POCKET-BOOK
FOR
MINERS
AND
METALLURGISTS

F. DANVERS POWER

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A POCKET-BOOK

FOR

MINERS AND METALLURGISTS

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MINERS AND METALLURGISTS

COMPRISING

Rules, Formulæ, Tables, and Notes

FOR USE IN FIELD AND OFFICE WORK

COMPILED BY

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PREFACE.

THIS little work is intended as a *vade mecum* for those engaged in mining and metallurgical industries. It is designed to furnish them with a collection of rules, formulæ, tables, and other such information as may be found useful, if only to refresh the memory, in the multifarious operations falling within the daily duties of the practical miner and metallurgist.

In field work, especially, persons connected with mining have long felt the want of a suitable POCKET-BOOK which should contain concise notes of the various sciences with which metal-mining is concerned —a volume which they could carry about with them on the field, when travelling, or when engaged away from their head-quarters and thus debarred from consulting works of reference. The notes and other information comprised in the following pages have been put together in their present form in the spare time of the compiler. Having been found of use to him in the actual exercise of his profession, they are now published in the hope that they may be found of like service to others.

Such a work as this is of necessity a compilation. A list of books is accordingly given (see page xv.) to which reference has been made. Where the author of a table or formula previously published is known, care has been taken to give due acknowledgment. But it is not always easy to discover the original authorit for material current in various publications.

The compiler's thanks are due to Messrs. S. J Becher and W. Harris for their assistance in checkin certain calculations contained in the work, and to th former gentleman, also, for his "Hints on Photo graphy." He is also indebted to Mr. E. Henry Davie for having revised the proof sheets.

The compiler will feel indebted to any one who wil kindly assist him by pointing out any errors whicl may possibly have escaped his observation, in orde that they may be corrected in future editions. He will also welcome any suggestions for the improve ment of the work.

F. D. P.

MELBOURNE (VICTORIA),
March, 1892.

NOTE TO THIRD EDITION.

In placing a new edition of this book before the public, the compiler has to thank Mr. F. A. Eastaugh, A.R.S.M., for rewriting the greater portion of the section on Assaying. The classifications of rocks adopted are those more likely to be of service to the miner than that given in former editions; the section on Slags has been extended, the portion on Ore Dressing has been brought up to date, while several additions, e.g. Knots and Splices, use of Slide Rules, and notes on Mine Sampling have been made, which it is hoped will cause the book to be of greater value to those who use it.

F. D. P.

SYDNEY, N.S.W., 1913.

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Mineralogy and Geology.

Ore Dressing.

Mechanical Drawing.

Photography.

Toxicology.

POCKET BOOK

FOR

MINERS AND METALLURGISTS.

ARITHMETIC.

Fractions.

Addition of Vulgar Fractions.—

$\frac{1}{2}+\frac{1}{2}=\frac{2}{2}=1$ $\frac{6}{8}+\frac{3}{8}=\frac{9}{8}=1\frac{1}{8}$ $\frac{3}{7}+\frac{2}{3}=\frac{9+14}{21}=\frac{23}{21}=1\frac{2}{21}$

Subtraction of Vulgar Fractions.—

$\frac{1}{2}-\frac{1}{2}=0$ $\frac{6}{8}-\frac{2}{8}=\frac{4}{8}=\frac{1}{2}$ $3\frac{4}{7}-1\frac{2}{3}=\frac{25}{7}-\frac{5}{3}=\frac{75-35}{21}=\frac{40}{21}=1\frac{19}{21}$

Multiplication of Vulgar Fractions.—

$\frac{1}{2}\times\frac{1}{2}=\frac{1}{4}$ $\frac{4}{5}\times\frac{2}{3}=\frac{8}{15}$ $\frac{2}{3}\times\frac{3}{7}\times\frac{1}{2}=\frac{6}{42}=\frac{1}{7}$

Division of Vulgar Fractions.—

$\frac{1}{2}\div\frac{1}{2}=\frac{2}{2}=1$ $\frac{4}{5}\div\frac{2}{3}=\frac{12}{10}=\frac{6}{5}=1\frac{1}{5}$

To find the greatest common divisor of a Vulgar Fraction.—

Thus $\frac{70}{175}$

```
70)175(2
   140
    35)70(2        Ans. 35
       70
       ..
```

To reduce a Vulgar Fraction to its lowest terms.—Find the greatest common divisor and divide both the numerator and denominator by it.

Thus $\frac{70}{175}$, whose greatest common divisor as above is $35=\frac{2}{5}$.

To reduce a Vulgar Fraction to a decimal form.—Divide the numerator by the denominator.

Thus $\frac{8}{25}$

```
25)8·0(·32
   75
    50             Ans. ·32
    50
    ..
```

Ex.—Reduce 3 inches to the decimal of 1 foot, *i.e.*, 12 inches The question is therefore reduce $\frac{3}{12}$ to a decimal as above.

Ex.—How many feet are there in ·75 of a yard?

```
        ·75
         3 feet in a yard
Feet   2·25
        12 inches in a foot
In.    3·00
```

Ans. 2ft. 3ins.

Decimals.

Add together ·27 ·439 ·073 ·01

```
·27
·439
·073
·01
·792  Ans.
```

Subtract ·23 from ·94; also ·0001 from 1·3.

```
·94          1·3
·23           ·0001
·71          1·2999
```

Multiply ·734 by 1·02.

```
  ·734
  1·02
  1468
 734
·74868
```

Divide 14 357 by ·07.

```
7)1435·7(205·1
  14
    35
    35
      7
      7
```

Evolution or Extraction of Roots.

Square root expressed thus, $\sqrt{36}=6$.

Rule.—Separate the given number into periods of two figures each, by placing a point over the units figure, then over every second towards the left in whole numbers, and over every second figure towards the right in decimals, and proceed thus—

```
√5329;              5329(73
                    49
               143) 429                 Ans. 73
                    429
                    ...

√7·3441;            7·3441(2·71
                    4
                47)334
                    329                 Ans. 2·71
               541) 541
                    541
                    ...
```

Note.—For square and cube roots see Tables. Fourth, fifth roots, &c., are best done by logarithms.

ALGEBRA.

Powers, Roots.

$a^m . a^n = a^{m+n}$; $(a . b)^n = a^n . b^n$; $a^m \div a^n = a^{m-n}$; $a^{-n} = \frac{1}{a^n}$;

$(a^n)^m = a^{n \cdot m}$; $\left(\frac{a}{b}\right)^m = \frac{a^m}{b^m}$; $a^{-m} . a^n = a^{-m+n}$; $(a^m)^{-n} = a^{-m \cdot n}$;

$\frac{a^2 - b^2}{a - b} = a + b$; $\frac{a^2 - b^2}{a + b} = a - b$; $(a+b)(a-b) = a^2 - b^2$; $a^0 = 1$;

$(\sqrt[n]{a})^n = \sqrt[n]{a^n} = a$; $\sqrt[n]{a . b} = \sqrt[n]{a} . \sqrt[n]{b}$; $\sqrt[n]{\frac{a}{b}} = \frac{\sqrt[n]{a}}{\sqrt[n]{b}}$; $\sqrt[n]{a^m} = a^{\frac{m}{n}}$;

$\sqrt[n]{a^m} = \sqrt[n \cdot r]{a^{m \cdot r}}$; $\sqrt[n]{\sqrt[m]{a}} = \sqrt[n \cdot m]{a}$;

Equations.

1st degree with one unknown quantity $ax + b = 0$ . . . $x = -\frac{b}{a}$;

1st degree with two unknown quantities $\left\{\begin{matrix} ax + by = c \\ a_1x + b_1y = c_1 \end{matrix}\right\}$ . . .

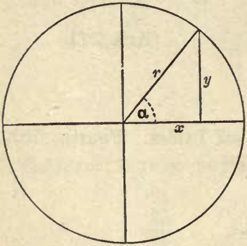
$$\ldots \left\{\begin{matrix} x = \frac{b_1c - bc_1}{ab_1 - a_1b}; \\ y = \frac{ac_1 - a_1c}{ab_1 - a_1b}; \end{matrix}\right.$$

2nd degree, common form, $ax^2+bx+c=0$ $\quad x=\dfrac{-b\pm\sqrt{b^2-4ac}}{2a}$

2nd degree, normal form, $x^2+px+q=0$ $\quad x=-\dfrac{p}{2}\pm\sqrt{\dfrac{p^2}{4}-q}$;

3rd degree, $Ax^3+Bx^2+Cx+D=0$ . . $x^3+ax^2+bx+c=0$

TRIGONOMETRY.



$\sin\alpha=\dfrac{y}{r}$ $\quad \cos\alpha=\dfrac{x}{r}$

$\tan\alpha=\dfrac{y}{x}$ $\quad \cot\alpha=\dfrac{x}{y}$

$\sec\alpha=\dfrac{r}{x}$ $\quad \operatorname{cosec}\alpha=\dfrac{r}{y}$

Between	0°	and	90°	the sin is	+	cos +	tan +	cot +
,,	90°	,,	180°	,,	+	,, −	,, −	,, −
,,	180°	,,	270°	,,	−	,, −	,, +	,, +
,,	270°	,,	360°	,,	−	,, +	,, −	,, −

Formulæ.

$$\sin\alpha=\sin(180-\alpha)=-\sin(180+\alpha)=-\sin(360-\alpha)=\cos(90-\alpha)\left\{\begin{matrix}=-1\\ >\\ <\\ =+1\end{matrix}\right\}$$

$$\cos\alpha=-\cos(180-\alpha)=-\cos(180+\alpha)=+\cos(360-\alpha)=\sin(90-\alpha)\left\{\begin{matrix}=-1\\ >\\ <\\ =+1\end{matrix}\right\}$$

$\sin(-\alpha)=-\sin\alpha$;

$\cos(-\alpha)=+\cos\alpha$;

$\tan\alpha=\dfrac{\sin\alpha}{\cos\alpha}\left\{\begin{matrix}-\infty\\ \text{to}\\ +\infty\end{matrix}\right\}$; $\quad \cot\alpha=\dfrac{\cos\alpha}{\sin\alpha}\left\{\begin{matrix}-\infty\\ \text{to}\\ +\infty\end{matrix}\right\}$;

$\tan\alpha\,.\,\cot\alpha=1$;

$\sin^2\alpha+\cos^2\alpha=1$; $\quad \sin\alpha=\sqrt{1-\cos^2\alpha}$; $\quad \cos\alpha=\sqrt{1-\sin^2\alpha}$;

$\sin 2\alpha = 2 \sin \alpha \cos \alpha$; $\cos 2\alpha = \cos^2 \alpha - \sin^2 \alpha$;

$\sin(\alpha \pm \beta) = \sin \alpha \cos \beta \pm \cos \alpha \sin \beta$; $\sec \alpha . \cos \alpha = 1$;

$\cos(\alpha \pm \beta) = \cos \alpha \cos \beta \mp \sin \alpha \sin \beta$; $\operatorname{cosec} \alpha . \sin \alpha = 1$;

$\tan(\alpha \pm \beta) = \dfrac{\tan \alpha \pm \tan \beta}{1 \mp \tan \alpha . \tan \beta}$ $\cot(\alpha \pm \beta) = \dfrac{\cot \alpha \cot \beta \mp 1}{\cot \alpha \pm \cot \beta}$;

$\tan 2\alpha = \dfrac{2 \tan \alpha}{1 - \tan^2 \alpha}$; $\sin \tfrac{1}{2}\alpha = \pm \sqrt{\dfrac{1 - \cos \alpha}{2}}$;

$\cos \tfrac{1}{2}\alpha = \pm \sqrt{\dfrac{1 + \cos \alpha}{2}}$;

$\sin 2\alpha + \sin 2\beta = 2 \sin(\alpha + \beta) \cos(\alpha - \beta)$;

$\sin 2\alpha - \sin 2\beta = 2 \sin(\alpha - \beta) \cos(\alpha + \beta)$;

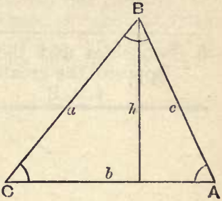
$\cos 2\alpha + \cos 2\beta = 2 \cos(\alpha + \beta) \cos(\alpha - \beta)$;

$\cos 2\alpha - \cos 2\beta = -2 \sin(\alpha + \beta) \sin(\alpha - \beta)$;

$$\sin \alpha = \frac{\tan \alpha}{\sqrt{1 + \tan^2 \alpha}} = \frac{1}{\sqrt{1 + \cot^2 \alpha}} = \frac{1}{\operatorname{cosec} \alpha};$$

$$\cos \alpha = \frac{1}{\sqrt{1 + \tan^2 \alpha}} = \frac{\cot \alpha}{\sqrt{1 + \cot^2 \alpha}} = \frac{1}{\sec \alpha}$$

In the oblique angled triangle, A, B, C—



(1) $\dfrac{a}{\sin A} = \dfrac{b}{\sin B} = \dfrac{c}{\sin C}$.

(2) $a^2 = b^2 + c^2 - 2\, b\, c \cos A$.

(3) $\tan \dfrac{A}{2} = \sqrt{\dfrac{(a + b - c)(a + c - b)}{(a + b + c)(b + c - a)}}$.

(4) $\dfrac{a + b}{a - b} = \dfrac{\tan \dfrac{A + B}{2}}{\tan \dfrac{A - B}{2}}$

(5) Area of the triangle, A, B, C $= \dfrac{b\,h}{2} = \dfrac{a\,b \sin C}{2} = \dfrac{c^2 \sin B \sin A}{2 \sin C} = \sqrt{s\,(s - a)\,(s - b)\,(s - c)}$

where h = height

s = sum of the sides divided by 2.

Examples

Given.	Required.
1. One side and two adjacent angles a, B, C	b and c by equation (1) $A = 180 - (B + C)$ Area from equation (5)

Given.	Required.
2. One side, one adjacent and one opposite angle a, B, A	b and c by equation (1) $C=180-(A+B)$ area from equation (5)
3. Three sides a, b, c	Two angles by (2) or (3) When the third will be 180 − the other two area by (5)
4. Two sides and the included angle b, c, A	$B=\frac{B+C}{2}+\frac{B-C}{2}$ $C=\frac{B+C}{2}-\frac{B-C}{2}$ $\frac{B+C}{2}=\frac{180-A}{2}$; $\frac{B-C}{2}$ from (4) A from equation (1) area " (5)
5. Two sides and the angle opposite the greater side b, c, B	By equation (4)

MENSURATION.

s = side; b = base; h = height; d = diameter; r = radius; c = circumference; a = area; V = volume; $\pi = 3.1416$; e = length of arc; o = chord; α = central angle.

Triangles.—$a=\frac{1}{2}\ b\times h$;

Squares.—$a=s^2$;

Parallelograms.—$a=b\times h$;

Trapezoids.—$a=\frac{\text{the two parallel } s\times h}{2}$;

Trapeziums.—a = divide into triangles and add their areas together.

Polygons.—$a=s\times h$ (from centre of figure to centre of side) × half the number of sides.

Circles.—$a=\pi r^2=\pi\frac{d^2}{4}$; $c=2\pi r=d\pi$. $d=\frac{c}{\pi}=\frac{c\times 7}{22}$.

To find the diameter of a circle equal in area to a given square, multiply one side of the square by 1·12838.

To find the side of a square equal in area to a given circle, multiply the diameter by 0·88623.

Sectors.—$a=\frac{e\times r}{2}=\frac{a}{360}\pi r^2=\frac{a}{360}\pi\frac{d^2}{4}$;

$$e=\frac{a}{360}\pi 2r=\frac{a}{360}\pi d;$$

Segments.—$a=\left(\frac{a}{360}2\pi-\sin a\right)\frac{r^2}{2}$;

For flat segments $a=$ about $\frac{2}{3}oh$; $e=o\left(1+\frac{h}{3r}\right)$.

Circular rings.—$a=$area of the smaller circle subtracted from the area of the greater.

Ellipse.—$a=$product of diameters $\times$ 0·7854.

Parabola.—$a=\frac{2}{3}b\times h$.

Cubes.—$V=s^3$.

Prisms.—$V=$area of base $\times h$.

Pyramids.—$V=\frac{\text{area of base}\times h}{3}$.

Prismoids.—Add together the areas of the two parallel surfaces, and four times the area of the section taken halfway between them and parallel to them: multiply the sum by the perpendicular distance between the two parallel sides, and divide the product by 6.

Wedges.—$V=\frac{(\text{length of edge }+2\ s\text{ parallel to the edge})\ h\times s\text{ at right angles to edge}}{6}$.

Cylinders.—$V=\pi r^2h$;

Cones.—$V=\frac{\text{area of base}\times h}{3}$.

To find the surface of any regular cone, multiply the circumference of its base by the *slant* height; take half the product.

Sphere.—$V=0,5236d^3=4·1888r^3=\frac{4}{3}\pi r^3=\frac{1}{6}\pi d^3$. Surface $=\pi d^2=3·1416\ d^2=4\pi r^2=12·5664\ r^2$.

Spherical segment.—Volume=square of the radius of its base multiplied by 3, add to the product the square of its height, multiply the sum by the height, and multiply this last product by 0·5236.

Cylindrical rings.—Volume=area of cross section of bar of which ring is made $\times\frac{1}{2}$ sum of inner and outer diameters $\times$ 3·141593. Surface=circumference of bar of which ring is made $\times\frac{1}{2}$ sum of inner and outer diameters $\times$ 3·141593.

Paraboloid.—$V=\frac{1}{2}\pi r^2h$

TABLES.

Table of Logarithms of Numbers from 10 to 1200.

The index of the logarithm of a number greater than unity is one less than the number of figures in the integral part of that number.

The index of the logarithm of a number less than unity is negative, and is a higher number by one than the number of zeros that follow the decimal point.

Example.—1892 is 3 : 18·92 is 1 ; 0·1892 is $\bar{1}$; 0·001892 is $\bar{3}$.

Nr.	0	1	2	3	4	5	6	7	8	9	Diff.
10	00000	00432	00860	01284	01703	02119	02531	02938	03342	03743	396
11	04139	04532	04922	05308	05690	06070	06446	06819	07188	07555	363
12	07918	08279	08636	08991	09342	09691	10037	10380	10721	11059	335
13	11394	11727	12057	12385	12710	13033	13354	13672	13988	14301	312
14	14613	14922	15229	15534	15836	16137	16435	16732	17026	17319	290
15	17609	17898	18184	18469	18752	19033	19312	19590	19866	20140	272
16	20412	20683	20952	21219	21484	21748	22011	22272	22531	22789	256
17	23045	23300	23553	23805	24055	24304	24551	24797	25042	25285	242
18	25527	25768	26007	26245	26482	26717	26951	27184	27416	27646	229
19	27875	28103	28330	28556	28780	29003	29226	29447	29667	29885	218
20	30103	30320	30535	30750	30963	31175	31387	31597	31806	32015	207
21	32222	32428	32634	32838	33041	33244	33445	33646	33846	34044	198
22	34242	34439	34635	34830	35025	35218	35411	35603	35793	35984	189
23	36173	36361	36549	36736	36922	37107	37291	37475	37658	37840	181
24	38021	38202	38382	38561	38739	38917	39094	39270	39445	39620	174
25	39794	39967	40140	40312	40483	40654	40824	40993	41162	41330	167
26	41497	41664	41830	41996	42160	42325	42488	42651	42813	42975	161
27	43136	43297	43457	43616	43775	43933	44091	44248	44404	44560	156
28	44716	44871	45025	45179	45332	45484	45637	45788	45939	46090	150
29	46240	46389	46538	46687	46835	46982	47129	47276	47422	47567	145
30	47712	47857	48001	48144	48287	48430	48572	48714	48855	48996	140
31	49136	49276	49415	49554	49693	49831	49969	50106	50243	50379	136
32	50515	50651	50786	50920	51055	51188	51322	51455	51587	51720	132
33	51851	51983	52114	52244	52375	52504	52634	52763	52892	53020	128
34	53148	53275	53403	53529	53656	53782	53908	54033	54158	54283	124
35	54407	54531	54654	54777	54900	55023	55145	55267	55388	55509	121
36	55630	55751	55871	55991	56110	56229	56348	56467	56585	56703	117
37	56820	56937	57054	57171	57287	57403	57519	57634	57749	57864	114
38	57978	58092	58206	58320	58433	58546	58659	58771	58883	58995	111
39	59106	59218	59329	59439	59550	59660	59770	59879	59988	60097	109
40	60206	60314	60423	60531	60638	60746	60853	60959	61066	61172	106
41	61278	61384	61490	61595	61700	61805	61909	62014	62118	62221	104
42	62325	62428	62531	62634	62737	62839	62941	63043	63144	63246	101
43	63347	63448	63548	63649	63749	63849	63949	64048	64147	64246	99
44	64345	64444	64542	64640	64738	64836	64933	65031	65128	65225	97
45	65321	65418	65514	65610	65706	65801	65896	65992	66087	66181	95
46	66276	66370	66464	66558	66652	66745	66839	66932	67025	67117	93
47	67210	67302	67394	67486	67578	67669	67761	67852	67943	68034	90
48	68124	68215	68305	68395	68485	68574	68664	68753	68842	68931	89
49	69020	69108	69197	69285	69373	69461	69548	69636	69723	69810	87
Nr.	0	1	2	3	4	5	6	7	8	9	Diff.

TABLE OF LOGARITHMS OF NUMBERS (*continued*).

Nr.	0	1	2	3	4	5	6	7	8	9	Diff.
50	69897	69984	70070	70157	70243	70329	70415	70501	70586	70672	86
51	70757	70842	70927	71012	71096	71181	71265	71349	71433	71517	84
52	71600	71684	71767	71850	71933	72016	72099	72181	72263	72346	83
53	72428	72509	72591	72673	72754	72835	72916	72997	73078	73159	81
54	73239	73320	73400	73480	73560	73640	73719	73799	73878	73957	80
55	74036	74115	74194	74273	74351	74429	74507	74586	74663	74741	78
56	74819	74896	74974	75051	75128	75205	75282	75358	75435	75511	77
57	75587	75664	75740	75815	75891	75967	76042	76118	76193	76268	76
58	76343	76418	76492	76567	76641	76716	76790	76864	76938	77012	74
59	77085	77159	77232	77305	77379	77452	77525	77597	77670	77743	73
60	77815	77887	77960	78032	78104	78176	78247	78319	78390	78462	72
61	78533	78604	78675	78746	78817	78888	78958	79029	79099	79169	71
62	79239	79309	79379	79449	79518	79588	79657	79727	79796	79865	69
63	79934	80003	80072	80140	80209	80277	80346	80414	80482	80550	68
64	80618	80686	80754	80821	80889	80956	81023	81090	81158	81224	67
65	81291	81358	81425	81491	81558	81624	81690	81757	81823	81889	66
66	81954	82020	82086	82151	82217	82282	82347	82413	82478	82543	65
67	82607	82672	82737	82802	82866	82930	82995	83059	83123	83187	64
68	83251	83315	83378	83442	83506	83569	83632	83696	83759	83822	63
69	83885	83948	84011	84073	84136	84198	84261	84323	84386	84448	63
70	84510	84572	84634	84696	84757	84819	84880	84942	85003	85065	62
71	85126	85187	85248	85309	85370	85431	85491	85552	85612	85673	61
72	85733	85794	85854	85914	85974	86034	86094	86153	86213	86273	60
73	86332	86392	86451	86510	86570	86629	86688	86747	86806	86864	59
74	86923	86982	87040	87099	87157	87216	87274	87332	87390	87448	58
75	87506	87564	87622	87679	87737	87795	87852	87910	87967	88024	58
76	88081	88138	88195	88252	88309	88366	88423	88480	88536	88593	57
77	88649	88705	88762	88818	88874	88930	88986	89042	89098	89154	56
78	89209	89265	89321	89376	89432	89487	89542	89597	89653	89708	55
79	89763	89818	89873	89927	89982	90037	90091	90146	90200	90255	55
80	90309	90363	90417	90472	90526	90580	90634	90687	90741	90795	54
81	90849	90902	90956	91009	91062	91116	91169	91222	91275	91328	53
82	91381	91434	91487	91540	91593	91645	91698	91751	91803	91855	52
83	91908	91960	92012	92065	92117	92169	92221	92273	92324	92376	52
84	92428	92480	92531	92583	92634	92686	92737	92788	92840	92891	51
85	92942	92993	93044	93095	93146	93197	93247	93298	93349	93399	51
86	93450	93500	93551	93601	93651	93702	93752	93802	93852	93902	50
87	93952	94002	94052	94101	94151	94201	94250	94300	94349	94399	50
88	94448	94498	94547	94596	94645	94694	94743	94792	94841	94890	49
89	94939	94988	95036	95085	95134	95182	95231	95279	95328	95376	49
90	95424	95472	95521	95569	95617	95665	95713	95761	95809	95856	48
91	95904	95952	95999	96047	96095	96142	96190	96237	96284	96332	47
92	96379	96426	96473	96520	96567	96614	96661	96708	96755	96802	47
93	96848	96895	96942	96988	97035	97081	97128	97174	97220	97267	46
94	97313	97359	97405	97451	97497	97543	97589	97635	97681	97727	46
95	97772	97818	97864	97909	97955	98000	98046	98091	98137	98182	45
96	98227	98272	98318	98363	98408	98453	98498	98543	98588	98632	45
97	98677	98722	98767	98811	98856	98900	98945	98989	99034	99078	45
98	99123	99167	99211	99255	99300	99344	99388	99432	99476	99520	44
99	99564	99607	99651	99695	99739	99782	99826	99870	99913	99957	44
100	00000	00043	00087	00130	00173	00217	00260	00303	00346	00389	43
Nr.	0	1	2	3	4	5	6	7	8	9	Diff.

TABLE OF LOGARITHMS OF NUMBERS (*continued*).

Nr.	0	1	2	3	4	5	6	7	8	9	Diff.
101	00432	00475	00518	00561	00604	00647	00689	00732	00775	00817	43
102	00860	00903	00945	00988	01030	01072	01115	01157	01199	01242	42
103	01284	01326	01368	01410	01452	01494	01536	01578	01620	01662	42
104	01703	01745	01787	01828	01870	01912	01953	01995	02036	02078	42
105	02119	02160	02202	02243	02284	02325	02366	02407	02449	02490	41
106	02531	02572	02612	02653	02694	02735	02776	02816	02857	02898	41
107	02938	02979	03019	03060	03100	03141	03181	03222	03262	03302	41
108	03342	03383	03423	03463	03503	03543	03583	03623	03663	03703	40
109	03743	03782	03822	03862	03902	03941	03981	04021	04060	04100	40
110	04139	04179	04218	04258	04297	04336	04376	04415	04454	04493	39
111	04532	04571	04610	04650	04689	04727	04766	04805	04844	04883	39
112	04922	04961	04999	05038	05077	05115	05154	05192	05231	05269	39
113	05308	05346	05385	05423	05461	05500	05538	05576	05614	05652	38
114	05690	05729	05767	05805	05843	05881	05918	05956	05994	06032	38
115	06070	06108	06145	06183	06221	06258	06296	06333	06371	06408	38
116	06446	06483	06521	06558	06595	06633	06670	06707	06744	06781	37
117	06819	06856	06893	06930	06967	07004	07041	07078	07115	07151	37
118	07188	07225	07262	07298	07335	07372	07408	07445	07482	07518	37
119	07555	07591	07628	07664	07700	07737	07773	07809	07846	07882	36
Nr.	0	1	2	3	4	5	6	7	8	9	Diff.

Examples :

Find log. of 5065

Log. of 5060 = 3·70415

Prop. diff. 86 × 5 = 430

Log. required 3·704580

Find number of log. 3·771442

Log. of 5900 = 3·770850

592

Prop. diff. 73

$\frac{593}{73} = 8$ ∴ number is 5900

8

5908

To multiply by logarithms, add the logarithms together and find the corresponding number.

To divide by logarithms, subtract one from the other and find the corresponding number.

To extract the root, divide the logarithm by the index of the root and find the corresponding number.

To raise a number to any power, multiply the logarithm by the index of the power and find the corresponding number.

The Hyperbolic or Napierian logarithm is the common logarithm of the Table multiplied by 2·3025851.

TABLE OF POWERS (ROOT, CIRCUMFERENCE, AREA, SQUARE, CUBE, SQUARE ROOT, AND CUBE ROOT).

To find the $\sqrt{n}$ of a number which is wholly decimal. If the number is not separable into twos, add another cipher to make it so. Then begin at the first numerical figure, and including it assume the number to be a whole one. In the table find the number nearest the assumed one, take out its tabular square root, move the decimal point of this tabular root to the left half as many places as the finally modified decimal number has figures. *Example.*—$\sqrt{\cdot002}$? 1)·002 2)·00·20; 3) $\sqrt{20} = 4\cdot47$; 4) move decimal point two places: ·0447 ans. This rule is good up to three numerals inclusive.

To find the $\sqrt[3]{n}$ of a number which is wholly decimal. Proceed as in the former case for $\sqrt{n}$, only divide the figures into threes and point off to the left $\frac{1}{3}$ as many places as the finally modified decimal number has figures. *Example.*—$\sqrt[3]{\cdot002}$? 1)·002 ; 2) $\sqrt[3]{2} = 1\cdot26$; 3)·126 ans.

To find the square or cube of any whole number ending with ciphers, 1) omit all the final ciphers ; 2) take from the table the square or cube (as the case may be) of the rest of the number ; 3) to this square add twice as many ciphers as there were final ciphers in the original number. To the cube add three times as many as the original number. *Example.*—$28{,}000^2$? 1) $28^2 = 784$; 2) add six ciphers : 784,000,000 ans. *Example.*—$28{,}000^3$? 1) $28^3 = 21{,}952$; 2) add nine ciphers : 21,952,000,000,000 ans.

n	$n\pi$	$n^2\frac{\pi}{4}$	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
1·0	3·142	0·7854	1·000	1·000	1·0000	1·0000
1·1	3·456	0·9503	1·210	1·331	1·0488	1·0323
1·2	3·770	1·1310	1·440	1·728	1·0955	1·0627
1·3	4·084	1·3273	1·690	2·197	1·1402	1·0914
1·4	4·398	1·5394	1·960	2·744	1·1832	1·1187
1·5	4·712	1·7672	2·250	3·375	1·2247	1·1447
1·6	5·027	2·0106	2·560	4·096	1·2649	1·1696
1·7	5·341	2·2698	2·890	4·913	1·3038	1·1935
1·8	5·655	2·5447	3·240	5·832	1·3416	1·2164
1·9	5·969	2·8353	3·610	6·859	1·3784	1·2386
2·0	6·283	3·1416	4·000	8·000	1·4142	1·2599
2·1	6·597	3·4636	4·410	9·261	1·4491	1·2806

TABLE OF POWERS (*continued*).

n	$n\pi$	$n^2\frac{\pi}{4}$	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
2·2	6·912	3·8013	4·840	10·648	1·4832	1·3006
2·3	7·226	4·1548	5·290	12·167	1·5166	1·3200
2·4	7·540	4·5239	5·760	13·824	1·5492	1·3389
2·5	7·854	4·9087	6·250	15·625	1·5811	1·3572
2·6	8·168	5·3093	6·760	17·576	1·6125	1·3751
2·7	8·482	5·7256	7·290	19·683	1·6432	1·3925
2·8	8·797	6·1575	7·840	21·952	1·6733	1·4095
2·9	9·111	6·6052	8·410	24·389	1·7029	1·4260
3·0	9·425	7·0686	9·00	27·000	1·7321	1·4422
3·1	9·739	7·5477	9·61	29·791	1·7607	1·4581
3·2	10·053	8·0425	10·24	32·768	1·7889	1·4736
3·3	10·367	8·5530	10·89	35·937	1·8166	1·4888
3·4	10·681	9·0792	11·56	39·304	1·8439	1·5037
3·5	10·996	9·6211	12·25	42·875	1·8708	1·5183
3·6	11·310	10·179	12·96	46·656	1·8974	1·5326
3·7	11·624	10·752	13·69	50·653	1·9235	1·5467
3·8	11·938	11·341	14·44	54·872	1·9494	1·5605
3·9	12·252	11·946	15·21	59·319	1·9748	1·5741
4·0	12·566	12·566	16·00	64·000	2·0000	1·5874
4·1	12·881	13·203	16·81	68·921	2·0249	1·6005
4·2	13·195	13·854	17·64	74·088	2·0494	1·6134
4·3	13·509	14·522	18·49	79·507	2·0736	1·6261
4·4	13·823	15·205	19·36	85·184	2·0976	1·6386
4·5	14·137	15·904	20·25	91·125	2·1213	1·6510
4·6	14·451	16·619	21·16	97·336	2·1448	1·6631
4·7	14·765	17·349	22·09	103·823	2·1680	1·6751
4·8	15·080	18·096	23·04	110·592	2·1909	1·6869
4·9	15·394	18·857	24·01	117·649	2·2136	1·6985
5·0	15·708	19·6350	25·00	125·000	2·2361	1·7100
5·1	16·022	20·4282	26·01	132·651	2·2583	1·7213
5·2	16·336	21·2372	27·04	140·608	2·2804	1·7325
5·3	16·650	22·0618	28·09	148·877	2·3022	1·7435
5·4	16·965	22·9022	29·16	157·464	2·3238	1·7544
5·5	17·279	23·7583	30·25	166·375	2·3452	1·7652
5·6	17·593	24·6301	31·36	175·616	2·3664	1·7758
5·7	17·907	25·5176	32·49	185·193	2·3875	1·7863
5·8	18·221	26·4208	33·64	195·112	2·4083	1·7967
5·9	18·535	27·3397	34·81	205·379	2·4290	1·8070
6·0	18·850	28·2743	36·00	216·000	2·4495	1·8171
6·1	19·164	29·2247	37·21	226·981	2·4698	1·8272
6·2	19·478	30·1907	38·44	238·328	2·4900	1·8371

TABLE OF POWERS (*continued*).

n	$n\pi$	$n^2\frac{\pi}{4}$	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
6·3	19·792	31·1725	39·69	250·047	2·5100	1·8469
6·4	20·106	32·1699	40·96	262·144	2·5298	1·8566
6·5	20·420	33·1831	42·25	274·625	2·5495	1·8663
6·6	20·735	34·2119	43·56	287·496	2·5690	1·8758
6·7	21·049	35·2565	44·89	300·763	2·5884	1·8852
6·8	21·363	36·3168	46·24	314·432	2·6077	1·8945
6·9	21·677	37·3928	47·61	328·509	2·6268	1·9038
7·0	21·991	38·4845	49·00	343·000	2·6458	1·9129
7·1	22·305	39·5919	50·41	357·911	2·6646	1·9220
7·2	22·619	40·7150	51·84	373·248	2·6833	1·9310
7·3	22·934	41·8539	53·29	389·017	2·7019	1·9399
7·4	23·248	43·0084	54·76	405·224	2·7203	1·9487
7·5	23·562	44·1786	56·25	421·875	2·7386	1·9574
7·6	23·876	45·3646	57·76	438·976	2·7568	1·9661
7·7	24·190	46·5663	59·29	456·533	2·7749	1·9747
7·8	24·504	47·7836	60·84	474·552	2·7928	1·9832
7·9	24·819	49·0167	62·41	493·039	2·8107	1·9916
8·0	25·133	50·2655	64·00	512·000	2·8284	2·0000
8·1	25·447	51·5300	65·61	531·441	2·8461	2·0083
8·2	25·761	52·8102	67·24	551·368	2·8636	2·0165
8·3	26·075	54·1061	68·89	571·787	2·8810	2·0247
8·4	26·389	55·4177	70·56	592·704	2·8983	2·0328
8·5	26·704	56·7450	72·25	614·125	2·9155	2·0408
8·6	27·018	58·0880	73·96	636·056	2·9326	2·0488
8·7	27·332	59·4468	75·69	658·503	2·9496	2·0567
8·8	27·646	60·8212	77·44	681·472	2·9665	2·0646
8·9	27·960	62·2114	79·21	704·969	2·9833	2·0724
9·0	28·274	63·6173	81·00	729·000	3·0000	2·0801
9·1	28·588	65·0388	82·81	753·571	3·0166	2·0878
9·2	28·903	66·4761	84·64	778·688	3·0332	2·0954
9·3	29·217	67·9291	86·49	804·357	3·0496	2·1029
9·4	29·531	69·3978	88·36	830·584	3·0659	2·1105
9·5	29·845	70·8822	90·25	857·375	3·0822	2·1179
9·6	30·159	72·3823	92·16	884·736	3·0984	2·1253
9·7	30·473	73·8981	94·09	912·673	3·1145	2·1327
9·8	30·788	75·4296	96·04	941·192	3·1305	2·1400
9·9	31·102	76·9769	98·01	970·299	3·1464	2·1472
10·0	31·416	78·540	100·00	1000·000	3·1623	2·1544
10·1	31·730	80·119	102·01	1030·301	3·1780	2·1616
10·2	32·044	81·713	104·04	1061·208	3·1937	2·1687
10·3	32·358	83·323	106·09	1092·727	3·2094	2·1757

TABLE OF POWERS (*continued*).

n	$n\pi$	$n^2\frac{\pi}{4}$	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
10·4	32·673	84·949	108·16	1124·863	3·2249	2·1828
10·5	32·987	86·590	110·25	1157·625	3·2404	2·1897
10·6	33·301	88·247	112·36	1191·016	3·2558	2·1967
10·7	33·615	89·920	114·49	1225·043	3·2711	2·2036
10·8	33·929	91·609	116·64	1259·712	3·2863	2·2104
10·9	34·243	93·313	118·81	1295·029	3·3015	2·2172
11·0	34·558	95·033	121·00	1331·000	3·3166	2·2239
11·1	34·872	96·769	123·21	1367·631	3·3317	2·2307
11·2	35·186	98·520	125·44	1404·928	3·3466	2·2374
11·3	35·500	100·29	127·69	1442·897	3·3615	2·2441
11·4	35·814	102·07	129·96	1481·544	3·3764	2·2506
11·5	36·128	103·87	132·25	1520·875	3·3912	2·2572
11·6	36·442	105·68	134·56	1560·896	3·4059	2·2637
11·7	36·757	107·51	136·89	1601·613	3·4205	2·2702
11·8	37·071	109·36	139·24	1643·032	3·4351	2·2766
11·9	37·385	111·22	141·61	1685·159	3·4496	2·2831
12·0	37·699	113·10	144·00	1728·000	3·4641	2·2894
12·1	38·013	114·99	146·41	1771·561	3·4785	2·2957
12·2	38·327	116·90	148·84	1815·848	3·4928	2·3021
12·3	38·642	118·82	151·29	1860·867	3·5071	2·3084
12·4	38·956	120·76	153·76	1906·624	3·5214	2·3146
12·5	39·270	122·72	156·25	1953·125	3·5355	2·3208
12·6	39·584	124·69	158·76	2000·376	3·5496	2·3270
12·7	39·898	126·68	161·29	2048·383	3·5637	2·3331
12·8	40·212	128·68	163·84	2097·152	3·5777	2·3392
12·9	40·527	130·70	166·41	2146·689	3·5917	2·3453
13·0	40·841	132·73	169·00	2197·000	3·6056	2·3513
13·1	41·155	134·78	171·61	2248·091	3·6194	2·3573
13·2	41·469	136·85	174·24	2299·968	3·6332	2·3633
13·3	41·783	138·93	176·89	2352·637	3·6469	2·3693
13·4	42·097	141·03	179·56	2406·104	3·6606	2·3752
13·5	42·412	143·14	182·25	2460·375	3·6742	2·3811
13·6	42·726	145·27	184·96	2515·456	3·6878	2·3870
13·7	43·040	147·41	187·69	2571·353	3·7013	2·3928
13·8	43·354	149·57	190·44	2628·072	3·7148	2·3986
13·9	43·668	151·75	193·21	2685·619	3·7283	2·4044
14·0	43·982	153·94	196·00	2744·000	3·7417	2·4101
14·1	44·296	156·15	198·81	2803·221	3·7550	2·4159
14·2	44·611	158·37	201·64	2863·288	3·7683	2·4216
14·3	44·925	160·61	204·49	2924·207	3·7815	2·4272
14·4	45·239	162·86	207·36	2985·984	3·7947	2·4329

TABLE OF POWERS (*continued*).

n	$n\pi$	$n^2\frac{\pi}{4}$	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
14·5	45·553	165·13	210·25	3048·625	3·8079	2·4385
14·6	45·867	167·42	213·16	3112·136	3·8210	2·4441
14·7	46·181	169·72	216·09	3176·523	3·8341	2·4497
14·8	46·496	172·03	219·04	3241·792	3·8471	2·4552
14·9	46·810	174·37	222·01	3307·949	3·8600	2·4607
15·0	47·124	176·715	225·00	3375·000	3·8730	2·4662
15·1	47·438	179·079	228·01	3442·951	3·8859	2·4717
15·2	47·752	181·458	231·04	3511·808	3·8987	2·4771
15·3	48·066	183·854	234·09	3581·577	3·9115	2·4825
15·4	48·381	186·265	237·16	3652·264	3·9243	2·4879
15·5	48·695	188·692	240·25	3723·875	3·9370	2·4933
15·6	49·009	191·134	243·36	3796·416	3·9497	2·4987
15·7	49·323	193·593	246·49	3869·893	3·9623	2·5040
15·8	49·637	196·067	249·64	3944·312	3·9749	2·5093
15·9	49·951	198·557	252·81	4019·679	3·9875	2·5146
16·0	50·265	201·062	256·00	4096·000	4·0000	2·5198
16·1	50·580	203·583	259·21	4173·281	4·0125	2·5251
16·2	50·894	206·120	262·44	4251·528	4·0249	2·5303
16·3	51·208	208·672	265·69	4330·747	4·0373	2·5355
16·4	51·522	211·241	268·96	4410·944	4·0497	2·5407
16·5	51·836	213·825	272·25	4492·125	4·0620	2·5458
16·6	52·150	216·424	275·56	4574·296	4·0743	2·5509
16·7	52·465	219·040	278·89	4657·463	4·0866	2·5561
16·8	52·779	221·671	282·24	4741·632	4·0988	2·5612
16·9	53·093	224·318	285·61	4826·809	4·1110	2·5662
17·0	53·407	226·980	289·00	4913·000	4·1231	2·5713
17·1	53·721	229·658	292·41	5000·211	4·1352	2·5763
17·2	54·035	232·352	295·84	5088·448	4·1473	2·5813
17·3	54·350	235·062	299·29	5177·717	4·1593	2·5863
17·4	54·664	237·787	302·76	5268·024	4·1713	2·5913
17·5	54·978	240·528	306·25	5359·375	4·1833	2·5962
17·6	55·292	243·285	309·76	5451·776	4·1952	2·6012
17·7	55·606	246·057	313·29	5545·233	4·2071	2·6061
17·8	55·920	248·846	316·84	5639·752	4·2190	2·6110
17·9	56·235	251·649	320·41	5735·339	4·2308	2·6159
18·0	56·549	254·469	324·00	5832·000	4·2426	2·6207
18·1	56·863	257·304	327·61	5929·741	4·2544	2·6256
18·2	57·177	260·155	331·24	6028·568	4·2661	2·6304
18·3	57·491	263·022	334·89	6128·487	4·2778	2·6352
18·4	57·805	265·904	338·56	6229·504	4·2895	2·6400
18·5	58·119	268·803	342·25	6331·625	4·3012	2·6448

TABLE OF POWERS (*continued*).

n	$n\pi$	$n^2\frac{\pi}{4}$	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
18·6	58·434	271·716	345·96	6434·856	4·3128	2·6495
18·7	58·748	274·646	349·69	6539·203	4·3243	2·6543
18·8	59·062	277·591	353·44	6644·672	4·3359	2·6590
18·9	59·376	280·552	357·21	6751·269	4·3474	2·6637
19·0	59·690	283·529	361·00	6859·000	4·3589	2·6684
19·1	60·004	286·521	364·81	6967·871	4·3704	2·6731
19·2	60·319	289·529	368·64	7077·888	4·3818	2·6777
19·3	60·633	292·553	372·49	7189·057	4·3932	2·6824
19·4	60·947	295·592	376·36	7301·384	4·4045	2·6870
19·5	61·261	298·648	380·25	7414·875	4·4159	2·6916
19·6	61·575	301·719	384·16	7529·536	4·4272	2·6962
19·7	61·889	304·805	388·09	7645·373	4·4385	2·7008
19·8	62·204	307·907	392·04	7762·392	4·4497	2·7053
19·9	62·518	311·026	396·01	7880·599	4·4609	2·7099
20·0	62·832	314·16	400·00	8000·000	4·4721	2·7144
20·1	63·146	317·31	404·01	8120·601	4·4833	2·7189
20·2	63·460	320·47	408·04	8242·408	4·4944	2·7234
20·3	63·774	323·66	412·09	8365·427	4·5055	2·7279
20·4	64·088	326·85	416·16	8489·664	4·5166	2·7324
20·5	64·403	330·06	420·25	8615·125	4·5277	2·7368
20·6	64·717	333·29	424·36	8741·816	4·5387	2·7413
20·7	65·031	336·54	428·49	8869·743	4·5497	2·7457
20·8	65·345	339·80	432·64	8998·912	4·5607	2·7502
20·9	65·659	343·07	436·81	9129·329	4·5716	2·7545
21·0	65·973	346·36	441·00	9261·000	4·5826	2·7589
21·1	66·288	349·67	445·21	9393·931	4·5935	2·7633
21·2	66·602	352·99	449·44	9528·128	4·6043	2·7676
21·3	66·916	356·33	453·69	9663·597	4·6152	2·7720
21·4	67·230	359·68	457·96	9800·344	4·6260	2·7763
21·5	67·544	363·05	462·25	9938·375	4·6368	2·7806
21·6	67·858	366·44	466·56	10077·696	4·6476	2·7849
21·7	68·173	369·84	470·89	10218·313	4·6583	2·7893
21·8	68·487	373·25	475·24	10360·232	4·6690	2·7935
21·9	68·801	376·69	479·61	10503·459	4·6797	2·7978
22·0	69·115	380·13	484·00	10648·000	4·6904	2·8021
22·1	69·429	383·60	488·41	10793·861	4·7011	2·8063
22·2	69·743	387·08	492·84	10941·048	4·7117	2·8105
22·3	70·058	390·57	497·29	11089·567	4·7223	2·8147
22·4	70·372	394·08	501·76	11239·424	4·7329	2·8189
22·5	70·686	397·61	506·25	11390·625	4·7434	2·8231
22·6	71·000	401·15	510·76	11543·176	4·7539	2·8273

TABLE OF POWERS (*continued*).

