11	0
Crown	=	1	3	4

Silver.

Dollar (milreis)	=	0	4	2
Cruzada (with halves and quarters)	=	0	2	3
1 testoon = 100 reis . . .	=	0	0	5¼

Copper.

25 reis	=	0	0	1¼

Accounts kept in milreis and reis.
1000 reis = 1 milreis

Roumania.

The ley = the franc
Silver legal up to 50 ley.
The gold coins are 20, 10, and 5-ley pieces = 16*s.*, 8*s.*, and 4*s.*

Servia.

The dinar = 1 franc

Gold.

20 and 10 dinars = 16*s.* and 8*s.*

Silver.

2 and 1 dinars = 1*s.* 7*d.* and 9½.

Copper.

10 and 5 paras = 1*d.* and ½*d.*

Spain.

Gold.

25 pesetas . . .	= 20*s.* 0*d.*
20 „ or pistole .	= 16*s.* 0*d.*

Silver.

1 dollar	= 4*s.* 0*d.*
5 pesetas . . .	= 3*s.* 4*d.*
2 „	= 1*s.* 4*d.*
1 peseta = 100 centesimos	= 0*s.* 8*d.*
50 cents.	= 0*s.* 4*d.*

Bronze.

10 cents	= 0*s.* 1*d.*
5 „	= 0*s.* 0½*d.*

Accounts kept in pesetas.

Switzerland.

No gold coin.

Silver.

5 francs .	= 4*s.* 0*d.*
2 „ .	= 1*s.* 7*d.*
1 franc .	= 0*s.* 9½*d.*
50 centimes	= 0*s.* 4¾*d.*

Nickel.

20 centimes	= 0*s.* 2*d.*
10 „	= 0*s.* 1*d.*
5 „	= 0*s.* 0½*d.*

Accounts kept in francs and centimes.
100 centimes = 1 franc, as in France.

Uruguay.

Peso, or dollar = 100 centenas

Venezuela.

Bolivia = 1 franc

Weights, Measures, and Money of Greater Britain.

Imperial weights and measures are now legally in force in the following colonies, etc. :—

Antigua
Barbadoes
Bermuda
British Guiana
British Honduras
Canada
Cape of Good Hope
Ceylon
Cyprus
Dominica
Fiji
Grenada
Hong Kong
Jamaica
Malta
Natal
Nevis
New Brunswick
New South Wales
New Zealand
Nova Scotia
Queensland
Sierra Leone
Singapore
South Australia
St. Christopher
St. Helena
St. Vincent
Tobago
Trinidad
Vancouver's Island
Victoria
Western Australia

BARBADOES.

Pound . .	=	14*s*. 3*d*.
Crown . .	=	5*s*. 0*d*.
Dollar . .	=	4*s*. 6*d*.
Shilling .	=	0*s*. $8\frac{1}{2}\frac{1}{0}$*d*.
2 halfpennies	=	0*s*. 1*d*.

BRITISH GUIANA.

British gold and silver coin with a small circulation of guilders, half-guilders, and bits.

CANADA.

The British and United States coinage are both in general use.

Accounts kept in dollars and cents, of which
100 cents = 1 dollar = 4*s*. 2*d*.

Formerly accounts were kept in £ *s.* *d.*—

£1 currency = about 16*s.* 8*d.* sterling
£1 sterling = about £1 4*s.* 4*d.* currency
P. of E. = 4 dollars $86\frac{2}{3}$ cents = £1

Cape of Good Hope.

British money is exclusively used.
Old Dutch weights and measures are still used in many parts.

Leagner = 128 gallons
Half-aum = $15\frac{1}{2}$ „
Muid = 3 bushels

Ceylon.

The money is the rupee of British India, with cent in place of annas and pies ; thus Ceylon has a decimal coinage.
The measure of length and surface are the same as in England.

The parrah = 5·62 gallons
The seer = 1 quart
The candy = 500 lbs. (av.)

Cyprus.

English, Turkish, and French gold and English silver, Cyprus piastres, with half and quarter pieces.
9 piastres = 1*s.*

Gibraltar.

The legal currency is that of Spain.

The peseta = 1 franc
25 pesetas, nominally . . . . = £1
But P. of E. is generally over 29 pesetas = £1
British coins are also in use.

Hong Kong.

The Mexican dollar = 100 cents
The Chinese tael . = 10 mace
100 candareens . = 3*s.* 4*d.*
With 5, 10, 20, and 50-cent pieces.

MALTA.

Gold.

	£	s.	d.
Double louis . =	1	18	$1\frac{1}{4}$
Louis . . . =	0	19	$1\frac{1}{4}$
Half-louis . . =	0	9	$7\frac{3}{4}$

Silver.

1 pezza, or 30 tari =	0	4	0
Scudo . . =	0	1	$7\frac{1}{2}$

Accounts kept by the British Government in British money.

MAURITIUS.

Accounts kept in dollars and cents.

1 dollar = 4*s.* 2*d.*
100 cents = 1 dollar

Government accounts are all in British money.

NEW BRUNSWICK, NOVA SCOTIA, AND NEWFOUNDLAND.

Same as in Canada.

SINGAPORE.

Accounts kept in dollars and cents.

100 cents = 1 dollar = 4*s.* 2*d.*

Accounts are also kept in rupees, annas, and pies, as in India.

WEST INDIA ISLANDS (BRITISH).

Accounts kept in dollars and cents.

Weights, Measures, and Money of the United States.

Gold.

		£	s.	d.
20-dollar piece	=	4	2	6
10 ,, ,,	=	2	1	3
5 ,, ,,	=	1	10	7½
2½ ,, ,,	=	0	10	4
1 ,, ,,	=	0	4	2

Silver.

1 dollar .	=	0	4	2
50 cents .	=	0	2	1
25 ,, .	=	0	1	0½
10 ,, (dime)	=	0	0	5
5 ,, .	=	0	0	2½

Nickel.

5 cents .	=	0	0	2½

Copper.

2 cents .	=	0	0	1
1 cent .	=	0	0	0½

Exchange, 1 dollar = 4*s.* 0½*d.* to 4*s.* 2*d.*

The weights and measures are very nearly the same as in Great Britain, with the exception of capacity measure, where the old Winchester gallon and bushel are used.

1 wine gallon = 0·8331 gallon
1 ale ,, . = 1·0169 ,,
1 bushel . = 0·9694 ,,

Instead of the hundredweight the cental of 100 lbs. is used, consequently the ton = 2000 lbs.

Foreign Countries, each having its own System of Money, Weights, and Measures.

ABYSSINIA.

A dollar, or 23 harfs = 4*s.* 2*d.*
A sequin, or 2¼ dollar = 9*s.* 4½*d.*

Weights.

1 wakea = 400 grains
1 rottolo = 4800 grains, or 10 ozs. troy
1 mocha = 1 oz. troy

ARABIA.

		£	s.	d.
Tomaun	=	3	7	6
Sequin	=	0	7	6
Dollar ($1\frac{1}{4}$ piastre) . .	=	0	4	2
Piastre, or 80 caveers . .	=	0	3	5
Larin (and its subdivisions)	=	0	0	$10\frac{1}{8}$

1 noosfia = 1 quart
1 gudda = 2 gallons

Tomand = 40 kellah = 168 lbs. (av.)
1 maund . . . = 3 „
1 frazil . . . = 30 „
1 behar . . . = 450 „

BOLIVIA REPUBLIC.

Boliviano, or dollar = 5 francs = 100 centavos = 1*s.* 9*d.*

Spanish weights and measures are used along with the French metric system.

The marc = $\frac{1}{2}$ lb. (av.)

BULGARIA.

The leva = 100 stotinki = $9\frac{1}{2}$*d.*

The French metric weights and measures as well as the Turkish are used.

BURMAH.

Money same as in China.

1 pulgat = 1 inch
1 tha = 154 inches
1 tain = 1069·4 yards
1 dain = 2·4 miles

1 solay = 1 pint
1 sali = 1 gallon
1 teng = 1 bushel

CHINA.

10 cash	=	0s. 0¾d.
1 mace	=	0s. 7½d.
1 tael, or 1000 cash .	=	5s. 10d.
P. of E. = 3·07 taels of silver	=	20s. 0d.

The decimal system is used in all the weights and measures.

1 ts'un	=	1·41 inches
1 ch'ih	=	14·1 „
1 chang	=	141 „
1 yin	=	117·5 feet
1 ching	=	121 sq. feet
100 mou (1 ching) . .	=	72,600 „
1 li	=	2115 feet
1 ho	=	2 pints
1 shêng . . .	=	20 „
1 tou	=	100 „
1 tael	=	1·333 ozs. (av.)
1 chin, or chitty (16 taels)	=	1·333 lbs. (av.)
1 picul, or tan (100 chins)	=	133·333 lbs. (av.)

DENMARK.

The money of Norway and Sweden is in circulation here.

The pund = 100 kvint = 1000 ort	=	1·1 lb. (av.)
The certner	=	100·21 lbs. (av.)
„ ship last	=	2 tons
„ tomme	=	1·029 inches
„ fod	=	1·029 feet
2 fods	=	0·686 yards
The cubik fod	=	1·09 cubic feet
„ mil	=	4·680 miles
„ töndeland	=	1·36 acres
„ flaske	=	1·2743 pints
„ pot	=	0·2126 gallons
„ tönde (corn) . . .	=	3·8 bushels
„ „ (coal)	=	4·6775 „

EGYPT.

Gold.

50 piastres	= $\frac{1}{2}$ £E.	=	10*s.* 3*d.*
100 ,,	= 1 £E.	=	20*s.* 6*d.*

Silver.

10 piastres . .	= 2*s.* 0$\frac{1}{2}$*d.*
20 ,, . .	= 4*s.* 1*d.*
1 piastre . .	= 0*s.* 2$\frac{1}{2}$*d.*
2 piastres . .	= 0*s.* 5*d.*

Nickel.

5 millièmes .	= 0*s.* 1$\frac{1}{4}$*d.*
2 ,, . .	= 0*s.* 0$\frac{1}{2}$*d.*

Copper.

$\frac{1}{2}$ millième . .	= 0*s.* 0$\frac{1}{8}$*d.*
$\frac{1}{4}$,, . .	= 0*s.* 0$\frac{1}{16}$*d.*

1 kirat	= 1·125 inches
1 dra .	= 27 ,,
1 gasab	= 3 yards (nearly)
1 ardeb	= 4·9 bushels

(The ardeb is a variable quantity.)

1 kantar	= 99·8 lbs.
1 rotl .	= 1·008 ,,
1 oke .	= 2·7 ,,

INDIA.

Silver.

1 rupee, about .	= 1*s.* 2*d.*
8 annas . .	= 0*s.* 7*d.*
4 ,, . .	= 0*s.* 3$\frac{1}{2}$*d.*
2 ,, . .	= 0*s.* 1$\frac{3}{4}$*d.*

Bronze.

$\frac{1}{2}$ anna . .	= 0*s.* 0$\frac{1}{2}$*d.*
$\frac{1}{4}$,, . .	= 0*s.* 0$\frac{1}{4}$*d.*

Bombay.

1 guz	. . =	27 inches
1 beegah	. . =	3927 sq. yards
1 seer	. . =	2 lbs. (av.)
1 maund	. . =	28 „
1 candy	. . =	560 „

Bengal.

1 moote	. . =	3 inches
1 hânth	. . =	18 „
1 guz	. . =	1 yard
1 coss	. . =	2000 yards
1 jojun	. . =	8000 „
1 beegah	. . =	1600 sq. yards
1 „ (N.W.P.)	=	3025 „
1 ser	. . =	2·2046 lbs. (av.)
1 „	. . =	1·7619 pints

Madras.

1 kole, or guz	. =	32 inches
1 moolum	. =	19½ „
1 puddee	. . =	2·8852 pints
1 marcal	. . =	2·8852 gallons
1 parah	. . =	14·4261 „

JAPAN.

Money reckoned and accounts kept as in China.

Gold coins.

		£	s.	d.
20-yen piece	. =	4	3	4
10 „ „	. =	2	1	8
5 „ „	. =	1	0	10
2 „ „	. =	0	8	4
1 „ „	. =	0	4	2
10 rin = 1 sen	. =	0	0	0½
100 sen = 1 yen	=	0	4	2

Measures, etc.

1 sung .	=	1·1931 inches
1 shaku .	=	11·931 „
1 keng .	=	6 feet
1 jo . .	=	3·314 yards
1 ri . .	=	2·4 miles
1 square ri	=	5·9552 sq. miles
1 shō .	=	3·1 pints
1 to . .	=	3·703 gallons
1 koku .	=	4·96 bushels
1 kin .	=	1·325 lbs.

PERU—LIMA.

Silver.

Accounts kept in dollars and reals.

1 dollar	=	4*s.* 3*d.*
8 reals	=	1 dollar

PERSIA.

($\frac{1}{4}$, $\frac{1}{2}$, and 1-toman pieces.)

35 kerans . .			=	20*s.* 0*d.*
10 „	=	1 toman	=	6*s.* 7*d.*

There are also $\frac{1}{2}$, 1, and 2-kran pieces.

1 batman . .	=	13$\frac{1}{2}$ lbs.
1 gaz . .	=	25 inches
1 parasang .	=	4 miles

RUSSIA.

Gold.

Imperial = 10 roubles .	=	32*s.* 2$\frac{1}{4}$*d.*
Half-imperial . . .	=	16*s.* 1*d.*
Ducat	=	9*s.* 3$\frac{3}{4}$*d.*

Silver.

Rouble = 100 copecks .	=	3*s.* 1$\frac{1}{2}$*d.*
Poltin, or half-rouble. .	=	1*s.* 6$\frac{3}{4}$*d.*
Polpoltin, or quarter-rouble	=	0*s.* 9$\frac{1}{2}$*d.*
10-copeck piece . .	=	0*s.* 3$\frac{1}{2}$*d.*

Accounts kept in roubles and copecks, of which
100 copecks . . . . = 1 rouble
P. of E. = 6 roubles 40 copecks = 20*s.* 0*d.*

1 stopa .	= 14 inches
1 saschen .	= 7 feet
1 verst .	= 1166·66 yards
1 vedro .	= 2·704 gallons
1 pajak .	= 1·442 bushels
1 pood .	= 36·1127 lbs.
1 berkowits	= 360 lbs.