n	$n\pi$	$n^2\frac{\pi}{4}$	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
22·7	71·314	404·71	515·29	11697·083	4·7644	2·8314
22·8	71·628	408·28	519·84	11852·352	4·7749	2·8356
22·9	71·942	411·87	524·41	12008·989	4·7854	2·8397
23·0	72·257	415·48	529·00	12167·000	4·7958	2·8438
23·1	72·571	419·10	533·61	12326·391	4·8062	2·8479
23·2	72·885	422·73	538·24	12487·168	4·8166	2·8521
23·3	73·199	426·39	542·89	12649·337	4·8270	2·8562
23·4	73·513	430·05	547·56	12812·904	4·8373	2·8603
23·5	73·827	433·74	552·25	12977·875	4·8477	2·8643
23·6	74·142	437·44	556·96	13144·256	4·8580	2·8684
23·7	74·456	441·15	561·69	13312·053	4·8683	2·8724
23·8	74·770	444·88	566·44	13481·272	4·8785	2·8765
23·9	75·084	448·63	571·21	13651·919	4·8888	2·8805
24·0	75·398	452·39	576·00	13824·000	4·8990	2·8845
24·1	75·712	456·17	580·81	13997·521	4·9092	2·8885
24·2	76·027	459·96	585·64	14172·488	4·9193	2·8925
24·3	76·341	463 77	590·49	14348·907	4·9295	2·8965
24·4	76·655	467·60	595·36	14526·784	4·9396	2·9004
24·5	76·969	471·44	600·25	14706·125	4·9497	2·9044
24·6	77·283	475·29	605·16	14886·936	4·9598	2·9083
24·7	77·597	479·16	610·09	15069·223	4·9699	2·9123
24·8	77·911	483·05	615·04	15252·992	4·9799	2·9162
24·9	78·226	486·96	620·01	15438·249	4·9899	2·9201
25·0	78·540	490·874	625·00	15625·000	5·0000	2·9240
25·1	78·854	494·809	630·01	15813·251	5·0099	2·9279
25·2	79·168	498·759	635·04	16003·008	5·0199	2·9318
25·3	79·482	502·726	640·09	16194·277	5·0299	2·9357
25·4	79·796	506·708	645·16	16387·064	5·0398	2·9395
25·5	80·111	510·705	650·25	16581·375	5·0498	2·9434
25·6	80·425	514·719	655·36	16777·216	5·0596	2·9472
25·7	80·739	518·748	660·49	16974·593	5·0695	2·9511
25·8	81·053	522·792	665·64	17173·512	5·0794	2·9549
25·9	81·367	526·853	670·81	17373·979	5·0892	2·9587
26·0	81·681	530·929	676·00	17576·000	5·0990	2·9625
26·1	81·996	535·021	681·21	17779·581	5·1088	2·9663
26·2	82·310	539·129	686·44	17984·728	5·1186	2·9701
26·3	82·624	543·252	691·69	18191·447	5·1284	2·9738
26·4	82·938	547·391	696·96	18399·744	5·1381	2·9776
26·5	83·252	551·546	702·25	18609·625	5·1478	2·9814
26·6	83·566	555·716	707·56	18821·096	5·1575	2·9851
26·7	83·881	559·903	712·89	19034·163	5·1672	2·9888

TABLE OF POWERS (*continued*).

n	$n\pi$	$n^2\frac{\pi}{4}$	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
26·8	84·195	564·104	718·24	19248·832	5·1769	2·9926
26·9	84·509	568·322	723·61	19465·109	5·1865	2·9963
27·0	84·823	572·555	729·00	19683·000	5·1962	3·0000
27·1	85·137	576·804	734·41	19902·511	5·2058	3·0037
27·2	85·451	581·069	739·84	20123·648	5·2154	3·0074
27·3	85·765	585·349	745·29	20346 417	5·2249	3·0111
27·4	86·080	589·646	750·76	20570·824	5·2345	3·0147
27·5	86·394	593·957	756·25	20796·875	5·2440	3·0184
27·6	86·708	598·285	761·76	21024·576	5·2536	3·0221
27·7	87·022	602·628	767·29	21253·933	5·2631	3·0257
27·8	87·336	606·987	772·84	21484·952	5·2726	3·0293
27·9	87·650	611·362	778·41	21717·639	5·2820	3·0330
28·0	87·965	615·752	784·00	21952·000	5·2915	3·0366
28·1	88·279	620·158	789·61	22188·041	5·3009	3·0402
28·2	88·593	624·580	795·24	22425·768	5·3104	3·0438
28·3	88·907	629·018	800·89	22665·187	5·3198	3·0474
28·4	89·221	633·471	806·56	22906·304	5·3292	3·0510
28·5	89·535	637·940	812·25	23149·125	5·3385	3·0546
28·6	89·850	642·424	817·96	23393·656	5·3479	3·0581
28·7	90·164	646·925	823·69	23639·903	5·3572	3·0617
28·8	90·478	651·441	829·44	23887·872	5·3666	3·0652
28·9	90·792	655·972	835·21	24137·569	5·3759	3·0688
29·0	91·106	660·520	841·00	24389·000	5·3852	3·0723
29·1	91·420	665·083	846·81	24642·171	5·3944	3·0758
29·2	91·735	669·662	852·64	24897·088	5·4037	3·0794
29·3	92·049	674·256	858·49	25153·757	5·4129	3·0829
29·4	92·363	678·867	864·36	25412·184	5·4222	3·0864
29·5	92·677	683·493	870·25	25672·375	5·4314	3·0899
29·6	92·991	688·134	876·16	25934·336	5·4406	3·0934
29·7	93·305	692·792	882·09	26198·073	5·4498	3·0968
29·8	93·619	697·465	888·04	26463·592	5·4589	3·1003
29·9	93·934	702·154	894·01	26730·899	5·4681	3·1038
30·0	94·248	706·86	900·00	27000·000	5·4772	3·1072
30·1	94·562	711·58	906·01	27270·901	5·4863	3·1107
30·2	94·876	716·32	912·04	27543·608	5·4954	3·1141
30·3	95·190	721·07	918·09	27818·127	5·5045	3·1176
30·4	95·504	725·83	924·16	28094·464	5·5136	3·1210
30·5	95·819	730·62	930·25	28372·625	5·5226	3·1244
30·6	96·133	735·42	936·36	28652·616	5·5317	3·1278
30·7	96·447	740·23	942·49	28934·443	5·5407	3·1312
30·8	96·761	745·06	948·64	29218·112	5·5497	3·1346

TABLE OF POWERS (*continued*).

n	$n\pi$	$n^2\frac{\pi}{4}$	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
30·9	97·075	749·91	954·81	29503·629	5·5587	3·1380
31·0	97·389	754·77	961·00	29791·000	5·5678	3·1414
31·1	97·704	759·65	967·21	30080·231	5·5767	3·1448
31·2	98·018	764·54	973·44	30371·328	5·5857	3·1481
31·3	98·332	769·45	979·69	30664·297	5·5946	3·1515
31·4	98·646	774·37	985·96	30959·144	5·6035	3·1548
31·5	98·960	779·31	992·25	31255·875	5·6124	3·1582
31·6	99·274	784·27	998·56	31554·496	5·6213	3·1615
31·7	99·588	789·24	1004·89	31855·013	5·6302	3·1648
31·8	99·903	794·23	1011·24	32157·432	5·6391	3·1681
31·9	100·22	799·23	1017·61	32461·759	5·6480	3·1715
32·0	100·53	804·25	1024·00	32768·000	5·6569	3·1748
32·1	100·85	809·28	1030·41	33076·161	5·6656	3·1781
32·2	101·16	814·33	1036·84	33386·248	5·6745	3·1814
32·3	101·47	819·40	1043·29	33698·267	5·6833	3·1847
32·4	101·79	824·48	1049·76	34012·224	5·6921	3·1880
32·5	102·10	829·58	1056·25	34328·125	5·7008	3·1913
32·6	102·42	834·69	1062·76	34645·976	5·7096	3·1945
32·7	102·73	839·82	1069·29	34965·783	5·7183	3·1978
32·8	103·04	844·96	1075·84	35287·552	5·7271	3·2010
32·9	103·36	850·12	1082·41	35611·289	5·7358	3·2043
33·0	103·67	855·30	1089·00	35937·000	5·7446	3·2075
33·1	103·99	860·49	1095·61	36264·691	5·7522	3·2108
33·2	104·30	865·70	1102·24	36594·368	5·7619	3·2140
33·3	104·62	870·92	1108·89	36926·037	5·7706	3·2172
33·4	104·93	876·16	1115·56	37259·704	5·7792	3·2204
33·5	105·24	881·41	1122·25	37595·375	5·7879	3·2237
33·6	105·56	886·68	1128·96	37933·056	5·7965	3·2269
33·7	105·87	891·97	1135·69	38272·753	5·8051	3·2301
33·8	106·19	897·27	1142·44	38614·472	5·8137	3·2332
33·9	106·50	902·59	1149·21	38958·219	5·8223	3·2364
34·0	106·81	907·92	1156·00	39304·000	5·8310	3·2396
34·1	107·13	913·27	1162·81	39651·821	5·8395	3·2428
34·2	107·44	918·63	1169·64	40001·688	5·8480	3·2460
34·3	107·76	924·01	1176·49	40353·607	5·8566	3·2491
34·4	108·07	929·41	1183·36	40707·584	5·8651	3·2522
34.5	108·38	934·82	1190·25	41063·625	5·8736	3·2554
34·6	108·70	940·25	1197·16	41421·736	5·8821	3·2586
34·7	109·01	945·69	1204·09	41781·923	5·8906	3·2617
34·8	109·33	951·15	1211·04	42144·192	5·8991	3·2648
34·9	109·64	956·62	1218·01	42508·549	5·9076	3·2679

Table of Powers (*continued*).

n	$n\pi$	$n^2\frac{\pi}{4}$	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
35·0	109·96	962·113	1225·00	42875·000	5·9161	3·2711
35·1	110·27	967·618	1232·01	43243·551	5·9245	3·2742
35·2	110·58	973·140	1239·04	43614·208	5·9330	3·2773
35·3	110·90	978·677	1246·09	43986·977	5·9414	3·2804
35·4	111·21	984·230	1253·16	44361·864	5·9498	3·2835
35·5	111·53	989·798	1260·25	44738·875	5·9582	3·2866
35·6	111·84	995·382	1267·36	45118·016	5·9666	3·2897
35·7	112·15	1000·98	1274·49	45499·293	5·9749	3·2927
35·8	112·47	1006·60	1281·64	45882·712	5·9833	3·2958
35·9	112·78	1012·23	1288·81	46268·279	5·9917	3·2989
36·0	113·10	1017·88	1296·00	46656·000	6·0000	3·3019
36·1	113·41	1023·54	1303·21	47045·881	6·0083	3·3050
36·2	113·73	1029·22	1310·44	47437·928	6·0166	3·3080
36·3	114·04	1034·91	1317·69	47832·147	6·0249	3·3111
36·4	114·35	1040·62	1324·96	48228·544	6·0332	3·3141
36·5	114·67	1046·35	1332·25	48627·125	6·0415	3·3171
36·6	114·98	1052·09	1339·56	49027·896	6·0498	3·3202
36·7	115·30	1057·84	1346·89	49430·863	6·0581	3·3232
36·8	115·61	1063·62	1354·24	49836·032	6·0663	3·3262
36·9	115·92	1069·41	1361·61	50243·409	6·0745	3·3292
37·0	116·24	1075·21	1369·00	50653·000	6·0828	3·3322
37·1	116·55	1081·03	1376·41	51064·811	6·0910	3·3352
37·2	116·87	1086·87	1383·84	51478·848	6·0992	3·3382
37·3	117·18	1092·72	1391·29	51895·117	6·1074	3·3412
37·4	117·50	1098·58	1398·76	52313·624	6·1156	3·3442
37·5	117·81	1104·47	1406·25	52734·375	6·1237	3·3472
37·6	118·12	1110·36	1413·76	53157·376	6·1319	3·3501
37·7	118·44	1116·28	1421·29	53582·633	6·1400	3·3531
37·8	118·75	1122·21	1428·84	54010·152	6·1482	3·3561
37·9	119·07	1128·15	1436·41	54439·939	6·1563	3·3590
38·0	119·38	1134·11	1444·00	54872·000	6·1644	3·3620
38·1	119·69	1140·09	1451·61	55306·341	6·1725	3·3649
38·2	120·01	1146·08	1459·24	55742·968	6·1806	3·3679
38·3	120·32	1152·09	1466·89	56181·887	6·1887	3·3708
38·4	120·64	1158·12	1474·56	56623·104	6·1968	3·3737
38·5	120·95	1164·16	1482·25	57066·625	6·2048	3·3767
38·6	121·27	1170·21	1489·96	57512·456	6·2129	3·3796
38·7	121·58	1176·28	1497·69	57960·603	6·2209	3·3825
38·8	121·89	1182·37	1505·44	58411·072	6·2290	3·3854
38·9	122·21	1188·47	1513·21	58863·869	6·2370	3·3883
39·0	122·52	1194·59	1521·00	59319·000	6·2450	3·3912

TABLE OF POWERS (*continued*).

n	$n\pi$	$n^2\frac{\pi}{4}$	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
39·1	122·84	1200·72	1528·81	59776·471	6·2530	3·3941
39·2	123·15	1206·87	1536·64	60236·288	6·2610	3·3970
39·3	123·46	1213·04	1544·49	60698·457	6·2690	3·3999
39·4	123·78	1219·22	1552·36	61162·984	6·2769	3·4028
39·5	124·09	1225 42	1560·25	61629·875	6·2849	3·4056
39·6	124·41	1231·63	1568·16	62099·136	6·2929	3·4085
39·7	124·72	1237 86	1576·09	62570·773	6·3008	3·4114
39·8	125·04	1244·10	1584·04	63044·792	6·3087	3·4142
39·9	125·35	1250·36	1592·01	63521·199	6·3166	3·4171
40·0	125·66	1256·64	1600·00	64000·000	6·3246	3·4200
40·1	125·98	1262·93	1608·01	64481·201	6·3325	3·4228
40·2	126·29	1269·23	1616·04	64964·808	6·3404	3·4256
40·3	126·61	1275·56	1624·09	65450·827	6·3482	3·4285
40·4	126·92	1281·90	1632·16	65939·264	6·3561	3·4313
40·5	127·23	1288·25	1640·25	66430·125	6·3639	3·4341
40·6	127·55	1294·62	1648·36	66923·416	6·3718	3·4370
40·7	127·86	1301·00	1656·49	67419·143	6·3796	3·4398
40·8	128·18	1307·41	1664·64	67911·312	6·3875	3·4426
40·9	128·49	1313·82	1672·81	68417·929	6·3953	3·4454
41·0	128·81	1320·25	1681·00	68921·000	6·4031	3·4482
41·1	129·12	1326·70	1689·21	69426·531	6·4109	3·4510
41·2	129·43	1333·17	1697·44	69934·528	6·4187	3·4538
41·3	129·75	1339·65	1705·69	70444·997	6·4265	3·4566
41·4	130·06	1346·14	1713·96	70957·944	6·4343	3·4594
41·5	130·38	1352·65	1722·25	71473·375	6·4421	3·4622
41·6	130·69	1359·18	1730·56	71991·296	6·4498	3·4650
41·7	131·00	1365·72	1738·89	72511·713	6·4575	3·4677
41·8	131·32	1372·28	1747·24	73034·632	6·4653	3·4705
41·9	131·63	1378·85	1755·61	73560·059	6·4730	3·4733
42·0	131·95	1385·44	1764·00	74088·000	6·4807	3·4760
42·1	132·26	1392·05	1772·41	74618·461	6·4884	3·4788
42·2	132·58	1398·67	1780·84	75151·448	6·4961	3·4815
42·3	132·89	1405·31	1789·29	75686·967	6·5038	3·4843
42·4	133·20	1411·96	1797·76	76225·024	6·5115	3·4870
42·5	133·52	1418·63	1806·25	76765·625	6·5192	3·4898
42·6	133·83	1425·31	1814·76	77308·776	6·5268	3·4925
42·7	134·15	1432·01	1823·29	77854·483	6·5345	3·4952
42·8	134·46	1438·72	1831·84	78402·752	6·5422	3·4980
42·9	134·77	1445·45	1840·41	78953·589	6·5498	3·5007
43·0	135·09	1452·20	1849·00	79507·000	6·5574	3·5034
43·1	135·40	1458·96	1857·61	80062·991	6·5651	3·5061

Table of Powers (*continued*).

n	$n\pi$	$n^2\frac{\pi}{4}$	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
43·2	135·72	1465·74	1866·24	80621·568	6·5727	3·5088
43·3	136·03	1472·54	1874·89	81182·737	6·5803	3·5115
43·4	136·35	1479·34	1883·56	81746·504	6·5879	3·5142
43·5	136·66	1486·17	1892·25	82312·875	6·5954	3·5169
43·6	136·97	1493·01	1900·96	82881·856	6·6030	3·5196
43·7	137·29	1499·87	1909·69	83453·453	6·6106	3·5223
43·8	137·60	1506·74	1918·44	84027·672	6·6182	3·5250
43·9	137·92	1513·63	1927·21	84604·519	6·6257	3·5277
44·0	138·23	1520·53	1936·00	85184·000	6·6332	3·5303
44·1	138·54	1527·45	1944·81	85766·121	6·6408	3·5330
44·2	138·86	1534·39	1953·64	86350·888	6·6483	3·5357
44·3	139·17	1541·34	1962·49	86938·307	6·6558	3·5384
44·4	139·49	1548·30	1971·36	87528·384	6·6633	3·5410
44·5	139·80	1555·28	1980·25	88121·125	6·6708	3·5437
44·6	140·12	1562·28	1989·16	88716·536	6·6783	3·5463
44·7	140·43	1569·30	1998·09	89314·623	6·6858	3·5490
44·8	140·74	1576·33	2007·04	89915·392	6·6933	3·5516
44·9	141·06	1583·37	2016·01	90518·849	6·7007	3·5543
45·0	141·37	1590·43	2025·00	91125·000	6·7082	3·5569
45·1	141·69	1597·51	2034·01	91733·851	6·7157	3·5595
45·2	142·00	1604·60	2043·04	92345·408	6·7231	3·5622
45·3	142·31	1611·71	2052·09	92959·677	6·7305	3·5648
45·4	142·63	1618·83	2061·16	93576·664	6·7380	3·5674
45·5	142·94	1625·97	2070·25	94196·375	6·7454	3·5700
45·6	143·26	1633·13	2079·36	94818·816	6·7528	3·5726
45·7	143·57	1640·30	2088·49	95443·993	6·7602	3·5752
45·8	143·88	1647·48	2097·64	96071·912	6·7676	3·5778
45·9	144·20	1654·68	2106·81	96702·579	6·7750	3·5805
46·0	144·51	1661·90	2116·00	97336·000	6·7823	3·5830
46·1	144·83	1669·14	2125·21	97972·181	6·7897	3·5856
46·2	145·14	1676·39	2134·44	98611·128	6·7971	3·5882
46·3	145·46	1683·65	2143·69	99252·847	6·8044	3·5908
46·4	145·77	1690·93	2152·96	99897·344	6·8118	3·5934
46·5	146·08	1698·23	2162·25	100544·625	6·8191	3·5960
46·6	146·40	1705·54	2171·56	101194·696	6·8264	3·5986
46·7	146·71	1712·87	2180·89	101847·563	6·8337	3·6011
46·8	147·03	1720·21	2190·24	102503·232	6·8411	3·6037
46·9	147·34	1727·57	2199·61	103161·709	6·8484	3·6063
47·0	147·65	1734·94	2209·00	103823·000	6·8557	3·6088
47·1	147·97	1742·34	2218·41	104487·111	6·8629	3·6114
47·2	148·28	1749·74	2227·84	105154·048	6·8702	3·6139

Table of Powers (*continued*).

n	$n\pi$	$n^2\frac{\pi}{4}$	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
47·3	148·60	1757·16	2237·29	105823·817	6·8775	3·6165
47·4	148·91	1764·60	2246·76	106496·424	6·8848	3·6190
47·5	149·23	1772·05	2256·25	107171·875	6·8920	3·6216
47·6	149·54	1779·52	2265·76	107850·176	6·8993	3·6241
47·7	149·85	1787·01	2275·29	108531·333	6·9065	3·6267
47·8	150·17	1794·51	2284·84	109215·352	6·9138	3·6292
47·9	150·48	1802·03	2294·41	109902·239	6·9209	3·6317
48·0	150·80	1809·56	2304·00	110592·000	6·9282	3·6342
48·1	151·11	1817·11	2313·61	111284·641	6·9354	3·6368
48·2	151·42	1824·67	2323·24	111980·168	6·9426	3·6393
48·3	151·74	1832·25	2332·89	112678·587	6·9498	3·6418
48·4	152·05	1839·84	2342·56	113379·904	6·9570	3·6443
48·5	152·37	1847·45	2352·25	114084·125	6·9642	3·6468
48·6	152·68	1855·08	2361·96	114791·256	6·9714	3·6493
48·7	153·00	1862·72	2371·69	115501·303	6·9785	3·6518
48·8	153·31	1870·38	2381·44	116214·272	6·9857	3·6543
48·9	153·62	1878·05	2391·21	116930·169	6·9929	3·6568
49·0	153·94	1885·74	2401·00	117649·000	7·0000	3·6593
49·1	154·25	1893·45	2410·81	118370·771	7·0071	3·6618
49·2	154·57	1901·17	2420·64	119095·488	7·0143	3·6643
49·3	154·88	1908·90	2430·49	119823·157	7·0214	3·6668
49·4	155·19	1916·65	2440·36	120553·784	7·0285	3·6692
49·5	155·51	1924·42	2450·25	121287·375	7·0356	3·6717
49·6	155·82	1932·21	2460·16	122023·936	7·0427	3·6742
49·7	156·14	1940·00	2470·09	122763·473	7·0498	3·6767
49·8	156·45	1947·82	2480·04	123505·992	7·0569	3·6791
49·9	156·77	1955·65	2490·01	124251·499	7·0640	3·6816
50·0	157·08	1963·50	2500·00	125000·000	7·0711	3·6840
51·0	160·22	2042·82	2601·00	132651·000	7·1414	3·7084
52·0	163·36	2123·72	2704·00	140608·000	7·2111	3·7325
53·0	166·50	2206·19	2809·00	148877·000	7·2801	3·7563
54·0	169·64	2290·22	2916·00	157464·000	7·3485	3·7798
55·0	172·78	2375·83	3025·00	166375·000	7·4162	3·8030
56·0	175·93	2463·01	3136·00	175616·000	7·4833	3·8259
57·0	179·07	2551·76	3249·00	185193·000	7·5498	3·8485
58·0	182·21	2642·08	3364·00	195112·000	7·6158	3·8709
59·0	185·35	2733·97	3481·00	205379·000	7·6811	3·8930
60·0	188·49	2827·44	3600·00	216000·000	7·7460	3·9149
61·0	191·64	2922·47	3721·00	226981·000	7·8102	3·9365
62·0	194·77	3019·07	3844·00	238328·000	7·8740	3·9579
63·0	197·92	3117·25	3969·00	250047·000	7·9373	3·9791

TABLE OF POWERS (*continued*).

n	$n\pi$	$n^2\frac{\pi}{4}$	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
64·0	201·06	3216·99	4096·00	262144·000	8·0000	4·0000
65·0	204·20	3318·31	4225·00	274625·000	8·0623	4·0207
66·0	207·34	3421·20	4356·00	287496·000	8·1240	4·0412
67·0	210·49	3525·65	4489·00	300763·000	8·1854	4·0615
68·0	213·63	3631·68	4624·00	314432·000	8·2462	4·0817
69·0	216·77	3739·28	4761·00	328509·000	8·3066	4·1016
70·0	219·91	3848·45	4900·00	343000·000	8·3666	4·1213
71·0	223·05	3959·19	5041·00	357911·000	8·4261	4·1408
72·0	226·19	4071·50	5184·00	373248·000	8·4853	4·1602
73·0	229·34	4185·39	5329·00	389017·000	8·5440	4·1793
74·0	232·48	4300·84	5476·00	405224·000	8·6023	4·1983
75·0	235·62	4417·86	5625·00	421875·000	8·6603	4·2172
76·0	238·76	4536·46	5776·00	438976·000	8·7178	4·2358
77·0	241·90	4656·63	5929·00	456533·000	8·7750	4·2543
78·0	245·04	4778·36	6084·00	474552·000	8·8318	4·2727
79·0	248·19	4901·67	6241·00	493039·000	8·8882	4·2908
80·0	251·32	5026·55	6400·00	512000·000	8·9443	4·3089
81·0	254·47	5153·00	6561·00	531441·000	9·0000	4·3267
82·0	257·61	5281·02	6724·00	551368·000	9·0554	4·3445
83·0	260·75	5410·61	6889·00	571787·000	9·1104	4·3621
84·0	263·89	5541·77	7056·00	592704·000	9·1652	4·3795
85·0	267·04	5674·50	7225·00	614125·000	9·2195	4·3968
86·0	270·18	5808·80	7396·00	636056·000	9·2736	4·4140
87·0	273·32	5944·68	7569·00	658503·000	9·3274	4·4310
88·0	276·46	6082·12	7744·00	681472·000	9·3808	4·4480
89·0	279·60	6221·14	7921·00	704969·000	9·4340	4·4647
90·0	282·74	6361·73	8100·00	729000·000	9·4868	4·4814
91·0	285·88	6503·88	8281·00	753571·000	9·5394	4·4979
92·0	289·03	6647·61	8464·00	778688·000	9·5917	4·5144
93·0	292·17	6792·91	8649·00	804357·000	9·6437	4·5307
94·0	295·31	6939·78	8836·00	830584·000	9·6954	4·5468
95·0	298·45	7088·22	9025·00	857375·000	9·7468	4·5629
96·0	301·59	7238·23	9216·00	884736·000	9·7980	4·5789
97·0	304·73	7389·81	9409·00	912673·000	9·8489	4·5947
98·0	307·88	7542·96	9604·00	941192·000	9·8995	4·6104
99·0	311·02	7697·69	9801·00	970299·000	9·9499	4·6261
100·0	314·16	7853·98	10000·00	1000000·000	10·0000	4·6416

Table of Lengths of Circular Arcs, Chords, and Heights of Arcs to Radius 1.

Degrees.	Length of Arc.	Chord.	Height of Arc.	Degrees.	Length of Arc.	Chord.	Height of Arc.
1	0·0175	0·0175	0·0000	36	0·6283	0·6180	0·0489
2	0·0349	0·0349	0·0002	37	0·6458	0·6346	0·0517
3	0·0524	0·0524	0·0003	38	0·6632	0·6511	0·0545
4	0·0698	0·0698	0·0006	39	0·6807	0·6676	0·0574
5	0·0873	0·0872	0·0010	40	0·6981	0·6840	0·0603
6	0·1047	0·1047	0·0014	41	0·7156	0·7004	0·0633
7	0·1222	0·1221	0·0019	42	0·7330	0·7167	0·0664
8	0·1396	0·1395	0·0024	43	0·7505	0·7330	0·0696
9	0·1571	0·1569	0·0031	44	0·7679	0·7492	0·0728
10	0·1745	0·1743	0·0038	45	0·7854	0·7654	0·0761
11	0·1920	0·1917	0·0046	46	0·8029	0·7815	0·0795
12	0·2094	0·2091	0·0055	47	0·8203	0·7975	0·0829
13	0·2269	0·2264	0·0064	48	0·8378	0·8135	0·0865
14	0·2443	0·2437	0·0075	49	0·8552	0·8294	0·0900
15	0·2618	0·2611	0·0086	50	0·8727	0·8452	0·0937
16	0·2793	0·2783	0·0097	51	0·8901	0·8610	0·0974
17	0·2967	0·2956	0·0110	52	0·9076	0·8767	0·1012
18	0·3142	0·3129	0·0123	53	0·9250	0·8924	0·1051
19	0·3316	0·3301	0·0137	54	0·9425	0·9080	0·1090
20	0·3491	0·3473	0·0152	55	0·9599	0·9235	0·1130
21	0·3665	0·3645	0·0167	56	0·9774	0·9389	0·1171
22	0·3840	0·3816	0·0184	57	0·9948	0·9543	0·1212
23	0·4014	0·3987	0·0201	58	1·0123	0·9696	0·1254
24	0·4189	0·4158	0·0219	59	1·0297	0·9848	0·1296
25	0·4363	0·4329	0·0237	60	1·0472	1·0000	0·1340
26	0·4538	0·4499	0·0256	61	1·0647	1·0151	0·1384
27	0·4712	0·4669	0·0276	62	1·0821	1·0301	0·1428
28	0·4887	0·4838	0·0297	63	1·0996	1·0450	0·1474
29	0·5061	0·5008	0·0319	64	1·1170	1·0598	0·1520
30	0·5236	0·5176	0·0341	65	1·1345	1·0746	0·1566
31	0·5411	0·5345	0·0364	66	1·1519	1·0893	0·1613
32	0·5585	0·5512	0·0387	67	1·1694	1·1039	0·1661
33	0·5760	0·5680	0·0412	68	1·1868	1·1184	0·1710
34	0·5934	0·5847	0·0437	69	1·2043	1·1328	0·1759
35	0·6109	0·6014	0·0463	70	1·2217	1·1472	0·1808

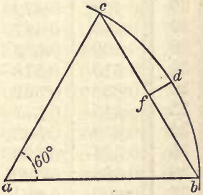
TABLE OF LENGTHS OF CIRCULAR ARCS, CHORDS, AND HEIGHTS OF ARCS TO RADIUS 1 (*continued*).

Degrees.	Length of Arc.	Chord.	Height of Arc.	Degrees.	Length of Arc.	Chord.	Height of Arc.
71	1·2392	1·1614	0·1859	106	1·8500	1·5972	0·3982
72	1·2566	1·1756	0·1910	107	1·8675	1·6077	0·4052
73	1·2741	1·1896	0·1961	108	1·8850	1·6180	0·4122
74	1·2915	1·2036	0·2014	109	1·9024	1·6282	0·4193
75	1·3090	1·2175	0·2066	110	1·9198	1·6383	0·4264
76	1·3265	1·2313	0·2120	111	1·9373	1·6483	0·4336
77	1·3439	1·2450	0·2174	112	1·9548	1·6581	0·4408
78	1·3614	1·2586	0·2229	113	1·9722	1·6678	0·4481
79	1·3788	1·2722	0·2284	114	1·9897	1·6773	0·4554
80	1·3963	1·2856	0·2340	115	2·0071	1·6868	0·4627
81	1·4137	1·2989	0·2396	116	2·0246	1·6961	0·4701
82	1·4312	1·3121	0·2453	117	2·0420	1·7053	0·4775
83	1·4486	1·3252	0·2510	118	2·0595	1·7143	0·4850
84	1·4661	1·3383	0·2569	119	2·0769	1·7233	0·4925
85	1·4835	1·3512	0·2627	120	2·0944	1·7321	0·5000
86	1·5010	1·3640	0·2686	121	2·1118	1·7407	0·5076
87	1·5184	1·3767	0·2746	122	2·1293	1·7492	0·5152
88	1·5359	1·3893	0·2807	123	2·1468	1·7576	0·5228
89	1·5533	1·4018	0·2867	124	2·1642	1·7659	0·5305
90	1·5708	1·4142	0·2929	125	2·1817	1·7740	0·5383
91	1·5882	1·4265	0·2991	126	2·1991	1·7820	0·5460
92	1·6057	1·4387	0·3053	127	2·2166	1·7899	0·5538
93	1·6232	1·4507	0·3116	128	2·2340	1·7976	0·5616
94	1·6406	1·4627	0·3180	129	2·2545	1·8052	0·5695
95	1·6580	1·4746	0·3244	130	2·2689	1·8126	0·5774
96	1·6755	1·4863	0·3309	131	2·2864	1·8199	0·5853
97	1·6930	1·4979	0·3374	132	2·3038	1·8271	0·5933
98	1·7104	1·5094	0·3439	133	2·3213	1·8341	0·6013
99	1·7279	1·5208	0·3506	134	2·3387	1·8410	0·6093
100	1·7453	1·5321	0·3572	135	2·3562	1·8478	0·6173
101	1·7628	1·5432	0·3639	136	2·3736	1·8544	0·6254
102	1·7802	1·5543	0·3707	137	2·3911	1·8608	0·6335
103	1·7977	1·5652	0·3775	138	2·4086	1·8672	0·6416
104	1·8151	1·5760	0·3843	139	2·4260	1·8733	0·6498
105	1·8326	1·5867	0·3912	140	2·4435	1·8794	0·6580

TABLE OF LENGTHS OF CIRCULAR ARCS, CHORDS, AND HEIGHTS OF ARCS TO RADIUS 1 (*continued*).

Degrees.	Length of Arc.	Chord.	Height of Arc.	Degrees.	Length of Arc.	Chord.	Height of Arc.
141	2·4609	1·8853	0·6662	161	2·8100	1·9726	0·8350
142	2·4784	1·8910	0·6744	162	2·8274	1·9754	0·8436
143	2·4958	1·8966	0·6827	163	2·8449	1·9780	0·8522
144	2·5133	1·9021	0·6910	164	2·8623	1·9805	0·8608
145	2·5307	1·9074	0·6993	165	2·8798	1·9829	0·8695
146	2·5482	1·9126	0·7076	166	2·8972	1·9851	0·8781
147	2·5656	1·9176	0·7160	167	2·9147	1·9871	0·8868
148	2·5831	1·9225	0·7244	168	2·9322	1·9890	0·8955
149	2·6005	1·9273	0·7328	169	2·9496	1·9908	0·9042
150	2·6180	1·9319	0·7412	170	2·9671	1·9924	0·9128
151	2·6354	1·9363	0·7496	171	2·9845	1·9938	0·9215
152	2·6529	1·9406	0·7581	172	3·0020	1·9951	0·9302
153	2·6704	1·9447	0·7666	173	3·0194	1·9963	0·9390
154	2·6878	1·9487	0·7750	174	3·0369	1·9973	0·9477
155	2·7053	1·9526	0·7836	175	3·0543	1·9981	0·9564
156	2·7227	1·9563	0·7921	176	3·0718	1·9988	0·9651
157	2·7402	1·9598	0·8006	177	3·0892	1·9993	0·9738
158	2·7576	1·9632	0·8092	178	3·1067	1·9997	0·9825
159	2·7751	1·9665	0·8178	179	3·1241	1·9999	0·9913
160	2·7925	1·9696	0·8264	180	3·1416	2·0000	1·0000

Example.—If we have an arc "*b d c*" of a circle whose radii *a b* or *a c* = 1, subtending an angle of 60°, the



Length of arc *b d c* . = 1·0472
Chord *b c* . . . = 1·0000
Height *f d* of arc . = 0·1340

Table of Natural Sines and Tangents to Radius 1.

Deg.	Sine.						
	0′	10′	20′	30′	40′	50′	
0	0·000	0·003	0·006	0·009	0·012	0·015	89
1	0·017	0·020	0·023	0·026	0·029	0·032	88
2	0·035	0·038	0·041	0·044	0·047	0·049	87
3	0·052	0·055	0·058	0·061	0·064	0·067	86
4	0·070	0·073	0·076	0·078	0·081	0·084	85
5	0·087	0·090	0·093	0·096	0.099	0·102	84
6	0·105	0·107	0·110	0·113	0·116	0·119	83
7	0·122	0·125	0·128	0·131	0·133	0·136	82
8	0·139	0·142	0·145	0·148	0·151	0·154	81
9	0·156	0·159	0·162	0·165	0·168	0·171	80
10	0·174	0·177	0·179	0·182	0·185	0·188	79
11	0·191	0·194	0·197	0·199	0·202	0·205	78
12	0·208	0·211	0·214	0·216	0·219	0·222	77
13	0·225	0·228	0·231	0·233	0·236	0·239	76
14	0·242	0·245	0·248	0·250	0·253	0·256	75
15	0·259	0·262	0·264	0·267	0·270	0·273	74
16	0·276	0·278	0·281	0·284	0·287	0·290	73
17	0·292	0·295	0·298	0·301	0·303	0·306	72
18	0·309	0·312	0·315	0·317	0·320	0·323	71
19	0·326	0·328	0·331	0·334	0·337	0·339	70
20	0·342	0·345	0·347	0·350	0·353	0·356	69
21	0·358	0·361	0·364	0·367	0·369	0·372	68
22	0·375	0·377	0·380	0·383	0·385	0·388	67
23	0·391	0·393	0·396	0·399	0·401	0·404	66
24	0·407	0·409	0·412	0·415	0·417	0·420	65
25	0·423	0·425	0·428	0·431	0·433	0·436	64
26	0·438	0·441	0·444	0·446	0·449	0·451	63
27	0·454	0·457	0·459	0·462	0·464	0·467	62
28	0·469	0·472	0·475	0·477	0·480	0·482	61
29	0·485	0·487	0·490	0·492	0·495	0·497	60
30	0·500	0·503	0·505	0·508	0·510	0·513	59
31	0·515	0·518	0·520	0·522	0·525	0·527	58
32	0·530	0·532	0·535	0·537	0·540	0·542	57
33	0·545	0·547	0·550	0·552	0·554	0·557	56
34	0·559	0·562	0·564	0·566	0·569	0·571	55
35	0·574	0·576	0·578	0·581	0·583	0·585	54
36	0·588	0·590	0·592	0·595	0·597	0·599	53
37	0·602	0·604	0·606	0·609	0·611	0·613	52
	60′	50′	40′	30′	20′	10′	
	Cosine.						D.

TABLE OF NATURAL SINES AND TANGENTS (*continued*).

Deg.	Sine.						
	0′	10′	20′	30′	40′	50′	
38	0·616	0·618	0·620	0·623	0·625	0·627	51
39	0·629	0·632	0·634	0·636	0·638	0·641	50
40	0·643	0·645	0·647	0·649	0·652	0·654	49
41	0·656	0·658	0·660	0·663	0·665	0·667	48
42	0·669	0·671	0·673	0·676	0·678	0·680	47
43	0·682	0·684	0·686	0·688	0·690	0·693	46
44	0·695	0·697	0·699	0·701	0·703	0·705	45
45	0·707						44
	60′	50′	40′	30′	20′	10′	
	Cosine.						D.

Deg.	Cosine.						
	0′	10′	20′	30′	40′	50′	
0	1·000	1·000	1·000	1·000	1·000	1·000	89
1	1·000	1·000	1·000	1·000	1·000	0·999	88
2	0·999	0·999	0·999	0·999	0·999	0·999	87
3	0·999	0·998	0·998	0·998	0·998	0·998	86
4	0·998	0·997	0·997	0·997	0·997	0·996	85
5	0·996	0·996	0·996	0·995	0·995	0·995	84
6	0·995	0·994	0·994	0·994	0·993	0·993	83
7	0·993	0·992	0·992	0·991	0·991	0·991	82
8	0·990	0·990	0·989	0·989	0·989	0·988	81
9	0·988	0·987	0·987	0·986	0·986	0·985	80
10	0·985	0·984	0·984	0·983	0·983	0·982	79
11	0·982	0·981	0·981	0·980	0·979	0·979	78
12	0·978	0·978	0·977	0·976	0·976	0·975	77
13	0·974	0·974	0·973	0·972	0·972	0·971	76
14	0·970	0·970	0·969	0·968	0·967	0·967	75
15	0·966	0·965	0·964	0·964	0·963	0·962	74
16	0·961	0·960	0·960	0·959	0·958	0·957	73
17	0·956	0·955	0·955	0·954	0·953	0·952	72
18	0·951	0·950	0·949	0·948	0·947	0·946	71
19	0·946	0·945	0·944	0·943	0·942	0·941	70
20	0·940	0·939	0·938	0·937	0·936	0·935	69
21	0·934	0·933	0·931	0·930	0·929	0·928	68
22	0·927	0·926	0·925	0·924	0·923	0·922	67
	60′	50′	40′	30′	20′	10′	
	Sine.						D.

TABLE OF NATURAL SINES AND TANGENTS (*continued*).

Deg.	Cosine. 0′	10′	20′	30′	40′	50′	
23	0·921	0·919	0·918	0·917	0·916	0·915	66
24	0·914	0·912	0·911	0·910	0·909	0·908	65
25	0·906	0·905	0·904	0·903	0·901	0·900	64
26	0·899	0·898	0·896	0·895	0·894	0·892	63
27	0·891	0·890	0·888	0·887	0·886	0·884	62
28	0·883	0·882	0·880	0·879	0·877	0·876	61
29	0·875	0·873	0·872	0·870	0·869	0·867	60
30	0·866	0·865	0·863	0·862	0·860	0·859	59
31	0·857	0·856	0·854	0·853	0·851	0·850	58
32	0·848	0·847	0·845	0·843	0·842	0·840	57
33	0·839	0·837	0·835	0·834	0·832	0·831	56
34	0·829	0·827	0·826	0·824	0·822	0·821	55
35	0·819	0·817	0·816	0·814	0·812	0·811	54
36	0·809	0·807	0·806	0·804	0·802	0·800	53
37	0·799	0·797	0·795	0·793	0·792	0·790	52
38	0·788	0·786	0·784	0·783	0·781	0·779	51
39	0·777	0·775	0·773	0·772	0·770	0·768	50
40	0·766	0·764	0·762	0·760	0·759	0·757	49
41	0·755	0·753	0·751	0·749	0·747	0·745	48
42	0·743	0·741	0·739	0·737	0·735	0·733	47
43	0·731	0·729	0·727	0·725	0·723	0·721	46
44	0·719	0·717	0·715	0·713	0·711	0·709	45
45	0·707						44
	60′	50′	40′	30′	20′	10′	
	Sine.						D.

For angles under 90°.—For sine and tang. add the diff. for cosine and cotang. Subtract diff.

Ex. sine 25° 17′.		cosine 25° 17′.	
25° 10′ =	0·4	25° 10′ =	0·9050
428 − 425 = 3		905 − 904 = 1	
Dif. 3 × 7′ =	21 +	Dif. 1 × 7′ =	7 −
	0·4271		0·9043

Versed sine.—From 1 take the nat. cosine.
Co-versed sine.—From 1 take the nat. sine.
Secant.—Divide 1 by the nat. cosine.
Cosecant.—Divide 1 by the nat. sine.

TABLE OF NATURAL SINES AND TANGENTS (*continued*).

Deg.	Tang.						
	0′	10′	20′	30′	40′	50′	
0	0·000	0·003	0·006	0·009	0·012	0·015	89
1	0·017	0·020	0·023	0·026	0·029	0·032	88
2	0·035	0·038	0·041	0·044	0·047	0·049	87
3	0·052	0·055	0·058	0·061	0·064	0·067	86
4	0·070	0·073	0·076	0·079	0·082	0·085	85
5	0·087	0·090	0·093	0·096	0·099	0·102	84
6	0·105	0·108	0·111	0·114	0·117	0·120	83
7	0·123	0·126	0·129	0·132	0·135	0·138	82
8	0·141	0·144	0·146	0·149	0·152	0·155	81
9	0·158	0·161	0·164	0·167	0·170	0·173	80
10	0·176	0·179	0·182	0·185	0·188	0·191	79
11	0·194	0·197	0·200	0·203	0·206	0·210	78
12	0·213	0·216	0·219	0·222	0·225	0·228	77
13	0·231	0·234	0·237	0·240	0·243	0·246	76
14	0·249	0·252	0·256	0·259	0·262	0·265	75
15	0·268	0·271	0·274	0·277	0·280	0·284	74
16	0·287	0·290	0·293	0·296	0·299	0·303	73
17	0·306	0·309	0·312	0·315	0·318	0·322	72
18	0·325	0·328	0·331	0·335	0·338	0·341	71
19	0·344	0·348	0·351	0·354	0·357	0·361	70
20	0·364	0·367	0·371	0·374	0·377	0·381	69
21	0·384	0·387	0·391	0·394	0·397	0·401	68
22	0·404	0·407	0·411	0·414	0·418	0·421	67
23	0·424	0·428	0·431	0·435	0·438	0·442	66
24	0·445	0·449	0·452	0·456	0·459	0·463	65
25	0·466	0·470	0·473	0·477	0·481	0·484	64
26	0·488	0·491	0·495	0·499	0·502	0·506	63
27	0·510	0·513	0·517	0·521	0·524	0·528	62
28	0·532	0·535	0·539	0·543	0·547	0·551	61
29	0·554	0·558	0·562	0·566	0·570	0·573	60
30	0·577	0·581	0·585	0·589	0·593	0·597	59
31	0·601	0·605	0·609	0·613	0·617	0·621	58
32	0·625	0·629	0·633	0·637	0·641	0·645	57
33	0·649	0·654	0·658	0·662	0·666	0·670	56
34	0·675	0·679	0·683	0·687	0·692	0·696	55
35	0·700	0·705	0·709	0·713	0·718	0·722	54
36	0·727	0·731	0·735	0·740	0·744	0·749	53
37	0·754	0·758	0·763	0·767	0·772	0·777	52
	60′	50′	40′	30′	20′	10′	
	Cotang.						D.

TABLE OF NATURAL SINES AND TANGENTS (*continued*).

Deg.	Tang. 0′	10′	20′	30′	40′	50′	
38	0·781	0·786	0·791	0·795	0·800	0·805	51
39	0·810	0·815	0·819	0·824	0·829	0·834	50
40	0·839	0·844	0·849	0·854	0·859	0·864	49
41	0·869	0·874	0·880	0·885	0·890	0·895	48
42	0·900	0·906	0·911	0·916	0·922	0·927	47
43	0·933	0·938	0·943	0·949	0·955	0·960	46
44	0·966	0·971	0·977	0·983	0·988	0·994	45
45	1·000						44
	60′	50	40′	30′	20′	10′	
	Cotang.						D.

Deg.	Cotang. 0′	10′	20′	30′	40′	50′	
0	∞	343·8	171·9	114·6	85·94	68·75	89
1	57·29	49·10	42·96	38·19	34·37	31·24	88
2	28·64	26·43	24·54	22·90	21·47	20·21	87
3	19·08	18·07	17·17	16·35	15·60	14·92	86
4	14·30	13·73	13·20	12·71	12·25	11·83	85
5	11·43	11·06	10·71	10·39	10·08	9·788	84
6	9·514	9·255	9·010	8·777	8·556	8·345	83
7	8·144	7·953	7·770	7·596	7·429	7·269	82
8	7·115	6·968	6·827	6·691	6·561	6·435	81
9	6·314	6·197	6·084	5·976	5·871	5·769	80
10	5·671	5·576	5·485	5·396	5·309	5·226	79
11	5·145	5·066	4·989	4·915	4·843	4·773	78
12	4·705	4·638	4·574	4·511	4·449	4·390	77
13	4·331	4·275	4·219	4·165	4·113	4·061	76
14	4·011	3·962	3·914	3·867	3·821	3·776	75
15	3·732	3·689	3·647	3·606	3·566	3·526	74
16	3·487	3·450	3·412	3·376	3·340	3·305	73
17	3·271	3·237	3·204	3·172	3·140	3·108	72
18	3·078	3·047	3·018	2·989	2·960	2·932	71
19	2·904	2·877	2·850	2·824	2·798	2·773	70
20	2·747	2·723	2·699	2·675	2·651	2·628	69
21	2·605	2·583	2·560	2·539	2·517	2·496	68
22	2·475	2·455	2·434	2·414	2·394	2·375	67
	60′	50′	40′	30′	20′	10′	
	Tang.						D.

TABLE OF NATURAL SINES AND TANGENTS—(*continued*).

Deg.	Cotang. 0′	10′	20′	30′	40′	50′	
23	2·356	2·337	2·318	2·300	2·282	2·264	66
24	2·246	2·229	2·211	2·194	2·177	2·161	65
25	2·145	2·128	2·112	2·097	2·081	2·066	64
26	2·050	2·035	2·020	2·006	1·991	1·977	63
27	1·963	1·949	1·935	1·921	1·907	1·894	62
28	1·881	1·868	1·855	1·842	1·829	1·816	61
29	1·804	1·792	1·780	1·767	1·756	1·744	60
30	1·732	1·720	1·709	1·698	1·686	1·675	59
31	1·664	1·653	1·643	1·632	1·621	1·611	58
32	1·600	1·590	1·580	1·570	1·560	1·550	57
33	1·540	1·530	1·520	1·511	1·501	1·492	56
34	1·483	1·473	1·464	1·455	1·446	1·437	55
35	1·428	1·419	1·411	1·402	1·393	1·385	54
36	1·376	1·368	1·360	1·351	1·343	1·335	53
37	1·327	1·319	1·311	1·303	1·295	1·288	52
38	1·280	1·272	1·265	1·257	1·250	1·242	51
39	1·235	1·228	1·220	1·213	1·206	1·199	50
40	1·192	1·185	1·178	1·171	1·164	1·157	49
41	1·150	1·144	1·137	1·130	1·124	1·117	48
42	1·111	1·104	1·098	1·091	1·085	1·079	47
43	1·072	1·066	1·060	1·054	1·048	1·042	46
44	1·036	1·030	1·024	1·018	1·012	1·006	45
45	1·000						44
	60′	50′	40′	30′	20′	10′	D.
	Tang.						