TURKEY.

100 piastres	= 1 gold medjidie (Turkish pound, or liva)	= 18*s.* 0*d.*
20 ,,	= 1 silver medjidie	= 3*s.* 4*d.*
1 piastre of 40 paras		= 0*s.* 2¼*d.*
P. of E. = 110 piastres		= 20*s.* 0*d.*

1 pik	= 27·25 inches
1 agatsch	= 3·115 miles
1 cantar	= 31·4 gallons
1 almund	= 1·152 ,,
1 killon	= 0·912 bushels
1 oka	= 2·826 lbs. (av.)
1 cantur	= 127·3 ,,
1 quintal	= 199 ,,

Tables of Exchange.

AMOUNT OF FOREIGN MONEY THAT SHOULD BE PAID FOR ENGLISH MONEY.

English money.			Belgium, Bulgaria, Chili, Congo, Free State, Italy, Salvador, Servia, Switzerland, Uruguay.		France and Algeria, Luxemburg, Roumania, Tunis, and Austria.		Germany.		Netherlands and Dutch East Indies.		Denmark, Iceland, and Danish West Indies, Norway, and Sweden.		Portugal, Azores, and Madeira.	Egypt.		United States, Canada, and Hawaii.	
£	*s.*	*d.*	Francs.	Cents.	Francs.	Cents.	Marks.	Pfen.	Florins.	Cents.	Kroner.	Ore.	Reis.	Pounds, Egyptian.	Millièmes.	Dollars.	Cents.
0	0	1	0	10	0	10	0	08	0	05	0	07	10	0	004	0	02
0	0	2	0	20	0	21	0	17	0	10	0	15	30	0	008	0	04
0	0	3	0	30	0	31	0	25	0	15	0	22	50	0	012	0	06
0	0	4	0	40	0	42	0	34	0	20	0	30	70	0	016	0	08
0	0	5	0	50	0	52	0	42	0	25	0	37	90	0	020	0	10
0	0	6	0	60	0	63	0	51	0	30	0	45	110	0	024	0	12
0	0	7	0	70	0	73	0	59	0	35	0	52	130	0	028	0	14
0	0	8	0	80	0	84	0	68	0	40	0	60	150	0	032	0	16
0	0	9	0	90	0	94	0	76	0	45	0	68	170	0	036	0	18
0	0	10	1	00	1	05	0	85	0	50	0	75	190	0	040	0	20
0	0	11	1	10	1	15	0	93	0	55	0	83	200	0	044	0	22
0	1	0	1	20	1	26	1	02	0	60	0	90	220	0	048	0	24
0	2	0	2	50	2	52	2	04	1	20	1	81	450	0	097	0	49
0	3	0	3	70	3	78	3	06	1	81	2	72	680	0	146	0	73
0	4	0	5	00	5	04	4	08	2	41	3	62	910	0	195	0	97
0	5	0	6	30	6	30	5	10	3	02	4	53	1,140	0	243	1	22
0	6	0	7	50	7	56	6	12	3	62	5	43	1,370	0	292	1	46
0	7	0	8	80	8	82	7	14	4	22	6	35	1,590	0	341	1	71
0	8	0	10	00	10	08	8	16	4	83	7	25	1,820	0	390	1	95
0	9	0	11	30	11	34	9	18	5	43	8	15	2,050	0	438	2	19
0	10	0	12	60	12	60	10	20	6	04	9	06	2,280	0	487	2	44
0	11	0	13	80	13	86	11	22	6	64	9	96	2,510	0	536	2	68
0	12	0	15	10	15	12	12	24	7	24	10	87	2,740	0	585	2	92
0	13	0	16	30	16	38	13	26	7	85	11	77	2,970	0	633	3	17
0	14	0	17	60	17	64	14	28	8	45	12	68	3,190	0	682	3	41
0	15	0	18	90	18	90	15	30	9	06	13	59	3,420	0	731	3	65
0	16	0	20	10	20	16	16	32	9	66	14	49	3,650	0	780	3	90
0	17	0	21	40	21	42	17	34	10	26	15	41	3,880	0	828	4	14
0	18	0	22	60	22	68	18	36	10	87	16	31	4,110	0	877	4	38
0	19	0	23	90	23	94	19	38	11	47	17	21	4,340	0	926	4	63
1	0	0	25	20	25	20	20	40	12	08	18	12	4,570	0	975	4	87
2	0	0	50	40	50	40	40	80	24	16	36	24	9,140	1	950	9	74
3	0	0	75	60	75	60	61	20	36	24	54	36	13,710	2	925	14	61
4	0	0	100	80	100	80	81	60	48	32	72	48	18,280	3	900	19	48
5	0	0	126	00	126	00	102	00	60	40	90	60	22,850	4	875	24	35
6	0	0	151	20	151	20	122	40	72	48	108	72	27,420	5	850	29	22
7	0	0	176	40	176	40	142	80	84	56	126	84	31,990	6	825	34	09
8	0	0	201	60	201	60	163	20	96	64	144	96	36,560	7	800	38	96
9	0	0	226	80	226	80	183	60	108	72	163	08	41,130	8	775	43	83
10	0	0	252	00	252	00	204	00	120	80	181	20	45,700	9	750	48	70

Rupees to Pounds, and Vice Versâ.

Pence per rupee.	Multiply Rupees to pounds by	Multiply Pounds to rupees by	Pence per rupee.	Multiply Rupees to pounds by	Multiply Pounds to rupees by
12	0·0500	20·000	18	0·0750	13·333
¼	0·0510	19·592	¼	0·0760	13·151
½	0·0521	19·200	½	0·0771	12·973
¾	0·0531	18·824	¾	0·0781	12·800
13	0·0542	18·461	19	0·0792	12·632
¼	0·0552	18·113	¼	0·0802	12·468
½	0·0563	17·777	½	0·0813	12·308
¾	0·0573	17·454	¾	0·0823	12·152
14	0·0583	17·143	20	0·0833	12·000
¼	0·0594	16·842	¼	0·0844	11·852
½	0·0604	16·552	½	0·0854	11·707
¾	0·0615	16·271	¾	0·0865	11·566
15	0·0625	16·000	21	0·0875	11·429
¼	0·0635	15·738	¼	0·0885	11·294
½	0·0646	15·484	½	0·0896	11·163
¾	0·0656	15·238	¾	0·0906	11·034
16	0·0667	15·000	22	0·0917	10·909
¼	0·0677	14·769	¼	0·0927	10·787
½	0·0688	14·545	½	0·0938	10·667
¾	0·0698	14·328	¾	0·0948	10·549
17	0·0708	14·118	23	0·0958	10·435
¼	0·0719	13·913	¼	0·0969	10·323
½	0·0729	13·714	½	0·0979	10·213
¾	0·0740	13·521	¾	0·0990	10·105

Royal Mint Statistics.

Coins struck at the Royal Mint, London.

Coinage of the Year 1902.

IMPERIAL.