Ex. Tang. 55° 27′.

55° 20′ = 1·446
455 − 446 = 9
Dif. 9 × 7 = 63 +
1·4523

Ex. Cot. 28° 16′.

28° 10′ = 1·868
868 − 855 = 13
Dif. 13 × 6 = 78 −
1·8602

For angles exceeding 90° : to find the sine, cosine, tangent, cotang., secant or cosec. (but not the versed sine), take the angle from 180° ; if between 180° and 270° take 180° from the angle ; if between 270° and 360° take the angle from 360°, and take the remainder from the table. For the versed sine : if between 90° and 270° add cosine to 1 ; if between 270° and 360° take cosine from 1.

Table showing the Underlie and Perpendicular in Feet and Inches to every Degree of the Quadrant, in Six Feet = One Fathom.

Deg.	Base.		Perpendicular.		Deg.	Deg.	Base.		Perpendicular.		Deg.
	Ft.	Ins.	Ft.	Ins.			Ft.	Ins.	Ft.	Ins.	
0	6	0	0	0	90	23	5	$6\frac{1}{4}$	2	4	67
1	6	0	0	$1\frac{1}{4}$	89	24	5	6	2	$5\frac{1}{4}$	66
2	5	$11\frac{3}{4}$	0	$2\frac{1}{2}$	88	25	5	$5\frac{1}{4}$	2	$6\frac{3}{8}$	65
3	5	$11\frac{2}{3}$	0	$3\frac{3}{4}$	87	26	5	$4\frac{3}{4}$	2	$7\frac{1}{2}$	64
4	5	$11\frac{5}{8}$	0	5	86	27	5	$4\frac{1}{8}$	2	$8\frac{5}{8}$	63
5	5	$11\frac{1}{2}$	0	$6\frac{1}{8}$	85	28	5	$3\frac{5}{8}$	2	$9\frac{7}{8}$	62
6	5	$11\frac{3}{8}$	0	$7\frac{1}{2}$	84	29	5	3	2	11	61
7	5	$11\frac{1}{4}$	0	$8\frac{5}{8}$	83	30	5	$2\frac{3}{8}$	3	0	60
8	5	$11\frac{1}{8}$	0	10	82	31	5	$1\frac{3}{4}$	3	1	59
9	5	11	0	11	81	32	5	1	3	$2\frac{1}{8}$	58
10	5	$10\frac{7}{8}$	1	$0\frac{1}{4}$	80	33	5	$0\frac{1}{2}$	3	$3\frac{1}{4}$	57
11	5	$10\frac{5}{8}$	1	$1\frac{3}{4}$	79	34	4	$11\frac{3}{4}$	3	$4\frac{1}{8}$	56
12	5	$10\frac{3}{8}$	1	3	78	35	4	11	3	$5\frac{1}{4}$	55
13	5	$10\frac{1}{8}$	1	4	77	36	4	$10\frac{1}{4}$	3	$6\frac{1}{4}$	54
14	5	$9\frac{7}{8}$	1	$5\frac{3}{8}$	76	37	4	$9\frac{1}{2}$	3	$7\frac{1}{4}$	53
15	5	$9\frac{5}{8}$	1	$6\frac{1}{2}$	75	38	4	$8\frac{7}{8}$	3	$8\frac{1}{4}$	52
16	5	$9\frac{1}{4}$	1	8	74	39	4	8	3	$9\frac{1}{8}$	51
17	5	$8\frac{7}{8}$	1	9	73	40	4	$7\frac{1}{4}$	3	$10\frac{1}{8}$	50
18	5	$8\frac{1}{2}$	1	$10\frac{1}{4}$	72	41	4	$6\frac{1}{2}$	3	$11\frac{1}{8}$	49
19	5	$8\frac{1}{8}$	1	$11\frac{3}{8}$	71	42	4	$5\frac{5}{8}$	4	0	48
20	5	$7\frac{3}{4}$	2	$0\frac{1}{2}$	70	43	4	$4\frac{3}{4}$	4	1	47
21	5	$7\frac{1}{4}$	2	$1\frac{3}{4}$	69	44	4	4	4	2	46
22	5	$6\frac{3}{4}$	2	3	68	45	4	3	4	3	45
	Ft.	Ins.	Ft.	Ins.			Ft.	Ins.	Ft.	Ins.	
Deg.	Perpendicular.		Base.		Deg.	Deg.	Perpendicular.		Base.		Deg.

This table is calculated for the quadrant taking its angles from the horizon.

When the angle exceeds 45°, read from foot of table and take base and perpendicular marked there.

Example.—Angle 25°, length 9 fm. 3 ft. See opposite 25°, $5'\ 5\frac{1}{4}'' \times 9$ fm. 3 ft. $= 51'\ 7\frac{7}{8}''$ for base and $2'\ 6\frac{3}{8}'' \times 9$ fm. 3ft. $= 24{\cdot}0\frac{3}{16}$ fm. perpendicular.

COMPARISON OF ANGLE DEGREES AND SLOPE.

Angle.	Slope.	Angle.	Slope.	Angle.	Slope.
3°	1 in 19·08	10°	1 in 5·67	17°	1 in 3·27
4°	1 in 14·30	11°	1 in 5·14	18°	1 in 3·07
5°	1 in 11·43	12°	1 in 4·70	19°	1 in 2·90
6°	1 in 9·51	13°	1 in 4·33	20°	1 in 2·74
7°	1 in 8·14	14°	1 in 4·01	25°	1 in 2·14
8°	1 in 7·11	15°	1 in 3·73	30°	1 in 1·73
9°	1 in 6·31	16°	1 in 3·48		

TABLE OF INCLINED MEASURE. (G. G. André.)

Showing the reduction in links and decimals of a link to be made per chain for every half-degree of inclination from 3° to 30° (100 × versed side of the inclination).

Angle. ° ′	Reduction. Links.	Angle ° ′	Reduction. Links.	Angle. ° ′	Reduction. Links.
3 0	0·15	12 30	2·37	21 30	6·96
3 30	0·19	13 0	2·56	22 0	7·28
4 0	0·24	13 30	2·76	22 30	7·61
4 30	0·31	14 0	2·97	23 0	7·95
5 0	0·38	14 30	3·19	23 30	8·29
5 30	0·46	15 0	3·41	24 0	8·65
6 0	0·55	15 30	3·64	24 30	9·01
6 30	0·64	16 0	3·87	25 0	9·37
7 0	0·75	16 30	4·12	25 30	9·74
7 30	0·86	17 0	4·37	26 0	10·13
8 0	0·97	17 30	4·63	26 30	10·51
8 30	1·10	18 0	4·89	27 0	10·90
9 0	1·23	18 30	5·17	27 30	11·30
9 30	1·37	19 0	5·45	28 0	11·71
10 0	1·53	19 30	5·74	28 30	12·11
10 30	1·67	20 0	6·03	29 0	12·53
11 0	1·84	20 30	6·33	29 30	12·96
11 30	2·01	21 0	6·64	30 0	13·40
12 0	2·19				

Example.—An incline of 19° is 12 chains 25 links long, what is the horizontal distance?

In column of angles, opposite 19°, we find 5·45 links, this × 12 chains = 65·40 links.

Since 25 links = ¼ of a chain, 5·45 links ÷ 4 = 1·36 links.

65·40 links + 1·36 links = 66·76 links, which must be reduced from the original length.

12 chains 25 links − 66·76 links = 11 chains 58·24 links, the true horizonta ldistance.

WEIGHTS AND MEASURES.

Avoirdupois Weight.

Systematic Name.	Dram. dr.	Ounce oz.	Pound lb.	Stone. st.	Quarter. qr.	Cental, or New Hundred-weight.	Hundred-weight. cwt.	Ton.	Metric equivalent (grammes).
Dram dr.	1	·0625	·0039	·000279	·000139	·000039	·000035	·00000174	1·771846
Ounce oz.	16	1	·0625	·00446	·00223	·000625	·000558	·000028	28·34954
Pound lb.	256	16	1	·0714	·0357	·01	·00893	·000447	453·5926
Stone st.	3584	224	14	1	·5	·14	·125	·00625	6350·302
Quarter qr.	7168	448	28	2	1	·28	·25	·0125	12700·60
Cental or New Hundredweight	25600	1600	100	7·1428	3·5714	1	·893	·0447	45359·25
Hundredweight cwt.	28672	1792	112	8	4	1·12	1	·05	50802·42
Ton	573440	35840	2240	160	80	22·40	20	1	1016048

1 dram = 27·346 troy grains. 1 pound = 7000·576 troy grains.
1 sack of coal = 2 hundredweight, or 224 lbs.; 10 sacks or 2240 lbs. go to the ton.
A pack of wool weighs 240 lbs.
A truss of straw weighs 36 lbs.; a truss of old hay 56 lbs., and of new, 60 lbs.
A load consists of 36 trusses.

Used in trade and commerce for larger and coarser sorts of goods.

A short ton = 2,000 lbs.

TROY WEIGHT.

Systematic Name.	Grain. gr.	Penny-weight. dwt.	Ounce. oz.	Pound. lb.	Metric equivalent (grammes).
Grain gr.	1	0·04167	0·002083	0·0001736	0·0648
Pennyweight dwt.	24	1	0·05	0·004167	1·555
Ounce oz.	480	20	1	0·0833	31·1035
Pound lb.	5760	240	12	1	373·242

1 gr. troy avoirdupois and apothecaries are equal.

Troy weight is used for gold and silver. Perfectly pure gold is worth £4 4*s.* 11·45*d.*, or $20·67183 per troy oz. Fine gold is said to be 24-carat. Standard gold is 22-carat alloyed with two parts of some other metal. Standard silver is 11 oz. 2 dwt. fine to 18 dwt. alloy.

The jeweller's carat is 3·17 gr. in England, 3·18 gr. in France, 3·0 gr. in Holland, and 3·2 gr. in the United States; the carat is divided into 4 jeweller's grains, and the jewellery ounce into 151½ carats.

APOTHECARIES' WEIGHT.

Systematic Name.	Grain. gr.	Scruple ℈	Dram. ʒ	Ounce. ℥	Pound. lb.
Grain gr.	1	0·05	0·016	0·002083	0·00017361
Scruple ℈	20	1	0·3	0·0416	0·003472
Dram ʒ	60	3	1	0·125	0·010416
Ounce ℥	480	24	8	1	0·083
Pound lb.	5760	288	96	12	1

In troy and apothecaries' weights the grain, ounce, and pound are the same. Used for medical prescriptions. Drugs are bought and sold in quantities by avoirdupois.

Apothecaries' Fluid Measure.

60 minims (♏)	=	1 fluid drachm	f℥.
8 drachms	=	1 ounce	f℥.
20 ounces	=	1 pint	O.
8 pints	=	1 gallon	gal.
1 drop	=	1 grain.	
60 drops	=	1 drachm.	
4 drachms	=	1 tablespoonful.	
2 ounces	=	1 wineglassful.	
3 ounces	=	1 teacupful.	

Liquid Measure, U.S. only.

4 gills	=	1 pint	=	28·875 cub. in.
2 pints	=	1 quart	=	57·750 „
4 quarts	=	1 gallon	=	231·000 „
63 gallons	=	1 hogshead.		
2 hogsheads	=	1 pipe or butt.		
2 pipes	=	1 tun.		

Dry Measure, U.S. only.

2 pints	=	1 quart	=	67·2006 cub. in.
4 quarts	=	1 gallon	=	268·8025 „
2 gallons	=	1 peck	=	537·6050 „
4 pecks	=	1 struck bushel	=	2150·4200 „

Old Diggers' Measure.

1 dish = about 572 cub. in.	=	1 two-gall. household bucket.
2 two-gal. household buckets	=	1 nail can.
4 nail cans	=	1 tub.
1 tub	=	½ a porter cask.
10 tubs	=	1 load.
1 load	=	not quite 1 cub. yard loose gravel.
120 dishes	=	1 cub. yard *in situ*.

British Imperial Measure of Capacity.

Systematic Name.	Gill.	Pint.	Quart.	Pottle.	Gallon.	Peck.	Bushel.	Coomb.	Quarter.	Cub. Ft.	Litres.
Gill . . .	1	0·25	0·125	·0625	·03125	·015625	·003906	·0009765	·0004882	0·005	0·1419
Pint . .	4	1	0·5	0·25	0·125	0·0625	0·01562	·003905	0·00195	0·02	0·5676
Quart . .	8	2	1	0·5	0·25	0·125	·03125	·0078125	·003906	0·04	1·1352
Pottle . .	16	4	2	1	0·5	0·25	0·0625	·015625	·007812	0·08	2·2704
Gallon . .	32	8	4	2	1	0·5	0·125	·03125	0·0156	0·1604	4·541
Peck . .	64	16	8	4	2	1	0·25	·0625	0·03125	0·3208	9·082
Bushel . .	256	64	32	16	8	4	1	0·25	0·125	1·283	36·32816
Coomb . .	1024	256	128	64	32	16	4	1	0·5	5·132	145·31264
Quarter . .	2048	512	256	128	64	32	8	2	1	10·264	290·625

	Galls.	Qts.	Pts.
Firkin or quarter barrel . . .	9	36	72
Kilderkin or half barrel	18	72	144
Barrel	36	144	288
Hogshead = $1\frac{1}{2}$ barrels	54	216	432
Puncheon	72	288	576
Butt = 3 barrels	108	432	864

10 lbs. distilled water = $277\frac{1}{4}$ cub. in. = 0·16 cub. ft. = 1 gallon.
Cubic inches × 0·003607 = gallons.
Cubic feet × 6·2355 = gallons.

Long Measure.

Systematic Name.	Inch. in.	Foot. ft.	Yard. yd.	Rod, pole, or perch. pl.	Chain. ch.	Furlong. fl.	Mile. m.	Metric Equivalent metres.
Inch in.	1	0·083	0·02778	0·005	0·00126	0·000126	0·0000158	0·0254
Foot ft.	12	1	0·333	0·0606	0·01515	0·00151	0·0001894	0·3048
Yard yd.	36	3	1	0·182	0·045	0·00454	0·000568	0·9144
Rod, pole or perch pl.	198	16½	5½	1	0·25	0·0091	0·001136	1·8287
Chain ch.	792	66	22	4	1	0·025	0·003125	5·0291
Furlong fl.	7,920	660	220	40	10	1	0·125	201·16
Mile m.	63,360	5280	1,760	320	80	8	1	1609·315

1 point = $\frac{1}{72}$ of an inch ; 1 line = $\frac{1}{12}$ of an inch ; 1 link = 7·92 inches ; 100 links = 1 Gunter's chain ; 1 fathom = 6 feet ; 1 league = 3 miles ; 1 degree = $69\frac{1}{8}$ miles = 60 nautical knots or geographical miles ; 1 geographical mile = 6,082·66 feet ; 80 Gunter's chains = 1 mile.

Square or Surface Measure, for Land, Boards, Painting. Paving, Plastering, &c.

	Sq. in.	Sq. ft.	Sq. yd.	Sq. pl.	Sq. ch.	Ro.	Ac.	Value in sq. metres.
1 Square foot .	**144**	1	0·111	0·00367309	0·000229568	0·0000091827	0·0000229568	·092894
1 Square yard.	1296	**9**	1	0·0330578	0·00206611	0·000082644	0·000206611	·836046
1 Square pole or rod .	39204	272¼	**30¼**	1	0·0625	0·025	0·00625	25·302915
1 Square chain	627264	4356	484	**16**	1	0·4	0·1	404·8466
1 Rood . .	1568160	10890	1210	**40**	**2½**	1	0·25	1012·1166
1 Acre . .	6272640	43560	4840	160	**10**	**4**	1	4048·4664
1 Square mile	4014489600	27878400	3097600	102400	6400	2560	**640**	2591018·49

One square mile = 1 section = 640 acres; 36 square miles (a square with a six-mile side) = 1 township; 10 square chains or 100,000 square links = 1 acre; a "hide" of land = 100 acres. In measuring flooring, roofing, plastering, &c., a "square" = 100 square feet.

Cubic or Solid Measure, for Timber, Stone, Boxes, Packages, Rooms. &c.

	Cub. in.	Cub. ft.	Cub. yd.	Value in cub. metre.
1 Cubic foot . .	**1728**	1	0·037	·02831
1 Cubic yard . .	46656	**27**	1	·76437

1 ton or load = 40 cubic feet of rough or 50 cubic feet of hewn timber.

1 shipping ton = 42 cubic feet of timber; 1 ton shipping = 40 cubic feet.

1 stack of wood = 108 cubic feet; 1 cord of wood = 128 cubic feet = a pile 4 ft. high, 4 ft. wide, and 8 feet long; 1 cord foot is a foot in length of such a pile.

1 register ton = 100 cubic feet; 1 cubic yard of ordinary earth is called a load; 1 board foot is 1 ft. long, 1 ft. wide, and 1 in. thick; 12 board feet = 1 cubic foot; a barrel's bulk = 50 cubic feet; 1 cubic foot of water = about $6\frac{1}{4}$ gallons = 62·321 lbs.; 1 gallon = $277\frac{1}{4}$ cub. in. = 0·16 cubic feet.

1 ton weight of shingle . .	=	about	23	cubic	feet.
„ „ „ coarse gravel	=	„	19	„	„
„ „ „ pit sand .	=	„	22	„	„
„ „ „ clay or marl	=	„	18	„	„

Calculate 100 tons of coal per inch per acre, which allows about 25°/₀ for loss of every kind.

Carpenters', Bricklayers', and Builders' Measurements.

Stock bricks . . .	$8\frac{3}{4}$	inches	× $4\frac{1}{4}$	×	$2\frac{3}{4}$.
Welsh fire-bricks . .	9	„	× $4\frac{1}{2}$	×	$2\frac{3}{4}$.
Dutch clinkers . .	$9\frac{1}{4}$	„	× 3	×	$1\frac{1}{2}$.

500 bricks = a load. 5 courses of bricks in the height of a wall are called a foot. 1 rod of brickwork = 306 cubic feet = $11\frac{1}{3}$ cubic yards, and contains about 4,500 bricks with about 75 cubic feet of mortar.

Measure of Timber.

Boards of	7	in. wide	=	battens.
„	9	„	=	deals.
„	12	„	=	planks.

100 superficial feet of planking .	=	1 square.
120 deals	=	1 hundred.
50 cub. ft. squared timber . . .	=	1 load.
40 cub. ft. unhewn timber . .	=	1 load.
600 superficial feet of inch planking	=	1 load.

Props are bought and sold per 72 running feet, the price depending on the diameter.

Sizes of Slates.

Princesses	24 in. × 14 in.	Ladies	16 in. × 8 in.
Duchesses	24 ,, × 12 ,,	Ditto	15 ,, × 8 ,,
Marchionesses	22 ,, × 12 ,,	Ditto	14 ,, × 12 ,,
Countesses	20 ,, × 10 ,,	Ditto	14 ,, × 8 ,,
Viscountesses	18 ,, × 10 ,,	Plantations	13 ,, × 11 ,,
Ditto	18 ,, × 9 ,,	Doubles	13 ,, × 18 ,,
Ladies	18 ,, × 10 ,,	Ditto	12 ,, × 20 ,,

Angular Measure.

60 seconds . . = 1 minute.
60 minutes . . = 1 degree.
30 degrees . . = 1 sign.
90 degrees . . . = 1 quadrant.
4 quadrants or 360° = 1 circumference or great circle.

Power.

A kilogrammetre = 7·23308 foot pounds.

A foot pound = 0·138254 kilogrammetre.

A British horse-power = 550 ft. lbs. per sec. = 33,000 ft. lbs. per min.

The equivalent electrical energy of a H.-P. $= \frac{\text{volts} \times \text{amperes}}{746}$

$= \frac{\text{amperes}^2 \times \text{ohms}}{746} = \frac{\text{volts}^2}{746 \times \text{ohms}}$.

Paper.

1 ream = 20 quires = 480 sheets.
1 quire = 24 sheets.

Drawing Paper.

Cap	13 × 16 inches.
Demy	20 × 15 ,,
Medium	22 × 17 ,,
Royal	24 × 19 ,,
Super Royal	27 × 19 ,,
Imperial	30 × 21 ,,
Elephant	28 × 22 ,,
Columbier	34 × 23 ,,
Atlas	33 × 26 ,,
Theorem	34 × 28 ,,
Double Elephant	40 × 26 ,,
Antiquarian	52 × 31 ,,
Emperor	40 × 60 ,,
Uncle Sam	48 × 120 ,,

Metrical System of Weights and Measures.

The Metrical system is based upon the length of the fourth part of a terrestrial meridian. The ten-millionth part of this arc was chosen as the unit of measures of length, and called a *Mètre*. The cube of the tenth part of the mètre was adopted as the unit of capacity, and denominated a *Litre*. The weight of a litre of distilled water at its greatest density was called a *Kilogramme*, of which the thousandth part, or *Gramme*, was adopted as the unit of weight. The multiples of these, proceeding in decimal progression, are distinguished by the employment of the prefixes *deca*, *hecto*, *kilo*, and *myria*, from the Greek, and the subdivisions by *deci*, *centi*, and *milli*, from the Latin.

Measures of Length (unit Metre).

Equal to	Inches.	Feet.	Yards.	Fathoms.	Miles.
Millimètre	0·03937...	0·003281...	0·0010936...	0·0005468...	0·0000006
Centimètre	0·39371...	0·032809...	0·0109363...	0·0054682...	0·0000062
Décimètre	3·93708...	0·328090...	0·1093633...	0·0546816...	0·0000621
MÈTRE	39·37079...	3·280899..	1·0936331...	0·5468165...	0·0006214
Décamètre	393·70790...	32·808992...	10·9363306...	5·4681653...	0·0062138
Hectomètre	3937·07900...	328·089917...	109·3633056...	54·6816528...	0·0621382
Kilomètre	39370·79000...	3280·899167...	1093·6330556...	546·8165278...	0·6213824
Myriamètre	393707·90000...	32808·991667...	10936·3305556...	5468·1652778...	6·2138242

Cubic, or Measures of Capacity (unit Litre).

Equal to	Cubic Inches.	Cubic Feet.	Pints.	Gallons.	Bushels.
Millilitre, or cubic centimètre	0·06103...	0·000035...	0·00176...	0·0002201...	0·0000275
Centilitre, 10 cubic centimètres	0·61027...	0·000353...	0·01761...	0·0022010...	0·0002751
Décilitre, 100 cubic centimètres	6·10271...	0·003532...	0·17608...	0·0220097...	0·0027512
LITRE, or cubic Décimètre	61·02705...	0·035317...	1·76077...	0·2200967...	0·0275121
Décalitre or Centistère	610·27052...	0·353166...	17·60773...	2·2009668...	0·2751208
Hectolitre or Décistère	6102·70515...	3·531658...	176·07734...	22·0096677...	2·7512085
Kilolitre, or Stère, or cubic mètre	61027·05152...	35·316581...	1760·77341...	220·0966767...	27·5120846
Myrialitre, or Décastère	610270·51519...	353·165807...	17607·73414...	2200·9667675...	275·1208459

Measures of Weight (unit Gramme).

Equal to	Grains.	Troy Oz.	Avoirdupois lb.	Cwt.=112 lb.	Tons=20 cwt.
Milligramme	0·01543	0·000032	0·0000022	0·0000000	0·0000000
Dentigramme	0·15432	0·000322	0·0000220	0·0000002	0·0000000
Décigramme	1·54323	0·003215	0·0002205	0·0000020	0·0000001
Gramme	15·43235	0·032151	0·0022046	0·0000197	0·0000010
Cécagramme	154·32349	0·321507	0·0220462	0·0001968	0·0000098
Hectogramme	1543·23488	3·215073	0·2204621	0·0019684	0·0000984
Kilogramme	15432·34880	32·150727	2·2046213	0·0196841	0·0009842
Myriagramme	154323·48800	321·507267	22·0462126	0·1968412	0·0098421

Square, or Measures of Surface (unit Are).

Equal to	Sq. Feet.	Sq. Yards.	Sq. Perches.	Sq. Roods.	Sq. Acres.
Centiare, or square mètre	10·764299	1·196033	0·0395383	0·0009885	0·0002471
Are, or 100 square mètres	1076·429934	119·603326	3·9538290	0·0988457	0·0247114
Hectare, or 10,000 square mètres	107642·993419	11960·332602	395·3828059	9·8845724	2·4711431

To convert mètres or parts of mètres into yards, add $\frac{1}{11}$.
To convert mètres into inches, multiply by 40.
To convert inches into mètres, divide by 40, or multiply by 0·02540.
To convert lbs. per sq. inch into kilograms per sq. centimètre, multiply by 0·0703.
To convert kilograms per sq. centimètre into lbs. per sq. inch, multiply by 14·2247.
To convert kilograms into lbs., multiply by 2·2046.
To convert litres to gallons, multiply by 0·22.
To convert gallons to litres, multiply by 4·548.
To convert pints to cub. centimètres, multiply by 567·936.
To convert grams to grains, multiply by 15·432.
To convert grains to grams, multiply by 0·0648.
To convert ounces to grams, multiply by 28·349.

Table for the Conversion of Metric Weights and Measures into English.

Mètres	into yards.	Kilomètres	to miles	and yards.	Litres	into gallons	and quarts.	Hectolitres	into quarts	and bushels.	Kilogrammes	into cwts.	qrs.	lbs.	oz.	Hectares	into acres	r.	p.
1^m =	1·094	1^k =	0	1094	1^l =	0	0·880	1^h =	0	2·751	1^k =	0	0	2	3¼	1^h =	2	1	35
2	2·187	2	1	427	2	0	1·761	2	0	5·502	2	0	0	4	6½	2	4	3	31
3	3·281	3	1	1521	3	0	2·641	3	1	0·254	3	0	0	6	9¾	3	7	1	26
4	4·374	4	2	855	4	0	3·521	4	1	3·005	4	0	0	8	13	4	9	3	22
5	5·468	5	3	188	5	1	0·402	5	1	5·756	5	0	0	11	0¼	5	12	1	17
6	6·562	6	3	1282	6	1	1·282	6	2	0·507	6	0	0	13	3½	6	14	3	12
7	7·655	7	4	615	7	1	2·163	7	2	3·258	7	0	0	15	7	7	17	1	8
8	8·749	8	4	1709	8	1	3·043	8	2	6·010	8	0	0	17	10¼	8	19	3	3
9	9·843	9	5	1043	9	1	3·923	9	3	0·761	9	0	0	19	13½	9	22	0	38
10	10·936	10	6	376	10	2	0·804	10	3	3·512	10	0	0	22	0¾	10	24	2	34
20	21·873	20	12	753	20	4	1·608	20	6	7·024	20	0	1	16	1½	20	49	1	28
30	32·809	30	18	1129	30	6	2·412	30	10	2·536	30	0	2	10	2½	30	74	0	21
40	43·745	40	24	1805	40	8	3·215	40	13	6·048	40	0	3	4	3	40	98	3	15
50	54·682	50	31	122	50	11	0·019	50	17	1·560	50	0	3	26	3¾	50	123	2	9
60	65·618	60	37	498	60	13	0·823	60	20	5·072	60	1	0	20	4½	60	148	1	3
70	76·554	70	43	874	70	15	1·627	70	24	0·585	70	1	1	14	5¼	70	172	3	37
80	87·491	80	49	1251	80	17	2·431	80	27	4·097	80	1	2	8	6	80	197	2	38
90	98·427	90	55	1627	90	19	3·235	90	30	7·609	90	1	3	2	6½	90	222	1	24
100	109·363	100	62	243	100	22	0·039	100	34	3·121	100	1	3	24	7	100	247	0	18
200	218·727	200	124	487	200	44	0·077	200	68	6·242	200	3	3	20	15	200	494	0	37
300	328·090	300	186	730	300	66	0·116	300	103	1·362	300	5	3	17	6	300	741	1	15
400	437·453	400	248	973	400	88	0·155	400	137	4·483	400	7	3	13	14	400	988	1	33
500	546·816	500	310	1217	500	110	0·193	500	171	7·604	500	9	3	10	5	500	1235	2	11

Perpetual Calendar for Ascertaining the Day of the Week.

Table of Dominical Letters.

Year of the Century.				Centuries. 1700, 2100	1800, 2200	1900, 2300	2000, 2400
0	28	56	84	C	E	G	A
1	29	57	85	B	D	F	G
2	30	58	86	A	C	E	F
3	31	59	87	G	B	D	E
4	32	60	88	E	G	B	C
5	33	61	89	D	F	A	B
6	34	62	90	C	E	G	A
7	35	63	91	B	D	F	G
8	36	64	92	G	B	D	E
9	37	65	93	F	A	C	D
10	38	66	94	E	G	B	C
11	39	67	95	D	F	A	B
12	40	68	96	B	D	F	G
13	41	69	97	A	C	E	F
14	42	70	98	G	B	D	E
15	43	71	99	F	A	C	D
16	44	72		D	F	A	B
17	45	73		C	E	G	A
18	46	74		B	D	F	G
19	47	75		A	C	E	F
20	48	76		F	A	C	D
21	49	77		E	G	B	C
22	50	78		D	F	A	B
23	51	79		C	E	G	A
24	52	80		A	C	E	F
25	53	81		G	B	D	E
26	54	82		F	A	C	D
27	55	83		E	G	B	C

Month.	Dominical Letter.						
Jan. Oct.	A	B	C	D	E	F	G
Feb. Mar. Nov.	D	E	F	G	A	B	C
Jan. Apr. July	G	A	B	C	D	E	F
May	B	C	D	E	F	G	A
June	E	F	G	A	B	C	D
Feb. Aug.	C	D	E	F	G	A	B
Sept. Dec.	F	G	A	B	C	D	E

1	8	15	22	29	S̶	S	F	Th	W	Tu	M
2	9	16	23	30	M	S̶	S	F	Th	W	Tu
3	10	17	24	31	Tu	M	S̶	S	F	Th	W
4	11	18	25		W	Tu	M	S̶	S	F	Th
5	12	19	26		Th	W	Tu	M	S̶	S	F
6	13	20	27		F	Th	W	Tu	M	S̶	S
7	14	21	28		S	F	Th	W	Tu	M	S̶

Explanation.—Under the *Century*, and in the line with the *Year of the Century*, is the Dominical Letter of the Year. Then in the line with the month find the column containing this letter; in this column, and in the line with the day of the month, is the day of the week. In Leap-years, the letters for January and February are in the lines where these months are printed in *italics*.

Examples.—For Dec. 31st, 1871: for 1871 the letter is A; under A, in a line with 31, is Sunday; and for *Jan.* 1st, 1872 the letter is F; under F, and in a line with 1, is Monday.

MONEY TABLES.

TABLE CONVERTING AMERICAN INTO ENGLISH MONEY.

American cents	1	2	3	4	5	6	7	8	9	10	11
English money	d. ½	d. 1	d. 1½	d. 2	d. 2½	d. 3	d. 3½	d. 4	d. 4½	d. 5	d. 5½
American cents	12	13	14	15	16	17	18	19	20	21	22
English money	d. 6	d. 6½	d. 7	d. 7½	d. 8	d. 8½	d. 9	d. 9½	d. 10	d. 10½	d. 11
American cents	23	24	25	26	27	28	29	30	31	32	33
English money	d. 11½	s. d. 1 0	s. d. 1 0½	s. d. 1 1	s. d. 1 1½	s. d. 1 2	s. d. 1 2½	s. d. 1 3	s. d. 1 3½	s. d. 1 4	s. d. 1 4½
American cents	34	35	36	37	38	39	40	41	42	43	44
English money	s. d. 1 5	s. d. 1 5½	s. d. 1 6	s. d. 1 6½	s. d. 1 7	s. d. 1 7½	s. d. 1 8	s. d. 1 8½	s. d. 1 9	s. d. 1 9½	s. d. 1 10

Example.—If you want to convert $94·62, table shows that $90 equals £18 15s.: $4 equals 16s. 8d.: 62 cents equals 2s. 7d.; total, £19 14s. 3d.

TABLE CONVERTING AMERICAN INTO ENGLISH MONEY—*continued*.

American cents . .	45	46	47	48	49	50	51	52	53	54	55
English money . .	*s.* *d.* 1 10½	*s.* *d.* 1 11	*s.* *d.* 1 11½	*s.* *d.* 2 0	*s.* *d.* 2 0½	*s.* *d.* 2 1	*s.* *d.* 2 1½	*s.* *d.* 2 2	*s.* *d.* 2 2½	*s.* *d.* 2 3	*s.* *d.* 2 3½
American cents . .	56	57	58	59	60	61	62	63	64	65	66
English money . .	*s.* *d.* 2 4	*s.* *d.* 2 4½	*s.* *d.* 2 5	*s.* *d.* 2 5½	*s.* *d.* 2 6	*s.* *d.* 2 6½	*s.* *d.* 2 7	*s.* *d.* 2 7½	*s.* *d.* 2 8	*s.* *d.* 2 8½	*s.* *d.* 2 9
American cents . .	67	68	69	70	71	72	73	74	75	76	77
English money . .	*s.* *d.* 2 9½	*s.* *d.* 2 10	*s.* *d.* 2 10½	*s.* *d.* 2 11	*s.* *d.* 2 11½	*s.* *d.* 3 0	*s.* *d.* 3 0½	*s.* *d.* 3 1	*s.* *d.* 3 1½	*s.* *d.* 3 2	*s.* *d.* 3 2½
American cents . .	78	79	80	81	82	83	84	85	86	87	88
English money . .	*s.* *d.* 3 3	*s.* *d.* 3 3½	*s.* *d.* 3 4	*s.* *d.* 3 4½	*s.* *d.* 3 5	*s.* *d.* 3 5½	*s.* *d.* 3 6	*s.* *d.* 3 6½	*s.* *d.* 3 7	*s.* *d.* 3 7½	*s.* *d.* 3 8

TABLE CONVERTING AMERICAN INTO ENGLISH MONEY—*continued.*

American cents	89	90	91	92	93	94	95	96	97	98	99
English money	*s.* 3 *d.* 8½	*s.* 3 *d.* 9	*s.* 3 *d.* 9½	*s.* 3 *d.* 10	*s.* 3 *d.* 10½	*s.* 3 *d.* 11	*s.* 3 *d.* 11½	*s.* 4 *d.* 0	*s.* 4 *d.* 0½	*s.* 4 *d.* 1	*s.* 4 *d.* 1½

American dollars	1	2	3	4	5	6	7
English money	£0 *s.* 4 *d.* 2	£0 *s.* 8 *d.* 4	£0 *s.* 12 *d.* 6	£0 *s.* 16 *d.* 8	£1 *s.* 0 *d.* 10	£1 *s.* 5 *d.* 0	£1 *s.* 9 *d.* 2

American dollars	8	9	10	20	30	40
English money	£1 *s.* 13 *d.* 4	£1 *s.* 17 *d.* 6	£2 *s.* 1 *d.* 8	£4 *s.* 3 *d.* 4	£6 *s.* 5 *d.* 0	£8 *s.* 6 *d.* 8

American dollars	50	60	70	80	90	100
English money	£10 *s.* 8 *d.* 4	£12 *s.* 10 *d.* 0	£14 *s.* 11 *d.* 8	£16 *s.* 13 *d.* 4	£18 *s.* 15 *d.* 0	£20 *s.* 16 *d.* 8

TABLE SHEWING EQUIVALENT RATES PER LB., CWT., AND TON.

Per lb.	Per cwt.		Per ton.			Per lb.	Per cwt.		Per ton.		
d.	s.	d.	£	s.	d.	d.	s.	d.	£	s.	d.
¼	2	4	2	6	8	6¼	58	4	58	6	8
½	4	8	4	13	4	6½	60	8	60	13	4
¾	7	0	7	0	0	6¾	63	0	63	0	0
1	9	4	9	6	8	7	65	4	65	6	8
1¼	11	8	11	13	4	7¼	67	8	67	13	4
1½	14	0	14	0	0	7½	70	0	70	0	0
1¾	16	4	16	6	8	7¾	72	4	72	6	8
2	18	8	18	13	4	8	74	8	74	13	4
2¼	21	0	21	0	0	8¼	77	0	77	0	0
2½	23	4	23	6	8	8½	79	4	79	6	8
2¾	25	8	25	13	4	8¾	81	8	81	13	4
3	28	0	28	0	0	9	84	0	84	0	0
3¼	30	4	30	6	8	9¼	86	4	86	6	8
3½	32	8	32	13	4	9½	88	8	88	13	4
3¾	35	0	35	0	0	9¾	91	0	91	0	0
4	37	4	37	6	8	10	93	4	93	6	8
4¼	39	8	39	13	4	10¼	95	8	95	13	4
4½	42	0	42	0	0	10½	98	0	98	0	0
4¾	44	4	44	6	8	10¾	100	4	100	6	8
5	46	8	46	13	4	11	102	8	102	13	4
5¼	49	0	49	0	0	11¼	105	0	105	0	0
5½	51	4	51	6	8	11½	107	4	107	6	8
5¾	53	8	53	13	4	11¾	109	8	109	13	4
6	56	0	56	0	0	12	112	0	112	0	0

Income Table for the year, Quarter, Calendar Month, Week, or Day.

Yearly.			Quarterly.			Monthly.			Weekly.			Daily.		
£6	0	0	£1	10	0	£0	10	0	£0	2	3¾	£0	0	4
6	10	0	1	12	6	0	10	10	0	2	6	0	0	4¼
7	0	0	1	15	0	0	11	8	0	2	8¼	0	0	4½
7	10	0	1	17	6	0	12	6	0	2	10½	0	0	5
8	0	0	2	0	0	0	13	4	0	3	0¾	0	0	5¼
8	10	0	2	2	6	0	14	2	0	3	3	0	0	5½
9	0	0	2	5	0	0	15	0	0	3	5½	0	0	6
9	10	0	2	7	6	0	15	10	0	3	7¾	0	0	6¼
10	0	0	2	10	0	0	16	8	0	3	10	0	0	6½
10	10	0	2	12	6	0	17	6	0	4	0¼	0	0	7
11	0	0	2	15	0	0	18	4	0	4	2¾	0	0	7¼
11	10	0	2	17	6	0	19	2	0	4	5	0	0	7½
12	0	0	3	0	0	1	0	0	0	4	7¼	0	0	8
12	10	0	3	2	6	1	0	10	0	4	10½	0	0	8¼
13	0	0	3	5	0	1	1	8	0	5	0	0	0	8½
13	10	0	3	7	6	1	2	6	0	5	2¼	0	0	9
14	0	0	3	10	0	1	3	4	0	5	4¼	0	0	9¼
14	10	0	3	12	6	1	4	2	0	5	6¾	0	0	9½
15	0	0	3	15	0	1	5	0	0	5	9	0	0	10
15	10	0	3	17	6	1	5	10	0	5	11¼	0	0	10¼
16	0	0	4	0	0	1	6	8	0	6	1¾	0	0	10½
16	10	0	4	2	6	1	7	6	0	6	4	0	0	11
17	0	0	4	5	0	1	8	4	0	6	6¼	0	0	11¼
17	10	0	4	7	6	1	9	2	0	6	8½	0	0	11½
18	0	0	4	10	0	1	10	0	0	6	11	0	0	11¾
18	10	0	4	12	6	1	10	10	0	7	1¼	0	1	0
19	0	0	4	15	0	1	11	8	0	7	3½	0	1	0½
19	10	0	4	17	6	1	12	6	0	7	5¾	0	1	1
20	0	0	5	0	0	1	13	4	0	7	8	0	1	1¼
30	0	0	7	10	0	2	10	0	0	11	6	0	1	7¾
40	0	0	10	0	0	3	6	8	0	15	4½	0	2	2¼
50	0	0	12	10	0	4	3	4	0	19	2¾	0	2	9
60	0	0	15	0	0	5	0	0	1	3	1	0	3	3½
70	0	0	17	10	0	5	16	8	1	6	11	0	3	10
80	0	0	20	0	0	6	13	4	1	10	9¼	0	4	4¾
90	0	0	22	10	0	7	10	0	1	14	7¼	0	4	11½
100	0	0	25	0	0	8	6	8	1	18	5½	0	5	6
200	0	0	50	0	0	16	13	4	3	16	11	0	10	11¾
300	0	0	75	0	0	25	0	0	5	15	4	0	16	5¾
400	0	0	100	0	0	33	6	8	7	13	10	1	1	11¾
500	0	0	125	0	0	41	13	4	9	12	3½	1	7	5¾

COMPOUND INTEREST TABLE, SHOWING THE AMOUNT OF £1, $1, FR.1, M.1, &C., AT 2½ TO 5 PER CENT., FOR FROM 1 TO 60 YEARS. (*Smart.*)

Years.	2½ per cent.	3 per cent.	3½ per cent.	4 per cent.	4½ per cent	5 per cent.
1	1·0250000	1·0300000	1·0350000	1·0400000	1·0450000	1·0500000
2	1·0506250	1·0609000	1·0712250	1·0816000	1·0920250	1·1025000
3	1·0768906	1·0927270	1·1087178	1·1248640	1·1411661	1·1576250
4	1·1038128	1·1255088	1·1475230	1·1698585	1·1925186	1·2155062
5	1·1314082	1·1592740	1·1876863	1·2166529	1·2461819	1·2762815
6	1·1596934	1·1940523	1·2292553	1·2653190	1·3022601	1·3400956
7	1·1886857	1·2298738	1·2722792	1·3159317	1·3608618	1·4071004
8	1·2184029	1·2667700	1·3168090	1·3685690	1·4221006	1·4774554
9	1·2488629	1·3047731	1·3628973	1·4233118	1·4860951	1·5513282
10	1·2800845	1·3439163	1·4105987	1·4802442	1·5529694	1·6288946
11	1·3120866	1·3842338	1·4599697	1·5394540	1·6228530	1·7103393
12	1·3448888	1·4257608	1·5110686	1·6010322	1·6958814	1·7958563
13	1·3785110	1·4685337	1·5639560	1·6650735	1·7721961	1·8856491
14	1·4129738	1·5125897	1·6186945	1·7316764	1·8519449	1·9799316
15	1·4482981	1·5579674	1·6753488	1·8009435	1·9352824	2·0789281
16	1·4845056	1·6047064	1·7339860	1·8729812	2·0223701	2·1828745
17	1·5216182	1·6528476	1·7946755	1·9479005	2·1133768	2·2920183
18	1·5596587	1·7024330	1·8574892	2·0258165	2·2084787	2·4066192
19	1·5986501	1·7535060	1·9225013	2·1068491	2·3078603	2·5269502
20	1·6386164	1·8061112	1·9897888	2·1911231	2·4117140	2·6532977

COMPOUND INTEREST TABLE, SHOWING THE AMOUNT OF £1, $1, F.1, M.1, &c., AT 2½ TO 5 PER CENT. FOR FROM 1 TO 60 YEARS (*continued*).

Years.	2½ per cent.	3 per cent.	3½ per cent.	4 per cent.	4½ per cent.	5 per cent.
21	1·6795818	1·8602945	2·0594314	2·2787680	2·5202411	2·7859625
22	1·7215714	1·9161034	2·1315115	2·3699187	2·6336520	2·9252607
23	1·7646106	1·9735865	2·2061144	2·4647155	2·7521663	3·0715237
24	1·8087259	2·0327941	2·2833284	2·5633041	2·8760138	3·2250999
25	1·8539441	2·0937779	2·3632449	2·6658363	3·0054344	3·3863549
26	1·9002927	2·1565912	2·4459585	2·7724697	3·1406790	3·5556726
27	1·9478000	2·2212890	2·5315671	2·8833685	3·2820095	3·7334563
28	1·9964950	2·2879276	2·6201719	2·9987033	3·4296999	3·9201291
29	2·0464073	2·3565655	2·7118779	3·1186514	3·5840364	4·1161356
30	2·0975675	2·4272624	2·8067937	3·2433975	3·7453181	4·3219423
31	2·1500067	2·5000803	2·9050314	3·3731334	3·9138574	4·5380394
32	2·2037569	2·5750827	3·0067075	3·5080587	4·0899810	4·7649414
33	2·2588508	2·6523352	3·1119423	3·6483811	4·2740301	5·0031885
34	2·3153221	2·7319053	3·2208603	3·7943163	4·4663615	5·2533479
35	2·3732051	2·8138624	3·3335904	3·9460889	4·6673478	5·5160153
36	2·4325353	2·8982783	3·4502661	4·1039325	4·8773784	5·7918161
37	2·4933487	2·9852266	3·5710254	4·2680898	5·0968604	6·0814069
38	2·5556824	3·0747834	3·6960113	4·4388134	5·3262192	6·3854772
39	2·6195744	3·1670269	3·8253717	4·6163659	5·5658990	6·7047511
40	2·6850638	3·2620377	3·9592597	4·8010206	5·8163645	7·0399887

COMPOUND INTEREST TABLE, SHOWING THE AMOUNT OF £1, $1, F.1, M.1, &c., AT 2½ TO 5 PER CENT. FOR FROM 1 TO 60 YEARS (*continued.*)

Years.	2½ per cent.	3 per cent.	3½ per cent.	4 per cent.	4½ per cent.	5 per cent.
41	2·7521904	3·3598989	4·0978338	4·9930614	6·0781009	7·3919881
42	2·8209952	3·4606958	4·2412579	5·1927839	6·3516154	7·7615875
43	2·8915200	3·5645167	4·3897020	5·4004952	6·6374381	8·1496669
44	2·9638080	3·6714522	4·5433416	5·6165150	6·9361229	8·5571502
45	3·0379032	3·7815958	4·7023585	5·8411756	7·2482484	8·9850077
46	3·1138508	3·8950437	4·8669411	6·0748227	7·5744196	9·4342581
47	3·1916971	4·0118950	5·0372840	6·3178156	7·9152684	9·9059710
48	3·2714895	4·1322518	5·2135889	6·5705282	8·2714555	10·4012696
49	3·3532768	4·2562194	5·3960645	6·8333493	8·6436710	10·9213331
50	3·4371087	4·3839060	5·5849268	7·1066833	9·0326362	11·4673997
51	3·5230364	4·5154232	5·7803993	7·3909506	9·4391049	12·0407697
52	3·6111123	4·6508859	5·9827132	7·6865887	9·8638646	12·6428082
53	3·7013901	4·7904124	6·1921082	7·9940522	10·3077385	13·2749486
54	3·7939249	4·9341248	6·4088320	8·3138143	10·7715867	13·9386961
55	3·8887730	5·0821485	6·6331411	8·6463669	11·2563081	14·6356309
56	3·9859923	5·2346130	6·8653010	8·9922216	11·7628420	15·3674124
57	4·0856421	5·3916514	7·1055866	9·3519104	12·2921699	16·1357830
58	4·1877832	5·5534009	7·3542821	9·7259868	12·8453175	16·9425722
59	4·2924778	5·7200030	7·6116820	10·1150263	13·4233568	17·7897008
60	4·3997897	5·8916031	7·8780909	10·5196274	14·0274079	18·6791858

Wages Table. (Forty-eight Hours per Week.)