Denomination.	Number of pieces.	Nominal value. £	s.	d.
Gold—				
Five-pound pieces . .	34,911	174,555	0	0
Two-pound pieces . .	45,807	91,614	0	0
Sovereigns . . .	4,737,796	4,737,796	0	0
Half-sovereigns . .	4,244,457	2,122,228	10	0
	9,062,971	**7,126,193**	**10**	**0**
Silver—				
Crowns	256,020	64,005	0	0
Half-crowns . . .	1,316,008	164,501	0	0
Florins	2,189,575	218,957	10	0
Shillings	7,809,481	390,474	1	0
Sixpences . . .	6,367,378	159,184	9	0
Fourpences (Maundy) .	10,117	168	12	4
Threepences . . .	8,287,060	103,588	5	0
Twopences (Maundy) .	14,079	117	6	6
Pence (Maundy) . .	21,278	88	13	2
	26,270,996	**1,101,084**	**17**	**0**
Bronze—				
Pence	26,976,768	112,403	4	0
Halfpence	13,672,960	28,485	6	8
Farthings	5,125,120	5,338	13	4
	45,774,848	**146,227**	**4**	**0**
Totals	**81,108,815**	**8,373,505**	**11**	**0**

Denomination.	Number of pieces.	Currency value.	Nominal value.		
Canada.					
Silver—		$	£	*s.*	*d.*
Fifty cents . . .	120,000	60,000	12,500	0	0
Twenty-five cents . .	464,000	116,000	24,166	13	4
Ten cents . . .	720,000	72,000	15,000	0	0
Five cents . . .	2,120,000	106,000	22,083	6	8
Bronze—					
Cents	3,000,000	30,000	6,250	0	0
	6,424,000	**384,000**	**80,000**	**0**	**0**
Ceylon.					
Silver—		Rupees.			
Fifty cents . . .	200,000	100,000	6,666	13	4
Twenty-five cents . .	400,000	100,000	6,666	13	4
Ten cents . . .	1,000,000	100,000	6,666	13	4
	1,600,000	**300,000**	**20,000**	**0**	**0**
Cyprus.					
Bronze—		£			
Quarter piastres . .	72,000	100	100	0	0
	72,000	**100**	**100**	**0**	**0**
Hong Kong.					
Silver—		$			
Fifty cents . . .	100,000	50,000	10,416	13	4
Twenty cents . . .	250,000	50,000	10,416	13	4
Ten cents . . .	18,000,000	1,800,000	375,000	0	0
Bronze—					
Cents	5,000,000	50,000	10,416	13	4
	23,350,000	**1,950,000**	**406,250**	**0**	**0**
Jamaica.					
Nickel—		£			
Pence	60,000	250	250	0	0
Halfpence . . .	48,000	100	100	0	0
Farthings . . .	144,000	150	150	0	0
	252,000	**500**	**500**	**0**	**0**
Malta.					
Bronze—					
One-third farthings . .	288,000	100	100	0	0
	288,000	**100**	**100**	**0**	**0**
Straits Settlements.					
Silver—		$			
Fifty cents . . .	148,000	74,000	15,416	13	4
Twenty cents . . .	1,105,000	221,000	46,041	13	4
Ten cents . . .	6,118,735	611,873·5	127,473	12	11
Five cents . . .	1,920,000	96,000	20,000	0	0
	9,291,735	**1,002,873·5**	**208,931**	**19**	**7**
Totals . . .	**41,277,735**		**715,881**	**19**	**7**

SUMMARY FOR 1902.

Description.	Number of pieces.	Nominal value.		
		£	s.	d.
Imperial	81,108,815	8,373,505	11	0
Colonial	41,277,735	715,881	19	7
Totals . . .	**122,386,550**	**9,089,387**	**10**	**7**

Currency Issues from the Royal Mint, London.

The following table gives a summary of the currency issues from the Royal Mint during recent years :—

Metal.	1902.	1901.	Mean of 10 years, 1892–1901.
	£	£	£
Gold . .	6,908,000	2,599,000	6,974,437
Silver . .	937,202	914,201	1,207,122
Bronze . .	148,499	120,280	92,199
Totals .	**7,993,701**	**3,633,481**	**8,273,758**

Gold and Silver Imports and Exports.

The following tables from Messrs. Mocatta and Goldsmid's Circular show the imports and exports of gold and silver for the years 1898–1902 :—

GOLD.

Year.	Imports.	Exports.
	£	£
1898	44,000,000	35,800,000
1899	31,500,000	21,000,000
1900	26,700,000	18,800,000
1901	20,700,000	13,500,000
1902	20,500,000	15,000,000

SILVER.

Year.	Imports.	Exports.
	£	£
1898	15,700,000	15,500,000
1899	13,500,000	13,400,000
1900	13,900,000	14,100,000
1901	12,200,000	11,800,000
1902	10,500,000	10,000,000

Yields of Gold from British Possessions.

The following table shows the yields and value of gold from various British Possessions for the year 1902 :*—

	Ounces (Troy).	Approximate value.
		£
Western Australia . . .	1,871,037	7,484,148
Transvaal	1,718,921	7,301,501
Victoria	765,507	3,062,028
Queensland	640,463	2,720,639
† India	517,639	1,970,230
New Zealand . . .	508,045	1,951,433
British Columbia . . .	280,000	1,120,000
New South Wales . .	270,193	1,080,773
Rhodesia	194,169	776,676
British Guiana . . .	108,552	434,208
Tasmania	70,996	283,984
Totals . . .	**6,955,522**	**27,985,620**

During the year 1902 29,953 tons of gold ore were mined in the United Kingdom.

* Per favour of the Comptroller-General of the Commercial Department, Board of Trade.

† In India gold was only extracted from mines in the provinces of Burma and Mysore in 1902. No account, it is stated, is taken of the small quantities of gold produced in parts of Northern India from the washings of river sands, as no details are available.

Rand Gold Outputs.

The London secretary of the Transvaal Chamber of Mines has obtained the following data from Johannesburg. The gold output for October, 1903, of the mines which have so far restarted working on the Witwatersrand, amounted to 275,664 ozs. fine gold, and from outside districts 8880 ozs. fine gold. Total 284,544 ozs., valued at £1,208,669, as against 276,197 ozs., valued at £1,173,211, for September.

The following table shows the total Transvaal gold output in ounces month by month since 1898 :—

	1903.	1902.	1901.	1900.	1899.	1898.
	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.
January .	199,279	70,304	—	80,785	431,010	336,577
February .	196,513	81,405	—	64,408	425,166	321,238
March .	217,465	104,127	—	84,546	464,036	347,643
April .	227,871	119,588	—	54,772	460,349	353,243
May .	234,125	138,602	7,478	64,249	466,452	365,016
June .	238,320	142,780	19,799	—	467,271	365,091
July . .	251,643	149,179	25,960	—	478,494	382,006
August .	271,918	162,750	28,225	—	482,109	398,285
September	276,197	170,802	31,936	—	426,556	408,502
October .	284,544	181,439	33,393	—	26,904	423,217
November	—	187,375	39,075	—	65,041	413,517
December	—	196,023	52,897	—	68,525	440,674
Totals	2,397,875	1,704,374	238,743	348,760	4,252,813	4,555,009

The decrease in the output of recent years being due to the South African War and labour difficulties.