Detailing the wages from $\frac{1}{2}$ hour to 6 days—the day being reckoned at 8 hours—at rates per week of from 5*s.* to £5. (Original.)

D. H.	5s. Per Week.			6s. Per Week.			7s. Per Week.			7s. 6d. Per Week.			8s. Per Week.			9s. Per Week.		
	£	*s.*	*d.*	£	*s.*	*d.*	£	*s.*	*d.*	£	*s.*	*d.*	£	*s.*	*d.*	£	*s.*	*d.*
$\frac{1}{2}$	0	0	$0\frac{5}{8}$	0	0	$0\frac{3}{4}$	0	0	$0\frac{7}{8}$	0	0	$0\frac{15}{16}$	0	0	1	0	0	$1\frac{1}{8}$
1	0	0	$1\frac{1}{4}$	0	0	$1\frac{1}{2}$	0	0	$1\frac{3}{4}$	0	0	$1\frac{7}{8}$	0	0	2	0	0	$2\frac{1}{4}$
2	0	0	$2\frac{1}{2}$	0	0	3	0	0	$3\frac{1}{2}$	0	0	$3\frac{3}{4}$	0	0	4	0	0	$4\frac{1}{2}$
3	0	0	$3\frac{3}{4}$	0	0	$4\frac{1}{2}$	0	0	$5\frac{1}{4}$	0	0	$5\frac{5}{8}$	0	0	6	0	0	$6\frac{3}{4}$
4	0	0	5	0	0	6	0	0	7	0	0	$7\frac{1}{2}$	0	0	8	0	0	9
5	0	0	$6\frac{1}{4}$	0	0	$7\frac{1}{2}$	0	0	$8\frac{3}{4}$	0	0	$9\frac{3}{8}$	0	0	10	0	0	$11\frac{1}{4}$
6	0	0	$7\frac{1}{2}$	0	0	9	0	0	$10\frac{1}{2}$	0	0	$11\frac{1}{4}$	0	1	0	0	1	$1\frac{1}{2}$
7	0	0	$8\frac{3}{4}$	0	0	$10\frac{1}{2}$	0	1	$0\frac{1}{4}$	0	1	$1\frac{1}{8}$	0	1	2	0	1	$3\frac{3}{4}$
1 = 8	0	0	10	0	1	0	0	1	2	0	1	3	0	1	4	0	1	6
2 = 16	0	1	8	0	2	0	0	2	4	0	2	6	0	2	8	0	3	0
3 = 24	0	2	6	0	3	0	0	3	6	0	3	9	0	4	0	0	4	6
4 = 32	0	3	4	0	4	0	0	4	8	0	5	0	0	5	4	0	6	0
5 = 40	0	4	2	0	5	0	0	5	10	0	6	3	0	6	8	0	7	6
6 = 48	0	5	0	0	6	0	0	7	0	0	7	6	0	8	0	0	9	0

D. H.	10s. Per Week.			11s. Per Week.			12s. Per Week.			12s. 6d. Per Week.			13s. Per Week.			14s. Per Week.		
	£	*s.*	*d.*	£	*s.*	*d.*	£	*s.*	*d.*	£	*s.*	*d.*	£	*s.*	*d.*	£	*s.*	*d.*
$\frac{1}{2}$	0	0	$1\frac{1}{4}$	0	0	$1\frac{3}{8}$	0	0	$1\frac{1}{2}$	0	0	$1\frac{9}{16}$	0	0	$1\frac{5}{8}$	0	0	$1\frac{3}{4}$
1	0	0	$2\frac{1}{2}$	0	0	$2\frac{3}{4}$	0	0	3	0	0	$3\frac{1}{8}$	0	0	$3\frac{1}{4}$	0	0	$3\frac{1}{2}$
2	0	0	5	0	0	$5\frac{1}{2}$	0	0	6	0	0	$6\frac{1}{4}$	0	0	$6\frac{1}{2}$	0	0	7
3	0	0	$7\frac{1}{2}$	0	0	$8\frac{1}{4}$	0	0	9	0	0	$9\frac{3}{8}$	0	0	$9\frac{3}{4}$	0	0	$10\frac{1}{2}$
4	0	0	10	0	0	11	0	1	0	0	1	$0\frac{1}{2}$	0	1	1	0	1	2
5	0	1	$0\frac{1}{2}$	0	1	$1\frac{3}{4}$	0	1	3	0	1	$3\frac{5}{8}$	0	1	$4\frac{1}{4}$	0	1	$5\frac{1}{2}$
6	0	1	3	0	1	$4\frac{1}{2}$	0	1	6	0	1	$6\frac{3}{4}$	0	1	$7\frac{1}{2}$	0	1	9
7	0	1	$5\frac{1}{2}$	0	1	$7\frac{1}{4}$	0	1	9	0	1	$9\frac{7}{8}$	0	1	$10\frac{3}{4}$	0	2	$0\frac{1}{2}$
1 = 8	0	1	8	0	1	10	0	2	0	0	2	1	0	2	2	0	2	4
2 = 16	0	3	4	0	3	8	0	4	0	0	4	2	0	4	4	0	4	8
3 = 24	0	5	0	0	5	6	0	6	0	0	6	3	0	6	6	0	7	0
4 = 32	0	6	8	0	7	4	0	8	0	0	8	4	0	8	8	0	9	4
5 = 40	0	8	4	0	9	2	0	10	0	0	10	5	0	10	10	0	11	8
6 = 48	0	10	0	0	11	0	0	12	0	0	12	6	0	13	0	0	14	0

WAGES TABLE (FORTY-EIGHT HOURS PER WEEK) (*continued*).

D. H.	15s. Per Week.			16s. Per Week.			17s. Per Week.			17s. 6d. Per Week.			18s. Per Week.			19s. Per Week.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
$\frac{1}{2}$	0	0	$1\frac{7}{8}$	0	0	2	0	0	$2\frac{1}{8}$	0	0	$2\frac{3}{16}$	0	0	$2\frac{1}{4}$	0	0	$2\frac{3}{8}$
1	0	0	$3\frac{3}{4}$	0	0	4	0	0	$4\frac{1}{4}$	0	0	$4\frac{3}{8}$	0	0	$4\frac{1}{2}$	0	0	$4\frac{3}{4}$
2	0	0	$7\frac{1}{2}$	0	0	8	0	0	$8\frac{1}{2}$	0	0	$8\frac{3}{4}$	0	0	9	0	0	$9\frac{1}{2}$
3	0	0	$11\frac{1}{4}$	0	1	0	0	1	$0\frac{3}{4}$	0	1	$1\frac{1}{8}$	0	1	$1\frac{1}{2}$	0	1	$2\frac{1}{4}$
4	0	1	3	0	1	4	0	1	5	0	1	$5\frac{1}{2}$	0	1	6	0	1	7
5	0	1	$6\frac{3}{4}$	0	1	8	0	1	$9\frac{1}{4}$	0	1	$9\frac{7}{8}$	0	1	$10\frac{1}{2}$	0	1	$11\frac{3}{4}$
6	0	1	$10\frac{1}{2}$	0	2	0	0	2	$1\frac{1}{2}$	0	2	$2\frac{1}{4}$	0	2	3	0	2	$4\frac{1}{2}$
7	0	2	$2\frac{1}{4}$	0	2	4	0	2	$5\frac{3}{4}$	0	2	$6\frac{5}{8}$	0	2	$7\frac{1}{2}$	0	2	$9\frac{1}{4}$
1 = 8	0	2	6	0	2	8	0	2	10	0	2	11	0	3	0	0	3	2
2 = 16	0	5	0	0	5	4	0	5	8	0	5	10	0	6	0	0	6	4
3 = 24	0	7	6	0	8	0	0	8	6	0	8	9	0	9	0	0	9	6
4 = 32	0	10	0	0	10	8	0	11	4	0	11	8	0	12	0	0	12	8
5 = 40	0	12	6	0	13	4	0	14	2	0	14	7	0	15	0	0	15	10
6 = 48	0	15	0	0	16	0	0	17	0	0	17	6	0	18	0	0	19	0

D. H.	20s. Per Week.			21s. Per Week.			22s. Per Week.			22s. 6d. Per Week.			23s. Per Week.			24s. Per Week.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
$\frac{1}{2}$	0	0	$2\frac{1}{2}$	0	0	$2\frac{5}{8}$	0	0	$2\frac{3}{4}$	0	0	$2\frac{13}{16}$	0	0	$2\frac{7}{8}$	0	0	3
1	0	0	5	0	0	$5\frac{1}{4}$	0	0	$5\frac{1}{2}$	0	0	$5\frac{5}{8}$	0	0	$5\frac{3}{4}$	0	0	6
2	0	0	10	0	0	$10\frac{1}{2}$	0	0	11	0	0	$11\frac{1}{4}$	0	0	$11\frac{1}{2}$	0	1	0
3	0	1	3	0	1	$3\frac{3}{4}$	0	1	$4\frac{1}{2}$	0	1	$4\frac{7}{8}$	0	1	$5\frac{1}{4}$	0	1	6
4	0	1	8	0	1	9	0	1	10	0	1	$10\frac{1}{2}$	0	1	11	0	2	0
5	0	2	1	0	2	$2\frac{1}{4}$	0	2	$3\frac{1}{2}$	0	2	$4\frac{1}{8}$	0	2	$4\frac{3}{4}$	0	2	6
6	0	2	6	0	2	$7\frac{1}{2}$	0	2	9	0	2	$9\frac{3}{4}$	0	2	$10\frac{1}{2}$	0	3	0
7	0	2	11	0	3	$0\frac{3}{4}$	0	3	$2\frac{1}{2}$	0	3	$3\frac{3}{8}$	0	3	$4\frac{1}{4}$	0	3	6
1 = 8	0	3	4	0	3	6	0	3	8	0	3	9	0	3	10	0	4	0
2 = 16	0	6	8	0	7	0	0	7	4	0	7	6	0	7	8	0	8	0
3 = 24	0	10	0	0	10	6	0	11	0	0	11	3	0	11	6	0	12	0
4 = 32	0	13	4	0	14	0	0	14	8	0	15	0	0	15	4	0	16	0
5 = 40	0	16	8	0	17	6	0	18	4	0	18	9	0	19	2	1	0	0
6 = 48	1	0	0	1	1	0	1	2	0	1	2	6	1	3	0	1	4	0

Wages Table (Forty-eight Hours per Week) (*continued*).

D. H.	25s. Per Week.			26s. Per Week.			27s. Per Week.			27s. 6d. Per Week.			28s. Per Week.			29s. Per Week.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
$\frac{1}{2}$	0	0	$3\frac{1}{8}$	0	0	$3\frac{1}{4}$	0	0	$3\frac{3}{8}$	0	0	$3\frac{7}{16}$	0	0	$3\frac{1}{2}$	0	0	$3\frac{5}{8}$
1	0	0	$6\frac{1}{4}$	0	0	$6\frac{1}{2}$	0	0	$6\frac{3}{4}$	0	0	$6\frac{7}{8}$	0	0	7	0	0	$7\frac{1}{4}$
2	0	1	$0\frac{1}{2}$	0	1	1	0	1	$1\frac{1}{2}$	0	1	$1\frac{3}{4}$	0	1	2	0	1	$2\frac{1}{2}$
3	0	1	$6\frac{3}{4}$	0	1	$7\frac{1}{2}$	0	1	$8\frac{1}{4}$	0	1	$8\frac{5}{8}$	0	1	9	0	1	$9\frac{3}{4}$
4	0	2	1	0	2	2	0	2	3	0	2	$3\frac{1}{2}$	0	2	4	0	2	5
5	0	2	$7\frac{1}{4}$	0	2	$8\frac{1}{2}$	0	2	$9\frac{3}{4}$	0	2	$10\frac{3}{8}$	0	2	11	0	3	$0\frac{1}{4}$
6	0	3	$1\frac{1}{2}$	0	3	3	0	3	$4\frac{1}{2}$	0	3	$5\frac{1}{4}$	0	3	6	0	3	$7\frac{1}{2}$
7	0	3	$7\frac{3}{4}$	0	3	$9\frac{1}{2}$	0	3	$11\frac{1}{4}$	0	4	$0\frac{1}{8}$	0	4	1	0	4	$2\frac{3}{4}$
1 = 8	0	4	2	0	4	4	0	4	6	0	4	7	0	4	8	0	4	10
2 = 16	0	8	4	0	8	8	0	9	0	0	9	2	0	9	4	0	9	8
3 = 24	0	12	6	0	13	0	0	13	6	0	13	9	0	14	0	0	14	6
4 = 32	0	16	8	0	17	4	0	18	0	0	18	4	0	18	8	0	19	4
5 = 40	1	0	10	1	1	8	1	2	6	1	2	11	1	3	4	1	4	2
6 = 48	1	5	0	1	6	0	1	7	0	1	7	6	1	8	0	1	9	0

D. H.	30s. Per Week.			31s. Per Week.			32s. Per Week.			32s. 6d. Per Week.			33s. Per Week.			34s. Per Week.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
$\frac{1}{2}$	0	0	$3\frac{3}{4}$	0	0	$3\frac{7}{8}$	0	0	4	0	0	$4\frac{1}{16}$	0	0	$4\frac{1}{8}$	0	0	$4\frac{1}{4}$
1	0	0	$7\frac{1}{2}$	0	0	$7\frac{3}{4}$	0	0	8	0	0	$8\frac{1}{8}$	0	0	$8\frac{1}{4}$	0	0	$8\frac{1}{2}$
2	0	1	3	0	1	$3\frac{1}{2}$	0	1	4	0	1	$4\frac{1}{4}$	0	1	$4\frac{1}{2}$	0	1	5
3	0	1	$10\frac{1}{2}$	0	1	$11\frac{1}{4}$	0	2	0	0	2	$0\frac{3}{8}$	0	2	$0\frac{3}{4}$	0	2	$1\frac{1}{2}$
4	0	2	6	0	2	7	0	2	8	0	2	$8\frac{1}{2}$	0	2	9	0	2	10
5	0	3	$1\frac{1}{2}$	0	3	$2\frac{3}{4}$	0	3	4	0	3	$4\frac{5}{8}$	0	3	$5\frac{1}{4}$	0	3	$6\frac{1}{2}$
6	0	3	9	0	3	$10\frac{1}{2}$	0	4	0	0	4	$0\frac{3}{4}$	0	4	$1\frac{1}{2}$	0	4	3
7	0	4	$4\frac{1}{2}$	0	4	$6\frac{1}{4}$	0	4	8	0	4	$8\frac{7}{8}$	0	4	$9\frac{3}{4}$	0	4	$11\frac{1}{2}$
1 = 8	0	5	0	0	5	2	0	5	4	0	5	5	0	5	6	0	5	8
2 = 16	0	10	0	0	10	4	0	10	8	0	10	10	0	11	0	0	11	4
3 = 24	0	15	0	0	15	6	0	16	0	0	16	3	0	16	6	0	17	0
4 = 32	1	0	0	1	0	8	1	1	4	1	1	8	1	2	0	1	2	8
5 = 40	1	5	0	1	5	10	1	6	8	1	7	1	1	7	6	1	8	4
6 = 48	1	10	0	1	11	0	1	12	0	1	12	6	1	13	0	1	14	0

WAGES TABLE (FORTY-EIGHT HOURS PER WEEK) (*continued*).

D. H.	35s. Per Week.			36s. Per Week.			37s. Per Week.			37s. 6d. Per Week.			38s. Per Week.			39s. Per Week.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
$\frac{1}{2}$	0	0	$4\frac{3}{8}$	0	0	$4\frac{1}{2}$	0	0	$4\frac{5}{8}$	0	0	$4\frac{11}{16}$	0	0	$4\frac{3}{4}$	0	0	$4\frac{7}{8}$
1	0	0	$8\frac{3}{4}$	0	0	9	0	0	$9\frac{1}{4}$	0	0	$9\frac{3}{8}$	0	0	$9\frac{1}{2}$	0	0	$9\frac{3}{4}$
2	0	1	$5\frac{1}{2}$	0	1	6	0	1	$6\frac{1}{2}$	0	1	$6\frac{3}{4}$	0	1	7	0	1	$7\frac{1}{2}$
3	0	2	$2\frac{1}{4}$	0	2	3	0	2	$3\frac{3}{4}$	0	2	$4\frac{1}{8}$	0	2	$4\frac{1}{2}$	0	2	$5\frac{1}{4}$
4	0	2	11	0	3	0	0	3	1	0	3	$1\frac{1}{2}$	0	3	2	0	3	3
5	0	3	$7\frac{3}{4}$	0	3	9	0	3	$10\frac{1}{4}$	0	3	$10\frac{7}{8}$	0	3	$11\frac{1}{2}$	0	4	$0\frac{3}{4}$
6	0	4	$4\frac{1}{2}$	0	4	6	0	4	$7\frac{1}{2}$	0	4	$8\frac{1}{4}$	0	4	9	0	4	$10\frac{1}{2}$
7	0	5	$1\frac{1}{4}$	0	5	3	0	5	$4\frac{3}{4}$	0	5	$5\frac{5}{8}$	0	5	$6\frac{1}{2}$	0	5	$8\frac{1}{4}$
1 = 8	0	5	10	0	6	0	0	6	2	0	6	3	0	6	4	0	6	6
2 = 16	0	11	8	0	12	0	0	12	4	0	12	6	0	12	8	0	13	0
3 = 24	0	17	6	0	18	0	0	18	6	0	18	9	0	19	0	0	19	6
4 = 32	1	3	4	1	4	0	1	4	8	1	5	0	1	5	4	1	6	0
5 = 40	1	9	2	1	10	0	1	10	10	1	11	3	1	11	8	1	12	6
6 = 48	1	15	0	1	16	0	1	17	0	1	17	6	1	18	0	1	19	0

D. H.	40s. Per Week.			41s. Per Week.			42s. Per Week.			42s. 6d. Per Week.			43s. Per Week			44s. Per Week.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
$\frac{1}{2}$	0	0	5	0	0	$5\frac{1}{8}$	0	0	$5\frac{1}{4}$	0	0	$5\frac{5}{16}$	0	0	$5\frac{3}{8}$	0	0	$5\frac{1}{2}$
1	0	0	10	0	0	$10\frac{1}{4}$	0	0	$10\frac{1}{2}$	0	0	$10\frac{5}{8}$	0	0	$10\frac{3}{4}$	0	0	11
2	0	1	8	0	1	$8\frac{1}{2}$	0	1	9	0	1	$9\frac{1}{4}$	0	1	$9\frac{1}{2}$	0	1	10
3	0	2	6	0	2	$6\frac{3}{4}$	0	2	$7\frac{1}{2}$	0	2	$7\frac{7}{8}$	0	2	$8\frac{1}{4}$	0	2	9
4	0	3	4	0	3	5	0	3	6	0	3	$6\frac{1}{2}$	0	3	7	0	3	8
5	0	4	2	0	4	$3\frac{1}{4}$	0	4	$4\frac{1}{2}$	0	4	$5\frac{1}{8}$	0	4	$5\frac{3}{4}$	0	4	7
6	0	5	0	0	5	$1\frac{1}{2}$	0	5	3	0	5	$3\frac{3}{4}$	0	5	$4\frac{1}{2}$	0	5	6
7	0	5	10	0	5	$11\frac{3}{4}$	0	6	$1\frac{1}{2}$	0	6	$2\frac{3}{8}$	0	6	$3\frac{1}{4}$	0	6	5
1 = 8	0	6	8	0	6	10	0	7	0	0	7	1	0	7	2	0	7	4
2 = 16	0	13	4	0	13	8	0	14	0	0	14	2	0	14	4	0	14	8
3 = 24	1	0	0	1	0	6	1	1	0	1	1	3	1	1	6	1	2	0
4 = 32	1	6	8	1	7	4	1	8	0	1	8	4	1	8	8	1	9	4
5 = 40	1	13	4	1	14	2	1	15	0	1	15	5	1	15	10	1	16	8
6 = 48	2	0	0	2	1	0	2	2	0	2	2	6	2	3	0	2	4	0

WAGES TABLE (FORTY-EIGHT HOURS PER WEEK) (*continued*).

D. H.	45s. Per Week.			46s. Per Week.			47s. Per Week.			47s. 6d. Per Week.			48s. Per Week.			49s. Per Week.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
$\frac{1}{2}$	0	0	5$\frac{5}{8}$	0	0	5$\frac{3}{4}$	0	0	5$\frac{7}{8}$	0	0	5$\frac{15}{16}$	0	0	6	0	0	6$\frac{1}{8}$
1	0	0	11$\frac{1}{4}$	0	0	11$\frac{1}{2}$	0	0	11$\frac{3}{4}$	0	0	11$\frac{7}{8}$	0	1	0	0	1	0$\frac{1}{4}$
2	0	1	10$\frac{1}{2}$	0	1	11	0	1	11$\frac{1}{2}$	0	1	11$\frac{3}{4}$	0	2	0	0	2	0$\frac{1}{2}$
3	0	2	9$\frac{3}{4}$	0	2	10$\frac{1}{2}$	0	2	11$\frac{1}{4}$	0	2	11$\frac{5}{8}$	0	3	0	0	3	0$\frac{3}{4}$
4	0	3	9	0	3	10	0	3	11	0	3	11$\frac{1}{2}$	0	4	0	0	4	1
5	0	4	8$\frac{1}{4}$	0	4	9$\frac{1}{2}$	0	4	10$\frac{3}{4}$	0	4	11$\frac{3}{8}$	0	5	0	0	5	1$\frac{1}{4}$
6	0	5	7$\frac{1}{2}$	0	5	9	0	5	10$\frac{1}{2}$	0	5	11$\frac{1}{4}$	0	6	0	0	6	1$\frac{1}{2}$
7	0	6	6$\frac{3}{4}$	0	6	8$\frac{1}{2}$	0	6	10$\frac{1}{4}$	0	6	11$\frac{1}{8}$	0	7	0	0	7	1$\frac{3}{4}$
1 = 8	0	7	6	0	7	8	0	7	10	0	7	11	0	8	0	0	8	2
2 = 16	0	15	0	0	15	4	0	15	8	0	15	10	0	16	0	0	16	4
3 = 24	1	2	6	1	3	0	1	3	6	1	3	9	1	4	0	1	4	6
4 = 32	1	10	0	1	10	8	1	11	4	1	11	8	1	12	0	1	12	8
5 = 40	1	17	6	1	18	4	1	19	2	1	19	7	2	0	0	2	0	10
6 = 48	2	5	0	2	6	0	2	7	0	2	7	6	2	8	0	2	9	0

D. H.	50s. Per Week.			51s. Per Week.			52s. Per Week.			52s. 6d. Per Week.			53s. Per Week.			54s. Per Week.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
$\frac{1}{2}$	0	0	6$\frac{1}{4}$	0	0	6$\frac{3}{8}$	0	0	6$\frac{1}{2}$	0	0	6$\frac{9}{16}$	0	0	6$\frac{5}{8}$	0	0	6$\frac{3}{4}$
1	0	1	0$\frac{1}{2}$	0	1	0$\frac{3}{4}$	0	1	1	0	1	1$\frac{1}{8}$	0	1	1$\frac{1}{4}$	0	1	1$\frac{1}{2}$
2	0	2	1	0	2	1$\frac{1}{2}$	0	2	2	0	2	2$\frac{1}{4}$	0	2	2$\frac{1}{2}$	0	2	3
3	0	3	1$\frac{1}{2}$	0	3	2$\frac{1}{4}$	0	3	3	0	3	3$\frac{3}{8}$	0	3	3$\frac{3}{4}$	0	3	4$\frac{1}{2}$
4	0	4	2	0	4	3	0	4	4	0	4	4$\frac{1}{2}$	0	4	5	0	4	6
5	0	5	2$\frac{1}{2}$	0	5	3$\frac{3}{4}$	0	5	5	0	5	5$\frac{5}{8}$	0	5	6$\frac{1}{4}$	0	5	7$\frac{1}{2}$
6	0	6	3	0	6	4$\frac{1}{2}$	0	6	6	0	6	6$\frac{3}{4}$	0	6	7$\frac{1}{2}$	0	6	9
7	0	7	3$\frac{1}{2}$	0	7	5$\frac{1}{4}$	0	7	7	0	7	7$\frac{7}{8}$	0	7	8$\frac{3}{4}$	0	7	10$\frac{1}{2}$
1 = 8	0	8	4	0	8	6	0	8	8	0	8	9	0	8	10	0	9	0
2 = 16	0	16	8	0	17	0	0	17	4	0	17	6	0	17	8	0	18	0
3 = 24	1	5	0	1	5	6	1	6	0	1	6	3	1	6	6	1	7	0
4 = 32	1	13	4	1	14	0	1	14	8	1	15	0	1	15	4	1	16	0
5 = 40	2	1	8	2	2	6	2	3	4	2	3	9	2	4	2	2	5	0
6 = 48	2	10	0	2	11	0	2	12	0	2	12	6	2	13	0	2	14	0

Wages Table (Forty-eight Hours per Week) (*continued*).

D. H.	55s. Per Week.			56s. Per Week.			57s. Per Week.			57s. 6d. Per Week.			58s. Per Week			59s. Per Week.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
$\frac{1}{2}$	0	0	$6\frac{7}{8}$	0	0	7	0	0	$7\frac{1}{8}$	0	0	$7\frac{3}{16}$	0	0	$7\frac{1}{4}$	0	0	$7\frac{3}{8}$
1	0	1	$1\frac{3}{4}$	0	1	2	0	1	$2\frac{1}{4}$	0	1	$2\frac{3}{8}$	0	1	$2\frac{1}{2}$	0	1	$2\frac{3}{4}$
2	0	2	$3\frac{1}{2}$	0	2	4	0	2	$4\frac{1}{2}$	0	2	$4\frac{3}{4}$	0	2	5	0	2	$5\frac{1}{2}$
3	0	3	$5\frac{1}{4}$	0	3	6	0	3	$6\frac{3}{4}$	0	3	$7\frac{1}{8}$	0	3	$7\frac{1}{2}$	0	3	$8\frac{1}{4}$
4	0	4	7	0	4	8	0	4	9	0	4	$9\frac{1}{2}$	0	4	10	0	4	11
5	0	5	$8\frac{3}{4}$	0	5	10	0	5	$11\frac{1}{4}$	0	5	$11\frac{7}{8}$	0	6	$0\frac{1}{2}$	0	6	$1\frac{3}{4}$
6	0	6	$10\frac{1}{2}$	0	7	0	0	7	$1\frac{1}{2}$	0	7	$2\frac{1}{4}$	0	7	3	0	7	$4\frac{1}{2}$
7	0	8	$0\frac{1}{4}$	0	8	2	0	8	$3\frac{3}{4}$	0	8	$4\frac{5}{8}$	0	8	$5\frac{1}{2}$	0	8	$7\frac{1}{4}$
1 = 8	0	9	2	0	9	4	0	9	6	0	9	7	0	9	8	0	9	10
2 = 16	0	18	4	0	18	8	0	19	0	0	19	2	0	19	4	0	19	8
3 = 24	1	7	6	1	8	0	1	8	6	1	8	9	1	9	0	1	9	6
4 = 32	1	16	8	1	17	4	1	18	0	1	18	4	1	18	8	1	19	4
5 = 40	2	5	10	2	6	8	2	7	6	2	7	11	2	8	4	2	9	2
6 = 48	2	15	0	2	16	0	2	17	0	2	17	6	2	18	0	2	19	0

D. H.	60s. Per Week.			61s. Per Week.			62s. Per Week.			62s. 6d. Per Week.			63s. Per Week.			64s. Per Week.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
$\frac{1}{2}$	0	0	$7\frac{1}{2}$	0	0	$7\frac{5}{8}$	0	0	$7\frac{3}{4}$	0	0	$7\frac{13}{16}$	0	0	$7\frac{7}{8}$	0	0	8
1	0	1	3	0	1	$3\frac{1}{4}$	0	1	$3\frac{1}{2}$	0	1	$3\frac{5}{8}$	0	1	$3\frac{3}{4}$	0	1	4
2	0	2	6	0	2	$6\frac{1}{2}$	0	2	7	0	2	$7\frac{1}{4}$	0	2	$7\frac{1}{2}$	0	2	8
3	0	3	9	0	3	$9\frac{3}{4}$	0	3	$10\frac{1}{2}$	0	3	$10\frac{7}{8}$	0	3	$11\frac{1}{4}$	0	4	0
4	0	5	0	0	5	1	0	5	2	0	5	$2\frac{1}{2}$	0	5	3	0	5	4
5	0	6	3	0	6	$4\frac{1}{4}$	0	6	$5\frac{1}{2}$	0	6	$6\frac{1}{8}$	0	6	$6\frac{3}{4}$	0	6	8
6	0	7	6	0	7	$7\frac{1}{2}$	0	7	9	0	7	$9\frac{3}{4}$	0	7	$10\frac{1}{2}$	0	8	0
7	0	8	9	0	8	$10\frac{3}{4}$	0	9	$0\frac{1}{2}$	0	9	$1\frac{3}{8}$	0	9	$2\frac{1}{4}$	0	9	4
1 = 8	0	10	0	0	10	2	0	10	4	0	10	5	0	10	6	0	10	8
2 = 16	1	0	0	1	0	4	1	0	8	1	0	10	1	1	0	1	1	4
3 = 24	1	10	0	1	10	6	1	11	0	1	11	3	1	11	6	1	12	0
4 = 32	2	0	0	2	0	8	2	1	4	2	1	8	2	2	0	2	2	8
5 = 40	2	10	0	2	10	10	2	11	8	2	12	1	2	12	6	2	13	4
6 = 48	3	0	0	3	1	0	3	2	0	3	2	6	3	3	0	3	4	0

Wages Table (Forty-eight Hours per Week) (*continued*).

D. H.	65s. Per Week.			66s. Per Week.			67s. Per Week.			67s. 6d. Per Week.			68s. Per Week.			69s. Per Week.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
$\frac{1}{2}$	0	0	$8\frac{1}{8}$	0	0	$8\frac{1}{4}$	0	0	$8\frac{3}{8}$	0	0	$8\frac{7}{16}$	0	0	$8\frac{1}{2}$	0	0	$8\frac{5}{8}$
1	0	1	$4\frac{1}{4}$	0	1	$4\frac{1}{2}$	0	1	$4\frac{3}{4}$	0	1	$4\frac{7}{8}$	0	1	5	0	1	$5\frac{1}{4}$
2	0	2	$8\frac{1}{2}$	0	2	9	0	2	$9\frac{1}{2}$	0	2	$9\frac{3}{4}$	0	2	10	0	2	$10\frac{1}{2}$
3	0	4	$0\frac{3}{4}$	0	4	$1\frac{1}{2}$	0	4	$2\frac{1}{4}$	0	4	$2\frac{5}{8}$	0	4	3	0	4	$3\frac{3}{4}$
4	0	5	5	0	5	6	0	5	7	0	5	$7\frac{1}{2}$	0	5	8	0	5	9
5	0	6	$9\frac{1}{4}$	0	6	$10\frac{1}{2}$	0	6	$11\frac{3}{4}$	0	7	$0\frac{3}{8}$	0	7	1	0	7	$2\frac{1}{4}$
6	0	8	$1\frac{1}{2}$	0	8	3	0	8	$4\frac{1}{2}$	0	8	$5\frac{1}{4}$	0	8	6	0	8	$7\frac{1}{2}$
7	0	9	$5\frac{3}{4}$	0	9	$7\frac{1}{2}$	0	9	$9\frac{1}{4}$	0	9	$10\frac{1}{8}$	0	9	11	0	10	$0\frac{3}{4}$
1 = 8	0	10	10	0	11	0	0	11	2	0	11	3	0	11	4	0	11	6
2 = 16	1	1	8	1	2	0	1	2	4	1	2	6	1	2	8	1	3	0
3 = 24	1	12	6	1	13	0	1	13	6	1	13	9	1	14	0	1	14	6
4 = 32	2	3	4	2	4	0	2	4	8	2	5	0	2	5	4	2	6	0
5 = 40	2	14	2	2	15	0	2	15	10	2	16	3	2	16	8	2	17	6
6 = 48	3	5	0	3	6	0	3	7	0	3	7	6	3	8	0	3	9	0

D. H.	70s. Per Week.			71s. Per Week.			72s. Per Week.			72s. 6d. Per Week.			73s. Per Week.			74s. Per Week.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
$\frac{1}{2}$	0	0	$8\frac{3}{4}$	0	0	$8\frac{7}{8}$	0	0	9	0	0	$9\frac{1}{16}$	0	0	$9\frac{1}{8}$	0	0	$9\frac{1}{4}$
1	0	1	$5\frac{1}{2}$	0	1	$5\frac{3}{4}$	0	1	6	0	1	$6\frac{1}{8}$	0	1	$6\frac{1}{4}$	0	1	$6\frac{1}{2}$
2	0	2	11	0	2	$11\frac{1}{2}$	0	3	0	0	3	$0\frac{1}{4}$	0	3	$0\frac{1}{2}$	0	3	1
3	0	4	$4\frac{1}{2}$	0	4	$5\frac{1}{4}$	0	4	6	0	4	$6\frac{3}{8}$	0	4	$6\frac{3}{4}$	0	4	$7\frac{1}{2}$
4	0	5	10	0	5	11	0	6	0	0	6	$0\frac{1}{2}$	0	6	1	0	6	2
5	0	7	$3\frac{1}{2}$	0	7	$4\frac{3}{4}$	0	7	6	0	7	$6\frac{5}{8}$	0	7	$7\frac{1}{4}$	0	7	$8\frac{1}{2}$
6	0	8	9	0	8	$10\frac{1}{2}$	0	9	0	0	9	$0\frac{3}{4}$	0	9	$1\frac{1}{2}$	0	9	3
7	0	10	$2\frac{1}{2}$	0	10	$4\frac{1}{4}$	0	10	6	0	10	$6\frac{7}{8}$	0	10	$7\frac{3}{4}$	0	10	$9\frac{1}{2}$
1 = 8	0	11	8	0	11	10	0	12	0	0	12	1	0	12	2	0	12	4
2 = 16	1	3	4	1	3	8	1	4	0	1	4	2	1	4	4	1	4	8
3 = 24	1	15	0	1	15	6	1	16	0	1	16	3	1	16	6	1	17	0
4 = 32	2	6	8	2	7	4	2	8	0	2	8	4	2	8	8	2	9	4
5 = 40	2	18	4	2	19	2	3	0	0	3	0	5	3	0	10	3	1	8
6 = 48	3	10	0	3	11	0	3	12	0	3	12	6	3	13	0	3	14	0

Wages Table (Forty-eight Hours per Week) (*continued*).

D. H.	75s. Per Week.			76s. Per Week.			77s. Per Week.			77s. 6d. Per Week.			78s. Per Week.			79s. Per Week.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
½	0	0	9⅜	0	0	9½	0	0	9⅝	0	0	$9\frac{11}{16}$	0	0	9¾	0	0	9⅞
1	0	1	6¾	0	1	7	0	1	7¼	0	1	7⅜	0	1	7½	0	1	7¾
2	0	3	1½	0	3	2	0	3	2½	0	3	2¾	0	3	3	0	3	3½
3	0	4	8¼	0	4	9	0	4	9¾	0	4	10⅛	0	4	10½	0	4	11¼
4	0	6	3	0	6	4	0	6	5	0	6	5½	0	6	6	0	6	7
5	0	7	9¾	0	7	11	0	8	0¼	0	8	0⅞	0	8	1½	0	8	2¾
6	0	9	4½	0	9	6	0	9	7½	0	9	8¼	0	9	9	0	9	10½
7	0	10	11¼	0	11	1	0	11	2¾	0	11	3⅝	0	11	4½	0	11	6¼
1 = 8	0	12	6	0	12	8	0	12	10	0	12	11	0	13	0	0	13	2
2 = 16	1	5	0	1	5	4	1	5	8	1	5	10	1	6	0	1	6	4
3 = 24	1	17	6	1	18	0	1	18	6	1	18	9	1	19	0	1	19	6
4 = 32	2	10	0	2	10	8	2	11	4	2	11	8	2	12	0	2	12	8
5 = 40	3	2	6	3	3	4	3	4	2	3	4	7	3	5	0	3	5	10
6 = 48	3	15	0	3	16	0	3	17	0	3	17	6	3	18	0	3	19	0

D. H.	80s. Per Week.			81s. Per Week.			82s. Per Week.			82s. 6d. Per Week.			83s. Per Week.			84s. Per Week.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
½	0	0	10	0	0	10⅛	0	0	10¼	0	0	$10\frac{5}{16}$	0	0	10⅜	0	0	10½
1	0	1	8	0	1	8¼	0	1	8½	0	1	8⅝	0	1	8¾	0	1	9
2	0	3	4	0	3	4½	0	3	5	0	3	5¼	0	3	5½	0	3	6
3	0	5	0	0	5	0¾	0	5	1½	0	5	1⅞	0	5	2¼	0	5	3
4	0	6	8	0	6	9	0	6	10	0	6	10½	0	6	11	0	7	0
5	0	8	4	0	8	5¼	0	8	6½	0	8	7⅛	0	8	7¾	0	8	9
6	0	10	0	0	10	1½	0	10	3	0	10	3¾	0	10	4½	0	10	6
7	0	11	8	0	11	9¾	0	11	11½	0	12	0⅜	0	12	1¼	0	12	3
1 = 8	0	13	4	0	13	6	0	13	8	0	13	9	0	13	10	0	14	0
2 = 16	1	6	8	1	7	0	1	7	4	1	7	6	1	7	8	1	8	0
3 = 24	2	0	0	2	0	6	2	1	0	2	1	3	2	1	6	2	2	0
4 = 32	2	13	4	2	14	0	2	14	8	2	15	0	2	15	4	2	16	0
5 = 40	3	6	8	3	7	6	3	8	4	3	8	9	3	9	2	3	10	0
6 = 48	4	0	0	4	1	0	4	2	0	4	2	6	4	3	0	4	4	0

Wages Table (Forty-eight Hours per Week) (*continued*).

D. H.	85s. Per Week.			86s. Per Week.			87s. Per Week.			87s. 6d. Per Week.			88s. Per Week.			89s. Per Week.		
	£	*s.*	*d.*	£	*s.*	*d.*	£	*s.*	*d.*	£	*s.*	*d.*	£	*s.*	*d.*	£	*s.*	*d.*
$\frac{1}{2}$	0	0	$10\frac{5}{8}$	0	0	$10\frac{3}{4}$	0	0	$10\frac{7}{8}$	0	0	$10\frac{15}{16}$	0	0	11	0	0	$11\frac{1}{8}$
1	0	1	$9\frac{1}{4}$	0	1	$9\frac{1}{2}$	0	1	$9\frac{3}{4}$	0	1	$9\frac{7}{8}$	0	1	10	0	1	$10\frac{1}{4}$
2	0	3	$6\frac{1}{2}$	0	3	7	0	3	$7\frac{1}{2}$	0	3	$7\frac{3}{4}$	0	3	8	0	3	$8\frac{1}{2}$
3	0	5	$3\frac{3}{4}$	0	5	$4\frac{1}{2}$	0	5	$5\frac{1}{4}$	0	5	$5\frac{5}{8}$	0	5	6	0	5	$6\frac{3}{4}$
4	0	7	1	0	7	2	0	7	3	0	7	$3\frac{1}{2}$	0	7	4	0	7	5
5	0	8	$10\frac{1}{4}$	0	8	$11\frac{1}{2}$	0	9	$0\frac{3}{4}$	0	9	$1\frac{3}{8}$	0	9	2	0	9	$3\frac{1}{4}$
6	0	10	$7\frac{1}{2}$	0	10	9	0	10	$10\frac{1}{2}$	0	10	$11\frac{1}{4}$	0	11	0	0	11	$1\frac{1}{2}$
7	0	12	$4\frac{3}{4}$	0	12	$6\frac{1}{2}$	0	12	$8\frac{1}{4}$	0	12	$9\frac{1}{8}$	0	12	10	0	12	$11\frac{3}{4}$
1 = 8	0	14	2	0	14	4	0	14	6	0	14	7	0	14	8	0	14	10
2 = 16	1	8	4	1	8	8	1	9	0	1	9	2	1	9	4	1	9	8
3 = 24	2	2	6	2	3	0	2	3	6	2	3	9	2	4	0	2	4	6
4 = 32	2	16	8	2	17	4	2	18	0	2	18	4	2	18	8	2	19	4
5 = 40	3	10	10	3	11	8	3	12	6	3	12	11	3	13	4	3	14	2
6 = 48	4	5	0	4	6	0	4	7	0	4	7	6	4	8	0	4	9	0

D. H.	90s. Per Week.			91s. Per Week			92s. Per Week.			92s. 6d. Per Week.			93s. Per Week.			94s. Per Week.		
	£	*s.*	*d.*	£	*s.*	*d.*	£	*s.*	*d.*	£	*s.*	*d.*	£	*s.*	*d.*	£	*s.*	*d.*
$\frac{1}{2}$	0	0	$11\frac{1}{4}$	0	0	$11\frac{3}{8}$	0	0	$11\frac{1}{2}$	0	0	$11\frac{9}{16}$	0	0	$11\frac{5}{8}$	0	0	$11\frac{3}{4}$
1	0	1	$10\frac{1}{2}$	0	1	$10\frac{3}{4}$	0	1	11	0	1	$11\frac{1}{8}$	0	1	$11\frac{1}{4}$	0	1	$11\frac{1}{2}$
2	0	3	9	0	3	$9\frac{1}{2}$	0	3	10	0	3	$10\frac{1}{4}$	0	3	$10\frac{1}{2}$	0	3	11
3	0	5	$7\frac{1}{2}$	0	5	$8\frac{1}{4}$	0	5	9	0	5	$9\frac{3}{8}$	0	5	$9\frac{3}{4}$	0	5	$10\frac{1}{2}$
4	0	7	6	0	7	7	0	7	8	0	7	$8\frac{1}{2}$	0	7	9	0	7	10
5	0	9	$4\frac{1}{2}$	0	9	$5\frac{3}{4}$	0	9	7	0	9	$7\frac{5}{8}$	0	9	$8\frac{1}{4}$	0	9	$9\frac{1}{2}$
6	0	11	3	0	11	$4\frac{1}{2}$	0	11	6	0	11	$6\frac{3}{4}$	0	11	$7\frac{1}{2}$	0	11	9
7	0	13	$1\frac{1}{2}$	0	13	$3\frac{1}{4}$	0	13	5	0	13	$5\frac{7}{8}$	0	13	$6\frac{3}{4}$	0	13	$8\frac{1}{2}$
1 = 8	0	15	0	0	15	2	0	15	4	0	15	5	0	15	6	0	15	8
2 = 16	1	10	0	1	10	4	1	10	8	1	10	10	1	11	0	1	11	4
3 = 24	2	5	0	2	5	6	2	6	0	2	6	3	2	6	6	2	7	0
4 = 32	3	0	0	3	0	8	3	1	4	3	1	8	3	2	0	3	2	8
5 = 40	3	15	0	3	15	10	3	16	8	3	17	1	3	17	6	3	18	4
6 = 48	4	10	0	4	11	0	4	12	0	4	12	6	4	13	0	4	14	0

WAGES TABLE (FORTY-EIGHT HOURS PER WEEK) (*continued*).

D. H.	95s. Per Week. £	s.	d.	96s. Per Week. £	s.	d.
$\frac{1}{2}$	0	0	$11\frac{7}{8}$	0	1	0
1	0	1	$11\frac{3}{4}$	0	2	0
2	0	3	$11\frac{1}{2}$	0	4	0
3	0	5	$11\frac{1}{4}$	0	6	0
4	0	7	11	0	8	0
5	0	9	$10\frac{3}{4}$	0	10	0
6	0	11	$10\frac{1}{2}$	0	12	0
7	0	13	$10\frac{1}{4}$	0	14	0
1 = 8	0	15	10	0	16	0
2 = 16	1	11	8	1	12	0
3 = 24	2	7	6	2	8	0
4 = 32	3	3	4	3	4	0
5 = 40	3	19	2	4	0	0
6 = 48	4	15	0	4	16	0

D. H.	97s. Per Week. £	s.	d.	97s. 6d. Per Week. £	s.	d.
$\frac{1}{2}$	0	1	$0\frac{1}{8}$	0	1	$0\frac{3}{16}$
1	0	2	$0\frac{1}{4}$	0	2	$0\frac{3}{8}$
2	0	4	$0\frac{1}{2}$	0	4	$0\frac{3}{4}$
3	0	6	$0\frac{3}{4}$	0	6	$1\frac{1}{8}$
4	0	8	1	0	8	$1\frac{1}{2}$
5	0	10	$1\frac{1}{4}$	0	10	$1\frac{7}{8}$
6	0	12	$1\frac{1}{2}$	0	12	$2\frac{1}{4}$
7	0	14	$1\frac{3}{4}$	0	14	$2\frac{5}{8}$
1 = 8	0	16	2	0	16	3
2 = 16	1	12	4	1	12	6
3 = 24	2	8	6	2	8	9
4 = 32	3	4	8	3	5	0
5 = 40	4	0	10	4	1	3
6 = 48	4	17	0	4	17	6

D. H.	98s. Per Week. £	s.	d.	99s. Per Week. £	s.	d.
$\frac{1}{2}$	0	1	$0\frac{1}{4}$	0	1	$0\frac{3}{8}$
1	0	2	$0\frac{1}{2}$	0	2	$0\frac{3}{4}$
2	0	4	1	0	4	$1\frac{1}{2}$
3	0	6	$1\frac{1}{2}$	0	6	$2\frac{1}{4}$
4	0	8	2	0	8	3
5	0	10	$2\frac{1}{2}$	0	10	$3\frac{3}{4}$
6	0	12	3	0	12	$4\frac{1}{2}$
7	0	14	$3\frac{1}{2}$	0	14	$5\frac{1}{4}$
1 = 8	0	16	4	0	16	6
2 = 16	1	12	8	1	13	0
3 = 24	2	9	0	2	9	6
4 = 32	3	5	4	3	6	0
5 = 40	4	1	8	4	2	6
6 = 48	4	18	0	4	19	0

D. H.	100s. Per Week. £	s.	d.	D. H.	100s. Per Week. £	s.	d.	D. H.	100s. Per Week. £	s.	d.
$\frac{1}{2}$	0	1	$0\frac{1}{2}$	5	0	10	5	3 = 24	2	10	0
1	0	2	1	6	0	12	6	4 = 32	3	6	8
2	0	4	2	7	0	14	7	5 = 40	4	3	4
3	0	6	3	1 = 8	0	16	8	6 = 48	5	0	0
4	0	8	4	2 = 16	1	13	4				

CALCULATING RULES.

Slide Rule.

The body of the rule is known as the "stock," the sliding portion as the "slide," the metal and glass slide is called the "cursor" or "runner," and enables one to align divisions on the different scales, besides acting as a guide in certain cases: it may have a digit register attached as shown.

The upper scale on the stock is known as A, and the upper scale of the slide as B; while the lower scale of the slide is known as C, and the lower scale of stock as D. The scales A and B are similarly divided, so are C and D. The main divisions of the lower scales being twice the length of the corresponding divisions on the upper scales, the former are more suited for fine results.

Although the index figure is designated 1, it may be taken to represent any figure that is a multiple of 10, e.g. 1, 10, 100, or 0·1, 0·01, 0·001, etc., but once the initial value is assigned to the index for a calculation, the ratio of values must be retained throughout the whole scale. In calculations that involve the use of the upper and lower scales in conjunction, the value assigned to the left index figure of the D scale determines the value of all the divisions of the rule.

Multiplication.—Set the index of the B scale to the factor it is desired to multiply by on the A scale, and over the other factor on B read the product on A; or the index of C may be set to one factor on D and under the other factor on C read the product on D.

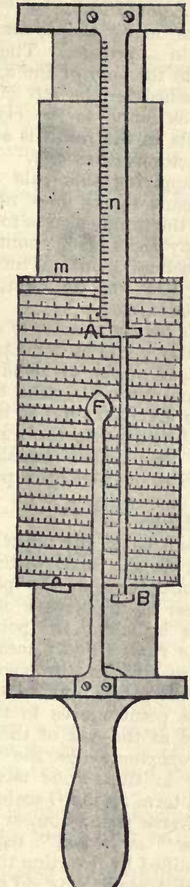
Division.—Set the divisor on B under the dividend on A, and read the quotient on A over the index of B; or set the divisor on C over the dividend on D, and read the quotient on D under the index of C.

Combined Multiplication and Division.—

$\frac{a \times b \times c}{d \times e \times f} = x$. Set d on C to a on D, bring runner to b on C. Bring e on C to the runner, and the runner to c on C, f on C to runner, then under the index of C read x on D.

By inverting the slide so that the C scale lies in contact with the A scale, and the right and left hand indices coinciding, it will be found that by multiplying any number on D by the coincident number on C′ is in all cases equal to 10. In consequence of this the numbers on C′ scale are the reciprocals of those coinciding with them on D scale or *vice versa*. As multiplying by the reciprocal of a number is equivalent to dividing by that number, and dividing a factor by the reciprocal of a number is equivalent to multiplying by that number, it


B
C
A
D


n
m
A
F
B

follows that by using the slide inverted the operation of multiplying and dividing are reversed.

To determine the number of digits in the final results of the several calculations.

When using the lower scale. Rule for the number of digits in a product. The number of digits in a product is equal to the sum of the digits in the two factors if the result is obtained on the *left* of the first factor; if, however, the result is found to the *right* of the first factor, the number of digits in the result is equal to the sum of the digits in the two factors *minus* one.

In applying this rule to decimal values, when the first significant figure does not immediately follow the decimal point, the minus sign is to be prefixed to the number of digits, as many digits being counted *minus* as there are 0's following the decimal point. Thus 15 has two digits, 1·5 has one digit, 0·15 has no digit, 0·015 has −1 digit, 0·0015 has −2 digits, etc.

Rule for the number of digits in a quotient.

If the quotient is obtained with the result appearing on the *right* of the dividend, the number of digits in the result is found by *subtracting* the digits in the divisor from those in the dividend; but if the quotient is read on the *left*, one is to be *added* to the number of digits obtained as above.

In complicated calculations the digit registering cursor facilitates matters, the pointer being moved in the direction of + or − when a + or − is the result of an intermediate calculation.

When using the upper scale: if the figures cannot be read direct on the scale without making a decimal of it, then if in multiplication, the point moves to the *left*, *add* to the number of digits read off as many more as the number of places by which the point was moved. If the point moves to the *right* these places must be *subtracted*.

If in division, the point in the divisor is moved to the *left*, then the places must be *subtracted* at the end of the operation. If the point moves to the *right*, then these places must be *added* at the end of the operation.

Proportion.—Set the first term of a proportion on the C scale to the second term on the D scale, and opposite the third term on the C scale read the fourth term on the D scale.

Inverse proportion, or problems in which "more" requires "less" or "less" requires "more", the work may be simplified by inverting the slide so that the C scale is adjacent to the A scale. By aid of the runner the value on the inverted C (written C′) scale and on the D scale can be read off.

To reduce a vulgar fraction to the decimal equivalent, place the numerator on C to the denominator on D when over the index of D we read the decimal equivalent on C. For the inverse operation, set the decimal on C to the index of D, and then opposite to any numerator on C is found the corresponding denominator of the fraction on C.

Squares and Square Roots.—The scale is so constructed that over any number on D will be found its square on A; likewise over any number on C will be found its square on B. Conversely it follows that under any number on A is found its square root on D, and under any number on B is its square root on C.

To ascertain the number of figures in the square of a number, if the result is read on the right-hand scale of A, the number of digits is equal to twice the number of digits in the original numbers; but if the result is read on the left-hand scale of A the number of digits is one less than twice the number in the original numbers.

Cube and Cube Roots.—Bring the right or left-hand index of C to the given number on D, and over the same number on the left-hand B scale read the required cube on A.

To extract the cube root: move the slide, either from right to left or from left to right, until under the given number on A is found a number on the left-hand B scale identical with the number which is simultaneously found on D under the right- or left-hand index of C. This number is the required cube root.

As by using the four scales it becomes possible by working in the manner described to find three values for the root, in order to decide which of these is the value sought it is necessary to point off the given number into sections of three figures as in the arithmetical method of extraction, commencing at the decimal point and proceeding to the left for numbers greater than unity, and to the right for numbers less than unity; then if the first section of figures, reading from the left, consists of one figure, the number is to be taken on the left-hand scale of A, and the slide is to project to the *right*. If of two figures, the number is to be taken on the right-hand scale of A with the slide to the *right*. If of three figures, the number is to be taken on the left-hand scale of A, the slide projecting to the *left*.

Fourth Power and Roots.—Set the right- or left-hand index of C to the given number on D, and over the number on C read the fourth power on A.

The fourth root may also be extracted by extracting the square root of the square root.

Logarithms.—The mantissa of a logarithm may be read off on the scale L marked on the reverse side of the slide. Set the left-hand index of the C scale to the given number on the D scale; then turn the rule over and the mantissa will be read on L scale at the index line in the aperture at the right-hand end of the rule.

The number corresponding to a given logarithm may be readily determined by a reversal of the above method.

The characteristic of a logarithm is equal to the number of digits in the number *minus* 1. If the number is wholly decimal, the index is equal to the number of ciphers following the decimal point *plus* 1. In the latter case the characteristic in *negative*, and is so distinguished by having the *minus* sign written over it.

To obtain higher roots than cubes it is easier to find the log. of the number and divide it by the root, then set the quotient to the index line in the aperture when the number corresponding to the log. will be found on the scale D under the left-hand index of the C scale.

Scale of Sines.—On the under side of the slide of the Calculating Rule the scale marked S is the scale of sines, while that marked T is the scale of tangents. The S scale is used to determine the natural sines of angles of from 35 min. to 90 deg. In order to determine the sine of an angle the slide is withdrawn from the stock of the rule and reinserted in such a manner that the scale marked S lies adjacent to the A scale of the rule, and with the right- and left-hand indices coinciding. When the slide is so placed the sine of any angle may be read off on the A scale, immediately above the angle on the S scale. The value of the sines of all angles read on the first half of the A scale, i.e. between 1 and 10, are such that the decimal point is always followed by 0, while those read on the right-hand half of the scale A, between 10 and 100, are prefixed by the decimal point only.

To multiply a number by the sine of an angle, place the 1 of the sine scale under the number on the A scale, when the product will be found on the A scale above the stated angle on the sine scale. If the result cannot be read by setting the left-hand index to the number on A, then set the right-hand index to the number.

Scale of Tangents.—In order to determine the tangent of an angle, the slide being reversed is inserted as in the case for sines, the T scale being placed next to the D scale, so that the right and left-hand indices coincide; the respective tangents of the angles marked on the scale T may then be read off on the D scale. The tangents of angles less than 5 deg. 43 min.

cannot be read directly from the 10 in. rule, but the corresponding sines may be substituted for them without material error, as the discrepancy only affects the fourth decimal place. If the angle whose tangent is required is greater than 45 deg., subtract the angle from 90 deg. and find the tangent of the remainder, then divide one by the figures obtained.

To multiply the tangent of an angle by a given figure, divide the tangent into the given number, and the quotient will be the figure required.

Fuller's Calculating Rule.

Let F be the fixed index, A the top movable index, and B the lower movable index.

When the indices are to be moved, the term Set is used; when the cylinder has to be moved, the term Bring is used.

The scale *n* is read from the lowest line of the top spiral, and *m* from the vertical edge of the scale *n*.

The same figures do not always mean the same amount; 1 may stand for 10, 100, 1000, or 0·1, 0·01, 0·001, etc. The value of results is obtained by rules based on the indices of the logarithms of numbers.

The index of the logarithms of numbers

between 1000 and 9999	is 3	between	0·1	and 0·9999	is	$\bar{1}$
,, 100 and 999·9	is 2	,,	0·01	and 0·09999	is	$\bar{2}$
,, 10 and 99·99	is 1	,,	0·001	and 0·009999	is	$\bar{3}$
,, 1 and 9·999	is 0					

Multiplication.—Start with F and read off the answer at F.

$$a \times b \left\{ \begin{array}{l} \text{Bring } a \text{ to F} \\ \text{Set A to 100} \\ \text{Bring } b \text{ to A or B} \\ \text{Product read at F} \end{array} \right.$$

$$a \times b \times c \left\{ \begin{array}{l} \text{Bring } a \text{ to F} \\ \text{Set A to 100} \\ \text{Bring } b \text{ to A or B} \\ \text{Set A to 100} \\ \text{Bring } c \text{ to A or B} \\ \text{Product read at F} \end{array} \right.$$

$$a \times b \times c \times d \left\{ \begin{array}{l} \text{Bring } a \text{ to F} \\ \text{Set A to 100} \\ \text{Bring } b \text{ to A or B} \\ \text{Set A to 100} \\ \text{Bring } c \text{ to A or B} \\ \text{Set A to 100} \\ \text{Bring } d \text{ to A or B} \\ \text{Product read at F} \end{array} \right.$$

To find the index of the product take the sum of the indices of the factors, and to this add one each time a factor is brought to B. The sum is the index of the product.

Division.—The numerator must have one factor more than the denominator; if it has not, make it so by bringing the 100 to A. Should there not be one factor less in the denominator than in the numerator, make it so by setting A to 100 for each factor wanting.

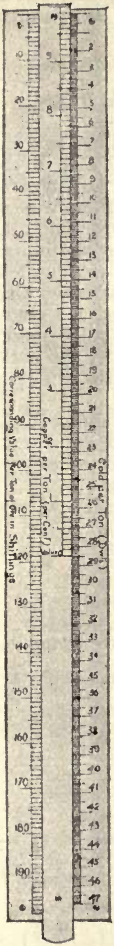
$\frac{a}{m}$	Bring a to F Set A or B to m Bring 100 to A Quotient read at F	$\frac{a \times b}{m}$	Bring a to F Set A or B to m Bring b to A or B Quotient read at F
$\frac{a \times b \times c}{m}$	Bring a to F Set A or B to m Bring b to A or B Set A to 100 Bring c to A or B Quotient read at F	$\frac{a}{m \times n}$	Bring a to F Set A or B to m Bring 100 to A Set A or B to n Bring 100 to A Quotient read at F
$\frac{a \times b}{m \times n}$	Bring a to F Set A or B to m Bring b to A or B Set A or B to n Bring 100 to A Quotient read at F	$\frac{a \times b \times c}{m \times n}$	Bring a to F Set A or B to m Bring b to A or B Set A or B to n Bring c to A or B Quotient read at F

Find the algebraical difference between the sum of the indices of the numerator and the sum of the indices of the denominator, and then every time a factor of the numerator is *brought* to B, add one to this, and every time B is *set* to a factor of the denominator deduct one. The result gives the index of the quotient.

Ratio.—When either of the movable indices is at one number and the fixed index at another, and the cylinder is turned into any other position, though the number at the indices will be different their ratio will remain constant.

Logarithms.—Place the upper movable index A to the number, and read the scales n and m. These together give the *mantissa* of the logarithm of the number. To this the *index* has to be added.

Powers.—To obtain powers not higher than the seventh the quickest way is by direct multiplication. For powers higher than the seventh multiply the logarithm or the number by the power. Then place the cylinder so that it reads on the scales n and m the decimal part of the quotient. The power is then at the index A. In the result the number of figures before the decimal point is *one more* than the number in the integral part of the quotient.



Roots.—Proceed as in the case of finding the power, only divide the logarithm by the root instead of multiplying by the power.

Roots of Decimal Fractions.—Write them as vulgar fractions, and multiply numerator and denominator by ten or a power of ten, so that the denominator may have a complete root. Then take the required root of the numerator by the method given above, and of the denominator by inspection.

$$\text{Ex. } \sqrt{\cdot 4} = \sqrt{\frac{4}{10}} = \sqrt{\frac{40}{10^2}} = \frac{\text{by rule}}{\text{by inspection}}$$

$$\frac{6\cdot3246}{10} = \cdot6325$$

SLIDE RULE FOR COMPUTING THE VALUE OF ORES.

A convenient slide rule for rapidly determining the value of an ore containing two metals may be constructed as follows, and is useful when a number of calculations have to be made. Take a gold-bearing copper ore as an example. Gold is worth 4·24*s.* per dwt., and let us assume Copper to be worth £60 per ton or 1,200 shillings, then one unit is worth 12*s.* Divide one side of the stationary scale into a convenient number of parts of a suitable size to represent pennyweights, say three divisions or pennyweights to an inch, and subdivide each of these into tenths, having zero at the top of the scale. On the other side of the stationary portion of the scale divide into shillings, making every 10*s.* more distinct. The zero for the shillings is also on the top of the scale, and the divisions of the scale are so made that 4·24*s.* correspond to the 1 dwt. line. The sliding portion of the scale is now divided into percents of copper, for as much copper as the ore is ever likely to contain. The zero is towards the bottom end of the scale; each percent is made equal to 12*s.*, and is subdivided into tenths.

To use the scale, place the percentage of copper against the pennyweight of gold as shown by assay, and read off the combined value on the money scale.

METHODS OF COMPUTING LODE VALUES.

1. *Arithmetical Mean.*—The sum of the values and the sum of the widths are added up separately, and each divided by the total number of samples. The results are incorrect since no allowance is made for the relative widths and values.

2. *Geometrical Mean.*—The width and corresponding value of each cut are multiplied together to give the width-assay expressed in feet-per cent, feet-ounces, inch-pennyweight, which happens to be most convenient. In the case of the first and last numbers, if at the beginning and end of a section the result should be divided by two, as these cuts only represent half the distance the other cuts do. The sum of the assay-widths are then divided by the sum of the widths, the result being the average proportional value.

This is the method commonly used as being simple, and if the samples are taken at short distances fairly correct, but it is based on the false assumption that the width and value remain the same for half the distance on each side of the cut.

The above assumes that the samples are taken at equal distances, but in practice this is often impossible. When the samples are taken at irregular distances the calculation becomes more tedious.

Let w_0, w_1, w_2, w_3, and w_4 = width of samples.
,, v_0, v_1, v_2, v_3, ,, v_4 = corresponding values.
,, d_0, d_1, d_2, and d_3 = distances between samples.

Then the geometrical mean value over the whole area sampled =

$$\frac{v_0\left(w_0 \times \frac{d_0}{2}\right) + v_1\left(w_1 \times \frac{d_0+d_1}{2}\right) + v_2\left(w_2 \times \frac{d_1+d_2}{2}\right) +}{\left(w_0 \times \frac{d_0}{2}\right) + \left(w_1 \times \frac{d_0+d_1}{2}\right) + \left(w_2 \times \frac{d_1+d_2}{2}\right) +}$$

$$\frac{v_3\left(w_3 \times \frac{d_2+d_3}{2}\right) + v_4\left(w_4 \times \frac{d_3}{2}\right)}{\left(w_3 \times \frac{d_2+d_3}{2}\right) + \left(w_4 \times \frac{d_3}{2}\right)}$$

3. *Prismoidal Method.*—In this case the prismoidal formula is used :—

$$\frac{\text{End area} + 4 \text{ times middle area} + \text{other end area}}{6} \times \text{length.}$$

The area of each end of a prism is obtained by multiplying the width of the sample cut by the assay value. The middle area is obtained by adding the end areas and dividing by two. The length is the distance between the two adjoining samples under consideration. This is more accurate than the geometric mean as the assay-width gradually increases or decreases between two dissimilar cuts ; but in nature the boundaries of lodes are generally irregular, not straight lines as assumed.

4. *Planimeter Method*, proposed by E. T. M. Garlick, is both quick and accurate, especially when the samples are taken at irregular distances and boundaries are not straight lines. Draw a base line, and mark off on it the distance apart of the various cuts to some convenient scale, say 10 feet to 1 inch. On one side of the base line and at right angles to it draw lines from these points to represent the assay-widths, also to scale. Draw connecting lines, straight or curved as they are likely to occur in nature, between the adjoining points, and close the ends of the figure. On the other side of the base draw a similar figure to represent the width of the lode. It is not necessary to use the same scale for the width as for the width-assay if the scale adopted would make the former area too small to measure accurately, or the latter area too unwieldy. If the scale adopted is 10 feet to 1 inch, and the assay-width lines are drawn to the scale of 30 feet to 1 inch, then the ratio would be 1 : 3, so the area of the assay-width would have to be multiplied by 3 in order to bring it to the same standard as the width area.

The area of the width figure obtained by means of a planimeter, divided into the assay-width area, gives the mean assay value.

5. *Stoping Width.*—It may be necessary in narrow lodes to take out a certain amount of rock in order to make room to work in, and it may be cheaper to treat than sort out the rock. Under such circumstances a correction must be made as follows :—

$$\frac{\text{Width of lode} \times \text{assay}}{\text{Total stoping width}} = \text{assay over stoping width.}$$

POINTS OF THE COMPASS.

	deg.		deg.
N.	360	S.	180
N. b E.	$11\frac{1}{4}$	S. b W.	$191\frac{1}{4}$
NNE.	$22\frac{1}{2}$	SSW.	$202\frac{1}{2}$
NE. b N.	$33\frac{3}{4}$	SW. b S.	$213\frac{3}{4}$
NE.	45	SW.	225
NE. b E.	$56\frac{1}{4}$	SW. b W.	$236\frac{1}{4}$
ENE.	$67\frac{1}{2}$	WSW.	$247\frac{1}{2}$
E. b N.	$78\frac{3}{4}$	W. b S.	$258\frac{3}{4}$
E.	90	W.	270
E. b S.	$101\frac{1}{4}$	W. b N.	$281\frac{1}{4}$
ESE.	$112\frac{1}{2}$	WNW.	$292\frac{1}{2}$
SE. b E.	$123\frac{3}{4}$	NW. b W.	$303\frac{3}{4}$
SE.	135	NW.	315
SE. b S.	$146\frac{1}{4}$	NW. b N.	$326\frac{1}{4}$
SSE.	$157\frac{1}{2}$	NNW.	$337\frac{1}{2}$
S. b E.	$168\frac{3}{4}$	N. b W.	$348\frac{3}{4}$

MORSE ALPHABET AND FIGURES.

a	· —	t	—
b	— · · ·	u	· · —
c	— · — ·	v	· · · —
d	— · ·	w	· — —
e	·	x	— · · —
f	· · — ·	y	— · — —
g	— — ·	z	— — · ·
h	· · · ·	ch	— — — —
i	· ·	1	· — — — —
j	· — — —	2	· · — — —
k	— · —	3	· · · — —
l	· — · ·	4	· · · · —
m	— —	5	· · · · ·
n	— ·	6	— · · · ·
o	— — —	7	— — · · ·
p	· — — ·	8	— — — · ·
q	— — · —	9	— — — — ·
r	· — ·	0	— — — — —
s	· · ·		

KNOTS AND SPLICES.

Simple Overhand or Thumb Knot (*Fig. 1*).—May be used as a stop on a rope to prevent the end from fraying or slipping through a block. A free end is necessary to make it.

Figure of Eight (*Fig. 2*).—Also used as a stop on a rope: it is less injurious to the fibre of the rope and is easier to undo than the overhand knot.

Reef Knot (*Fig. 3*).—Used for bending or joining ropes of the same size together.

Single Sheet Bend (*Fig. 4*).—For joining dry ropes of different sizes when no great strain is expected, also for small cords.

Double Sheet Bend (*Fig. 5*).—Used for greater security under the same circumstances as the single sheet bend; the second turn round the bight of the rope prevents jambing. It is also used for connecting wet ropes of different sizes.

Hawser Bend (*Fig. 6*).—For joining large cables. The half hitch bend as shown must have the ends seized, which makes a good permanent joint on heavy ropes, or the ends may be finished off with the bowline bend, which is strong and reliable but requires a considerable length of rope.

Sheep Shank (*Fig. 7*).—An effective method of quickly shortening a rope. The rope is doubled up so as to reduce it to the required length, a half hitch made round both ends of the fold, and the loop lashed as shown. No free end is required.

Bowline (*Fig. 8*).—Used to form a loop or bight at the end of a rope, which will not slip. It serves for a man to put his foot in when being lowered on the end of a rope, also for fastening a rope to a bucket.

Bowline on a Bight (*Fig. 9*).—For a loop in the middle with a doubled rope. The two loops may be used as a chair, a barrel sling, or as man harness, when one loop is placed under each shoulder and tightened it will not slip. When a man is being lowered down a shaft he may sit with one leg through the two loops so as to have the other leg free to guide himself with. If sampling, one loop can be made 2½ feet long and the other 3½ feet long: both loops are slipped over the shoulders, the smaller one arranged under the arm-pits, while the larger is fixed under the knees; this will allow the sampler to have the free use of his hands. An insensible man can be raised or lowered in a similar manner

Fig 1

Simple overhand Knot

Fig. 2

figure of Eight Knot

Fig 3

Reef Knot

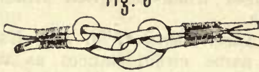
Fig 4

Single Sheet-Bend

Fig 5

Double Sheet Bend

Fig. 6

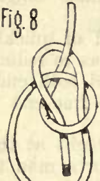


Hawser Bend

Fig. 7

Sheep Shank

Fig. 8

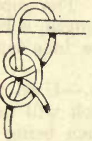


Bowline

Fig 9

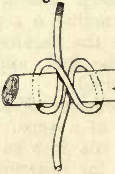
Bowline on a Bight

Fig 10



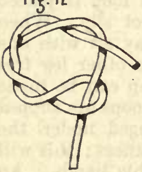
Two Half Hitches

Fig. 11



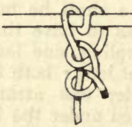
Clove Hitch

Fig. 12



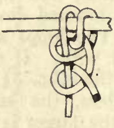
Timber Hitch

Fig. 13



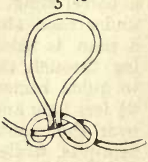
Round Turn and Two Half Hitches

Fig 14



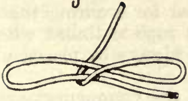
Fishermen's Bend

Fig 15



Man Harness Hitch

Fig. 16

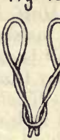


commenced

Cat's paw at end of Rope

Fig. 17

Fig. 18

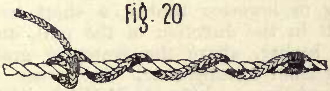


Cat's-paw on centre of Rope

Fig. 19

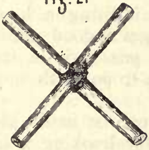
Blackwall Hitch

Fig. 20



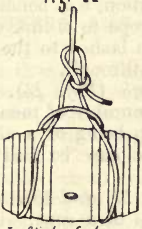
Stopper Hitch

Fig. 21



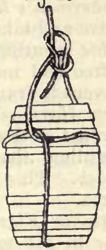
To lash two Spars together that tend to spring apart

Fig. 22



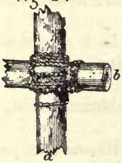
To Sling a Cask Horizontally

Fig. 23



To Sling a Cask Vertically

Fig. 24



To lash one Spar square across another

Fig. 25

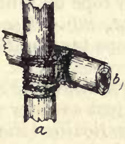


Fig. 26

To lash a Block to a Spar

without danger of falling out, and if the knot is made in the middle of the rope the lower portion can be used as a guy to steady him.

Two Half Hitches (*Fig. 10*).—Used for securing the loose ends of lashings, also for securing a rope to timber when no great pull is expected: the end must always be placed at the back away from the pull.

Clove Hitch (*Fig. 11*).—Used for the commencement and finish of lashings, for fastening guy lines to head of derrick, and all kind of rigging work. It is easily undone, or a bight may be put in instead of one end so as to use it as a slip. It will take a strain in either direction without slackening.

Timber Hitch (*Fig. 12*).—For handling timber when the weight will keep the hitch taut; for fastening a rope to a windlass barrel, also for starting lashings on scaffolding. For raising or lowering timber, a short length of rope should be left in the direction of the pull, and then a half hitch made higher, above the centre of gravity, to prevent the timber from canting over.

Round Turn and Two Half Hitches (*Fig. 13*).—For belaying or making a rope fast to an anchorage, so that the strain on the rope shall not jamb the hitch.

Fishermen's Bend (*Fig. 14*).—For making fast when there is a give-and-take motion, e.g. bending a cable to an anchor; also for securing a rope to a link or to the bail of a bucket. The free end may be lashed to the standing part of the rope to prevent it drawing through.

Man Harness Hitch (*Fig. 15*).—For forming a loop on drag ropes so that a number of men can get a good purchase for hauling, the loop being of a size to pass over a man's shoulder. This knot can be tied in a rope with neither end free.

Catspaw (*Figs. 16, 17, and 18*).—This can be made at the end or in the middle of a rope. Used for hooking a block on to.

Blackwall Hitch (*Fig. 19*).—Used with a pliant rope. It will only hold as long as the weight is applied: also convenient for returning an empty rope on a hook.

Stopper Hitch (*Fig. 20*).—Used when it is necessary to shift the strain off a rope temporarily, as when testing a cage from the drum.

To sling a Cask horizontally (*Fig. 22*).—Make a long bight with a bowline and adjust as shown.

To sling a Cask vertically (*Fig. 23*).—Place the cask in a bight at the end of the rope, and with the running end make a simple overhand knot round the standing part of the rope; open out the thumb knot, slip it down the side of the cask and secure with a bowline.

To lash one Spar square across another (*Figs. 24 and 25*).—Commence with a clove hitch on the spar *a* below *b* and twist the ends together, carry at least four times round the spars as shown in the figure, keeping outside previous turns on one spar and inside on the other; two or more frapping or cross turns are then taken, the corners of the lashings being well beaten in during the process, and finished off with two half hitches round the most convenient span.

To lash two Spars together that tend to spring apart (*Fig. 21*).—Begin with a timber hitch or running bowline round both spars and draw them together, then take three or four turns across each fork, and finish with frapping turns and two half hitches. Wedges with well-rounded points are often useful for tightening lashings; they should be driven in from the top.

To lash a Block to a Spar (*Fig. 26*).—Lay the back of the hook against the spar, make a clove hitch round the spar above the hook, then take several turns round the hook and spar, and finish off with two half hitches round the spar below the hook.

MINING ACCOUNTS AND COSTS.

Every year or half-year a Company should publish a report which includes a Balance Sheet, Profit and Loss Account, and sometimes a Working Account, together with other data that should permit a shareholder or intending shareholder to size up the position of the Company. Frequently the information supplied is too meagre to enable one to analyse the figures as desired, so that further details may have to be sought, which may or may not be available. Certain headings may convey no meaning to a critic. Some accounts are purposely lumped together with the object of masking individual profits or losses. As a matter of fact the ordinary Balance Sheet of a Mining Company is scarcely worth the paper it is printed on, and in order to obtain even an approximate idea of the value of the property other information is necessary, some of which is obtained in the Report, while some must be sought elsewhere. The comparison with previous Reports often supplies required data, and certainly assists one in becoming better acquainted with the condition of things. Sometimes the excuse is given by Directors that it is not for the benefit of the Company to make certain information public for fear competitors should make use of it. It is the part of a competitor's business to know what others in his line are doing, and knowing his own costs, it is not a very difficult matter to ascertain, near enough, the costs of others; while the shareholder, not having this knowledge, is kept in the dark. A shareholder wishes to ascertain if his capital is safe and what chance there is of legitimately earned profits being paid at stated times.

In order to get a fair insight into the real financial position of a Mining Company it is necessary for a critic to consider the items in detail and classify them in his own way. He must ascertain what assets have been hypothecated to secure special creditors; what is available for the benefit of unsecured creditors; and after discharging all liabilities, what is left. He should ascertain whether the interest accrued to the date of the Balance Sheet on secured loans is included amongst the liabilities under the heading relating to secured creditors. Then he wants to know the amount due to creditors for goods supplied in the ordinary course of business. The more detail that is given in an annual report the better position one is in to determine the true position of affairs, but as this is likely to lead to questions, essential points are frequently omitted. Besides the total expenses and receipts, and the profit or loss that has been made, one wants to know how the profit or loss has been earned or made, whether it is likely to continue, and if so for how long, what changes may be expected, probable variations in metal market, prospect of labour troubles or lawsuits, life of mine, whether returns are given in long or short tons, for calendar or lunar months, whether the season has been exceptionally favourable or adverse, etc. Figures extending over a long period are more reliable than those for a short time.

The Balance Sheet is a collection of balances left on the Trial Balance after the Profit and Loss Account items have been extracted, and should state the financial position of the Company, i.e. what it is worth. Often the Credit side of a Balance Sheet is headed "Assets" and the debit side "Liabilities." As the term "Asset" is now used in business to mean all available property and rights which can be applied in satisfaction of the liabilities, or which can be turned into money or money's worth, it is better not to use this word here, since a number of items on the Credit side of Balance Sheets are neither valuable property nor rights, and cannot be applied in satisfaction of liabilities or turned into money or money's worth.

A mine is a wasting asset, yet it is usual to see the original purchase price of the property passed on from year to year, with no attempt to write off the proper proportion, according to the assumed life of the mine. Besides the Mines Property Account, on the Credit side of the Balance Sheet, we have such headings as Mine Development, Mine Plant and Buildings, Office Furniture and Fittings, Stores on Hand, Reserve Fund Investment, Dividend Suspense Account, Ore Concentrates and Matte on Hand or in Transit (at estimated nett value, less advance payments), Sundry Debtors, Cash in Hand, Balance at Bank, and the Deficiency on Profit and Loss Account, if any. The Mine Development Account is the money which has been spent on developing the mine before it reached the producing stage, but should not include among preliminary expenses such items as commissions paid on issue of shares or debentures or discount given in respect of the issue of debentures, these being shown separately, and this has to be written off by degrees as Development Redemption. When once the mine becomes productive, the cost of development may either be added to the Mine Development Account and a certain proportion charged to each ton mined, or the mining has to stand the cost of all the fresh development done during the given period. The Plant and Building, and Furniture and Fittings Accounts should have depreciation written off every period. The depreciation should be so apportioned that the cost is nearly wiped off at the termination of the life of the mine, for the market value of the asset is very small by that time. If the life of a mine is long, some of the plant is out of date and has to be scrapped before it is worn out, for if taken care of, the machinery should in most cases be workable after many years of use. If the life of a mine is taken at, say, ten years, and 10 per cent. is written off for depreciation every year, the amount will not be redeemed in ten years, even if no additions are made in the meanwhile, for it is usual to write the 10 per cent. off the asset remaining, not 10 per cent. of the original asset. When comparing Balance Sheets of different years, should note if preliminary and other expenses are being gradually written off; if not, it is probably because the profit is too small to do this and pay dividends, or because there are no profits against which to charge it. Before the producing stage of a mine is reached, all expenditure should be charged to Capital Account, e.g. (1) Property, (2) Main Shafts and Adits, (3) Underground Development (including shafts sunk on ore), (4) Machinery and Plant, (5) Buildings, (6) Surface Work (reservoirs, railway sidings, roads, etc.), (7) General Expenditure (head office charges, etc.). Any Sundry Revenue received during this stage should be deducted from General Expenditure, and the balance distributed proportionally over the remaining heads of expenditure. Main Shafts and Adits should be written off under the heading of Depreciation each year for its expected life. Development up to the Revenue stage may be placed to a Temporary Development Account, or may be charged to Capital Account finally. After the producing stage is reached, all expenses in connection with deepening main shafts, cutting stations, and development should be charged direct to Working Costs, or to a Development Redemption Account. In the latter case every ton treated is debited with its proportion of redemption. No expenditure should be debited to Capital Account, except for large special items, e.g. purchase of additional property, increase of machinery, plant, or buildings (but not merely the replacement of them when worn out), sinking of new main shafts, excessive development of payable ore. All such items should bear their proportion of administration and general expenses, but not repairs and maintenance. If an old shaft or mill is replaced by a new one, the old mill or shaft should be written off from Capital Account against Revenue, either at once or by instalments; if this is not done, they should be charged direct to Revenue, if necessary, by instalments, so as to spread the expense over a longer period, and so equalize matters. Depreciation, when written off Profit and Loss Account, only accumulates cash for future shareholders, which reduces the rate of dividends for existing shareholders. Its main object is to make adequate provision out of Revenue for such new machinery, plant, etc., as are almost certain to be required before the mine is worked out, and incidentally it reduces the Income Tax and Fire Insurance Premiums. Instead of deducting depreciation, some prefer to make a small charge on every ton of ore treated, or they appropriate every year a certain proportion of the profits for a Reserve Fund. The gross or nett value of unfinished products, e.g. ore at grass, should not be considered as an asset, but when taken into account should be credited only with the cost, provided the cost does not exceed the market value; but bullion, concentrates, blister copper, and other marketable products ready for shipment, should be shown as assets in the Balance Sheet, and included as Revenue, after deducting all possible returning and other realization charges.

The assets may be classified into (1) those that are actual cash or which can immediately be converted into cash, e.g. cash in hand or balance at bankers; (2) assets which can be realized at comparatively short notice, e.g. investments that can be sold readily on the Stock Exchange; (3) assets which will take a certain time to realize, e.g. investments not quoted on the Exchange or which must be realized gradually, also amounts due from debtors; (4) doubtful assets which are only expected to realize a certain percentage of their value, e.g. machinery and buildings, doubtful debts—when debts are known to be irrecoverable they should be written off; (5) other items which can only be realized as long as the business is a going concern, e.g. the amount paid for the property; (6) unrealizable items, the inclusion of which may be quite proper so long as the mining company exists. Some companies have had to go into liquidation in spite of a surplus of assets over liabilities, in consequence of their resources being locked up. If a reserve fund has been created, this only means that a provision has been made from a book-keeping point of view for a possible deficieney or shrinkage in value of items appearing on the credit side of the Balance Sheet, and this amount should be represented by investments outside the business. When the balance brought forward from the Profit and Loss Account is on the credit side of the Balance Sheet it shows the concern has been working at a loss. A comparison with former Balance Sheets should show whether such loss has been persistent, or whether the profits and losses have fluctuated.

The grouped balances on the debit or liabilities side of the Balance Sheet often include items that are not strictly liabilities. On this side are set out the liabilities of the Company, including not only outside liabilities or debts due to creditors, but also the indebtedness of the concern itself to sundry impersonal accounts, including a surplus or undistributed balance standing to the credit of the Profit and Loss Account. It is usual to head the debit side with details in connection with the capital. The capital may consist of *ordinary shares* which bear the brunt of risks, and, in consequence, should be entitled to receive the larger share of the profits; *preference shares* which have the advantage of being entitled to a first claim on the profits of the undertaking, but usually to a limited extent; such shares may be given to vendors in part payment, or may be created when fresh capital is required. Preference shares may only be entitled to participate in profits earned in each particular year, without the right to have any deficiency made good out of the profits of succeeding years, or the shares may be known as *cumulative preference shares*, which entitles their holders to the full amount of their minimum dividends being satisfied out of future profits, no matter how much such dividends may be in arrear, before the owner of ordinary shares receives any return on their capital. The shares may be preferential for dividend-receiving purposes, but may or may not be preferential with regard to the distribution of assets when the Company is wound up. Money may be borrowed on debentures secured by a mortgage. Power is generally given to buy up a certain number of debentures a year till they are all redeemed; in the meanwhile an agreed interest has to be paid on those outstanding. A shareholder should know the terms in connection with preference shares and debentures, and he should be able to ascertain from the Balance Sheet whether and to what extent any of the creditors are secured, and what portion of the property has been hypothecated. Paper or nominal capital is never decreased, unless it is considered too unwieldy or it is desired to evade taxation. Its main care is to let the shareholder know what proportion he holds in a mine. The actual value is indicated by the market price of shares, which should vary with the conditions of the mine. The shareholder should consider whether the capital is sufficient to open up and equip the mine properly. The nominal capital is not always fully subscribed, and the shareholder should note whether more shares have been subscribed for since the last period, as it is on the distributed shares that dividends have to be paid. The formation of the company should be carefully investigated. If the vendors have been paid heavy premiums this may prevent the mine from paying adequate dividends to subscribing shareholders. It is a mistake to have too many shares at first; if they rise in value they can always be divided so as to be less cumbersome for ordinary investors to handle. If a mine does not float well, and the shares are left in a few hands, there is always a chance that large parcels may be forced on the market at one time. A large amount of capital does not imply security. If too little capital is provided the company gets into debt, and has to create new shares (generally preference shares to encourage outsiders to subscribe to what has so far been a failure) or money has to be raised on debentures, so the original shareholders may have to wait a long time for interest on their capital, if indeed they ever receive it. Vendors are sometimes given paid-up shares in part payment, and this is often put forward to show the faith the vendors have in the property. In most cases they have no choice, so make a virtue of necessity, but if they accept shares in lieu of cash they generally demand shares of a larger face value than the cash they were prepared to take, as in many cases they sell below par and incidentally bring down the value of the subscribed shares. Anyhow the paid-up shares created absorb a certain amount of profit, lessening the dividends for the subscribed shares. The balance of Profit and Loss

Account when carried to the debit side of the Balance Sheet shows the amount available for distribution. The sum of this and other items on the debit side must correspond with the sum of the items on the credit side, but the apparent balance may be fictitious if the proper proportion has not been written off depreciating assets.

The Profit and Loss Account, or as it is sometimes called the "Revenue Account" is a statement of income and expenditure. The income side should show the sale of metals, etc., and other items of income grouped under suitable headings, e.g. rents of cottages, discounts, rebates, interest, etc., and a comparison should be made with the Profit and Loss Accounts of the preceding few years. The expenditure side should show the various items of expenditure under their proper headings, e.g. office expenses (including directors' and auditors' fees), agency expenses, advertising and stationery, postages, telegrams, and petty cash, general expenses, legal expenses, cables, travelling expenses, rent and other charges in connection with mining leases, exchange and bank charges, land-tax, insurances, interest, donations to hospital, mining account, smelting account, freight, realization charges, dividend and income taxes, depreciation (written off), etc., and should include all unpaid accounts owing at the end of the period, the balance (if any) being profit carried to Balance Sheet. Sometimes the Profit and Loss Account is split up, a working account being shown which is debited with such items as mining, ore treatment, and freight, and credited with value received from products. The balance is then carried to the Profit and Loss Account, which is debited with such items as office expenses, rent, taxes, general expenses, etc., the balance being gross profit or loss. If the former, this is carried over to the credit side of a subdivision of the Profit and Loss Account, and added to any credit balance over from the previous year. On the debit side is shown how the money has been distributed, e.g. in depreciation, purchase of debentures, interest on debentures, etc., the balance being net profit carried to the Balance Sheet and available, if sufficient, for the payment of dividends.

The main subdivisions of the ordinary Profit and Loss Account should correspond with the main subdivisions of the cost sheet, e.g. (1) development, (2) ore extraction, (3) sorting at surface, preliminary crushing, and transport, (4) ore treatment (dressing, amalgamation, smelting, etc.), (5) administration charges and general charges at mine, (6) realization charges on products, (7) taxes and royalties of all kinds, shown separately, (8) head office charges.

Cost keeping gives an intimate knowledge of the inner working of a concern. The object is to obtain the total cost of work and an analysis of such cost. Intelligently used it enables a manager to detect waste of material, loss of time, in fact to lay his finger on leakages, so that he can reduce his expenditure and increase his profits. Costs are useful for future reference, and serve as a check on similar work. Cost keeping is a system of recording the materials used and the labour employed on a particular job. To draw up a system suitable for any particular mine, requires a man with practical experience of the requirements of mining and methods employed. The system of cost keeping need not be complicated, but the smaller the company the less elaborate it should be. The fact that a company has a large capital is no excuse for extravagance. It is generally found that when once the mine officials have the object and utility of costing properly explained to them they take a great interest in it; and their co-operation is necessary for the success of the scheme. The system should be made as automatic as possible by getting others to fill in the forms as far as they can. There should be no repetition necessitating copying, except totals; any duplicates required are done with carbon paper. So far as possible everything is worked out on the double entry system, which serves as a check against fraud and personal error. Technical results are expressed in ounces, per cent., tons, or feet, and should not be confused with commercial results expressed in £ *s.* *d.* The card system is used where applicable, as being time and labour saving. If no proper accounts are kept, material may be used on a job and never be entered up. Except during construction when requirements are abnormal, the storekeeper has the best idea of what stock should be kept in hand to suit local requirements, taking time for transit into consideration, rainy seasons, droughts, etc. The various foremen know beforehand if any special stock is likely to be required, and may notify the storekeeper personally or on a special form. A list of stores likely to be required is often printed, and tenders called for supplies. From the tenders the storekeeper can ascertain the current prices for, say, a year. When any stock gets low the storekeeper fills out an order form, stating the size, quantity, and quality of the article required. A carbon copy is made to be filed in the office and the price entered on it. The original is sent to the merchant and to it is attached the Company's duplicate invoice form; some of the blanks on it are filled in before the form leaves the office, others on its return, while the merchant fills in the other spaces. This serves the purpose of a Stores

Inward Book. The order number is the consecutive number of the order as sent out, commencing afresh every month; the storekeeper's progressive number also starts afresh every month, and is the consecutive number of invoice as received back. The sea freight is obtained from the agent, the railage from the railway company, but is of course checked as to rates. The total is then transferred to Stock Cards. The merchant returns the Company's duplicate invoice, together with his original invoice. The duplicate is filed at the mine, while the original is sent to the head office in support of vouchers for payment. There is a separate Stock Card for each kind or size of article, and they are printed on each side. The stock received is filled in from the duplicate invoice. What has been issued can be traced through the number of the Requisition form; the balance in stock can be seen at a glance, while the minimum stock that should be kept in hand is noted in one corner. Stores Requisition forms are printed in books with butts, and should be of such a size that they can easily fit in the foreman's pocket. They are worded in such a way that they can be filled in for any department. The form is filled in and initialled by a foreman, and when an article is given out it is signed for by the employee receiving it. Job cards are printed in two colours, one for surface jobs, the other for underground. Each job has its special number. A fresh card is used every month for each job. The total of the card is posted to its account in the Ledger, and the daily expenditure to the Daily Cost Sheet. Each man has a token with the number assigned to him on it. Before proceeding to work he hands this to the timekeeper who gives him a Labour Daily Time Check in exchange; this may be printed on different-coloured paper for the different shifts. The employee fills in the check with his name, the class of work he has been employed on, and the time occupied at the different jobs; this is signed by his foreman and handed to the timekeeper at the end of his day's work. The next day the timekeeper apportions the labour to the different jobs on which it has been employed and enters it on the Labour Job Cards, which, like the Stores Job Cards, are also in different colours for surface and underground jobs.

Cost Sheets are prepared periodically, say monthly, for the benefit of the Management and Directors (not for publication), in order to show the progress of business. All items which occur regularly should appear under the same heading each time. Suitable main headings are: (*A*) *Mining*. (1) Mine Capital Expenditure (shaft sinking, plat cutting, and shaft bins); (2) Mine Development (shaft sinking, plat cutting, driving, cross-cutting, rising, winzing, diamond drilling); (3) Ore Extraction (breaking ore, shovelling, filling stopes, trucking, hoisting ore). In connection with these, details should be given of gross figures for the following, as well as the cost per ton: (*a*) Shifts worked (by contract, by day labour), (*b*) Work done (footage sunk, risen, or driven, or tons broken), (*c*) Wages (miners, truckers, timbermen), (*d*) Management and General Office Expenses, (*e*) Stores (showing quantity and value of explosives, candles, timber, general), (*f*) Power (hoisting, drills, pumping), (*g*) General Charges, (*h*) Sampling, Assaying, and Surveying, (*i*) Total Expenses for the month, (*j*) Total Expenses to the end of previous month, (*k*) Total Expenses to date. (*B*) *Sorting at Surface, Preliminary Crushing and Transport.* This is intermediate work between the mine and the treatment works, and may have sub-headings, e.g. (*a*) Labour (pickers, breakers, truckers), (*b*) Management and General Office Expenses, (*c*) Stores, (*d*) Power, (*e*) General Charges, (*f*) Total Cost, (*g*) Gross Tonnage handled, (*h*) Proportion of different Classes of Ore Sorted and Waste discarded. (*C*) *Ore Treatment.* This naturally varies with the class of treatment, whether ore dressing, amalgamating, cyaniding, smelting, etc., and whether one or more methods are employed. Each department should have its own special detailed Cost Sheet; for instance, a gold-mine might have the following sub-headings: (1) Milling, (2) Concentrating, (3) Roasting, (4) Fine Grinding, (5) Cyaniding, (6) Filter Pressing, (7) Precipitation and Smelting, (8) Disposal of Residues, giving items, e.g. (*a*) the Quantities treated, (*b*) Labour, (*c*) Salaries, (*d*) Stores, (*e*) Repairs and Maintenance, (*f*) Power, (*g*) Water, (*h*) Assaying and Sampling, (*i*) Various Supplies (quicksilver, shoes, and dies, cyanide, lime, zinc, sulphuric acid, filter cloth, fluxes, coke, etc., giving their quantities and values). A smelting proposition, depending on its nature, may have headings such as Smelting, Calcining, Converting, Refining, etc., and the Various Supplies would contain such items as water-jackets, slag-pots, etc. (*D*) *Management and General Office Expenses.* This may have sub-headings such as (1) Consulting Engineer's and General Manager's Fees, (2) Office Staff, (3) Stationery, Postage, and Telegrams, (4) Medical and Sanitary Charges, (5) Travelling Expenses, (6) Fire and Accident Insurance, (7) Stabling, (8) Local Bank Charges. These are charged against different Departments in proportion to the costs of each Department. (*E*) *Realization Charges on Products*, with sub-headings of (1) Transport to Railway, (2) Railway Freight, (3) Shipping Charges, Agency, and Commission, (4) Sea Freight, Insurance, etc., (5) Selling Expenses, (6) Returning

Charges, etc. (*F*) *Income Tax, Royalties, and other Taxes.* Head office charges, e.g. rent, directors' fees, legal expenses, bank charges, auditors' fees, foreign agency expenses, advertising, and interest on loan or debentures, are not known at the mine, so cannot be added.