Returns from Australian Mints.

The following tables show the amount of gold received, value, expenditure and revenue, and composition of gold received at the Mints of Sydney, Melbourne, and Perth in recent years :—

Weight, Value, and Mint Charges.

Period.	Sydney. Gross weight.	Sydney. Value.	Sydney. Average mint charge per ounce.	Melbourne. Gross weight.	Melbourne. Value.	Melbourne. Average mint charge per ounce.	Perth. Gross weight.	Perth. Value.	Perth. Average mint charge per ounce.
	ozs.	£	d.	ozs.	£	d.	ozs.	£	d.
1899	948,743	3,377,761	1·844	1,520,739	5,834,916	2·135	201,314	732,165	5·666
1900	1,044,518	3,730,975	1·732	1,158,651	4,485,955	2·118	527,822	1,907,828	3·109
1901	864,634	3,039,503	2·671	1,048,239	4,077,194	2·072	827,510	2,919,354	3·211
1902	796,327	2,870,753	2·444	1,142,244	4,470,378	1·993	1,320,618	4,668,905	2·879

Expenditure and Revenue.

Period.	Sydney. (Annuity £15,000.) Expenditure.	Sydney. (Annuity £15,000.) Revenue.	Melbourne. (Annuity £20,000.) Expenditure.	Melbourne. (Annuity £20,000.) Revenue.	Perth. (Annuity £20,000.) Expenditure.	Perth. (Annuity £20,000.) Revenue.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
1899	14,488 4 5	15,610 4 0	17,081 2 7	25,145 5 7	14,209 2 10	4,753 8 6
1900	14,822 11 6	18,856 15 7	15,250 6 8	19,624 10 5	16,946 14 6	8,439 12 7
1901	14,599 7 11	18,211 11 3	15,928 6 10	16,664 12 4	16,948 7 1	13,603 7 4
1902	14,933 5 9	15,396 8 10	15,778 17 1	16,863 7 1	19,763 15 3	23,758 15 11

Average Composition of Bullion received.

Period.	Sydney. Gold.	Sydney. Silver.	Sydney. Base.	Melbourne. Gold.	Melbourne. Silver.	Melbourne. Base.	Perth. Gold.	Perth. Silver.	Perth. Base.
1899	834·4	113·2	52·4	903·5	57·7	38·8	856·2	94·4	49·4
1900	835·8	113·8	50·4	911·5	51·8	36·7	850·9	88·8	60·3
1901	822·3	127·4	50·3	915·7	48·8	35·5	830·5	101·2	68·3
1902	839·7	121·4	38·9	921·4	46·8	31·8	832·3	112·0	55·7

Western Australia Royal Mint—Perth Branch.

I.—Total Production of Gold in Western Australia since its First Discovery in 1886, and during the Year 1902.

Situation of goldfields		1886 to 1902. Production in ounces. Gross weight.	1886 to 1902. Production in ounces. Estimated fine content.	1902. Production in ounces. Gross weight.	1902. Production in ounces. Estimated fine content.
Within the tropics	Kimberley . / Pilbarra . . / Pilbarra West . / Ashburton .	235,581	210,387	14,432	12,401
Between 24° and 36° S. lat. and within 300 miles of west coast	Gascoyne . . / Peak Hill . . / Murchison . / Yalgoo . .	1,148,804	1,020,914	251,112	215,776
Inland (between 250 and 700 miles from west coast and south of lat. 26°)	Murchison East / Mount Margaret / Coolgardie . / Coolgardie East / Coolgardie N.E. / Coolgardie North / Broad Arrow . / Yilgarn . .	8,350,270	7,423,699	1,864,567	1,602,190
South-west coast	Donnybrook .	849	757	73	62
South coast .	Dundas . . / Phillips River .	225,747	200,827	44,787	38,48
Goldfields generally		13,212	11,755	2,471	2,123
Total production . . .		9,974,463	8,868,339	2,177,442	1,871,037

II.—RETURN OF THE WEIGHT AND VALUE OF GOLD RECEIVED FOR COINAGE; OF THE VALUE OF GOLD COIN AND BULLION ISSUED; AND OF THE REVENUE DERIVED FROM MINT CHARGES, ETC., FROM THE OPENING OF THE MINT ON JUNE 20, 1899, TO DECEMBER 31, 1902, INCLUSIVE.

Year.	Gold received.		Gold issued.						Revenue.			
			Coin.			Bullion.						
	Gross weight.	Value at £3 17s. 10½d. per ounce standard.	Sovereigns.	Half-sovereigns.	Total.	Weight.	Value.	Total.	From mint charges.	From sale of silver.	From other sources.	Total.
	ozs.	£ s. d.	£	£	£	ozs.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
1899	201,313·72	732,164 16 2	690,992	Nil	690,992	·70	2 14 6	690,994 14 6	4,753 8 6	Nil	Nil	4,753 8 6
1900	527,821·90	1,907,828 1 10	1,886,089	59,688	1,945,777	7·55	29 7 11	1,945,806 7 11	6,837 2 9	1,594 19 6	7 10 4	8,439 12 7
1901	827,510·04	2,919,353 15 10	2,889,333	Nil	2,889,333	5,042·64	21,225 2 11	2,910,558 2 11	11,069 10 11	1,608 9 9	925 6 8	13,603 7 4
1902	1,320,617·58	4,668,904 13 4	4,289,122	Nil	4,289,122	91,229·30	385,987 11 4	4,675,109 11 4	15,840 0 6	6,641 7 1	1,277 8 4	23,758 15 11
Total	2,877,263·24	10,228,251 7 2	9,755,536	59,688	9,815,224	96,280·79	407,244 16 8	10,222,468 16 8	38,500 2 8	9,844 16 4	2,210 5 4	50,555 4 4

Estimated Production of Gold in Australasia to the Year 1902, inclusive, from Returns furnished by the Government of each State.

Year.	New South Wales.		New Zealand.		Queensland.		South Australia.*		Tasmania.		Victoria.		Western Australia.		Total.	
	Gross.	Fine.	Gross.	Fine.	Gross.	Fine.	Gross.	Fine.	Gross.	Fine.	Gross.	Fine.	Gross.	Fine.	Gross.	Fine.
	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.
1851 to 1885	9,700,378	—	10,789,650	—	4,840,221	—	172,955	—	415,730	—	53,759,203	—	—	—	79,678,137	—
1886 to 1895	1,714,060	—	2,259,465	—	5,680,447	—	305,594	—	413,506	—	6,470,594	—	686,361	—	17,530,027	—
1896	296,071	—	263,722	—	638,000	—	29,004	—	62,586	—	805,087	—	281,265	—	2,375,735	—
1897	292,217	—	251,645	—	807,928	—	29,764	—	60,646	—	812,765	—	674,994	—	2,929,959	—
1898	340,494	—	280,175	—	920,048	—	49,372	—	69,549	—	837,258	—	1,050,183	—	3,547,079	—
1899	509,418	—	389,558	—	946,771	—	32,990	—	83,992	—	854,500	—	1,643,876	—	4,461,105	—
1900	345,650	—	371,993	—	963,189	—	29,397	—	81,175	—	807,407	—	1,580,950	—	4,179,761	—
	13,198,288	—	14,606,208	—	14,796,604	—	649,076	—	1,187,184	—	64,346,814	—	5,917,629	—	114,701,803	—
1901	267,061	216,888	455,561	412,876	835,553	598,382	34,060	28,951	75,831	69,491	789,562	730,453	1,879,390	1,703,416	4,337,018	3,760,457
1902	300,289†	254,435	508,045	459,406	860,453	640,463	29,503	24,082	— ‡	70,996	777,738	720,886	2,177,441	1,871,037	4,653,469§	4,041,285
	567,350	471,323	963,606	872,282	1,696,006	1,238,845	63,563	53,033	75,831‡	140,847	1,567,300	1,451,319	4,056,831	3,574,453	8,990,487	7,801,742

* Quantity received at Sydney and Melbourne mints. † Including a quantity of gold extracted by the smelting companies from imported auriferous ores.
‡ The Department of Mines, Tasmania, was unable to furnish yield in gross ounces for 1902. § Excluding Tasmania.