Separate accounts should be shown, giving on the debit side the cost, and on the credit side how it has been distributed to the main headings for Power, Hoisting, Compressed Air, Pumping, Sampling, Assaying, and Surveying, Repairs and Maintenance, General Charges (blacksmith, foremen, etc.), and if Construction and Equipment is being proceeded with, show sub-headings (1) Machinery and Plant, (2) Buildings, giving the cost of any job to the end of the previous month, the cost for the present month of labour, machinery, timber, stores, management, and general office expenses, etc., and the total expenditure to date. A Distribution form shows the total cost of wages and stores for Mining and Treatment, Extraction, and other headings. A Stores Account shows the value of stores on hand at end of the previous month, what has been received during the month, issued during the month, and on hand at date. A Cash Account shows the balance at Bank at the commencement of the month, the money received from head office, sundry receipts, expenditure for the month, and balance in Bank at date. A Summary shows the Expenditure to end of previous month, Expenditure for present month, Total Expenditure to end of the period for (*a*) development, (*b*) mining, (*c*) ore treatment, (*d*) construction and equipment, (*e*) general expenses, (*f*) realization on products, (*g*) total ordinary working costs. Technical details according to the class of treatment should have in tabulated form the number of hours run, tons of ore treated (from the mine, purchased ore), tons of revert (first matte, convertor slag, flue dust, etc.), fluxes (ironstone and limestone), weight of products, value of metals, yield per ton, percentage of extraction, ore on hand, etc. The Capital Account shows Development (after deducting charges to ore extraction), Construction, and Equipment, Total Expenditure, Less Sales of Plant, Nett total of Capital Account. The Working Account shows Ore Extraction (including charges on Ore from Development), Treatment, General Expenses, Realization, Total Ordinary Working Costs, Retreatment, Grand Total Working Account, Gross Income from all Sources, Nett excess (or loss) over working expenditure, Nett excess (or loss) over all expenditure. The tonnage of broken ore in the stopes at date and its cost per ton.

CORRECTIONS FOR THE PRESS.

𝒹 or ♈ (dele) delete, take out, expunge.
9 turn a reversed letter.
a space or more space between words, letters, or lines.
‿ less space or no space between words or letters.
L or ⌋ carry a word further to the right or left.
☐ indent, to begin further in from the margin.
[bring a word or words to the beginning of a line; also make a new paragraph.
¶ make a new paragraph.
— (underline), change from italic to roman, or roman to italic, as the case may be.
= (underline), put in small capitals.
⊓ elevate a letter, word, or character sunk below the proper level.
⊔ sink or depress a letter, word, or character that is raised above the proper level.
| shows that part of a paragraph projects laterally beyond the rest.
⊥ directs attention to a quadrat or space which improperly appears.
× or + directs attention to a broken or imperfect type.
w.f. wrong font, used when a character is of a wrong type, size, or style.
it. italic.
trs. transpose.
l.c. lower case, i.e. put in small or common letters a word or letter that has been printed in capitals or small capitals.
s. cap. or sm. c. put in small capitals.
qu., qy., or ? query.
out s.c. words are wanted, see copy.

WEIGHTS, DIMENSIONS, AND PROPERTIES OF VARIOUS ARTICLES.

TABLE OF WEIGHT OF WATER (AT 62¼ LBS. PER CUBIC FOOT) CONTAINED IN ONE FOOT LENGTH OF PIPES OF DIFFERENT BORES (*Trautwine*).

Bore. Ins.	Water. Lbs.	Bore, Ins.	Water. Lbs.	Bore. Ins.	Water. Lbs.	Bore. Ins.	Water. Lbs.
⅛	0·005320	6	12·25712	23	180·1116	62	1308·788
¼	0·021280	6¼	13·29983	24	196·1139	63	1351·347
⅜	0·047879	6½	14·38509	25	212·7972	64	1394·588
½	0·085119	6¾	15·51292	26	230·1615	65	1438·509
⅝	0·132998	7	16·68330	27	248·2067	66	1483·112
¾	0·191518	7¼	17·89625	28	266·9328	67	1528·395
⅞	0·260677	7½	19·15175	29	286·3399	68	1574·359
1	0·340476	7¾	20·44981	30	306·4280	69	1621·004
1⅛	0·430914	8	21·79044	31	327·1970	70	1668·330
1¼	0·531993	8¼	23·17362	32	348·6470	71	1716·337
1⅜	0·643712	8½	24·59936	33	370·7779	72	1765·025
1½	0·766070	8¾	26·06766	34	393·5897	73	1814·394
1⅝	0·899068	9	27·57852	35	417·0826	74	1864·444
1¾	1·042706	9¼	29·13194	36	441·2563	75	1915·175
1⅞	1·196984	9½	30·72792	37	466·1110	76	1966·587
2	1·361902	9¾	32·36646	38	491·6467	77	2018·680
2⅛	1·537460	10	34·04756	39	517·8633	78	2071·453
2¼	1·723658	10½	37·53743	40	544·7609	79	2124·908
2⅜	1·920495	11	41·19754	41	572·3394	80	2179·044
2½	2·127972	11½	45·02789	42	600·5989	81	2233·860
2⅝	2·346089	12	49·02848	43	629·5393	82	2289·358
2¾	2·574846	12½	53·19931	44	659·1607	83	2345·536
2⅞	2·814243	13	57·54037	45	689·4630	84	2402·396
3	3·064280	13½	62·05167	46	720·4463	85	2459·936
3⅛	3·324957	14	66·73321	47	752·1105	86	2518·157
3¼	3·596273	14½	71·58499	48	784·4557	87	2577·060
3⅜	3·878229	15	76·60700	49	817·4818	88	2636·643
3½	4·170826	15½	81·79925	50	851·1889	89	2696·907
3⅝	4·474062	16	87·16174	51	885·5769	90	2757·852
3¾	4·787938	16½	92·69447	52	920·6459	91	2819·478
3⅞	5·112453	17	98·39744	53	956·3958	92	2881·785
4	5·447609	17½	104·27064	54	992·8267	93	2944·773
4¼	6·149840	18	110·31408	55	1029·9386	94	3008·442
4½	6·894630	18½	116·52776	56	1067·7314	95	3072·792
4¾	7·681980	19	122·91168	57	1106·2051	96	3137·823
5	8·511889	19½	129·46583	58	1145·3598	97	3203·535
5¼	9·384358	20	136·19022	59	1185·1954	98	3269·927
5½	10·299386	21	150·14972	60	1225·7120	99	3337·001
5¾	11·256973	22	164·79017	61	1266·9096	100	3404·756

The weight of water in one foot length of any bore = inner diameter^2 × 0·339521.

TABLE OF APPROXIMATE PROPORTIONS AND WEIGHTS OF 9 FEET LENGTHS OF CAST-IRON PIPES OF VARIOUS SIZES.

Diameter of Bore.	Thickness of Metal.	Diameter of Flange.	Thickness of Flange.	Diameter through Bolt-holes.	Size of Holes.	Number of Holes.	Weight.		
Ins.	In.	In	In.	In.	In.	In.	Cwts.	Qrs.	Lbs.
2	$\frac{3}{8}$	$6\frac{1}{2}$	$\frac{9}{16}$	$4\frac{3}{4}$	$\frac{5}{8}$	4	0	3	0
3	$\frac{3}{8}$	$7\frac{1}{2}$	$\frac{5}{8}$	6	$\frac{5}{8}$	4	1	0	3
4	$\frac{1}{2}$	$9\frac{1}{2}$	$\frac{3}{4}$	$7\frac{3}{4}$	$\frac{3}{4}$	4	1	3	5
5	$\frac{1}{2}$	$10\frac{1}{2}$	$\frac{7}{8}$	$8\frac{3}{4}$	$\frac{3}{4}$	4	2	1	12
6	$\frac{5}{8}$	12	$\frac{7}{8}$	10	$\frac{7}{8}$	4	3	2	1
7	$\frac{5}{8}$	14	1	$11\frac{3}{4}$	$\frac{7}{8}$	6	4	3	17
8	$\frac{3}{4}$	15	1	$12\frac{3}{4}$	1	6	5	2	9
9	$\frac{3}{4}$	$16\frac{1}{2}$	$1\frac{1}{16}$	$14\frac{1}{4}$	1	6	6	1	12
10	$\frac{3}{4}$	$17\frac{1}{2}$	$1\frac{1}{8}$	$15\frac{1}{2}$	1	6	7	0	0
11	$\frac{7}{8}$	19	$1\frac{3}{16}$	$16\frac{3}{4}$	1	6	8	3	24
12	$\frac{7}{8}$	20	$1\frac{1}{4}$	$17\frac{3}{4}$	$1\frac{1}{8}$	6	9	3	5
13	$\frac{7}{8}$	21	$1\frac{1}{4}$	$18\frac{3}{4}$	$1\frac{1}{8}$	8	10	2	0
14	$\frac{7}{8}$	22	$1\frac{1}{4}$	$19\frac{3}{4}$	$1\frac{1}{8}$	8	11	0	26
15	$\frac{7}{8}$	23	$1\frac{1}{4}$	$20\frac{3}{4}$	$1\frac{1}{8}$	8	12	0	25
16	$\frac{7}{8}$	$24\frac{1}{2}$	$1\frac{5}{16}$	22	$1\frac{1}{4}$	8	12	3	8
17	$\frac{7}{8}$	$25\frac{1}{2}$	$1\frac{5}{16}$	23	$1\frac{1}{4}$	8	13	2	17
18	1	$26\frac{1}{2}$	$1\frac{3}{8}$	24	$1\frac{1}{4}$	8	16	1	15
19	1	28	$1\frac{3}{8}$	25	$1\frac{3}{8}$	8	17	2	13
20	1	29	$1\frac{3}{8}$	26	$1\frac{3}{8}$	8	18	0	26

TABLE OF THE WEIGHT OF 100 FEET OF WIRE IN POUNDS, WHEN THE SIZE IS MEASURED BY THE NEW STANDARD WIRE GAUGE OF 1884.

Size by Gauge.	Diameter in Inches.	Copper Wire.	Brass Wire.	Steel Wire.	Iron Wire.
No.		Lbs.	Lbs.	Lbs.	Lbs.
1	·300	26·8	25·7	24·0	23·4
2	·276	22·5	21·6	20·1	19·6
3	·252	18·8	18·1	16·8	16·4
4	·232	15·8	15·2	14·3	13·8
5	·212	13·4	12·7	11·9	11·6
6	·192	10·9	10·5	9·7	9·5
7	·176	9·2	8·8	8·2	8·0
8	·160	7·6	7·3	6·8	6·6
9	·144	6·1	5·8	5·4	5·3
10	·128	4·99	4·65	4·34	4·23
11	·116	4·00	3·80	3·55	3·46
12	·104	3·22	3·08	2·87	2·80
13	·092	2·48	2·37	2·22	2·16
14	·080	1·91	1·83	1·70	1·66
15	·072	1·53	1·46	1·36	1·33
16	·064	1·22	1·16	1·08	1·06
17	·056	0·92	0·88	0·82	0·80
18	·048	0·69	0·66	0·62	0·60
19	·040	0·46	0·44	0·41	0·40
20	·036	0·38	0·36	0·34	0·33

If any less quantity than 100 feet is required, multiply the weight of 100 feet as found in the table by the number of feet wanted, and divide by 100 thus—

Required the weight of 50 feet of No. 16 copper wire.

100 feet of No. 16 gauge copper wire weighs 1·22 lbs.; therefore 100 : 1·22 : : 50 : required weight = 0·61 lbs.

TABLE OF THE WEIGHT OF A SQUARE FOOT OF THE FOLLOWING METALS, WHEN THE THICKNESS IS MEASURED BY THE BOARD OF TRADE NEW LEGAL STANDARD WIRE GAUGE OF 1884.

Thickness by Gauge.	Thickness in Inches.	Lead.	Copper.	Gun Metal.	Brass.	White Metal.	Steel.	Wrought Iron.	Zinc.
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
7—0	·500	29·59	22·87	22·68	21·86	20·88	20·40	19·87	18·72
6—0	·464	27·66	21·18	21·04	20·28	19·36	18·93	18·44	17·37
5—0	·432	25·74	19·75	19·58	18·87	18·02	17·62	17·16	16·19
4—0	·400	23·67	18·26	18·14	17·45	16·68	16·32	15·89	14·97
3—0	·372	22·17	17·01	16·86	16·28	15·52	15·18	14·78	13·94
2—0	·348	20·74	15·92	15·78	15·21	14·52	14·20	13·83	13·05
1—0	·324	19·31	14·81	14·68	14·16	13·51	13·22	12·87	12·14
1	·300	17·75	13·70	13·60	13·08	12·51	12·24	11·92	11·23
2	·276	16·45	12·63	12·52	12·07	11·51	11·26	10·97	10·35
3	·252	15·03	11·53	11·43	11·02	10·52	10·29	10·02	9·45
4	·232	13·83	10·61	10·57	10·14	9·68	9·47	9·22	8·70
5	·212	12·64	9·70	9·67	9·27	8·85	8·66	8·43	7·95
6	·192	11·44	8·78	8·75	8·40	8·01	7·84	7·63	7·20
7	·176	10·29	7·90	7·87	7·55	7·20	7·04	6·86	6·48
8	·160	9·54	7·32	7·29	7·00	6·68	6·53	6·36	6·00
9	·144	8·58	6·58	6·56	6·30	6·00	6·13	5·72	5·40
10	·128	7·62	5·85	5·83	5·58	5·33	5·22	5·08	4·80
11	·116	6·91	5·31	5·29	5·07	4·84	4·73	4·61	4·35
12	·104	6·20	4·75	4·73	4·54	4·34	4·24	4·13	3·89

TABLE OF THE WEIGHT OF A SQUARE FOOT OF THE FOLLOWING METALS, ETC. (*continued*).

Thickness by Gauge.	Thickness in Inches.	Lead.	Copper.	Gun Metal.	Brass.	White Metal.	Steel.	Wrought Iron.	Zinc.
		Lbs	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
13	·092	5·49	4·21	4·17	4·03	3·84	3·76	3·66	3·45
14	·080	4·77	3·66	3·63	3·50	3·34	3·26	3·18	3·00
15	·072	4·30	3·30	3·26	3·14	3·00	2·94	2·86	2·70
16	·064	3·81	2·92	2·89	2·80	2·66	2·60	2·54	2·40
17	·056	3·21	2·46	2·44	2·35	2·25	2·19	2·14	2·02
18	·048	2·86	2·20	2·18	2·10	2·00	1·96	1·91	1·80
19	·040	2·38	1·83	1·81	1·75	1·67	1·63	1·59	1·49
20	·036	2·14	1·64	1·63	1·57	1·50	1·47	1·43	1·35
21	·032	1·92	1·47	1·46	1·41	1·34	1·31	1·28	1·24
22	·028	1·66	1·28	1·26	1·22	1·16	1·14	1·11	1·05
23	·024	1·43	1·09	1·08	1·04	1·00	0·97	0·95	0·89
24	·022	1·30	1·00	0·99	0·96	0·91	0·89	0·87	0·82
25	·020	1·18	0·91	0·90	0·87	0·83	0·81	0·79	0·74
26	·018	1·06	0·82	0·81	0·78	0·74	0·73	0·71	0·67
27	·0164	0·97	0·75	0·74	0·71	0·68	0·67	0·65	0·62
28	·0148	0·87	0·66	0·65	0·64	0·61	0·60	0·58	0·54
29	·0136	0·81	0·62	0·61	0·60	0·57	0·55	0·54	0·50
30	·0124	0·75	0·58	0·57	0·55	0·52	0·51	0·50	0·47

Example.—Find the weight of a sheet of copper $2\frac{1}{2}$ feet × 4 feet × 0·128 inch?

$2\frac{1}{2}$ feet × 4 feet = 10 square feet; 0·128 inch = No. 10 by gauge; 1 square foot of No. 10 copper sheet weighs 5·85 lbs. ∴ therefore 5·85 lbs. × 10 square feet = 58·5 lbs.—*Answer.*

TABLE OF SIZES, &c., OF BATTERY SCREENS.

No. of Needle.	Corre-sponding Mesh.	Width of Slot. (inches)	Thickness of Iron (Russian Gauge).	Thickness of Iron (American Gauge).	Weight per square foot.
5	20	$\frac{29}{1000}$	No. 14	No. 23¼	1·15 pounds.
6	25	$\frac{27}{1000}$	No. 13	No. 24	1·08 "
7	30	$\frac{24}{1000}$	No. 12	No. 24½	0·987 "
8	35	$\frac{22}{1000}$	No. 11	No. 25	0·918 "
9	40	$\frac{20}{1000}$	No. 10	No. 26	0·827 "
10	50	$\frac{18}{1000}$	No. 9	No. 27	0·735 "
11	55	$\frac{16}{1000}$	No. 8	No. 28	0·666 "
12	60	$\frac{15}{1000}$	No. 8	No. 28	0·666 "

TABLE OF APPROPRIATE SIZES AND PROPORTIONS FOR PUMP RODS. (*Curr.*)

Diameter of Pumps.	Spears.	Spear plates and bolts.				
	Scantling Square.	Length.	Breadth.	Thick-ness in the Middle.	Thick-ness at the ends.	Diameter of Bolt.
Inches.	Inches.	Feet.	Inches.	Inches.	Inches.	Inches.
6	3	6	2½	$\frac{3}{8}$	$\frac{3}{16}$	$\frac{5}{8}$
8	3½	6½	2¾	$\frac{7}{16}$	$\frac{3}{16}$	$\frac{11}{16}$
10	4	7	3	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{3}{4}$
12	4½	7½	3½	$\frac{9}{16}$	$\frac{5}{16}$	$\frac{3}{4}$
14	5	8	3½	$\frac{5}{8}$	$\frac{3}{8}$	$\frac{7}{8}$
16	5½	8½	4	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{7}{8}$
18	6	9	4	$\frac{13}{16}$	$\frac{9}{16}$	$\frac{15}{16}$
20	6½	9½	4½	$\frac{7}{8}$	$\frac{5}{8}$	1
22	7	10	4½	$\frac{15}{16}$	$\frac{11}{16}$	1⅛
24	7½	10½	4¾	1	$\frac{3}{4}$	1¼

Table of Acres Required per Mile and per Hundred Feet for different Widths.

Width. Feet.	Acres per Mile.	Acres per 100 Ft.	Width. Feet.	Acres per Mile.	Acres per 100 Ft.	Width. Feet.	Acres per Mile.	Acres per 100 Ft.
1	0·121	·002	35	4·24	·080	68	8·24	·156
2	0·242	·005	36	4·36	·083	69	8·36	·158
3	0·364	·007	37	4·48	·085	70	8·48	·161
4	0·485	·009	38	4·61	·087	71	8·61	·163
5	0·606	·011	39	4·73	·090	72	8·73	·165
6	0·727	·014	40	4·85	·092	73	8·85	·168
7	0·848	·016	41	4·97	·094	74	8·97	·170
8	0·970	·018	41¼	5·0	·094	74¼	9·0	·170
8¼	1·0	·019	42	5·09	·096	75	9·09	·172
9	1·09	·021	43	5·21	·099	76	9·21	·174
10	1·21	·023	44	5·33	·101	77	9·33	·177
11	1·33	·025	45	5·45	·103	78	9·45	·179
12	1·46	·028	46	5·58	·106	79	9·58	·181
13	1·58	·030	47	5·70	·108	80	9·70	·184
14	1·70	·032	48	5·82	·110	81	9·82	·186
15	1·82	·034	49	5·94	·112	82	9·94	·188
16	1·94	·037	49½	6·0	·114	82½	10·0	·189
16½	2·0	·038	50	6·06	·115	83	10·1	·190
17	2·06	·039	51	6·18	·117	84	10·2	·193
18	2·18	·041	52	6·30	·119	85	10·3	·195
19	2·30	·044	53	6·42	·122	86	10·4	·197
20	2·42	·046	54	6·55	·124	87	10·5	·200
21	2·55	·048	55	6·67	·126	88	10·7	·202
22	2·67	·051	56	6·79	·129	89	10·8	·204
23	2·79	·053	57	6·91	·131	90	10·9	·207
24	2·91	·055	57¾	7·0	·133	90¾	11·0	·209
24¾	3·0	·057	58	7·03	·133	91	11·0	·209
25	3·03	·057	59	7·15	·135	92	11·2	·211
26	3·15	·060	60	7·27	·138	93	11·3	·213
27	3·27	·062	61	7·39	·140	94	11·4	·216
28	3·39	·064	62	7·52	·142	95	11·5	·218
29	3·52	·067	63	7·64	·145	96	11·6	·220
30	3·64	·069	64	7·76	·147	97	11·8	·223
31	3·76	·071	65	7·88	·149	98	11·9	·225
32	3·88	·073	66	8·0	·151	99	12·0	·227
33	4·0	·076	67	8·12	·154	100	12·1	·230
34	4·12	·078						

Example.—To make a track 12 feet wide for 2½ miles, what area must be cleared ?

In the second column, opposite 12 in the first, it will be found that 1 mile occupies an area of 1·46 acres ; therefore 2 miles equals $1·46 \times 2 = 2·92$; and ½ a mile equals $1·46 \div 2 = 0·73$ so 2½ miles$= 2·92 + 0·73 = 3·65$ acres.

TABLE SHOWING AREA OF CROSS-SECTIONS OF CUTTINGS OR EMBANKMENTS 15 FEET IN WIDTH AT FORMATION-LEVEL, WITH SLOPES OF 1½ TO 1.

Depth in Feet.	Area in Sq. Feet.	Depth in Feet.	Area in Sq. Feet.	Depth in Feet.	Area in Sq. Feet.	Depth in Feet.	Area in Sq. Feet.	Depth in Feet.	Area in Sq. Feet.
·05	·7	2·45	45·7	4·85	108·0	7·25	187·5	9·65	284·4
·10	1·5	2·50	46·8	4·90	109·5	7·30	189·4	9·70	286·6
·15	2·2	2·55	48·0	4·95	111·0	7·35	191·2	9·75	288·8
·20	3·0	2·60	49·1	5·00	112·5	7·40	193·1	9·80	291·0
·25	3·8	2·65	50·2	5·05	114·0	7·45	195·0	9·85	293·2
·30	4·6	2·70	51·4	5·10	115·5	7·50	196·8	9·90	295·5
·35	5·4	2·75	52·5	5·15	117·0	7·55	198·7	9·95	297·7
·40	6·2	2·80	53·7	5·20	118·5	7·60	200·6	10·00	300·0
·45	7·0	2·85	54·9	5·25	120·0	7·65	202·4	10·05	302·2
·50	7·8	2·90	56·1	5·30	121·6	7·70	204·4	10·10	304·5
·55	8·7	2·95	57·3	5·35	123·1	7·75	206·3	10·15	306·7
·60	9·5	3·00	58·5	5·40	124·7	7·80	208·2	10·20	309·0
·65	10·3	3·05	59·7	5·45	126·3	7·85	210·1	10·25	311·3
·70	11·2	3·10	60·9	5·50	127·8	7·90	212·1	10·30	313·6
·75	12·0	3·15	62·1	5·55	129·4	7·95	214·0	10·35	315·9
·80	12·9	3·20	63·3	5·60	131·0	8·00	216·0	10·40	318·2
·85	13·8	3·25	64·5	5·65	132·6	8·05	217·9	10·45	320·5
·90	14·7	3·30	65·8	5·70	134·2	8·10	219·9	10·50	322·8
·95	15·6	3·35	67·0	5·75	135·8	8·15	221·8	10·55	325·2
1·00	16·5	3·40	68·3	5·80	137·4	8·20	223·8	10·60	327·5
1·05	17·4	3·45	69·6	5·85	139·0	8·25	225·8	10·65	329·8
1·10	18·3	3·50	70·8	5·90	140·7	8·30	227·8	10·70	332·2
1·15	19·2	3·55	72·1	5·95	142·3	8·35	229·8	10·75	335·6
1·20	20·1	3·60	73·4	6·00	144·0	8·40	231·8	10·80	336·9
1·25	21·0	3·65	74·7	6·05	145·6	8·45	233·8	10·85	339·3
1·30	22·0	3·70	76·0	6·10	147·3	8·50	235·8	10·90	341·7
1·35	22·9	3·75	78·3	6·15	148·9	8·55	237·9	10·95	343·1
1·40	23·9	3·80	78·6	6·20	150·0	8·60	239·9	11·00	346·5
1·45	24·9	3·85	79·9	6·25	152·3	8·65	241·9	11·05	348·9
1·50	25·8	3·90	81·3	6·30	154·0	8·70	244·0	11·10	351·3
1·55	26·8	3·95	82·6	6·35	156·7	8·75	246·0	11·15	353·7
1·60	27·8	4·00	84·0	6·40	157·4	8·80	248·1	11·20	356·1
1·65	28·8	4·05	85·3	6·45	159·1	8·85	250·2	11·25	358·5
1·70	29·8	4·10	86·7	6·50	160·8	8·90	252·3	11·30	361·0
1·75	30·9	4·15	88·0	6·55	162·6	8·95	254·5	11·35	363·4
1·80	31·8	4·20	89·4	6·60	164·3	9·00	256·5	11·40	365·9
1·85	32·8	4·25	90·8	6·65	166·0	9·05	258·6	11·45	368·4
1·90	33·9	4·30	92·2	6·70	167·8	9·10	260·7	11·50	370·8
1·95	34·9	4·35	93·6	6·75	169·5	9·15	262·8	11·55	373·3
2·00	36·0	4·40	95·0	6·80	171·3	9·20	264·9	11·60	375·8
2·05	37·0	4·45	96·4	6·85	173·1	9·25	267·0	11·65	378·3
2·10	38·1	4·50	97·8	6·90	174·9	9·30	269·2	11·70	380·8
2·15	39·1	4·55	99·3	6·95	176·7	9·35	271·3	11·75	383·8
2·20	40·2	4·60	100·7	7·00	178·5	9·40	273·5	11·80	385·8
2·25	41·3	4·65	102·1	7·05	180·3	9·45	275·7	11·85	388·3
2·30	42·4	4·70	103·6	7·10	182·1	9·50	277·8	11·90	390·9
2·35	43·5	4·75	105·0	7·15	183·9	9·55	280·0	11·95	393·4
2·40	44·6	4·80	106·5	7·2	185·7	9·60	282·2	12·00	396·0

TABLE SHOWING AREA OF CROSS-SECTIONS OF CUTTINGS OR EMBANKMENTS 12 FEET IN WIDTH AT FORMATION-LEVEL, WITH SLOPES OF $1\frac{1}{2}$ TO 1.

Depth in Feet.	Area in Sq. Feet.	Depth in Feet.	Area in Sq. Feet.	Depth in Feet.	Area in Sq. Feet.	Depth in Feet.	Area in Sq. Feet.	Depth in Feet.	Area in Sq. Feet.
·05	·6	2·45	38·3	4·85	93·4	7·25	165·8	9·65	255·4
·10	1·2	2·50	39·3	4·90	94·8	7·30	167·5	9·70	257·5
·15	1·8	2·55	40·3	4·95	96·1	7·35	169·2	9·75	259·5
·20	2·4	2·60	41·3	5·00	97·5	7·40	170·9	9·80	261·6
·25	3·0	2·65	42·3	5·05	98·7	7·45	172·6	9·85	263·7
·30	3·7	2·70	43·3	5·10	100·2	7·50	174·3	9·90	265·8
·35	4·3	2·75	44·3	5·15	101·5	7·55	176·1	9·95	267·9
·40	5·0	2·80	45·3	5·20	102·9	7·60	177·8	10·00	270·0
·45	5·7	2·85	46·3	5·25	104·3	7·65	179·5	10·05	272·1
·50	6·3	2·90	47·4	5·30	105·7	7·70	181·3	10·10	274·2
·55	7·0	2·95	48·4	5·35	107·1	7·75	183·0	10·15	276·3
·60	7·7	3·00	49·5	5·40	108·5	7·80	184·8	10·20	278·4
·65	8·4	3·05	50·5	5·45	109·9	7·85	186·6	10·25	280·5
·70	9·1	3·10	51·6	5·50	111·3	7·90	188·4	10·30	282·7
·75	9·8	3·15	52·6	5·55	112·7	7·95	190·2	10·35	284·8
·80	10·5	3·20	53·7	5·60	114·2	8·00	192·0	10·40	287·0
·85	11·2	3·25	54·8	5·65	115·6	8·05	193·7	10·45	289·2
·90	12·0	3·30	55·9	5·70	117·1	8·10	195·6	10·50	291·3
·95	12·7	3·35	57·0	5·75	118·5	8·15	197·4	10·55	293·5
1·00	13·5	3·40	58·1	5·80	120·0	8·20	199·2	10·60	295·7
1·05	14·2	3·45	59·2	5·85	121·5	8·25	201·0	10·65	297·9
1·10	15·0	3·50	60·3	5·90	123·0	8·30	202·9	10·70	300·1
1·15	15·7	3·55	61·4	5·95	124·5	8·35	204·7	10·75	302·3
1·20	16·6	3·60	62·6	6·00	126·0	8·40	206·6	10·80	304·5
1·25	17·3	3·65	63·7	6·05	127·4	8·45	208·5	10·85	306·7
1·30	18·0	3·70	64·9	6·10	129·0	8·50	210·3	10·90	309·0
1·35	18·9	3·75	66·0	6·15	130·5	8·55	212·2	10·95	311·2
1·40	19·7	3·80	67·2	6·20	132·0	8·60	214·1	11·00	313·5
1·45	20·5	3·85	68·4	6·25	133·5	8·65	216·0	11·05	315·7
1·50	21·3	3·90	69·6	6·30	135·1	8·70	217·9	11·10	318·0
1·55	22·1	3·95	70·7	6·35	136·6	8·75	219·8	11·15	320·2
1·60	23·0	4·00	72·0	6·40	138·2	8·80	221·7	11·20	322·5
1·65	23·8	4·05	73·1	6·45	139·8	8·85	223·6	11·25	324·8
1·70	24·7	4·10	74·4	6·50	141·3	8·90	226·6	11·30	327·1
1·75	25·5	4·15	75·6	6·55	142·9	8·95	227·5	11·35	329·4
1·80	26·4	4·20	76·8	6·60	144·5	9·00	229·5	11·40	331·7
1·85	27·3	4·25	78·0	6·65	146·1	9·05	231·4	11·45	334·0
1·90	28·2	4·30	79·3	6·70	147·7	9·10	233·4	11·50	336·3
1·95	29·0	4·35	80·5	6·75	149·3	9·15	235·3	11·55	338·7
2·00	30·0	4·40	81·8	6·80	150·9	9·20	237·3	11·60	341·0
2·05	30·9	4·45	82·9	6·85	152·5	9·25	239·3	11·65	343·3
2·10	31·8	4·50	84·3	6·90	154·2	9·30	241·3	11·70	345·7
2·15	32·7	4·55	85·6	6·95	155·8	9·35	243·3	11·75	348·0
2·20	33·6	4·60	86·9	7·00	157·5	9·40	245·3	11·80	350·4
2·25	34·5	4·65	88·2	7·05	159·1	9·45	247·3	11·85	352·8
2·30	35·5	4·70	89·5	7·10	160·8	9·50	249·3	11·90	355·2
2·35	36·4	4·75	90·8	7·15	162·4	9·55	251·4	11·95	357·6
2·40	37·4	4·80	92·1	7·20	164·1	9·60	253·4	12·00	360·0

Specific Gravity Degrees, comparing the Areometers of Baumé, Cartier, and Beck.

(For Liquids heavier than Water.)

Degrees. Baumé and Beck.	Baumé. Sp. Grv.	Beck. Sp. Grv	Degrees. Baumé and Beck.	Baumé. Sp. Grv.	Beck. Sp. Grv.
0	1·000	1·0000	37	1·337	1·2782
1	1·007	1·0059	38	1·349	1·2879
2	1·014	1·0119	39	1·361	1·2977
3	1·020	1·0180	40	1·375	1·3077
4	1·028	1·0241	41	1·388	1·3178
5	1·035	1·0303	42	1·401	1·3281
6	1·041	1·0366	43	1·414	1·3386
7	1·049	1·0429	44	1·428	1·3492
8	1·057	1·0494	45	1·442	1·3600
9	1·064	1·0559	46	1·456	1·3710
10	1·072	1·0625	47	1·470	1·3821
11	1·080	1·0692	48	1·485	1·3934
12	1·088	1·0759	49	1·500	1·4050
13	1·096	1·0828	50	1·515	1·4167
14	1·104	1·0897	51	1·531	1·4286
15	1·113	1·0968	52	1·546	1·4407
16	1·121	1·1039	53	1·562	1·4530
17	1·130	1·1111	54	1·578	1·4655
18	1·138	1·1184	55	1·596	1·4783
19	1·147	1·1258	56	1·615	1·4912
20	1·157	1·1333	57	1·634	1·5044
21	1·166	1·1409	58	1·653	1·5179
22	1·176	1·1486	59	1·671	1·5315
23	1·185	1·1565	60	1·690	1·5454
24	1·195	1·1644	61	1·709	1·5596
25	1·205	1·1724	62	1·729	1·5741
26	1·215	1·1806	63	1·750	1·5888
27	1·225	1·1888	64	1·771	1·6038
28	1·235	1·1972	65	1·793	1·6190
29	1·245	1·2057	66	1·815	1·6346
30	1·256	1·2143	67	1·839	1·6505
31	1·267	1·2230	68	1·864	1·6667
32	1·278	1·2319	69	1·885	1·6832
33	1·289	1·2409	70	1·909	1·7000
34	1·300	1·2500	71	1·935	--
35	1·312	1·2593	72	1·960	—
36	1·324	1·2680			

Formulæ for different Areometers: g = number of degrees, s = sp. grv. :—

$$\text{Baumé } s=\frac{144}{144-g}.$$

$$\text{Cartier } s=\frac{136{\cdot}8}{126{\cdot}1-g}.$$

$$\text{Beck } s=\frac{170}{170-g}.$$

Specific Gravity Degrees. comparing the Areometers of Baumé, Cartier, and Beck.

(For Liquids lighter than Water.)

Degrees, Baumé, Cartier & Beck.	Baumé.	Cartier.	Beck.	Degrees, Baumé, Cartier & Beck.	Baumé.	Cartier.	Beck.
	Sp. Grv.	Sp. Grv.	Sp. Grv.		Sp. Grv.	Sp. Grv.	Sp. Grv.
0	...	...	1·0000	36	0·848	0·837	0·8252
1	...	...	0·9941	37	0·843	0·831	0·8212
2	...	...	0·9883	38	0·838	0·826	0·8173
3	...	...	0·9826	39	0·833	0·820	0·8133
4	...	...	0·9770	40	0·829	0·815	0·8095
5	...	...	0·9714	41	0·824	0·810	0·8061
6	...	...	0·9659	42	0·819	0·805	0·8018
7	...	...	0·9604	43	0·815	0·800	0·7981
8	...	...	0·9550	44	0·810	...	0·7944
9	...	...	0·9497	45	0·806	...	0·7907
10	1·000	...	0·9444	46	0·801	...	0·7871
11	0·993	1·000	0·9392	47	0·797	...	0·7834
12	0·986	0·992	0·9340	48	0·792	...	0·7799
13	0·979	0·985	0·9289	49	0·788	....	0·7763
14	0·973	0·977	0·9239	50	0·784	...	0·7727
15	0·967	0·969	0·9189	51	0·781	...	0·7692
16	0·960	0·962	0·9139	52	0·776	...	0·7658
17	0·954	0·955	0·9090	53	0·771	...	0·7623
18	0·948	0·948	0·9042	54	0·769	...	0·7589
19	0·942	0·941	0·8994	55	0·763	...	0·7556
20	0·935	0·934	0·8947	56	0·759	...	0·7522
21	0·929	0·927	0·8900	57	0·755	...	0·7489
22	0·924	0·920	0·8854	58	0·751	...	0·7456
23	0·918	0·914	0·8808	59	0·748	...	0·7423
24	0·912	0·908	0·8762	60	0·744	...	0·7391
25	0·906	0·901	0·8717	61	0·740	...	0·7359
26	0·901	0·895	0·8673	62	0·736	...	0·7328
27	0·895	0·889	0·8629	63	...	...	0·7296
23	0·889	0·883	0·8585	64	...	...	0·7265
29	0·884	0·877	0·8542	65	...	...	0·7234
30	0·879	0·871	0·8500	66	...	...	0·7203
31	0·873	0·865	0·8457	67	...	...	0·7173
32	0·868	0·859	0·8415	68	...	...	0·7142
33	0·863	0·853	0·8374	69	...	...	0·7112
34	0·858	0·848	0·8333	70	...	...	0·7083
35	0·853	0·842	0·8292				

Formulæ for different Areometers: g = number of degrees, s = sp. grv. :—

$$\text{Brix } s = \frac{400}{400 + g}.$$

$$\text{Gay Lussac } s = \frac{100}{100 + g}$$

$$\text{Balling } s = \frac{200}{200 + g}.$$

Transformation of Columns of Water into Columns of Mercury.

Millim. of Water.	Millim. of Mercury.	Millim. of Water.	Millim. of Mercury.	Millim. of Water.	Millim. of Mercury.	Millim. of Water.	Millim. of Mercury.
1	·074	8	·59	35	2·58	65	4·80
2	·15	9	·66	40	2·95	70	5·17
3	·22	10	·74	45	3·32	75	5·54
4	·30	15	1·12	50	3·69	80	5·90
5	·37	20	1·48	55	4·06	85	6·27
6	·44	25	1·84	60	4·43	90	6·64
7	·52	30	2·21				

Table of Approximate Size and Weight of Rails for Loaded Waggons of certain Weights, the Sleepers being 2 Feet 2 Inches apart.

Weight of Loaded Truck.	Height of Rail.	Width of Rail.	Weight per Running Yard.
Cwt.	In.	In.	Lbs.
6	$1\frac{1}{2}$	$\frac{3}{8}$	6·26
10	2	$\frac{3}{8}$	7·83
14	$2\frac{1}{8}$	$\frac{1}{2}$	9·22
18	$2\frac{1}{6}$	$\frac{3}{5}$	14·11
24	$2\frac{3}{4}$	$\frac{3}{5}$	15·76
30	$2\frac{3}{4}$	$\frac{11}{16}$	20·68

Weight and depth gives solidity ; track and breadth of rail is necessary for the preservation of the wheels of the trucks.

Railway Curves. (*Pambour.*)

The outer rail of curves requires to be raised above the inner as follows, for a speed of 20 miles per hour :

500 feet radius . . . . . . 1·47 inches.
600 „ . . . . 0·98 „
700 „ . . . . 0·63 „
800 „ . . . . 0·37 „
900 „ . . . . 0·16 „

HEAT.

THERMOMETERS. COMPARISON OF CELSIUS, RÉAUMUR, AND FAHRENHEIT SCALES.

Celsius.	Réaumur.	Fahrenheit.	Celsius.	Réaumur.	Fahrenheit.
+100	+80	+212	+63	+50·4	+145·4
99	79·2	210·2	62	49·6	143·6
98	78·4	208·4	61	48·8	141·8
97	77·6	206·6	60	48	140
96	76·8	204·8	59	47·2	138·2
95	76	203	58	46·4	136·4
94	75·2	201·2	57	45·6	134·6
93	74·4	199·4	56	44·8	132·8
92	73·6	197·6	55	44	131
91	72·8	195·8	54	43·2	129·2
90	72	194	53	42·4	127·4
89	71·2	192·2	52	41·6	125·6
88	70·4	190·4	51	40·8	123·8
87	69·6	188·6	50	40	122
86	68·8	186·8	49	39·2	120·2
85	68	185	48	38·4	118·4
84	67·2	183·2	47	37·6	116·6
83	66·4	181·4	46	36·8	114·8
82	65·6	179·6	45	36	113
81	64·8	177·8	44	35·2	111·2
80	64	176	43	34·4	109·4
79	63·2	174·2	42	33·6	107·6
78	62·4	172·4	41	32·8	105·8
77	61·6	170·6	40	32	104
76	60·8	168·8	39	31·2	102·2
75	60	167	38	30·4	100·4
74	59·2	165·2	37	29·6	98·6
73	58·4	163·4	36	28·8	96·8
72	57·6	161·6	35	28	95
71	56·8	159·8	34	27·2	93·2
70	56	158	33	26·4	91·4
69	55·2	156·2	32	25·6	89·6
68	54·4	154·4	31	24·8	87·8
67	53·6	152·6	30	24	86
66	52·8	150·8	29	23·2	84·2
65	52	149	28	22·4	82·4
64	51·2	147·2	27	21·6	80·6

THERMOMETERS, COMPARISON OF—(*continued*).

Celsius.	Réaumur.	Fahrenheit.	Celsius.	Réaumur.	Fahrenheit.
+26	+20·8	+78·8	−8	−6·4	+17·6
25	20	77	9	7·2	·15·8
24	19·2	75·2	10	8	14
23	18·4	73·4	11	8·8	12·2
22	17·6	71·6	12	9·6	10·4
21	16·8	69·8	13	10·4	8·6
20	16	68	14	11·2	6·8
19	15·2	66·2	15	12	5
18	14·4	64·4	16	12·8	3·2
17	13·6	62·6	17	13·6	1·4
16	12·8	60·8	18	14·4	−0·4
15	12	59	19	15·2	2·2
14	11·2	57·2	20	16	4
13	10·4	55·4	21	16·8	5·8
12	9·6	53·6	22	17·6	7·6
11	8·8	51·8	23	18·4	9·4
10	8	50	24	19·2	11·2
9	7·2	48·2	25	20	13
8	6·4	46·4	26	20·8	14·8
7	5·6	44·6	27	21·6	16·6
6	4·8	42·8	28	22·4	18·4
5	4	42	29	23·2	20·2
4	3·2	39·2	30	24	22
3	2·4	37·4	31	24·8	23·8
2	1·6	35·6	32	25·6	25·6
1	0·8	33·8	33	26·4	27·4
0	0	32	34	27·2	29·2
−1	−0·8	30·2	35	28	31
2	1·6	28·4	36	28·8	32·8
3	2·4	26·6	37	29·6	34·6
4	3·2	24·8	38	30·4	36·4
5	4	23	39	31·2	38·2
6	4·8	21·2	40	32	40
7	5·6	19·4			

$$F^\circ : C^\circ = (F^\circ - 32) \times 5 \div 9.$$
$$F^\circ : R^\circ = (F^\circ - 32) \times 4 \div 9.$$
$$C^\circ : F^\circ = (C^\circ \times 9 \div 5) + 32.$$
$$C^\circ : R^\circ = C^\circ \times 4 \div 5.$$
$$R^\circ : F^\circ = (R^\circ \times 9 \div 4) + 32.$$
$$R^\circ : C^\circ = R^\circ \times 5 \div 4.$$

Specific Heat.

THE specific heat of a body is the ratio of the quantity of heat required to raise that body one degree, to the quantity required to raise an equal weight of water one degree in temperature. It is ascertained by multiplying the absolute heating power by the specific gravity.

TABLE OF SPECIFIC HEAT OF GASES AND VAPOURS.

	For Equal Volumes.	For Equal Weights.
Air	0·2374 0·2389	0·2374
Oxygen	0·2405	0·2175
Nitrogen	0·2368	0·2438
Hydrogen	0·2359	3·4090
Chlorine	0·2964	0·1210
Nitrous oxide	0·3447 0·3014	0·2262
Nitric oxide	0·2406	0·2317
Carbonic oxide	0·2370 0·2346	0·2450
Carbonic anhydride	0·3307 0·2985	0·20246
Carbonic disulphide	0·4122	0·1569
Ammonia	0·2996 0·2952	0·5083
Marsh gas	0·3277	0·5929
Sulphurous anhydride	0·3414	0·1553
Hydrochloric acid	0·2333	0·1852
Sulphuretted hydrogen	0·2857	0·2432
Water	0·2989	0·4805

TABLE OF APPROXIMATE TEMPERATURES INDICATED BY COLOUR OF FIRE.

Glowing in the dark	525°C.	Dark orange	1,100°C.
Dark red	700° ,,	Light orange	1,200° ,,
Dark cherry red	800° ,,	White heat	1,300° ,,
Cherry red	900° ,,	Welding heat	1,400° ,,
Light cherry red	1,000° ,,	Dazzling white	1,500° ,,

Table of Theoretical Heating Power developed by the burning of 1 Kilogram of

C	to CO	=	2383	Cal.
C	,, CO_2	=	8080	,,
CO	,, CO_2	=	2442	,,
H	,, H_2O liquid	=	34180	,,
H	,, H_2O gas	=	28780	,,
CH_4	,, CO_2+2H_2O liquid	=	13346	,,
CH_4	,, CO_2+2H_2O gas	=	11996	,,
C_2H_4	,, $2CO_2+2H_2O$ liquid	=	11957	,,
C_2H_4	,, $2CO_2+2H_2O$ gas	=	11186	,,
Fe	,, FeO	=	1353	,,
Fe	,, Fe_3O_4	=	1582	,,
Fe	,, Fe_2O_3	=	2028	,,
Si	,, SiO_2	=	7830	,,
Mn	,, MnO	=	1724	,,
Mn	,, MnO_2	=	2113	,,
Pb	,, PbO	=	266	,,
Cu	,, CuO	=	684	,,
Cu_2O	,, CuO	=	256	,,
Zn	,, ZnO	=	1291	,,
Sn	,, SnO_2	=	1147	,,
P	,, P_2O_5	=	5747	,,
S	,, SO_2	=	2220	,,

If a fuel contains *c* °/₀ carbon, *h* °/₀ hydrogen, *o* °/₀ oxygen, *s* °/₀ sulphur, and *w* °/₀ water, then the heat developed is :—

$$H = \frac{8080c + 28780(h - \frac{1}{8}o) + 2500s + 600w}{100}$$

Table of Melting-point of Easily Fusible Alloys.

Degrees Cent.	Parts by Weight.				Degrees Cent.	Parts by Weight.	
	Tin.	Lead.	Bismuth.	Cadmium.		Tin.	Lead.
65	4	8	15	3	135	3	2
77	3	5	8	...	137	2	1
99	1	1	1	...	144	3	1
116	2	2	1	...	151	1	1
124	3	3	1	...	155	6	1
128	4	4	1	...	183	1	2
					207	1	4

Walker's List of Frigorific Mixtures.

Mixture	Proportions	Thermometer sinks degrees F.
Ammonium nitrate Water	1 part 1 ,,	From + 40° to + 4°
Ammonium chloride Potassium nitrate Water	5 parts 5 ,, 16 ,,	From + 50° to + 10°
Ammonium chloride Potassium nitrate Sodium sulphate Water	5 parts 5 ,, 8 ,, 16 ,,	From + 50° to + 4°
Sodium nitrate Nitric acid, diluted	3 parts 2 ,,	From + 50° to − 3°
Ammonic nitrate Sodium carbonate Water	1 part 1 ,, 1 ,,	From + 50° to − 7°
Sodium phosphate Nitric acid, diluted	9 parts 4 ,,	From + 50° to + 12°
Sodium Sulphate Sulphuric acid, diluted	5 parts 4 ,,	From + 50° to + 3°
Sodium sulphate Ammonium chloride Potassium nitrate Nitric acid, diluted	6 parts 4 ,, 2 ,, 4 ,,	From + 50° to − 10
Sodium sulphate Ammonium nitrate Nitric acid, diluted	6 parts 5 ,, 4 ,,	From + 50° to − 40°
Snow, or pounded ice Sodium chloride	2 parts 1 part	to − 5°
Snow, or pounded ice Sodium chloride Ammonium chloride	5 parts 2 ,, 1 part	to − 12°
Snow, or pounded ice Sodium chloride Ammonium chloride Potassium nitrate	24 parts 10 ,, 5 ,, 5 ,,	to − 18°
Snow, or pounded ice Sodium chloride Ammonium nitrate	12 parts 5 ,, 5 ,,	to − 25°
Snow Sulphuric acid, diluted	3 parts 2 ,,	From + 32° to − 23°

Walker's List of Frigorific Mixtures (*continued*).

		Thermometer sinks degrees F.
Snow Hydrochloric acid	8 parts 5 ,,	From +32° to − 27°
Snow Nitric acid diluted	7 parts 4 ,,	From +32° to − 30°
Snow Calcium chloride	4 parts 5 ,,	From +32° to − 40°
Snow Calcium chloride, crystallized	2 parts 3 ,,	From +32° to − 50°
Snow Potash	3 parts 4 ,,	From +32° to − 51°

ELECTRICITY.