Gold at Indian Mints.

The following table shows the value in rupees of the gold tendered during the past three years at the mints of Calcutta and Bombay :—

Year.	Calcutta.	Bombay.
	Rs.	Rs.
1899–1900	21,203,239	65,325,755
1900–1901	38,834,952	41,228,213
1901-1902	20,433,266	21,295,525

Summary of the Coinages

Country.	Gold.		Silver.	
	Pieces.	Value.	Pieces.	Value.
		£		£
United Kingdom *	20,516,250	18,537,443	26,270,996	1,101,085
India †	—	—	62,134,555	3,423,182
British Colonies and Dependencies ‡	—	—	63,964,391	6,452,402
Total (British)	20,516,250	18,537,473	152,369,942	10,976,669
Arabia	—	—	58,800	420
Austria-Hungary	1,579,641	1,173,878	10,119,000	1,380,778
Belgium	—	—	—	—
Bolivia	—	—	—	—
Brazil	—	—	—	—
Bulgaria	—	—	—	—
China		No re	turns.	
Corea	—	—	1,411,186	43,235
Denmark	—	—	—	—
Ecuador	—	—	1,518,658	10,187
Egypt	—	—	—	—
France	2,403,707	1,954,966	11,778,172	475,563
French Colonies, etc.	100	48	13,903,554	1,023,168
Germany	4,638,044	4,388,086	21,577,269	2,205,279
German Colonies, etc.	—	—	151,019	10,068
Greece	—	—	—	—
Holland	—	—	1,300,000	45,833
Dutch Colonies, etc.	—	—	—	—
Italy	5,920	4,736	4,632,893	207,287
Japan	1,450,000	1,510,417	3,902,399	104,236
Luxemburg	—	—	—	—
Mexico §		No re	turns.	
Morocco	—	—	920,901	71,600
Norway	75,194	69,803	1,066,047	33,867
Persia	—	—	—	—
Peru	96,139	92,346	990,650	6,286
Portugal	—	—	—	—
Pudakota	—	—	—	—
Russia †	Com	plete returns	not received.	
Siam	—	—	5,004,899	212,660
Spain		No re	turns.	
Sweden	113,810	126,455	3,194,636	28,157
Switzerland	600,000	480,000	—	—
Turkey	187,343	180,514	11,958,711	140,635
United States §	5,428,551	12,912,619	68,212,454	6,274,244
Total (Foreign)	16,578,449	22,893,868	161,701,248	12,274,043
TOTAL	37,094,699	41,431,341	314,071,190	23,250,712

* Including gold coins struck at the Australian Branch mints.

‡ Inclusive of coins struck at Calcutta and Bombay (during the financial year 1901–02), and at the "Mint," Birmingham.

of the World, 1902.

Nickel.		Copper or bronze.		Total.	
Pieces.	Value.	Pieces.	Value.	Pieces.	Value.
	£		£		£
—	—	45,774,848	146,227	92,562,094	19,784,785
—	—	83,361,130	71,347	145,495,685	3,494,529
252,000	500	22,830,000	43,831	87,046,391	6,496,733
252,000	500	151,965,978	261,405	325,104,170	29,776,047
—	—	—	—	58,800	420
—	—	62,549,082	36,769	74,247,723	2,591,425
10,327,134	35,506	9,947,778	5,970	20,274,912	41,476
10,500,060	190,001	—	—	10,500,060	190,001
27,980,168	742,136	—	—	27,980,168	742,136
—	—	60,000,000	40,000	60,000,000	40,000
34,003,060	104,177	1,436,200	880	36,850,446	148,292
—	—	7,109,914	7,230	7,109,914	7,230
—	—	—	—	1,518,658	10,187
8,000,082	10,152	2,602,773	1,017	10,602,855	11,169
—	—	13,450,000	32,000	27,631,879	2,462,529
—	—	8,550,000	14,148	22,453,654	1,037,364
27,751,825	94,914	13,599,384	6,799	67,566,522	6,695,078
—	—	—	—	151,019	10,068
—	—	—	—	—	—
—	—	10,000,000	8,334	11,300,000	54,167
—	—	36,000,000	29,166	36,000,000	29,166
5,974,242	59,742	26,308	11	10,639,363	271,776
6,000,920	31,255	10,001,000	10,418	21,354,919	1,656,326
2,000,000	8,000	—	—	2,000,000	8,000
—	—	—	—	920,901	71,600
—	—	6,210,000	5,575	7,351,241	109,245
21,000,000	30,000	—	—	21,000,000	30,000
—	—	—	—	1,086,789	99,172
—	—	1,070,000	1,189	1,070,000	1,189
—	—	1,000,000	347	1,000,000	347
—	—	—	—	5,004,899	212,660
—	—	5,373,410	5,566	8,681,856	160,178
3,000,000	14,000	1,450,000	780	5,050,000	494,780
—	—	37,838,200	73,477	49,984,254	394,626
31,298,779	326,029	86,479,722	180,166	191,419,506	19,693,058
187,836,270	1,645,912	374,694,371	459,842	740,810,338	37,273,665
188,088,270	1,646,412	526,660,349	721,247	1,065,914,508	67,049,712

† Financial year, 1901–02.
§ Fiscal year ended June 30, 1902.

English Weights and Measures.

Avoirdupois Weight.

	Grains.	Drachms.	Ounces.	Pounds.	Stones.	Qtrs.	Cwts.
1 dram	27·34375						
1 oz.	437·5	16					
1 lb.	7,000	256	16				
1 stone	98,000	3,584	224	14			
1 quarter	196,000	7,168	448	28	2		
1 cwt.	784,000	28,672	1,792	112	8	4	
1 ton	15,680,000	573,440	35,840	2,240	160	80	20

Troy Weight.

	Grains.	Carats.	Dwts.	Ozs.
1 carat	$3\frac{1}{4}$			
1 pennyweight	24	$7\frac{1}{2}$		
1 ounce	480	150	20	
1 pound	5760	1800	240	12

Apothecary's Weight.

	Grains, or minims.	Scruples.	Drams.	Ozs.
1 scruple	20			
1 drachm	60	3		
1 ounce	480	24	8	
1 pound	5760	288	96	12

Table of Comparison.