Electroplating.

Solutions for electroplating small articles with simply strips zinc and copper for a battery.

Copper bronze solution.

To 4 oz. nitrate of copper, and
1 gall. cold water add
12 oz. sulphuric acid and
4 oz. ammonic chloride.

Silver solution.

To 5 dwts. silver chloride,
6 grs. bicarbonate of soda
1½ oz. cyanide of potassium
1½ pints water.
Boil for 5 minutes.

Gold solution.

To 15 grs. gold chloride,
3 grs. bicarbonate of soda,
3 drams cyanide of potassium,
4 oz. water.
Boil for 3 minutes.

ELECTRICAL UNITS. (*Munro and Jamieson.*)

Unit.	Symbol.	Name.	Derivation.	Value. C. G. S.	Value. Equivalent.
E. M. F.	E	Volt	Ampère × ohm	10^8	0·926 standard Daniell cell.
Resistance	R	Ohm	Volt ÷ Ampère	10^9	106 cm. mercury 1 sq. mm. section at 0° Cent.
Current	C	Ampère	Volt ÷ Ohm	10^{-1}	0·0000105 gramme of hydrogen liberated per second.
Quantity	Q	Coulomb	Ampère per second	10^{-1}	
Capacity	K	Farad	Coulomb ÷ Volt	10^{-9}	
„	„	Microfarad	1 millionth Farad	10^{-15}	2·5 knots of D. U. S. cable.
Power	P	Watt	Volt × Ampère	10^7	0·0013405 or $\frac{1}{746}$ horse power.
Work	W	Joule	Volt × Coulomb	„	0·7373 ft. lbs.
Heat			Amp² × Sec. × Ohm	„	0·238 Calorie.

C. G. S. system is made up of the fundamental units; centimetre (for length), the gramme (for mass), and the second (for time).

E. M. F. Electro-motive force.

ELECTRO-MOTIVE FORCES OF VARIOUS CELLS.

Batteries.	+ Plate.	Porous Cell.		− Plate.	Volts.
Daniell . .	Zinc amalg.	Sulphuric acid 7½ to 1	Saturated solution of copper sulphate	Copper .	1·079
"	"	22 to 1	" "	"	0·978
"	"	" "	Nitrate of copper saturated	"	1·000
"	"	" "	Sulphate of copper .	"	0·909
" P.O.	"	Sulphate of zinc satu-	" "	...	...
Standard . .	...	rated solution . .	Saturated solution . .	...	1·079
Grove . . .	"	Sulphuric acid 7½ to 1	Nitric acid (fuming) .	Platinum .	1·956
"	"	Salt water . . .	Nitric acid, sp. gr. 1·33	"	1·904
"	"	Sulphuric acid 22 to 1	" "	"	1·810
"	"	Sulphate of zinc . .	" "	"	1·672
Bunsen . .	"	Dilute sulphuric acid .	Nitric acid . . .	Carbon .	1·734
Smee . . .	Zinc . .	Sulphuric 1, Water 7		Platinised silver	0·47
Walker . .	"	"	"	" carbon	0·65
Callan . . .	Zinc amalg.	Dilute sulphuric acid .	Nitric acid . . .	Cast iron .	1·700
Poggendorf .	"	" "	Bichromate of potash .	Carbon .	1·796 / 2·028
Marié Davy . .	"	Sulphuric acid 22 to 1	Paste of sulphate of mercury . . .	"	1·524
"	"	Dilute sulphuric acid .	" "	"	1·33
Leclanché . .	"	Solution of sal ammoniac . .	Binoxide of Manganese	"	1·48
De la Rue . .	Zinc . .	Chloride of ammonium.		Silver & Ag Cl.	1·030
Skrivanov (pocket form)	"	Solution 75 caustic potash to 100 water		"	1·4 to 1·5
Becquerel . .	Zinc amalg.	Sulphate of zinc . .	Sulphate of lead . .	Lead . .	0·55

ELECTRO-MOTIVE FORCES OF VARIOUS CELLS (*continued*).

Batteries.	+ Plate.	Porous Cell.		− Plate.	Volts.
Niaudet	Zinc amalg.	Common salt	Chloride of lime	Carbon	1·65
Duchemin	"	" "	Perchloride of iron	Lead	1·541
"	Platinum	Dilute sulphuric acid	Dilute sulphuric acid	Platinum	1·79
Latimer Clark (standard cell)	Zinc amalg.	Sulphate of zinc	Paste of sulphate of mercury	Mercury	1·457
Howell's Manganese; internal res. = 1 ohm (Hockin)	"	Ammonic sulphate 25 grms. crystallized salt to 1 litre water	Sulphuric acid, 1 acid to 5 parts water	Carbon + MnO_2 + $MnSO_4$	2·04
Higgin's cascade, internal res. = 0·170 ohm	Zinc in mercury	Chromic acid	Sulphuric acid	Carbon	1·9
Thame's	Zinc	Dilute sulphuric acid	Nitric acid + $CrO_2 Cl_2$	Carbon	2
Bennet's, internal res. = 5 ohm	"	K H O with distilled water	Damped with K H O and water	Iron can with iron borings	1·3
Lalande - Chaperon	Zinc amalg.	Caustic soda solution	Oxide of copper or copper scale	Iron	1
Faure's secondary battery	Lead plate coated with minium	Dilute sulphuric acid	Dilute sulphuric acid	Lead plate coated with minium	2·0—2·2
Sellon - Volckmar	Lead plate primed with minium	Sol. sulphuric acid, sp. gr. 1·100°	Sol. sulphuric acid, sp. gr. 1·100°	Lead plate primed with minium	2·15
Planté	Lead	Dilute sulphuric acid	Dilute sulphuric acid	Lead (spongy)	2·0—2·2

Note.—These E. M. F.'s are 1·1 per cent. too high, and should be multiplied by ·9889, the ratio of the B. A. unit to the legal ohm.

AIR AND WATER.

WIND.

Velocity in Miles per Hour.	Velocity in Feet per Second.	Pressure in Pounds per Square Foot.	Remarks.
1	1·467	·005	Hardly perceptible.
2	2·933	·020	Pleasant.
3	4·400	·045	"
4	5·867	·080	"
5	7·33	·125	"
10	14·67	·5	"
12½	18·33	·781	Fresh breeze.
15	22·0	1·125	"
20	29·33	2·0	"
25	36·67	3·125	Brisk wind.
30	44·0	4·5	Strong wind.
40	58·67	8·0	High wind.
50	73·33	12·5	Storm.
60	88·0	18·0	Violent storm.
80	117·3	32·0	Hurricane.
100	146·7	50·0	Violent hurricane, uprooting large trees.

Windmills make use of about 29 per cent. of the energy imparted to them.

TABLE OF QUANTITY OF WATER PER ACRE FOR A GIVEN DEPTH OF RAINFALL.

Fall in Inches.	Cubic Feet per Acre.	Fall in Inches.	Cubic Feet per Acre.	Fall in Inches.	Cubic Feet per Acre.	Fall in Inches.	Cubic Feet per Acre.
2	7,260	$\frac{3}{8}$	1,361	$\frac{1}{10}$	363	$\frac{1}{40}$	91
1¾	6,352	$\frac{1}{4}$	907	$\frac{1}{12}$	302	$\frac{1}{50}$	73
1½	5,445	$\frac{1}{5}$	726	$\frac{1}{14}$	259	$\frac{1}{60}$	61
1¼	4,537	$\frac{1}{6}$	605	$\frac{1}{16}$	227	$\frac{1}{70}$	52
1	3,630	$\frac{1}{7}$	519	$\frac{1}{20}$	181	$\frac{1}{72}$ = 1 point	50
¾	2,723	$\frac{1}{8}$	454	$\frac{1}{30}$	121		
½	1,815	$\frac{1}{9}$	403				

Example.—What quantity of water has been deposited on 20 acres of land when the rainfall was $\frac{1}{9}$th of an inch?

In the column for "Fall in inches," opposite $\frac{1}{9}$th, we find 403, which is the number of cubic feet deposited on 1 acre for that rainfall. This multiplied by 20 gives the required quantity—403 cubic feet × 20 acres = 8,060 cubic feet. The quantity of water absorbed by the earth depends on the nature of the rain, time of year, lie of country, sort of rock, and the angle at which it is placed, &c.

One inch in depth per acre weighs 101 tons.

STATICS.

Pressure against Walls.

MULTIPLY the square of the height of the wall in feet, by the number contained in the last column of the subjoined table, for the pressure in lbs. per sq. foot acting horizontally against the back of the wall, at a point one-third of the height above the base.

Nature of the Earth.	Weight of Cubic Foot in Pounds.	Natural Slope.	Constant Multiplier.
Fine dry sand	94	30° 0′	15·666
,, ,, ...	119	40° 0′	12·938
Loose shingle, perfectly dry .	106	39° 0′	12·058
Common earth, perfectly dry and pulverulent . . .	94	43° 10′	8·815
Common earth, slightly moistened, or in its natural state	106	54° 0′	5·595
Earth, the most dense and compact	125	55° 0′	6·213

Vertical pressure of water per square foot = 62·5 × depth of water.

Horizontal pressure of water per square foot = 31·25 lbs. × the square of the depth at centre of pressure.

The total pressure against an upright wall is :—

$$\text{Length} \times \frac{2\ \text{depth}}{3} \times 62{\cdot}5\ \text{lbs.}$$

The total pressure against a sloping bank is :—

$$\text{Length} \times \frac{\text{depth}}{2} \times 62{\cdot}5\ \text{lbs.}$$

Centre of pressure : Of a rectangle is at two-thirds its depth from top. Of a triangle whose base is horizontal and upon the water-line at half depth.

Of a triangle whose summit is at the water-line, base horizontal and at the lower level, at three-quarters of depth.

DYNAMICS.

Velocity at the Circumference per Sec. with a given Number of Revolutions (n) per Min. for the Radius = 1.

$$u = \frac{2 \pi r n}{60}.$$

n	0	1	2	3	4	5	6	7	8	9
00	0·0000	0·1047	0·2094	0·3142	0·4189	0·5236	0·6283	0·7330	0·8378	0·9425
10	1·0472	1·1519	1·2566	1·3614	1·4661	1·5708	1·6755	1·7802	1·8850	1·9897
20	2·0944	2·1991	2·3038	2·4086	2·5133	2·6180	2·7227	2·8274	2·9322	3·0369
30	3·1416	3·2463	3·3510	3·4558	3·5605	3·6652	3·7699	3·8746	3·9794	4·0841
40	4·1888	4·2935	4·3982	4·5029	4·6077	4·7124	4·8171	4·9218	5·0265	5·1313
50	5·2360	5·3407	5·4454	5·5501	5·6549	5·7596	5·8643	5·9690	6·0737	6·1785
60	6·2832	6·3879	6·4926	6·5973	6·7021	6·8068	6·9115	7·0162	7·1209	7·2257
70	7·3304	7·4351	7·5398	7·6445	7·7493	7·8540	7·9587	8·0634	8·1681	8·2729
80	8·3776	8·4823	8·5870	8·6917	8·7965	8·9012	9·0059	9·1106	9·2153	9·3201
90	9·4248	9·5295	9·6342	9·7389	9·8437	9·9484	10·053	10·158	10·263	10·367
100	10·472	10·577	10·681	10·786	10·891	10·996	11·100	11·205	11·310	11·414
110	11·519	11·624	11·729	11·833	11·938	12·043	12·147	12·252	12·357	12·472
120	12·566	12·671	12·776	12·881	12·985	13·090	13·195	13·299	13·404	13·509
130	13·614	13·718	13·823	13·928	14·032	14·137	14·242	14·347	14·451	14·556
140	14·661	14·765	14·870	14·975	15·080	15·184	15·289	15·394	15·499	15·603
150	15·708	15·813	15·917	16·022	16·127	16·232	16·336	16·441	16·546	16·650
160	16·755	16·860	16·965	17·069	17·174	17·279	17·383	17·488	17·593	17·698
170	17·802	17·907	18·012	18·117	18·221	18·326	18·431	18·535	18·640	18·745
180	18·850	18·954	19·059	19·164	19·268	19·373	19·478	19·583	19·687	19·792
190	19·897	20·001	20·106	20·211	20·316	20·420	20·525	20·630	20·735	20·839
200	20·944	21·049	21·153	21·258	21·363	21·468	21·572	21·677	21·782	21·886
210	21·991	22·096	22·201	22·305	22·410	22·515	22·619	22·724	22·829	22·934
220	23·038	23·143	23·248	23·353	23·457	23·562	23·667	23·771	23·876	23·981
230	24·086	24·190	24·295	24·400	24·504	24·609	24·714	24·819	24·923	25·028
240	25·133	25·237	25·342	25·447	25·552	25·656	25·761	25·866	25·970	26·075

VELOCITY AT THE CIRCUMFERENCE PER SEC. WITH A GIVEN NUMBER OF REVOLUTIONS (n) PER MIN. FOR THE RADIUS=1 (*continued*).

$$=\frac{2\pi r n}{60}$$

n	0	1	2	3	4	5	6	7	8	9
250	26·180	26·285	26·389	26·494	26·599	26·704	26·808	26·913	27·018	27·122
260	27·227	27·332	27·437	27·541	27·646	27·751	27·855	27·960	28·065	28·170
270	28·274	28·379	28·484	28·588	28·693	28·798	28·903	29·007	29·112	29·217
280	29·322	29·426	29·531	29·636	29·740	29·845	29·950	30·055	30·159	30·264
290	30·369	30·473	30·578	30·683	30·788	30·892	30·997	31·102	31·206	31·311
300	31·416	31·521	31·625	31·730	31·835	31·940	32·044	32·149	32·254	32·358
310	32·463	32·568	32·673	32·777	32·882	32·987	33·091	33·196	33·301	33·406
320	33·510	33·615	33·720	33·824	33·929	34·034	34·139	34·243	34·348	34·453
330	34·558	34·662	34·767	34·872	34·976	35·081	35·186	35·291	35·395	35·500
340	35·605	35·709	35·814	35·919	36·024	36·128	36·233	36·338	36·442	36·547
350	36·652	36·757	36·861	36·966	37·071	37·176	37·280	37·385	37·490	37·594
360	37·699	37·804	37·909	38·013	38·118	38·223	38·327	38·432	38·537	38·642
370	38·746	38·851	38·956	39·060	39·165	39·270	39·375	39·479	39·584	39·689
380	39·794	39·898	40·003	40·108	40·212	40·317	40·422	40·527	40·631	40·736
390	40·841	40·945	41·050	41·155	41·260	41·364	41·469	41·574	41·678	41·783
400	41·888	41·993	42·097	42·202	42·307	42·412	42·516	42·621	42·726	42·330
410	42·935	43·040	43·145	43·249	43·354	43·459	43·563	43·668	43·773	43·878
420	43·982	44·087	44·192	44·296	44·401	44·506	44·611	44·715	44·820	44·925
430	45·029	45·134	45·239	45·344	45·448	45·553	45·658	45·763	45·867	45·972
440	46·077	46·181	46·286	46·391	46·496	46·600	46·705	46·810	46·914	47·019
450	47·124	47·229	47·333	47·438	47·543	47·647	47·752	47·857	47·962	48·066
460	48·171	48·276	48·381	48·485	48·590	48·695	48·799	48·904	49·009	49·114
470	49·218	49·323	49·428	49·532	49·637	49·742	49·847	49·951	50·056	50·161
480	50·265	50·370	50·475	50·580	50·684	50·789	50·894	50·999	51·103	51·208
490	51·313	51·417	51·522	51·627	51·732	51·836	51·941	52·046	52·150	52·255

Example.—A pulley having a radius of 1 foot revolves 45 times per minute: at what velocity does a point on its circumference travel? 4·7124 feet per second.

TABLE OF FALLING BODIES, GIVING THE SPACE FALLEN THROUGH TO ACQUIRE CERTAIN VELOCITIES.

Velocity in Feet per Sec.	Space.		Velocity in Feet per Sec.	Space.		Velocity in Feet per Sec.	Space.	
	Ft.	Ins.		Ft.	Ins.		Ft.	Ins.
1	0	$0\frac{3}{16}$	21	6	10	41	26	1
2	0	$0\frac{3}{4}$	22	7	6	42	27	5
3	0	$1\frac{5}{8}$	23	8	3	43	28	9
4	0	3	24	9	0	44	30	1
5	0	$4\frac{5}{8}$	25	9	9	45	31	5
6	0	$6\frac{3}{4}$	26	10	6	46	32	10
7	0	$9\frac{1}{8}$	27	11	4	47	34	4
8	1	0	28	12	3	48	36	10
9	1	$3\frac{1}{4}$	29	13	0	49	37	4
10	1	$6\frac{3}{4}$	30	14	0	50	38	11
11	1	$10\frac{1}{2}$	31	14	11	52	42	0
12	2	3	32	15	11	54	45	4
13	2	$7\frac{1}{2}$	33	16	11	56	50	0
14	3	$0\frac{3}{4}$	34	18	0	58	52	0
15	3	6	35	19	0	60	56	0
16	4	0	36	20	1	62	59	8
17	4	6	37	21	5	64	63	8
18	5	0	38	22	6	66	67	8
19	5	7	39	23	9	68	72	0
20	6	3	40	24	11	70	76	0

FALLING BODIES.

Time in Seconds.	Whole Space Fallen.		Velocity Acquired, Feet per Second.	Time in Seconds.	Whole Space Fallen.		Velocity Acquired, Feet per Second.
	Ft.	Ins.	Ft.		Ft.	Ins.	Ft.
$\frac{1}{10}$	0	$1\frac{15}{16}$	3·2	$1\frac{1}{10}$	19	$4\frac{3}{8}$	35·2
$\frac{2}{10}$	0	$7\frac{5}{8}$	6·4	$1\frac{2}{10}$	23	$0\frac{1}{2}$	38·4
$\frac{3}{10}$	1	$5\frac{1}{4}$	9·6	$1\frac{3}{10}$	27	$0\frac{1}{2}$	41·6
$\frac{4}{10}$	2	$6\frac{3}{4}$	12·8	$1\frac{4}{10}$	31	$4\frac{3}{8}$	44·8
$\frac{5}{10}$	4	0	16·0	$1\frac{5}{10}$	36	0	48·0
$\frac{6}{10}$	5	$9\frac{1}{8}$	19·2	$1\frac{6}{10}$	41	0	51·2
$\frac{7}{10}$	7	10	22·4	$1\frac{7}{10}$	46	$2\frac{5}{8}$	54·4
$\frac{8}{10}$	10	$2\frac{7}{8}$	25·6	$1\frac{8}{10}$	51	1	57·6
$\frac{9}{10}$	12	$11\frac{1}{2}$	28·8	$1\frac{9}{10}$	57	$9\frac{1}{8}$	60·8
1	16	0	32·0	2	64	0	64·0

MOTORS

Self-acting Inclines.[1]

Let a be the angle of inclination.

C the coefficient of friction of trucks and rope.

W the weight in lbs. of the loaded truck.

w the weight in lbs. of the empty truck.

r the weight of the rope for the length of the incline in lbs.

C′ the coefficient of friction for the drum.

f the amount of resistance due to friction for drum in lbs., or $= 2\ C' \ [(w+r) \sin a + C\,(w+r) \cos a]$.

The coefficient of friction is equal to the tangent of the angle of inclination (also known as "the angle of friction," "the limiting angle of frictional stability," or the "angle of repose"), on which the force exerted by gravity is exactly counterbalanced by the frictional resistance.

When a waggon (W) is placed on an inclined plane, the force with which it tends to move down the plane, disregarding friction, is—

$$W \sin a$$

As the amount of friction equals the pressure multiplied by the coefficient of friction, the amount of friction encountered in moving a waggon (W) on an inclined plane is—

$$WC \cos a.$$

When $W \sin a = WC \cos a$ or $\frac{\sin a}{\cos a} = \tan\ a = C$ the force with which the waggon tends to move downhill is exactly held in equilibrium by the amount of friction. The force with which a loaded waggon tends to move down the plane when the angle of inclination exceeds the angle of friction is—

$$W \sin a - WC \cos a,$$

and under the same conditions, the force with which the empty waggon resists motion up the hill is

$$W \sin a + WC \cos a.$$

The smaller the difference between (W) and (w) the greater the angle of slope required to make a self-acting plane.

One must also consider the weight of the rope and its friction on the rollers of the incline, and the friction on the periphery and axle of the drum round which the rope passes. The principal factors in determining the coefficient of friction for wheeled carriages moving on rails are the ratio of the diameter of the wheel to that of the axle, the quality of the lubricant, and the smoothness of the contact surfaces. Take the coefficient of friction for the rope on the rollers

[1] A. Bowie, "Problems in Hauling and Hoisting." T. Aus. I.M.E., 1901, vol. xxxi, p. 265.

as being the same as that of the waggon, though it should really be a little greater on account of the sag of the rope and the roughness of its surface; the resistance offered by the rope will be continually decreasing as the empty car ascends the plane. The required angle of inclination will increase with the length of the incline.

So long as $W \sin a > (w+r) \sin a + C(W+w+r) \cos a$, the conditions permit a self-acting plane, but when $W \sin a$ is equal to or smaller than the second number of this formula, no motion can be produced by gravity alone.

As the weights for steel ropes are nearly in proportion to their respective safe working strengths, if the load is increased the weight of the rope in the same ratio must also be increased. Therefore the angle sought would be the same for any number of waggons per trip as for one waggon. But if the rope used for a one waggon trip is stronger than necessary, so that additional waggons can be put on without using a heavier rope, then it may be possible to make the plane sufficiently self acting by simply increasing the number of waggons in a set.

As the resistance of the empty waggon and rope to the motion up the plane is—

$$(w+r) \sin a + C(w+r) \cos a$$

the strain executed by the loaded car to move down must be at least equal to this, hence the strain on the drum round which the connecting rope passes must be at least

$$2 \left[(w+r \sin a + C(w+r) \cos a\right].$$

The tangent of angle of minimum grade of a self-acting gravity incline when all resistance of gravity and friction are considered, equals—

$$\frac{C(W+w+r) \times \frac{f}{\cos a}}{W-(w+r)}$$

If there is not much to spare above the necessary grade, there should be a short piece of level track at the bottom of the incline, and, if necessary, a heavier grade at the top, so that the waggons can start easier. It is best practice to have the grade as nearly uniform as possible. Anyhow, there should not be too sudden a change in level, or else the waggon when passing from a steep grade to a lighter one may have the upper wheels lifted off the track by the rope. The frictional resistance encountered in starting from a state of rest may be taken as at about twice the friction of motion. If the grade is made greater at the top and lighter at the bottom, the speed due to acceleration will diminish, as the motive force varies with the size of the angle of inclination; the inertia carries the waggons over the flat portion.

Aerial Ropeways.

In principal these may be classified under five headings.

1. One fixed rope down which carriers run uncontrolled. Suitable for goods that cannot be damaged. No intermediate supports are required; the rope which may be $\frac{1}{2}$ inch diameter is anchored at the top end, and tightened at the lower by a Spanish windlass. The speed may be regulated to a certain extent by the sag of the rope. Has been used for spans up to 7,000 feet.

2. One fixed rope and an endless hauling rope. One carrier is drawn backwards and forwards by an endless rope. The motive-power must have reversing gear. The return hauling rope is supported on a pulley attached to an arm outside each post. Will work on inclines of 1 in 1, and for spans up to 6,000 feet. Can be used for loads up to 5 tons.

3. Two fixed ropes and one hauling rope with a carrier at each end. Worked by gravity, controlled by break gear if grade not less than 15 in 100. Can run at a speed of 30–40 miles per hour when towers are not used, otherwise must reduce speed to 10 miles per hour. Can use spans up to 6,000 feet and loads up to 6 tons. For ordinary work the carrier rope is $\frac{3}{4}$ inch diameter, and the hauling rope $\frac{1}{4}$ inch diameter. Must have a station at every change in direction.

4. Two fixed ropes with an endless hauling rope. The hauling rope is driven from one end and tightened at the other. A series of buckets, weighing when loaded 4 to 14 cwt., are clipped to the hauling rope at intervals of about 130 feet. The carrying rope is from 0·8 to 1·4 inch diameter for full buckets, and 0·6 to 1·2 inch diameter for empties, and last from five to ten years. The hauling rope is 0·63 inch diameter and lasts about eight years. A gradient of 1 in 7 is self-operating. Travels at a speed of $3\frac{1}{2}$ miles per hour. If distances are over 15,000–18,000 feet have intermediate stations, and where distances between stations exceed 8,000 feet have an intermediate tightening gear. May have spans 1,500 feet long. Two men with scoop buckets can load about 6 tons per hour into moving buckets. With automatic loader one man can fill 30 tons an hour. Suitable for quantities between 40 and 80 tons per hour. This system is economical in wear and tear, but first cost is great. The rope should be supported every 50 to 60 yards when possible. Clips may be fixed or adjustable.

5. Endless running rope with carriers hanging therefrom, either loose, fixed, or detachable. Suitable for flat or uneven country. It is advisable to have ropeways in a straight line, but can construct for angles if absolutely necessary. For quantities not exceeding 30 tons an hour. Speed not over 175 feet per minute. Can fill by hand, if not run faster than 2 to $2\frac{1}{2}$ miles an hour.

Work of a Man against Known Resistances.

Kind of Exertion.	R. Lbs.	V. Ft. per Sec.	$\frac{T''}{3600}$ Hours per Day.	R.V. Ft. Lbs. per Sec.	R.V.T. Ft. Lbs. per Day.
1. Raising his own weight up stair or ladder . .	143	0·5	8	72·5	2,088,000
2. Hauling up weights with rope, and lowering the rope unloaded . .	40	0·75	6	30	648,000
3. Lifting weights by hand . .	44	0·55	6	24·2	522,720
4. Carrying weights up stairs and returning unloaded	143	0·13	6	18·5	399,600
5. Shovelling up earth to a height of 5′3″	6	1·3	10	7·8	280,800
6. Wheeling earth in a barrow up slope of 1 in 12 ½ horiz. veloc. 0·9 per ft. sec. and returning unloaded	132	0·075	10	9·9	356,400
7. Pushing or pulling horizontally (capstan or bar) .	26·5	2·0	8	53	1,526,400
8. Turning a crank or winch .	12·5	5·0	?	62·5	...
	18·0	2·5	8	45	1,296,000
	20·0	14·4	2 min.	288	...
9. Working pump .	13·2	2·5	10	33	1,188,000

Seven men are considered equal to one horse.

Work of a Horse against Known Resistances.

In the following table (page 115), R = resistance; V = effective velocity = dist. through which R is overcome ÷ total time occupied, including time of moving unloaded, if any; T'' = time of working, in sec., per day; $\frac{T''}{3600}$, same time, in hours per day; R.V., effective power in foot pounds per second; R.V.T. daily work in foot pounds. A horse should be put down a pit at about five to seven years of age; should travel from fourteen to sixteen miles per day in a fairly level mine at a walking pace, and last about seven years. One horse-keeper is required for twelve horses, or for sixteen ponies. A pony should not be put into the pit under three years of age.

A horse is most efficient at a low speed (two or three miles per hour), and can do 22,000 ft. lbs. per min., or about $\frac{2}{3}$ of a mechanical horse-power.

Three 14-hand ponies = two horses; two small ponies = one horse.

Kind of Exertion.	R. Lbs.	V. Ft. per Sec.	$\frac{T''}{3,600}$ Hours per Day.	R.V. Ft. Lbs. per Sec.	R.V.T. Ft. Lbs. per Day.
1. Cantering and trotting, drawing a light railway carriage (thoroughbred)	min. $22\frac{1}{2}$ mean $30\frac{1}{2}$ max. 50	$14\frac{2}{3}$	4	$447\frac{1}{2}$	6,444,000
2. Horse drawing cart or boat walking (draught horse)	120	3·6	8	432	12,441,600
3. Horse drawing a gin or mill, walking . .	100	3·0	8	300	8,640,000
4. Ditto trotting .	66	6·5	$4\frac{1}{2}$	429	6,950,000

Steam Engines.

Horse Power.—One horse-power = 33,000 foot pounds per minute = 42·75 British thermal units per min.

For the actual horse-power exerted by an engine:—

Let p = the mean effective pressure of steam in lbs. per sq. inch, less 3 pounds per sq. inch frictional allowance.

" A = the area of the cylinder in square inches.

" L = the length of the stroke in feet.

" N = the number of strokes per min. = revolution × 2.

" H.P. = the horse-power.

$$H.P. = \frac{p\,L\,A\,N}{33,000}.$$

In the best class of engines, and with the best steam coal, the average consumption per indicated horse-power per hour should be as follows :—

Compound condensing engine . .	from	$1\frac{1}{2}$ lbs.	to	2 lbs.
Locomotive engines	,,	2	,,	$2\frac{1}{2}$,,
High-pressure non-condensing engines	,,	3	,,	4 ,,

Lubricants.—For light pressure where the temperature is low use mineral or rock oil. Equal parts of lard oil and paraffin make a good lubricant. For very heavy bearings use grease or tallow mixed with oil, or grease and plumbago.

Steam Boilers.

The boiling point of any liquid is that point on the temperature scale when the tension throughout its mass just overcomes the surrounding pressure.

The boiling points of fresh water at different pressures are approximately as follows :—

Under a pressure of	$\frac{1}{8}$	atmosphere	123° F.
,, ,,	$\frac{1}{4}$	,,	150°
,, ,,	$\frac{1}{2}$	,,	179°
,, ,,	1	,,	212°
,, ,,	2	,,	249°
,, ,,	3	,,	273°
,, ,,	4	,,	291°
,, ,,	5	,,	306°
,, ,,	6	,,	319°

To find the Nominal Horse-Power of Boilers.—CORNISH BOILERS :—Add the diameter of boiler and diameter of flue together in feet, multiply the sum by the length in feet, and divide the product by 8.

LANCASHIRE BOILERS :—Add the diameters of both flues and the diameter of the boiler together in feet, multiply the sum by the length in feet, and divide the product by 8.

VERTICAL TUBULAR BOILERS :—Add together the diameter of the shell, the diameter of the fire-box, and the diameters of all the tubes, all in feet; multiply the sum by the length in feet and divide by 12.

The actual horse-power of a boiler can be obtained by calculating the number of cubic feet water evaporated per hour.

To find the Number of Cubic Feet of Water Evaporated per Hour.—Multiply the number of square feet of water surface by the evaporation in inches of gauge glass, multiply the product by 5, and divide the result by the number of minutes occupied in evaporation.

The Lever Safety Valve—

Let P = pressure of steam in lbs. per square inch less atmospheric pressure.

„ L = length of lever from fulcrum to weight, in inches.

„ W = weight of load in pounds.

„ W′ = weight of lever in pounds.

„ W″ = weight of valve in pounds.

„ D = distance of the centre of gravity of the lever from the fulcrum in inches.

„ A = area of valve in square inches.

„ I = length of lever between fulcrum and valve, in inches.

$$P = \frac{\frac{WL}{I} + \frac{W'D}{I} + W''}{A}$$

Weight of a Boiler.—Weight in pounds = surface in square feet × 6 for plates $\frac{1}{8}$ inch thick.

Fuel.

Evaporative Power of Fuels.—The following quantities of fuels will evaporate 9 lbs. water when raised to 212° F.

1 lb. steam coal.	$3\frac{1}{2}$ lbs. brushwood.
2 lbs. dry peat.	$3\frac{3}{4}$ lbs. straw.
$2\frac{1}{2}$ lbs. dry wood.	4 lbs. sugar-cane refuse.
$3\frac{1}{4}$ lbs. cotton stalks.	

The British Thermal Unit is the quantity of heat required to raise 1 lb. of water 1° F. when at its maximum density, *i. e.*, from 39°·1 to 40°·1 F.

To find the Quantity of Water in Pounds Evaporated per Pound of Coal.—Multiply the number of cubic feet water evaporated per hour by 62·5, and divide the product by the quantity of coals consumed per hour.

TABLE SHOWING THE PROPER DIAMETER AND HEIGHT OF A CHIMNEY FOR ANY KIND OF FUEL. (*Armstrong.*)

Nominal Horse-power of Boiler.	Height of Chimney in Feet.	Inside Diameter at Top.		Nominal Horse-power of Boiler.	Height of Chimney in Feet.	Inside Diameter at Top.	
		Ft.	In.			Ft.	In.
10	60	1	6	70	120	3	6
12	75	1	8	90	120	4	0
16	90	1	10	120	135	4	6
20	99	2	0	160	150	5	0
30	105	2	6	200	165	5	6
50	120	3	0	250	180	6	0

The area of stacks for stationary boilers that have no other source of draught should be one-fifth greater than the total area of all the flues or tubes.

PRESSURES IN ATMOSPHERES.

Atmospheres.	Lbs. on the Square Inch.	Lbs. on the Square Foot.	Kilogrammes on the Square Metre.	Millimetres of Mercury.	Inches of Mercury.	Feet of Water.
1	14·7	2116	10333	760	29·922	33·9
2	29·4	4233	20666	1520	59·844	67·8
3	44·1	6349	30999	2280	89·765	101·7
4	58·8	8465	41332	3040	119·687	135·6
5	73·5	10581	51665	3800	149·609	169·5
6	88·2	12698	61998	4560	179·531	203·4
7	102·9	14814	72331	5320	209·453	237·3
8	117·6	16930	82664	6080	239·374	271·2
9	132·3	19047	92997	6840	269·296	305·1
10	147·0	21163	103330	7600	299·218	339·0

TRANSMISSION OF POWER.

Belting.

Castor oil is the best preservative for leather.

Driving-belts should be washed with warm water and greased three or four times a year. A good leather grease may be made from 4 parts fish oil ; 1 part lard or tallow ; 1 part calophonium ; 1 part wood tar.

If a belt is dry or husky, should grease it with a mixture of neatsfoot oil and tallow, and dried in by the heat of the fire or sun.

Leather belts with the grain side to the pulley can drive 34°/ₒ more than the flesh side.

When practicable, the driving half of horizontal belts should be the lower half, as, when the belt stretches, the upper half will cover more of the pulley's surface. Long horizontal belts are better than short ones, as their weight increases their contact with the pulley.

Belts running on pulleys perpendicular to each other should be kept tightly strained, as their weight tends to decrease their contact with the lower pulley. The full stretch of a belt is at least 2°/ₒ or about 1 inch in 4 feet.

To calculate the width of belts required for transmitting different numbers of horse-power :—

Let n = number of horse-power.
v = length in feet the belt is to travel per minute.
s = feet or parts of a foot of belt in contact with smaller pulley.
w = width of belt in inches.

$$w = \frac{\frac{36{,}000 \times n}{v}}{\frac{s}{6}}$$

To calculate the number of horse-power a belt will transmit :

Let v = its velocity in feet per minute.
s = number of square inches in contact with the smaller pulley.
n = number of horse-power the belt will transmit.

$$n = \frac{\frac{s}{2} \times v}{36{,}000}$$

Cotton belting is made 4-ply from 1″ to 6″, 6-ply from 3″ to 12″, 8-ply 6″ to 30″, and 10-ply one to five feet wide.

Single leather belts are used for drums under 2½ feet diameter, and double belts over that diameter; more than two-fold leather is not used.

For the transmission of each horse-power there should be :—

45 superficial inches in contact with the smaller pulley in leather.
50 „ „ „ „ india-rubber.
25–30 „ „ „ „ cotton belting.

Leather belts on smooth iron drums slip about . . .	3°/ₒ
Rubber „ „ „ „ . .	12°/ₒ
Cotton „ „ „ „ . .	25–30°/ₒ

Speeding of Machinery.

Speeding by Pulleys—

Let V = velocity or number of revolutions per minute of the driving pulley.
v = velocity or number of revolutions per minute of the driven pulley.
D = diameter in inches of driving pulley.
d = diameter in inches of driven pulley.

Then $v = \frac{VD}{d}$; $V = \frac{vd}{D}$; $d = \frac{VD}{v}$; $D = \frac{vd}{V}$.

Speeding by Wheels—

Let N = number of teeth in driving wheel.
n = number of teeth in driven wheel.
V = velocity or number of revolutions of driving wheel.
v = veloc. or no. of revolutions of driven wheel per min.

Then $v = \frac{NV}{n}$; $V = \frac{nv}{N}$; $n = \frac{NV}{v}$; $N = \frac{nv}{V}$.

HYDRAULICS.

GREATEST VELOCITIES OF CURRENT CLOSE TO THE BED OF A STREAM CONSISTENT WITH THE STABILITY OF THE MATERIAL OVER WHICH THE WATER FLOWS.

	Ft. per Sec.		Ft. per Sec.
River mud, liquid earth	·25	Large shingle . .	3·00
Common clay, loam .	·50	Broken stones . . .	4·00
River sand . . .	1·00	Soft Schistose rock .	4·50
Gravel, size of beans .	1·50	Rocks with distinct layers	6·00
„ 1 inch . . .	2·00	Hard rocks . . .	10·00

The mean velocities of current will be about 1⅓ times the velocities given above.

TABLE SHOWING THE PROPER ANGLE FOR THE SIDES OF AQUEDUCTS OF DIFFERENT MATERIAL, AND THE RATE OF FLOW THAT SHOULD NOT BE EXCEEDED.

Nature of Sides of Aqueduct.	Angle of Sides.	Maximum Rate of Flow.
	Degrees.	
Brickwork, masonry, or solid rock	90	5 feet to 10 feet per second.
Stone without mortar .	60	4 feet per second.
Clay	45	...
Coarse gravel	40	3 feet per second.
Fine "	35	2 feet per second.
Sand	30	1 foot per second.
Ordinary soil	20	3 inches per second.

Water flows quicker over hard than soft material. The flow should be at least 1 to 1½ feet per second to prevent deposits or growth of plants.

TABLE SHOWING VELOCITIES OF WATER IN CHANNELS IN EARTH FOR VARIOUS SLOPES AND HYDRAULIC MEAN DEPTHS, THE HYDRAULIC MEAN DEPTH BEING THE SECTIONAL AREA OF WATERWAY DIVIDED BY THE WETTED BORDER OF THE CHANNEL.

Hydraulic Mean Depth.	Fall per Mile.							
	6 Ins.	9 Ins.	12 Ins.	18 Ins.	24 Ins.	30 Ins.	36 Ins.	48 Ins.
	Ft. per Min.	Ft. per Min.	Ft. per Min.	Ft. per Min.	Ft. per Min.	Ft. per Min.	Ft. per Min.	Ft. per Min.
·5	...	...	...	...	36·7	41·3	45·5	52·8
·75	...	...	35·0	43·6	50·8	57·2	62·8	72·9
1·00	...	37·7	44·1	54·8	63·7	71·6	78·6	91·0
1·25	36·2	45·1	52·6	65·1	75·6	84·9	93·2	108·0
1·50	41·8	52·0	60·6	74·8	86·8	97·3	106·8	123·7
1·75	47·3	58·6	68·1	84·0	97·4	109·1	119·7	
2·00	52·5	64·9	75·3	92·8	107·5	120·4		
2·50	62·4	76·8	88·9	109·2	126·3			
3·00	71·6	87·8	101·8	124·5				
3·50	80·4	98·3	113·5					
4·00	88·7	108·3	124·8					
5·00	104·4	126·9						
6·00	118·9							

Velocity of Efflux.—V = velocity in feet per second; H = head of water in feet, then :—$V = \sqrt{H} \times 8$.

Discharge in Gallons.—G = gallons discharged per minute; H = head of water in feet; d = diameter of orifice in inches, then :—$G = \sqrt{H} \times d^2 \times 16{\cdot}3$.

The above being the *theoretical* velocities discharged require modification according to the particular form of orifice.

TABLE OF THE THEORETICAL DISCHARGE OF WATER BY ROUND APERTURES OF VARIOUS DIAMETERS, AND UNDER DIFFERENT HEADS OF WATER PRESSURE (*Box.*)

Diam. in Inches.	Head of Water in Inches.								
	1	2	3	4	5	6	7	8	9
	Discharge in Gallons per Minute.								
1	4·7	6·6	8·1	9·4	10·5	11·5	12·4	13·3	14·1
2	18·8	26·4	32·4	37·6	42·0	46·0	49·6	53·2	56·4
3	42·2	59·4	72·9	84·6	94·5	103	112	120	127
4	75·2	106	130	150	168	184	198	213	225
5	117	165	203	235	262	287	310	332	352
6	169	237	291	338	378	414	446	479	507
7	230	310	397	460	514	563	607	652	691
8	301	422	518	601	672	736	793	851	902
9	381	534	656	761	850	931	1006	1077	1142
10	470	660	810	940	1050	1150	1240	1330	1411
12	676	952	1168	1353	1512	1656	1785	1915	2030
14	920	1241	1588	1842	2058	2254	2430	2606	2764
16	1203	1690	2074	2406	2688	2944	3174	3405	3610
18	1523	2138	2624	3045	3402	3726	4018	4309	4568
20	1880	2640	3240	3760	4200	4600	4960	5320	5640
22	2275	3194	3920	4550	5082	5566	6002	6437	6824
24	2704	3808	4672	5414	6048	6624	7140	7660	8120
30	4230	5940	7290	8460	9450	10350	11160	11970	12690
Vel. in ft. per sec.	2·32	3·275	4·01	4·63	5·18	5·67	6·13	6·55	6·95

TABLE OF THE THEORETICAL DISCHARGE OF WATER BY ROUND APERTURES OF VARIOUS DIAMETERS, AND UNDER DIFFERENT HEADS OF WATER PRESSURE (*continued*).

Diam. in Inches.	Head of Water in Inches.							
	10	12	14	16	18	20	22	24
	Discharge in Gallons per Minute.							
1	14·8	16·2	17·6	18·8	19·9	21	22	23
2	59·2	64·8	70·4	75·2	79·6	84	88	92
3	133	146	158	169	179	189	198	207
4	237	259	281	301	318	336	352	368
5	370	405	440	470	497	525	550	575
6	533	583	663	677	716	756	792	828
7	725	794	862	921	975	1029	1078	1127
8	947	1037	1126	1203	1273	1344	1408	1472
9	1199	1312	1425	1523	1612	1701	1782	1863
10	1480	1620	1760	1880	1990	2100	2200	2300
12	2134	2333	2534	2707	2865	3024	3170	3312
14	2901	3175	3450	3684	3900	4116	4312	4508
16	3789	4147	4506	4813	5094	5376	5632	5888
18	4795	5249	5702	6091	6447	6804	7128	7452
20	5920	6480	7040	7520	7960	8400	8800	9200
22	7163	7841	8518	9099	9632	10164	10648	11132
24	8536	9332	10136	10829	11460	12096	12680	13248
30	13320	14580	15840	16920	17910	18900	19800	20700
Vel. in ft. per sec.	7·32	8·03	8·67	9·27	9·83	10·36	10·87	11·35

Example.—Find the theoretical discharge, through an aperture 8″ in diameter, under a head of 18″. *Ans.* 1273 gallons per minute.

Discharge through an Orifice in a Thin Plate.—The stream contracts at a distance from the plate of half the diameter of the orifice, and its diameter is 0·784, that of the orifice being 1.

$$G = \sqrt{H} \times d^2 \times 10.$$

$$H = \left(\frac{G}{d^2 \times 10}\right)^2.$$

$$d = \left(\frac{G}{\sqrt{H} \times 10}\right)^{\frac{1}{2}}$$

Discharge by Short Tubes when not less than twice the diameter of the orifice gives a greater discharge than thin plates. Used for calculating the miner's inch.

$$G = \sqrt{H} \times d^2 \times 13.$$

$$H = \left(\frac{G}{d^2 \times 13}\right)^2.$$

$$d = \left(\frac{G}{\sqrt{H} \times 13}\right)^{\frac{1}{2}}$$

Friction of Long Pipes.—To calculate the loss of head by friction :—

Let d = diameter of pipe in inches. L = length of pipe in yards. H = head of water in feet. G = gallons per minute.

$$G = \left(\frac{(3d)^5 \times H}{L}\right)^{\frac{1}{2}}.$$

$$H = \frac{G^2 \times L}{(3d)^5}.$$

$$d = \left(\frac{G^2 \times L}{H}\right)^{\frac{1}{5}} \div 3$$

$$L = \frac{(3d)^5 \times H}{G^2}.$$

Loss of Head by Bends.—Let H = head due to change of direction in inches. r = radius of the bore of the pipe in inches. R = radius of the centre line of the bend, in inches. ϕ = angle of bend in degrees. V = velocity of discharge in feet per second.

$$H = \left\{0{\cdot}131 + (1{\cdot}847 \times \left(\frac{r}{R}\right)^{\frac{7}{2}}\right\} \times \frac{V^2 \times \phi}{960}.$$

$$V^2 = \frac{960 \times H}{\phi \times \left\{0{\cdot}131 + (1{\cdot}847 \times \left(\frac{r}{R}\right)^{\frac{7}{2}}\right\}}$$

TABLE OF THE ACTUAL DISCHARGE BY SHORT TUBES OF VARIOUS DIAMETERS, WITH SQUARE EDGES AND UNDER DIFFERENT HEADS OF WATER PRESSURE, BEING EIGHT-TENTHS OF THE THEORETICAL DISCHARGE. (*Box.*)

Diam. in Inches.	Head of Water in Inches.																
	1	2	3	4	5	6	7	8	9	10	12	14	16	18	20	22	24
	Discharge in Gallons per Minute.																
1	3·76	5·28	6·48	7·52	8·4	9·2	9·9	10·6	11·3	11·8	13·0	14·1	15·0	15·9	16·8	17·6	18·4
2	15·04	21·12	25·9	30·1	33·6	36·8	39·7	42·6	45·1	47·4	51·8	56·3	60·2	63·7	67·2	70·4	73·6
3	33·8	47·5	58·3	67·7	75·6	82·4	89·6	96·0	101·6	106·4	116·8	126	135	143	151	158	166
4	60·2	84·8	104	120	130	147	158	170	180	189	207	225	241	254	269	282	294
5	93·6	132	162	188	210	230	248	266	282	296	324	352	376	398	420	440	460
6	135	190	233	270	302	331	357	382	406	426	466	530	542	573	605	634	662
7	194	248	318	368	411	450	486	522	553	580	636	689	737	780	823	862	902
8	241	338	414	481	538	589	634	681	722	758	829	901	962	1018	1075	1126	1178
9	305	427	525	609	680	745	805	863	914	959	1049	1140	1218	1290	1361	1426	1490
10	376	528	648	752	840	920	992	1064	1129	1184	1296	1408	1504	1592	1680	1760	1840
12	541	762	934	1082	1210	1325	1428	1532	1624	1707	1866	2027	2166	2292	2419	2536	2650
14	736	993	1268	1474	1646	1803	1944	2085	2211	2321	2540	2760	2947	3120	3293	3450	3606
15	846	1188	1458	1692	1890	2070	2232	2394	2288	2664	2916	3168	3384	3582	3780	3960	4140
16	962	1352	1659	1925	2150	2355	2539	2724	2888	3031	3318	3605	3850	4075	4301	4406	4710
18	1218	1710	2099	2436	2722	2981	3214	3447	3662	3836	4199	4562	4873	5158	5443	5702	5962
20	1504	2112	2592	3008	3360	3680	3968	4256	4512	4736	5184	5632	6016	6368	6720	7040	7360
22	1820	2552	3136	3640	4065	4452	4801	5149	5459	5730	6272	6814	7279	7705	8131	8518	8905
24	2163	3046	3737	4331	4838	5299	5712	6128	6496	6828	7465	8108	8663	9168	9676	10144	10598
30	3384	4752	5832	6768	7560	8280	8928	9576	10152	10656	11664	12672	13536	14328	15120	15840	16560

TABLE FOR BENDS IN WATER PIPES SHOWING THE LOSS OF HEAD DUE TO CHANGE OF DIRECTION BY ONE BEND OF 90°. (*Box.*)

Diam. of the Pipe in Inches.	Radius of Centre Line of Bend in Inches.	Head of Water in Inches Lost by One Bend of 90°.														
		$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{4}$	1	$1\frac{1}{2}$	2	3	4	5	6	9	12	18	24
		Gallons Discharged per Minute.														
2	12	25	36	51	63	73	81	103	126	146	163	179	219	252	309	358
3	12	58	83	117	144	166	203	235	288	332	371	407	498	576	705	814
4	12	102	145	205	252	291	356	411	504	582	650	713	873	1008	1233	1426
5	18	162	229	324	396	458	561	648	793	916	1024	1122	1374	1586	1944	2244
6	18	232	328	464	568	656	803	928	1136	1312	1467	1607	1968	2272	2784	3124
7	18	309	437	618	757	874	1070	1236	1514	1748	1954	2141	2622	3028	3708	4282
8	18	402	568	804	985	1137	1393	1608	1970	2274	2542	2786	3411	3940	4824	5572
9	18	501	709	1002	1228	1418	1737	2005	2456	2836	3170	3474	4254	4912	6015	6948
10	18	606	857	1212	1484	1714	2100	2424	2968	3428	3832	4199	5142	5936	7272	8398
12	21	866	1225	1733	2122	2451	3003	3466	4245	4902	5480	6005	7353	8490	10398	12010
15	24	1317	1864	2635	3228	3728	4567	5271	6457	7456	8336	9134	11184	12914	15813	18268
18	27	1857	2626	3714	4549	5253	6435	7428	9098	10506	11745	12870	15759	18196	22284	25740
21	30	2467	3490	4935	6044	6980	8550	9870	12089	13960	15607	17100	20940	24178	29610	34200
24	33	3165	4477	6330	7754	8954	10968	12661	15508	17908	20021	21937	26862	31016	37983	43870

TABLE FOR QUICK BENDS.