	Avoirdupois. grains.	Avoirdupois. lb.	oz.	dr.	gr.	Troy. lb.	oz.	dwt.	gr.	Apothecary's. lb.	oz.	dr.	sc.	gr.
1 scruple (apoth.)	20	0	0	0	20	0	0	0	20	0	0	0	1	0
1 pennyweight (troy)	24	0	0	0	24	0	0	1	0	0	0	0	1	4
1 drachm (av.)	27	0	0	1	0	0	0	1	$3\frac{1}{2}$	0	0	0	1	$7\frac{1}{2}$
1 drachm (apoth.)	60	0	0	1	$5\frac{1}{3}$	0	0	2	22	0	0	1	0	0
1 ounce (av.)	437	0	1	0	0	0	0	18	$5\frac{1}{2}$	0	0	7	0	$1\frac{3}{4}$
1 ounce (troy and apoth.)	480	0	1	1	$15\frac{1}{6}$	0	1	0	0	0	1	0	0	0
1 pound (troy and apoth.)	5760	0	13	2	$17\frac{3}{4}$	1	0	0	0	1	0	0	0	0
1 pound (av.)	7000	1	0	0	0	1	2	11	16	1	2	4	2	0

MEASURE OF LENGTH.

	Inches.	Links.	Feet.	Yards.	Rods, poles, or perches.	Chns.	Furs.
1 link	= 7·92						
1 foot	= 12	= 1·515					
1 yard	= 36	= 4·545	= 3				
1 rod, pole, or perch	= 198	= 25	= 16½	= 5½			
1 chain	= 792	= 100	= 66	= 22	= 4		
1 furlong	= 7,920	= 1000	= 660	= 220	= 40	= 10	
1 mile	= 63,360	= 8000	= 5280	= 1760	= 320	= 80	= 8

SPECIAL MEASURE OF LENGTH.

6 feet = 1 fathom
6082·66 feet = 1 nautical mile or knot
3 nautical miles = 1 league
60 nautical miles, or 69·121 English miles = 1 degree
360 degrees = the earth's circuit

SURFACE OR SQUARE MEASURE.

	Sq. ins.	Sq. ft.	Sq. yds.	Sq. rods, poles, or perches.	Sq. chns.	Sq. roods.	Sq. acrs.
1 sq. foot =	144						
1 sq. yard =	1,296 =	9					
1 sq. rod, pole, or perch =	39,204 =	272¼ =	30¼				
1 sq. chain =	627,264 =	4,356 =	484 =	16			
1 sq. rood =	1,568,160 =	10,890 =	1,210 =	40 =	2½		
1 sq. acre =	6,272,640 =	43,560 =	4,840 =	160 =	10 =	4	
1 sq. mile =	...	...	= 3,097,600 =	102,400 =	6400	2560 =	640

Measures of Capacity.

Solid Measure.

1728 cubic inches	=	1 cubic foot
27 cubic feet	=	1 cubic yard
13 " "	=	1 ton of solid quartz
23 " "	=	1 ton of broken quartz
40 " "	=	1 ton rough timber
40½ " "	=	1 ton coal
42 " "	=	1 ton of shipping
48 " "	=	1 ton Admiralty measure
50 " "	=	1 ton firewood
52 " "	=	1 ton hewn timber
128 " "	=	1 cord firewood

Liquid and Corn Measure.

	Gills.	Pints.	Quarts.	Gallons.	Pecks.	Bushels.
1 pint =	4					
1 quart =	8 =	2				
1 gallon =	32 =	8 =	4			
1 peck =	64 =	16 =	8 =	2		
1 bushel =	256 =	64 =	32 =	8 =	4	
1 quarter =	2048 =	512 =	256 =	64 =	32 =	8

Various Constants.

1 gallon . .	=	277·276 cubic inches
1 pint . . .	=	34·659 "
1 fluid ounce .	=	1·7329 "
1 litre . . .	=	61·02705 "
1 cubic centimetre	=	0·06102705 "
1 cubic inch .	=	16·386176 cubic centimetres

1 cubic inch of distilled water in air at 62° F. = 252·336 grains
1 " " " *in vacuo* at 62° F. = 252·645 "

1 minim is the volume of 0·91 grain of water
1 fluid drachm " of 54·68 grains of water
1 fluid ounce " of 437·5 " "
1 gallon is the " of 10 lbs. or 70,000 grains of water.

Weights and Measures of the British Pharmacopœia of 1867.

Weights.

1 grain (gr.)		
1 ounce (oz.)		= 437·5 grains
1 pound (lb.)	= 16 ozs.	= 7000 „

Measures of Capacity.

1 minim (min.)	
1 fluid drachm (fl. drm.)	= 60 minims
1 fluid ounce (fl. oz.)	= 8 fluid drachms
1 pint (O)	= 20 fluid ounces
1 gallon (C)	= 8 pints

Measures of Length.

1 line $= \frac{1}{12}$ inch

1 inch $= \frac{1}{39{\cdot}1393}$ seconds—pendulum

12 inches = 1 foot

36 „ = 3 feet = 1 yard

Weights and Measures of the Metrical System.

Weights.

1 milligram	= 0·001 grm.
1 centigram	= 0·01 „
1 decigram	= 0·1 „
1 gram .	= weight of a cubic centimetre of water at 4° C.
1 decagram	= 10 grms.
1 hectogram	= 100 „
1 kilogram	= 1000 „

K

Measures of Capacity.

1 millilitre = 1 cubic centimetre of water at 4° C.
1 centilitre = 10 cubic centimetres
1 decilitre = 100 " "
1 litre = 1000 " "

Measures of Length.

1 millimetre = 0·001 metre
1 centimetre = 0·01 "
1 decimetre = 0·1 "
1 metre = the ten-millionth part of a quarter of the earth's meridian (nearly).

Tables for Conversion of Metrical and English Measures.

A. LENGTH.

Metrical to English.		English to Metrical.	
(1) Millimetres to inches.	(2) Metres to feet.	(3) Inches to millimetres.	(4) Feet to metres.
1 = 0·03937079	1 = 3·2808992	1 = 25·39954	1 = 0·30479449
2 = 0·07874158	2 = 6·5617984	2 = 50·79908	2 = 0·60958898
3 = 0·11811237	3 = 9·8426976	3 = 76·19862	3 = 0·91438347
4 = 0·15748316	4 = 13·1235968	4 = 101·59816	4 = 1·21917796
5 = 0·19685395	5 = 16·4044960	5 = 126·99770	5 = 1·52397245
6 = 0·23622474	6 = 19·6853952	6 = 152·39724	6 = 1·82876694
7 = 0·27559553	7 = 22·9662944	7 = 177·79678	7 = 2·13356143
8 = 0·31496632	8 = 26·2471936	8 = 203·19632	8 = 2·43835592
9 = 0·35433711	9 = 29·5280928	9 = 228·59586	9 = 2·74315041

B. CAPACITY.

Metrical to English.

(1) Cubic centimetres to cubic inches.	(2) Litres to fluid ounces.	(3) Litres to pints.	(4) Litres to gallons.
1 = 0·06102705	1 = 35·215468	1 = 1·7607734	1 = 0·22009668
2 = 0·12205410	2 = 70·430936	2 = 3·5215468	2 = 0·44019336
3 = 0·18308115	3 = 105·646404	3 = 5·2823202	3 = 0·66029004
4 = 0·24410820	4 = 140·861872	4 = 7·0430936	4 = 0·88038672
5 = 0·30513525	5 = 176·077340	5 = 8·8038670	5 = 1·10048340
6 = 0·36616230	6 = 211·292808	6 = 10·5646404	6 = 1·32058008
7 = 0·42718935	7 = 246·508276	7 = 12·3254138	7 = 1·54067676
8 = 0·48821640	8 = 281·723744	8 = 14·0861872	8 = 1·76077344
9 = 0·54924345	9 = 316·939212	9 = 15·8469606	9 = 1·98087012

English to Metrical.

(1) Cubic inches to cubic centimetres.	(2) Fluid ounces to cubic centimetres.	(3) Pints to litres.	(4) Gallons to litres.
1 = 16·386176	1 = 28·396612	1 = 0·567932	1 = 4·543458
2 = 32·772352	2 = 56·793224	2 = 1·135864	2 = 9·086916
3 = 49·158528	3 = 85·189856	3 = 1·703796	3 = 13·630374
4 = 65·544704	4 = 113·586448	4 = 2·271728	4 = 18·173832
5 = 81·930880	5 = 141·983060	5 = 2·839660	5 = 22·717290
6 = 98·317056	6 = 170·379672	6 = 3·407592	6 = 27·270748
7 = 114·703232	7 = 198·776284	7 = 3·975524	7 = 31·804206
8 = 131·089408	8 = 227·172896	8 = 4·543456	8 = 36·347664
9 = 147·475584	9 = 255·569608	9 = 5·111388	9 = 40·891122

C. WEIGHT.

Metrical to English.

(1) Grams to grains.	(2) Kilograms to ounces.	(3) Kilograms to pounds.
1 = 15·4323488	1 = 35·27394	1 = 2·20462
2 = 30·8646976	2 = 70·54788	2 = 4·40924
3 = 46·2970464	3 = 105·82182	3 = 6·61386
4 = 61·7293952	4 = 141·09576	4 = 8·81848
5 = 77·1617440	5 = 176·36970	5 = 11·02310
6 = 92·5940928	6 = 211·64364	6 = 13·22772
7 = 108·0264416	7 = 246·91758	7 = 15·43234
8 = 123·4587904	8 = 282·19152	8 = 17·63696
9 = 138·8911392	9 = 317·46546	9 = 19·84158

ENGLISH TO METRICAL.

(1) Grains to grams.	(2) Ounces to grams.	(3) Pounds to kilograms.	(4) Hundredweights to kilograms.
1 = 0·0647989	1 = 28·34954	1 = 0·45359265	1 = 50·8023768
2 = 0·1295978	2 = 56·69908	2 = 0·90718530	2 = 101·6047536
3 = 0·1943967	3 = 85·04862	3 = 1·36077795	3 = 152·4071304
4 = 0·2591956	4 = 113·39816	4 = 1·81437060	4 = 203·2095072
5 = 0·3239945	5 = 141·74770	5 = 2·26796325	5 = 254·0118840
6 = 0·3887934	6 = 170·09724	6 = 2·72155590	6 = 304·8142608
7 = 0·4535923	7 = 198·44678	7 = 3·17514855	7 = 355·6166376
8 = 0·5183912	8 = 226·79632	8 = 3·62874120	8 = 406·4190144
9 = 0·5831901	9 = 255·14586	9 = 4·08233385	9 = 457·2213912

Symbols and Atomic Weights of the Elements.

Element.	Symbol.	Atomic weight.	Observer.
Aluminium	Al	27·02	Mallet.
Antimony	Sb	120·00	Schneider, Cooke.
Arsenic	As	75·15	Kessler.
Barium	Ba	136·84	Marignac.
Bismuth	Bi	210·00	Dumas.
Boron	B	11·04	Berzelius.
Bromine	Br	79·76	Stas.
Cadmium	Cd	112·04	Lenssen.
Cæsium	Cs	133·00	Bunsen.
Calcium	Ca	39·90	Erdmann.
Carbon	C	11·97	Dumas, Liebig.
Cerium	Ce	138·24	Rammelsberg.
Chlorine	Cl	35·37	Stas.
Chromium	Cr	52·08	Siewart.
Cobalt	Co	58·74	Russell.
Copper	Cu	63·12	Millon and Commaille.
Didymium	D	142·44	Hermann.
Erbium	E	168·90	Bahr and Bunsen.
Fluorine	F	18·96	Luca, Louyet.
Gallium	Ga	69·80	Lecoq de Boisbaudran.

SYMBOLS AND ATOMIC WEIGHTS OF THE ELEMENTS—*continued.*

Element.	Symbol.	Atomic weight.	Observer.
Glucinum	Gl	9·30	Awdejew, Klatzo.
Gold	Au	196·71	Berzelius.
Hydrogen	H	1·00	Dulong and Berzelius.
Indium	In	113·40	Winkler, Bunsen.
Iodine	I	126·54	Stas.
Iridium	Ir	196·87	Berzelius.
Iron	Fe	56·00	Dumas.
Lanthanum	La	139·33	Hermann.
Lead	Pb	206·40	Stas.
Lithium	Li	7·00	Stas.
Magnesium	Mg	23·94	Dumas.
Manganese	Mn	54·04	Schneider.
Mercury	Hg	200·00	Erdmann.
Molybdenum	Mo	96·00	Dumas, Debray.
Nickel	Ni	58·74	Russell.
Niobium	Nb	94·00	Marignac.
Nitrogen	N	14·01	Stas.
Osmium	Os	199·03	Berzelius.
Oxygen	O	15·96	
Palladium	Pd	106·57	Berzelius.
Phosphorus	P	30·96	Schrötter.
Platinum	Pt	194·38	Seubert.
Potassium	K	39·04	Stas.
Rhodium	Rh	104·21	Berzelius.
Rubidium	Rb	85·40	Bunsen, Piccard.
Ruthenium	Ru	104·40	Berzelius.
Selenium	Se	79·46	Dumas.
Silver	Ag	107·67	Stas.
Silicon	Si	28·10	Dumas.
Sodium	Na	22·99	Stas.
Strontium	Sr	87·54	Marignac.
Sulphur	S	31·996	Stas.
Tantalum	Ta	182·300	Marignac.
Tellurium	Te	128·06	V. Hauer.
Thallium	Tl	203·66	Crookes.
Thorium	Th	231·44	Delafontaine.
Tin	Sn	118·10	Dumas.
Titanium	Ti	50·00	Pierre.
Tungsten	W	184·00	Schneider, Roscoe.

SYMBOLS AND ATOMIC WEIGHTS OF THE ELEMENTS—*continued.*

Element.	Symbol.	Atomic weight.	Observer.
Uranium	U	237·60	Ebelman.
Vanadium	V	51·35	Roscoe.
Yttrium	Y	92·55	Bahr and Bunsen.
Zinc	Zn	65·16	Oxel Erdmann.
Zirconium	Zr	89·60	Marignac.

INDEX.

4

THE END.

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