Diam. of the Pipe in Inches.	Radius of Centre Line of Bend in Inches.	Head of Water in Inches Lost by One Bend of 90°.														
		1/8	1/4	1/2	3/4	1	1½	2	3	4	5	6	9	12	18	24
		Gallons Discharged per Minute.														
2	3	23	32	46	56	65	79	92	112	130	145	159	195	214	276	318
3	3½	44	63	89	109	126	154	178	218	252	282	309	378	436	534	618
4	4	69	98	139	170	197	241	278	341	394	440	480	591	682	834	966
5	4½	96	136	172	236	272	333	385	472	544	608	666	816	944	1155	1332
6	5	128	181	256	314	362	443	512	629	724	809	886	1086	1258	1536	1774
7	5½	161	229	322	396	458	561	645	793	917	1024	1122	1374	1586	1935	2244
8	6	199	281	398	487	563	689	796	975	1126	1259	1379	1689	1950	2388	2758

Example.—A 6-inch pipe with a bend having a radius of 18 inches, which discharges 1,607 gallons per minute, consumes 6 inches of head.

Example.—A 6-inch pipe with a bend having a radius of 5 inches, which discharges 1,536 gallons per minute, consumes 18 inches of head.

The above table, although arranged for quarter bends or angles of 90°, is applicable to any other angle, the radius being the same, as the head is proportional to the angle; thus, a half quarter bend, *i.e.*, angle of 45°, consumes half the head of a bend of 90°, and a bend of 180° takes double, &c.

Table of the Discharge of Pipes by Prony's Formula.

$\frac{H \times d}{L}$.	Velocity in Feet per Second.	Diameter of the Pipe in Inches. Gallons Discharged per Minute. 1	1½	2	2½	3	3½	4
·00002402	·025	·0511	·1150	·2045	·3196	·4602	·6260	·8180
·00005437	·05	·1022	·2301	·4091	·6392	·9204	1·252	1·636
·00009108	·075	·1534	·3450	·6136	·9588	1·381	1·878	2·454
·0001341	·100	·2045	·4602	·8182	1·278	1·841	2·504	3·273
·0001836	·125	·2556	·5750	1·023	1·598	2·301	3·130	4·090
·0002394	·15	·3067	·6900	1·227	1·917	2·761	3·756	4·908
·0003016	·175	·3578	·8053	1·432	2·237	3·221	4·382	5·728
·0003702	·2	·4090	·9204	1·636	2·557	3·682	5·008	6·546
·0004452	·225	·4601	1·035	1·841	2·876	4·142	5·634	7·363
·0005266	·25	·5112	1·150	2·045	3·196	4·602	6·260	8·180
·0006140	·275	·5624	1·265	2·250	3·515	5·062	6·886	9·000
·0007080	·3	·6135	1·381	2·454	3·835	5·522	7·512	9·819
·0008087	·325	·6646	1·496	2·659	4·154	5·982	8·138	10·64
·0009154	·35	·7157	1·611	2·864	4·474	6·443	8·764	11·46
·0010286	·375	·7669	1·726	3·068	4·794	6·903	9·390	12·27
·0011480	·4	·8180	1·841	3·273	5·113	7·363	10·02	13·09
·001274	·425	·8691	1·955	3·477	5·433	7·823	10·64	13·91
·001406	·45	·9202	2·071	3·682	5·757	8·284	11·27	14·73
·001545	·475	·9713	2·186	3·886	6·077	8·744	11·89	15·55
·001690	·5	1·023	2·301	4·091	6·392	9·204	12·52	16·37
·002	·55	1·125	2·531	4·500	7·031	10·12	13·77	18·00
·00233	·6	1·227	2·761	4·909	7·670	11·04	15·02	19·64
·002693	·65	1·329	2·991	5·318	8·309	11·96	16·28	21·27
·003079	·7	1·431	3·221	5·727	8·948	12·88	17·53	22·91
·003490	·75	1·533	3·450	6·136	9·588	13·81	18·78	24·54
·003926	·8	1·636	3·682	6·544	10·23	14·73	20·03	26·18
·004388	·85	1·738	3·912	6·954	10·86	15·65	21·29	27·82
·004876	·9	1·841	4·142	7·363	11·51	16·57	22·53	29·46
·005928	1·0	2·045	4·602	8·182	12·78	18·41	25·04	32·73
·00648	1·05	2·147	4·832	8·591	13·42	19·33	26·29	34·37
·00708	1·1	2·249	5·062	9·000	14·06	20·25	27·54	36·00
·007691	1·15	2·351	5·292	9·409	14·70	21·15	28·80	37·64
·008338	1·2	2·454	5·522	9·818	15·34	22·09	30·05	39·28
·009	1·25	2·556	5·753	10·23	15·98	23·01	31·30	40·91
·009694	1·3	2·658	5·983	10·64	16·62	23·93	32·55	42·55
·010407	1·35	2·761	6·213	11·04	17·26	24·85	33·80	44·18
·01115	1·4	2·863	6·443	11·45	17·90	25·77	35·06	45·82
·01192	1·45	2·965	6·673	11·86	18·53	26·69	36·31	47·46
·0127	1·5	3·067	6·900	12·27	19·18	27·61	37·56	49·08

TABLE OF THE DISCHARGE OF PIPES BY PRONY'S FORMULA (*continued*).

$\frac{H \times d}{L}$.	Velocity in Feet per Second.	Diameter of the Pipe in Inches. 5	6	7	8	9	10	12
		Gallons Discharged per Minute.						
·00002402	·025	1·278	1·841	2·504	3·272	4·142	5·113	7·362
·00005437	·05	2·556	3·682	5·008	6·544	8·284	10·23	14·72
·00009108	·075	3·834	5·523	7·512	9·816	12·43	15·34	22·09
·0001341	·100	5·113	7·363	10·02	13·09	16·57	20·45	29·45
·0001836	·125	6·390	9·205	12·52	16·36	20·71	25·57	36·81
·0002394	·15	7·668	11·05	15·02	19·63	24·85	30·67	44·17
·0003016	·175	8·947	12·88	17·53	22·95	28·99	35·79	51·53
·0003702	·2	10·23	14·73	20·03	26·18	33·13	40·91	58·90
·0004452	·225	11·50	16·57	22·54	29·45	37·28	46·02	66·26
·0005266	·25	12·78	18·41	25·04	32·72	41·42	51·13	73·62
·0006140	·275	14·06	20·25	27·54	36·00	45·56	56·25	80·98
·0007080	·3	15·34	22·09	30·05	39·27	49·70	61·36	88·35
·0008087	·325	16·62	23·93	32·55	42·54	53·84	66·46	95·71
·0009154	·35	17·89	25·77	35·06	45·81	57·98	71·59	103·1
·0010286	·375	19·17	27·61	37·56	49·08	62·13	76·69	110·4
·0011480	·4	20·45	29·45	40·06	52·36	66·27	81·81	117·8
·001274	·425	21·73	31·29	42·57	55·63	70·41	86·94	125·2
·001406	·45	23·01	33·13	45·07	58·90	74·55	92·03	132·5
·001545	·475	24·29	34·97	47·58	62·17	78·70	97·14	139·8
·001690	·5	25·57	36·82	50·08	65·45	82·83	102·3	147·2
·002	·55	28·12	40·50	55·09	72·00	91·12	112·5	162·0
·00233	·6	30·68	44·18	60·10	78·54	99·40	122·7	176·7
·002693	·65	33·23	47·86	65·10	85·08	107·7	132·9	191·4
·003079	·7	35·79	51·54	70·11	91·63	116·0	143·2	206·1
·003490	·75	38·34	55·23	75·12	98·16	124·3	153·4	220·9
·003926	·8	40·90	58·90	80·13	104·7	132·5	163·6	235·6
·004388	·85	43·46	62·59	85·14	111·3	140·8	173·8	250·3
·004876	·9	46·02	66·27	90·14	117·8	149·1	184·2	265·1
·005928	1·0	51·13	73·63	100·2	130·9	165·7	204·5	294·5
·00648	1·05	53·69	77·31	105·2	137·4	174·0	214·7	309·2
·00708	1·1	56·24	80·99	110·2	144·0	182·2	224·9	324·0
·007691	1·15	58·80	84·67	115·2	150·5	190·5	235·2	338·7
·008338	1·2	61·36	88·36	120·2	157·1	198·8	245·4	353·4
·009	1·25	63·91	92·04	125·2	163·6	207·1	255·7	368·1
·009694	1·3	66·47	95·72	130·2	170·2	215·4	265·9	382·8
·010407	1·35	69·02	99·40	135·2	176·7	223·6	276·1	397·6
·01115	1·4	71·58	103·1	140·2	183·3	231·9	286·4	412·3
·01192	1·45	74·14	106·8	145·2	189·8	240·2	296·6	427·0
·0127	1·5	76·68	110·5	150·2	196·3	248·5	306·8	441·7

TABLE OF THE DISCHARGE OF PIPES BY PRONY'S FORMULA (*continued*).

$\frac{H \times d}{L}$.	Velocity in Feet per Second.	Diameter of the Pipe in Inches.						
		14	15	16	18	20	21	24
		Gallons Discharged per Minute.						
·00002402	·025	10·02	11·50	13·09	16·56	20·45	22·53	29·45
·00005437	·05	20·03	23·00	26·18	33·12	40·91	45·07	58·90
·00009108	·075	30·05	34·50	39·27	49·68	61·36	67·61	88·35
·0001341	·100	40·06	46·02	52·36	66·23	81·81	90·14	117·8
·0001836	·125	50·08	57·50	65·45	82·80	102·3	112·7	147·3
·0002394	·15	60·10	69·00	78·54	99·36	122·7	135·2	176·7
·0003016	·175	70·11	80·54	91·63	115·9	143·2	157·7	206·1
·0003702	·2	80·13	92·04	104·7	132·5	163·6	180·3	235·6
·0004452	·225	90·14	103·5	117·8	149·0	184·1	202·8	265·1
·0005266	·25	100·2	115·0	130·9	165·6	204·5	225·3	294·5
·0006140	·275	110·2	126·5	144·0	182·1	225·0	247·9	323·9
·0007080	·3	120·2	138·1	157·1	198·7	245·4	270·4	353·4
·0008087	·325	130·2	149·6	170·2	215·2	265·9	293·0	382·8
·0009154	·35	140·2	161·1	183·3	231·8	286·4	315·5	412·3
·0010286	·375	150·2	172·6	196·4	248·4	306·8	338·0	441·7
·0011480	·4	160·2	184·1	209·4	264·9	327·2	360·6	471·2
·001274	·425	170·3	195·6	222·5	281·5	347·7	383·1	500·6
·001406	·45	180·3	207·1	235·6	298·0	368·2	405·6	530·1
·001545	·475	190·3	218·6	248·7	314·6	388·6	428·2	559·5
·001690	·5	200·3	230·1	261·8	331·1	409·1	450·7	589·0
·002	·55	220·3	253·0	288·0	364·3	450·0	495·8	647·9
·00233	·6	240·4	276·1	314·2	397·4	490·9	540·8	706·8
·002693	·65	260·4	299·1	340·3	430·5	531·8	585·9	765·7
·003079	·7	280·5	322·1	366·5	463·6	572·7	631·0	824·6
·003490	·75	300·5	345·0	392·7	496·8	613·6	676·0	883·5
·003926	·8	320·5	368·2	418·9	529·8	654·5	721·1	942·4
·004388	·85	340·5	391·2	445·1	563·0	695·4	766·2	1001
·004876	·9	360·6	414·2	471·2	596·1	736·3	811·3	1060
·005928	1·0	400·6	460·0	523·6	662·3	818·1	901·4	1178
·00648	1·05	420·6	483·0	549·8	695·4	859·0	946·5	1237
·00708	1·1	440·6	506·0	576·0	728·5	900·0	991·6	1296
.007691	1·15	460·7	529·0	602·1	761·6	940·9	1037	1355
·008338	1·2	480·7	552·2	628·3	794·8	981·9	1082	1414
·009	1·25	500·8	575·2	654·5	827·9	1023	1127	1472
·009694	1·3	520·8	598·2	680·7	861·0	1064	1172	1531
·010407	1·35	540·8	621·3	706·9	894·1	1104	1217	1590
·01115	1·4	560·9	644·3	733·0	927·2	1145	1262	1649
·01192	1·45	580·9	667·3	759·2	960·3	1186	1307	1708
·0127	1·5	601·0	690·0	785·4	993·6	1227	1352	1767

Effect of Contour of Section.—The hydraulic mean gradient corresponds to a straight line drawn between the points of entry and exit of a pipe. No loss of effect will arise from the pipe following the section of the ground, so long as the contour of the pipe does not anywhere along the line rise above the hydraulic mean gradient. Where it is necessary to conduct water over a hill above the hydraulic mean gradient, but below the top of the pipe, the first section of piping, having a low head, must be of a greater diameter than the subsequent section, which has a greater head.

General Laws for Pipes.—When the diameter and length are constant, the discharge varies directly as the square root of the head. Conversely, the head is directly as the square of the discharge.

When the head and length are constant, the discharge is directly as the 2·5 power of the diameter. Conversely, the diameter will vary directly as the 2·5 root of the discharge.

When the discharge and length are constant, the head will be inversely as the 5th power of the diameter. Conversely, the diameter will be inversely as the 5th root of the head.

When the head and diameter are constant, the discharge will be inversely as the square root of the length. Conversely, the length varies inversely as the square of the discharge.

When discharge and diameter are constant, the head is directly and simply as the length.

Head for very Low Velocities.—Prony's Rule. Let d= diameter of the pipe inches. H=head of water in inches. L=length of pipe in feet. G=gallons per minute.

$$G = \left(\left(16{\cdot}353 \times \frac{H \times d}{L} + 0{\cdot}00665\right)^{\frac{1}{2}} - 0{\cdot}0816 \right) \times d^2 \times 2{\cdot}04.$$

$$H = \frac{\left(\left(\frac{G}{2{\cdot}04 \times d^2} + 0{\cdot}0816 \right)^2 - 0{\cdot}00665 \right) \times \frac{L}{d}}{16{\cdot}353}$$

Head due to Velocity in Open Channels.—When a stream leaves a reservoir by a channel the bottom of which is level with that of the reservoir, and its entrance is well rounded, the velocity is 0·96 of that due to gravity; but if the sides of the inlet opening are square, the velocity will be 0·86 of that due to gravity. With an opening in a sluice gate of small thickness, the head of water being above the lower edge of the gate, the velocity is only 0·635 of that due to gravity. In the case of a weir, the contraction occurring on three sides only, the co-efficient rises to 0·667.

TABLE OF THE VELOCITIES IN FEET PER SECOND DUE TO GIVEN HEADS. (BOX.)

Head in Inches.	A. Coef. 1·0.	B. Coef. 0·96.	C. Coef. 0·86.	D. Coef. 0·635.	Head in Inches.	A. Coef. 1·0	B. Coef. 0·96.	C. Coef. 0·86.	D. Coef. 0·635.
$\frac{1}{64}$	·29	·2784	·2494	·18415	1	2·317	2·2224	1·9930	1·4713
$\frac{1}{32}$	·41	·3936	·3524	·2603	$1\frac{1}{4}$	2·590	2·4864	2·2270	1·6446
$\frac{1}{16}$	·58	·5568	·4988	·3683	$1\frac{1}{2}$	2·837	2·7235	2·4398	1·8015
$\frac{1}{8}$	·82	·7872	·7052	·5207	$1\frac{3}{4}$	3·065	2·9424	2·6360	1·9463
$\frac{3}{16}$	1·0	·9600	·8600	·6350	2	3·276	3·145	2·8174	2·0803
$\frac{1}{4}$	1·158	1·1117	·9959	·7353	$2\frac{1}{4}$	3·475	3·336	2·9885	2·2066
$\frac{5}{16}$	1·295	1·2432	1·1140	·8223	$2\frac{1}{2}$	3·663	3·516	3·1502	2·3260
$\frac{3}{8}$	1·418	1·3613	1·2195	·9004	$2\frac{3}{4}$	3·842	3·688	3·3041	2·4397
$\frac{7}{16}$	1·532	1·4707	1·3175	·9728	3	4·012	3·851	3·4503	2·5476
$\frac{1}{2}$	1·638	1·5725	1·4087	1·0401	$3\frac{1}{4}$	4·176	4·009	3·5914	2·6517
$\frac{9}{16}$	1·737	1·6675	1·4938	1·1030	$3\frac{1}{2}$	4·334	4·161	3·7272	2·7521
$\frac{5}{8}$	1·831	1·7577	1·5747	1·1627	$3\frac{3}{4}$	4·486	4·306	3·8580	2·8486
$\frac{11}{16}$	1·921	1·8442	1·652	1·2198	4	4·633	4·448	3·9844	2·9420
$\frac{3}{4}$	2·006	1·9258	1·725	1·2738	$4\frac{1}{2}$	4·914	4·717	4·2260	3·1204
$\frac{13}{16}$	2·088	2·0045	1·796	1·3259	5	5·180	4·973	4·455	3·2893
$\frac{7}{8}$	2·167	2·0803	1·863	1·376	$5\frac{1}{2}$	5·433	5·216	4·672	3·450
$\frac{15}{16}$	2·243	2·1533	1·929	1·424	6	5·675	5·448	4·881	3·6036

Discharge of Water Courses. Find the maximum central surface velocity by means of a float, take 84°/ₒ of this for the mean velocity throughout the section, multiply this by the sectional area for the discharge per cubic foot.

Head to overcome Friction of Channel. Let L = length of channel in yards. A = cross sectional area of the stream in square feet. P = the perimeter, or wetted border in feet. F = the fall, or difference of level at the two ends of the channel in inches. C = cubic feet discharged per minute.

$$F = \frac{\left(\frac{C}{A}\right)^2 \times L \times P}{874520 \times A}; \qquad C = \left(\frac{874520 \times F \times A}{L \times P}\right)^{\frac{1}{2}} \times A.$$

Submerged Openings.—The velocity of discharge through a submerged opening is governed by the difference of the level of water at the two sides of it, or by the head, and is not affected by the depth below the surface at which it is placed.

Head for Low Velocities.

Let V = mean velocity over the whole area in feet per second.

R = the hydraulic radius in feet, or $\frac{\text{area in square feet}}{\text{border in feet}}$.

S = the slope, or $\frac{\text{fall in inches}}{\text{length in inches}}$.

$$\frac{(V + 0{\cdot}1089)^2 - 0{\cdot}0118858}{8975} = R.S.$$

To find the Velocity—

$$\frac{\text{Area of channel in square feet} \times \text{fall in inches}}{\text{Border in feet} \times \text{length of the channel in inches}}$$

find the nearest number thereto in column B of the following Table, and opposite to that number in column A is the required velocity.

To find the Fall in inches—

$$\frac{\text{The given discharge}}{\text{The given area} \times 60} = \text{mean velocity in feet per second.}$$

$$\frac{\text{Nearest number to velocity in feet per second in column A} \times \text{border in feet} \times \text{length of channel in inches}}{\text{area in square feet.}}$$

FOR THE DISCHARGE OF CANALS, RIVERS, ETC., BY EYTELWEIN'S RULE.

Mean Velocity in Feet per Second.	R. S.	Mean Velocity in Feet per Second.	R. S.	Mean Velocity in Feet per Second.	R. S.
·025	·0000006734	·375	·00002477	·95	·0001236
·05	·000001489	·4	·00002753	1·0	·0001357
·075	·00000244	·425	·00003043	1·1	·00016146
·1	·000003538	·45	·000033484	1·2	·0001895
·125	·000004771	·475	·00003666	1·3	·00021984
·15	·000006144	·5	·00003998	1·4	·0002524
·175	·000007656	·55	·00004705	1·5	·00028703
·2	·000009307	·6	·00005466	1·6	·00032402
·225	·0000111	·65	·00006284	1·7	·0003632
·25	·00001303	·7	·00007158	1·8	·0004047
·275	·00001510	·75	·00008087	1·9	·000448
·3	·00001730	·8	·00009072	2·0	·0004943
·325	·00001966	·85	·00010112	2·5	·000757
·35	·00002214	·9	·0001121	3·0	·001075
A.	B.	A.	B.	A.	B.

Table of the Velocities of Discharge in Open Channels, Rivers, etc., with Different Heads.

$V = (F \times R \times 497)^{\frac{1}{2}}$. V = Mean velocity in feet per minute. F = Fall in inches per mile. R = Hydraulic radius, or area in square feet, divided by border in feet.

Hydraulic Radius in Feet.	Fall in Inches per Mile and per Yard.													
	1	2	3	4	5	6	7	8	9	10	11	12	15	18
	·000568	·00114	·0017	·00227	·00284	·00341	·00398	·00454	·00511	·00568	·00625	·00682	·00852	·01023
	Mean Velocity throughout the whole Cross Sectional Area, in Feet per Minute.													
·1	7·0	10·0	12·2	14·1	15·8	17·3	18·6	19·9	21·1	22·3	23·4	24·4	27·3	29·9
·2	10·0	14·1	17·3	19·9	22·3	24·4	26·4	28·2	29·9	31·5	33·1	34·5	38·6	42·3
·3	12·2	17·3	21·1	24·4	27·3	29·9	32·3	34·5	36·6	38·6	40·5	42·3	47·3	51·8
·4	14·1	19·9	24·4	28·2	31·5	34·5	37·3	39·9	42·3	44·6	46·8	48·8	54·6	59·8
·5	15·8	22·3	27·3	31·5	35·3	38·6	41·7	44·6	47·3	49·8	52·3	54·6	61·0	66·9
·6	17·3	24·4	29·9	34·5	38·6	42·3	45·7	48·8	51·8	54·6	57·3	59·8	66·9	73·3
·7	18·6	26·4	32·3	37·3	41·7	45·7	49·4	52·8	55·9	59·0	61·9	64·6	72·1	79·1
·8	19·9	28·2	34·5	39·7	44·6	48·8	52·8	56·4	59·8	63·1	66·1	69·1	77·1	84·6
·9	21·1	29·9	36·6	42·3	47·3	51·8	56·0	59·8	63·4	66·9	70·1	73·3	81·9	89·7
1·0	22·3	31·5	38·6	44·6	49·8	54·6	59·0	63·0	66·9	70·5	73·9	77·2	86·4	94·5
1·1	23·4	33·1	40·5	46·8	52·3	57·3	61·9	66·1	70·1	73·9	77·5	81·0	90·6	99·2
1·2	24·4	34·5	42·3	48·8	54·6	59·8	64·6	69·1	73·3	77·2	81·0	84·6	94·5	103·6
1·3	25·4	35·9	44·0	50·8	56·8	62·3	67·3	71·9	76·3	80·4	84·3	88·1	98·4	107·8
1·4	26·4	37·3	45·7	52·8	59·0	64·6	69·8	74·6	79·1	83·4	87·5	91·4	102·1	111·9
1·5	27·3	38·6	47·3	54·6	61·1	66·9	72·2	77·2	81·9	86·3	90·6	94·6	105·7	115·8
1·6	28·2	39·9	48·8	56·4	63·1	69·1	74·6	79·8	84·6	89·2	93·5	97·7	109·2	119·6
1·7	29·1	41·1	50·3	58·1	65·0	71·2	76·9	82·2	87·2	91·9	96·4	100·7	112·5	123·3
1·8	29·9	42·3	51·8	59·8	66·9	73·3	79·1	84·6	89·7	94·6	99·2	103·6	115·9	126·9
1·9	30·7	43·5	53·2	61·5	68·7	75·3	81·3	86·9	92·2	97·2	101·9	106·4	119·0	130·4
2·0	31·5	44·6	54·6	63·0	70·5	77·2	83·4	89·2	94·6	99·7	104·5	109·2	122·1	133·7
2·2	33·1	46·8	57·3	66·1	73·9	81·0	87·5	93·5	99·2	104·6	109·8	114·5	128·0	140·3
2·4	34·5	48·8	59·8	69·1	77·2	84·6	91·4	97·7	103·6	109·2	114·6	119·6	133·7	146·5
2·6	35·9	50·8	62·3	71·9	80·4	88·1	95·1	101·7	107·8	113·6	119·2	124·5	139·2	152·5

THE VELOCITIES OF DISCHARGE IN OPEN CHANNELS, RIVERS, ETC. (*continued*).

Hydraulic Radius in Feet.	Fall in INCHES per Mile and per Yard.													
	1	2	3	4	5	6	7	8	9	10	11	12	15	18
	·000568	·00114	·0017	·00227	·00284	·00341	·00398	·00454	·00511	·00568	·00625	·00682	·00852	·01023
	Mean Velocity throughout the whole Cross Sectional Area, in Feet per Minute.													
2·8	37·3	52·8	64·6	74·6	83·4	91·4	98·7	105·5	111·9	118·0	123·7	129·2	144·4	158·3
3·0	38·6	54·6	66·9	77·2	86·3	94·6	102·2	109·2	115·8	122·1	128·1	133·7	149·5	163·8
3·2	39·9	56·4	69·1	79·8	89·2	97·7	105·4	112·8	119·6	126·0	132·2	138·1	154·4	169·2
3·4	41·1	58·1	71·2	82·2	91·9	100·7	108·7	116·2	123·3	130·0	136·3	142·4	159·2	174·4
3·6	42·3	59·8	73·3	84·6	94·6	103·6	111·9	119·6	126·9	133·8	140·2	146·5	163·8	179·5
3·8	43·5	61·5	75·3	86·9	97·2	106·3	115·0	122·9	130·4	137·4	144·0	150·5	168·3	184·4
4·0	44·6	63·1	77·2	89·2	99·7	109·1	117·9	126·1	133·7	141·0	147·9	154·5	172·7	189·1
4·4	46·8	66·1	81·0	93·5	104·6	114·5	123·7	132·3	140·3	147·9	155·0	162·0	181·1	198·4
4·8	48·8	69·1	84·6	97·7	109·2	119·6	129·2	138·1	146·5	154·4	161·9	169·2	189·1	207·2
5·2	50·8	71·9	88·1	101·7	113·7	124·5	134·5	143·8	152·5	160·7	168·6	176·1	196·9	215·7
5·6	52·7	74·6	91·4	105·5	118·0	129·2	139·5	149·2	158·3	166·8	175·0	182·7	204·3	223·8
6·0	54·6	77·2	94·6	109·2	122·1	133·8	144·4	154·5	163·8	172·7	181·1	189·2	211·5	231·7
7·0	59·0	83·4	101·9	118·0	131·9	144·4	156·0	166·8	176·9	186·5	195·5	203·8	228·4	250·2
8·0	63·0	89·2	109·1	126·1	141·0	154·4	166·8	178·3	189·1	199·3	209·1	218·2	244·2	267·5
9·0	66·9	94·6	115·8	133·8	149·4	163·8	177·0	189·2	200·6	211·5	221·8	231·6	259·0	283·7
10·0	70·5	99·7	122·1	141·0	157·6	172·7	186·5	199·4	211·5	222·9	233·8	244·2	273·0	299·1

Example.—Find the discharge of a channel 8 feet wide, 3 feet deep, with a fall of 10 inches per mile. $\frac{\text{Sectional area}}{\text{perimeter}}$ = hydraulic radius $\therefore \frac{24}{14} = 1{\cdot}7$. According to the table in a line with 1·7 under the head of 10 inches, we find 91·9, which, multiplied by the sectional area 24 = 2205·6 cubic feet per minute.

Example.—Find the fall in a similar channel 500 yards long, giving a discharge of 2205·6 cubic feet per minute. $\frac{2205{\cdot}6}{24} = 91{\cdot}9$ feet per minute mean velocity. Looking along the line 1·7 we find 91·9 to be under the head of 10 in. per mile, or 0·00568 inches per yard, which multiplied by 500 yards = 2.84 in. fall.

Table of the Velocities of Discharge in Open Channels, Rivers, etc., with Different Heads.

Hydraulic Radius in Feet.	Fall in Feet per Mile and Inches per Yard.															
	2	3	4	5	6	7	8	9	10	12	15	20	25	30	40	50
	·01364	·02045	·02727	·03409	·04091	·04773	·05454	·06136	·06818	·08182	·1023	·1364	·1704	·2045	·2727	·3409
	Mean Velocity throughout the whole Cross Sectional Area in Feet per Minute.															
·1	34·5	42·3	48·8	54·6	59·8	64·6	69·1	73·2	77	84	94	109	122	134	154	173
·2	48·8	59·8	69·1	77·2	84·6	91·4	97·7	103	109	120	134	154	173	189	218	244
·3	59·8	73·2	84·6	94·6	104	112	120	127	134	146	164	189	211	232	268	299
·4	69·1	84·6	97·7	109	120	129	138	146	154	169	189	218	244	267	308	345
·5	77·2	94·6	109	122	134	144	154	164	173	189	211	244	272	299	346	386
·6	84·6	103·6	120	134	147	158	169	179	189	207	232	268	299	328	378	423
·7	91·4	111·9	129	144	158	171	183	194	204	224	250	289	323	354	408	457
·8	97·7	119·6	138	154	169	183	195	207	218	239	267	309	345	378	436	488
·9	103·6	126·9	146	164	179	194	207	220	232	254	284	328	366	401	464	518
1·0	109·2	133·7	154	173	189	204	218	232	244	267	299	345	386	423	488	546
1·1	114·5	140·3	162	181	198	214	229	243	256	280	314	362	405	444	512	573
1·2	119·6	146·5	169	189	207	224	239	254	267	293	328	378	423	463	534	598
1·3	124·5	152·5	176	197	216	233	249	264	278	305	341	394	440	482	556	623
1·4	129·2	158·3	183	204	224	242	258	274	289	316	354	409	457	500	578	646
1·5	133·8	163·8	189	211	232	250	267	284	299	328	366	423	473	518	598	669
1·6	138·1	169·2	195	218	239	258	276	293	309	338	378	437	488	535	618	691
1·7	142·4	174·4	201	225	247	266	285	302	318	349	390	450	503	551	636	712
1·8	146·5	179·4	207	232	254	274	293	311	327	359	401	464	518	567	654	733
1·9	150·5	184·4	213	238	261	282	301	319	336	369	412	476	532	583	672	753

TABLE OF THE VELOCITY OF DISCHARGE IN OPEN CHANNELS, RIVERS, ETC. (*continued*).

Hydraulic Radius in Feet.	Fall in FEET per Mile and Inches per Yard.															
	2	3	4	5	6	7	8	9	10	12	15	20	25	30	40	50
	·01364	·02045	·02727	·03409	·04091	·04773	·05454	·06136	·06818	·08182	·1023	·1364	·1704	·2045	·2727	·3409
	Mean Velocity throughout the whole Cross Sectional Area in Feet per Minute.															
2·0	154·4	189·1	218	244	267	289	309	328	345	378	423	488	546	598	690	772
2·2	162·0	198·4	229	256	281	303	324	344	362	397	444	512	573	628	724	810
2·4	169·2	207·2	239	267	293	316	338	359	378	414	463	535	598	655	756	846
2·6	176·1	215·6	249	278	305	329	352	374	394	431	482	557	623	682	788	880
2·8	182·7	223·8	258	289	317	342	365	388	409	448	500	578	646	708	818	914
3·0	189·2	231·7	267	299	328	354	378	401	423	463	518	598	669	733	846	946
3·2	195·4	239·3	276	309	338	365	391	414	437	478	535	618	691	756	874	977
3·4	201·4	246·6	285	318	349	377	403	427	450	493	551	637	712	780	900	1007
3·6	207·3	253·8	293	328	359	388	414	440	463	508	567	655	733	803	926	1036
3·8	212·8	260·7	301	337	369	398	425	452	476	522	583	673	753	824	952	1063
4·0	218·2	267·5	309	345	378	409	436	463	488	535	598	691	772	846	976	1091
4·4	229·0	280·5	324	362	397	429	458	486	512	561	627	724	810	887	1024	1145
4·8	239·2	293·2	338	378	414	448	478	508	535	586	655	757	846	926	1070	1196
5·2	249·0	305·2	352	394	431	466	498	528	557	610	682	788	881	964	1114	1245
5·6	258·4	316·6	365	409	448	483	517	548	578	633	708	817	914	1001	1156	1292
6·0	267·6	327·6	378	423	463	500	535	567	598	655	733	846	946	1036	1196	1338
7·0	288·8	353·9	408	457	500	540	577	611	646	708	791	914	1019	1119	1292	1444
8·0	308·8	378·3	436	488	535	578	618	655	691	757	846	977	1091	1196	1382	1544
9·0	327·6	401·3	463	518	567	613	655	695	733	803	896	1036	1158	1269	1466	1638
10·0	345·4	422·9	488	546	598	646	691	733	772	846	946	1092	1221	1337	1544	1727

Weirs.

Let G = gallons discharged per minute.
d = depth of overflow in inches.
l = length of weir in inches.
Then with thin plates we have

$$G = d \times \sqrt{d} \times l \times 2{\cdot}67.$$

$$l = \frac{G}{d \times \sqrt{d} \times 2{\cdot}67}.$$

$$d = \left(\sqrt[3]{\frac{G}{l \times 2{\cdot}67}}\right)^2.$$

If thin plate, weir 10′ long has a ratio of discharge	1·000
And plank 2″ thick, square edged, weirs 3′, 6′, 10′ long	0·845
„ crest 3′ thick level at the top	0·712
„ „ „ sloped at top 1 in 12 to 1 in 18	0·760

we have the coefficients which will enable us to adapt the following table to forms commonly met with in practice.

Example.—A river weir 30′ wide with 6½″ overfall, the crest having a slope of 1 in 12 has a discharge of 44·25 gallons × 360″ × 0·76 coefficient = 12·107 gallons per minute, or $\frac{12107}{6{\cdot}23} = 1943$ cubic feet.

If the channel is of small area the water will have a sensible velocity as it approaches the aperture, for which a correction must be made by adding to the measured head, that due to the observed velocity of approach.

For short weirs a correction must be made, as the stream suffers contraction at the ends; when contracted at both ends it is found that the effective length of the weir is reduced 0·2 inch for each inch in depth of overfall.

Square and Rectangular Pipes.—The case of square or rectangular pipes may be assimilated to that of round ones, and the head or discharge may then be calculated by the same rules that are given for the latter. The velocity of discharge, whatever may be the form of the pipe or channel, is proportional to the hydraulic radius, *i.e.*, the sectional area, divided by the circumference or perimeter; in round pipes this is always equal to ¼ of the diameter; so by multiplying the hydraulic radius of a square or rectangular pipe by 4, we obtain the diameter of the round pipe it is equal to.

Common Overflow Pipe.—When the water to be carried off is just sufficient to fill a short pipe, the discharge will be given approximately by the following rule:—

$$G = d^{2\cdot5} \times 3{\cdot}2$$

in which G = gallons discharged per minute.
d = diameter of pipe in inches.

TABLE OF THE DISCHARGE OF OUTLET PIPES. (Box.)

Diameter, Inches.	Gallons per Minute.	Diameter, Inches.	Gallons per Minute.	Diameter, Inches.	Gallons per Minute.
1	3·2	5	179	13	1950
1½	8·8	6	283	14	2346
2	18·1	7	415	15	2788
2½	31·6	8	580	16	3277
3	50·0	9	778	17	3814
3½	73·3	10	1012	18	4400
4	112·4	11	1284	19	5037
4½	138·0	12	1600	20	5725

STRENGTH OF MATERIALS.

Thick Pipes.

Let S = the cohesive strength of the metal per square inch.
P = the internal pressure per square inch, in the same terms as S.
R = the radius of the inside of the pipe in inches.
T = the thickness of the metal in inches.

For cast iron may take S as 7,142 tons, or 16,000 lbs. per square inch; for lead as 2,745 lbs.

$$\text{Then } T = \frac{R \times P}{S - P}$$

$$P = \frac{S \times T}{R + T}$$

$$S = \frac{(R + T) \times P}{T}$$

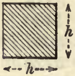
Thin Pipes.

Let D = the diameter of the pipe in inches.
H = the safe head of water in feet.
t = the thickness of metal in inches.

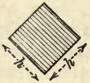
$$\text{Then } t = \left(\frac{\sqrt{D}}{10} + 0{\cdot}15\right) + \left(\frac{H \times D}{25000}\right).$$

Moment of Resistance (w) and Moment of Inertia (J) for different Cross-sections.

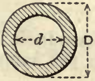
$$w=\frac{bh^2}{6} \qquad J=\frac{hb^3}{12}$$



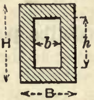
$$w=\frac{h^3}{6} \qquad J=\frac{h^4}{12}$$



$$w=0{\cdot}118h^3 \qquad J=\frac{h^4}{12}$$



$$w=\frac{\pi}{32}\,\frac{D^4-d^4}{D} \qquad J=\frac{\pi}{64}\,(D^4-d^4)$$

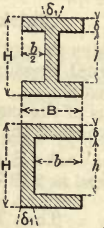


$$w=\frac{BH^3-bh^3}{6H} \qquad J=\frac{BH^3-bh^3}{12}$$

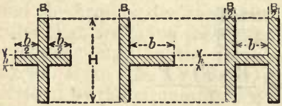
$$w=\frac{5r^3}{8} \qquad J=0{\cdot}5413r^4$$

$$w=0{\cdot}5413r^3 \qquad J=0{\cdot}5413\ ^4$$

$$w=\frac{\pi d^3}{32}=0{\cdot}0982d^3 \qquad J=\frac{\pi d^4}{64}=0{\cdot}0491d^4$$



$$w=\frac{BH^3-bh^3}{6\,H} \qquad J=\frac{BH^3-bh^3}{12}$$



$$w=\frac{BH^3+bh^3}{6\,H} \qquad J=\frac{BH^3+bh^3}{12}$$

The coefficient of resistance of any given material equals 18 times the centre breaking load of a beam of the given material, 1 inch square, 1 foot span, supported at both ends. For average rolled iron this is about 20 tons per square inch; for cast iron 16 tons; for good straight-grained well seasoned white pine or spruce, $3\frac{6}{10}$ tons; yellow pine, 4 tons; good oak, $4\frac{1}{2}$ tons, but owing to defects in large beams and imperfect seasoning should not take more than about ⅜ of these constants.

$$\text{Total breaking load in pounds} = \frac{\text{Moment of Inertia} \times \text{Coefficient of resistance} \times m}{\text{Distance in inches from neutral axis to farthest fibre} \times \text{span in inches}}$$

When the beam is firmly fixed at one end and loaded at the other . . . . $m=1$
When the beam is firmly fixed at one end and loaded uniformly . . . . $m=2$
When the beam is merely supported at both ends and loaded at the centre . . . . $m=4$
When the beam is merely supported at both ends and loaded uniformly . . . . $m=8$
When the beam is firmly fixed at both ends and loaded at the centre . . . . $m=8$
When the beam is firmly fixed at both ends and loaded uniformly . . . . $m=16$

Round Ropes.

W = Breaking load in tons.
C = Circumference of rope in inches.

Hemp ropes $W = 0{\cdot}25\ C^2 \therefore C = \sqrt{\frac{W}{0{\cdot}25}}$.

Iron wire ropes $W = 1{\cdot}50\ C^2 \therefore C = \sqrt{\frac{W}{1{\cdot}5}}$.

Crucible steel wire ropes $W = 3\ C^2 = \sqrt{\frac{W}{3}}$.

Improved plough steel wire ropes $W = 4\ C^2 \therefore C = \sqrt{\frac{W}{4}}$.

A = Area in square inches.
d = Diameter in inches.

$C = 3{\cdot}1416\ d = \sqrt{12{\cdot}5664\ A}$.

$A = 0{\cdot}7854\ d^2 = \frac{C\ d}{4} = 0{\cdot}07958\ C^2$.

$d = \frac{C}{3{\cdot}1416} = 0{\cdot}3183\ C = \sqrt{\frac{A}{0{\cdot}7854}}$

L = Load in tons.
M = Factor of safety (from 6—10).
F = Depth of shaft in fathoms.

For hemp. $C = \sqrt{\dfrac{L}{\dfrac{0{\cdot}25}{M} - \dfrac{F}{4 \times 2240}}}.$

For iron. $C = \sqrt{\dfrac{L}{\dfrac{1{\cdot}5}{M} - \dfrac{F}{1{\cdot}2 \times 2240}}}.$

For crucible steel. $C = \sqrt{\dfrac{L}{\dfrac{3}{M} - \dfrac{F}{1{\cdot}2 \times 2240}}}.$

For improved plough steel. $C = \sqrt{\dfrac{L}{\dfrac{4}{M} - \dfrac{F}{1{\cdot}2 \times 2240}}}.$

Round Taper Ropes.

A = Area of rope at any point in square inches.
a = Area of rope at bottom end in square inches.
w = Weight of one cubic inch of the rope in lbs. (Approx. for iron and steel, W = 0·14; for hemp rope, W = 0·043.)
L = Safe load in lbs. per square inch of section of rope. (Say iron, 7,000; steel, 11,500; plough steel, 13,440; hemp, 740.)
D = Distance in inches from A to a.
W = Weight of rope in lbs.
e = 2·7182.

$$A = a\,e^{\frac{wD}{L}}.$$

$$W = L\,a\left(e^{\frac{wD}{L}} - 1\right) = L\,(A - a).$$

Flat Ropes.

The strength of flat ropes is equal to the sum of the strength of the round ropes of which it is made, minus 10 %.

WEIGHTS AND BREAKING LOADS OF MANILLA ROPES.

Diameter.	Circumference.	Weight per foot.	Breaking Load.	
Inches.	Inches.	Lbs.	Tons.	Lbs.
·239	$\frac{3}{4}$	·019	·25	560
·318	1	·033	·35	784
·477	$1\frac{1}{2}$	·074	·70	1,568
·636	2	·132	1·21	2,733
·795	$2\frac{1}{2}$	·206	1·91	4,278
·955	3	·297	2·73	6,115
1·11	$3\frac{1}{2}$	·404	3·81	8,534
1·27	4	·528	5·16	11,558
1·43	$4\frac{1}{2}$	·668	6·60	14,784
1·59	5	·825	8·20	18,368
1·75	$5\frac{1}{2}$	·998	9·80	21,952
1·91	6	1·19	11·4	25,536
2·07	$6\frac{1}{2}$	1·39	13·0	29,120
2·23	7	1·62	14·6	32,704
2·39	$7\frac{1}{2}$	1·86	16·2	36,288
2·55	8	2·11	17·8	39,872
2·86	9	2·67	21·0	47,040
3·18	10	3·30	24·2	54,208
3·50	11	3·99	27·4	61,376
3·82	12	4·75	30·6	68,544
4·14	13	5·58	33·8	75,712
4·45	14	6·47	37·0	82,880

The above figures are for ropes of average quality, as pieces from the same coil may vary 25 per cent.

A few months of exposed work weakens ropes 20 per cent. to 50 per cent.

Example.—What is the weight of 300 feet of a 2·07 inch diameter Manilla rope?

Opposite 2·07 inch, under the heading of "weight per foot," is found 1·39 lbs.; this multiplied by 300 will give the desired weight, 1·39 lbs. × 300 feet = 417 lbs.

A rope wound round a barrel offers the following frictional resistance to sliding:—

24	when	the rope	is wound	1	time	round	the barrel.
111	"	"		$1\frac{1}{2}$	"	"	
535	"	"		2	"	"	
2,575	"	"		$2\frac{1}{2}$	"	"	

Wet ropes expand in diameter and contract in length.

Tarred ropes are weaker than white ropes.

Chains.

W = Breaking load in tons.

D = Diameter in sixteenths of an inch.

$$W = \frac{D^2}{9}; \quad D = \sqrt{9\,W}.$$

STRENGTH AND WEIGHT OF CLOSE-LINK CRANE CHAINS. AND SIZE OF EQUIVALENT HEMP ROPE.

Diameter of Iron.	Weight of Chain.	Breaking Strength.	Testing Load.	Girth of Equivalent Rope.	Weight of Rope.	Greatest Working Load.
Inches.	Lbs. per fathom.	Tons.	Tons.	Inches.	Lbs. per fathom.	
$\frac{1}{4}$	3·5	1·9	·75	2	$1\frac{3}{8}$	One-half the test load.
$\frac{5}{16}$	6·0	3·0	1·10	$2\frac{1}{2}$	$1\frac{1}{2}$	
$\frac{3}{8}$	8·5	4·3	1·6	$3\frac{1}{4}$	$2\frac{1}{2}$	
$\frac{7}{16}$	11·0	5·9	2·3	4	$3\frac{3}{4}$	
$\frac{1}{2}$	14·0	7·7	3·0	$4\frac{3}{4}$	5	
$\frac{9}{16}$	18·0	9·7	3·8	$5\frac{1}{2}$	7	
$\frac{5}{8}$	24·0	12·0	4·6	$6\frac{1}{4}$	$8\frac{1}{2}$	
$\frac{11}{16}$	28·0	14·6	5·6	7	$10\frac{1}{2}$	
$\frac{3}{4}$	31·5	17·3	6·8	$7\frac{1}{2}$	12	
$\frac{13}{16}$	37·0	20·4	7·9	$8\frac{1}{4}$	15	
$\frac{7}{8}$	44·0	23·1	9·1	9	$17\frac{1}{2}$	
$\frac{15}{16}$	50·0	26·1	10·5	$9\frac{1}{2}$	$19\frac{1}{2}$	
1	56·0	29·3	12·0	10	22	
$1\frac{1}{8}$	71·0	36·3	15·3	$11\frac{1}{4}$	$27\frac{3}{4}$	
$1\frac{1}{4}$	87·5	44·1	18·8	$12\frac{1}{2}$	$34\frac{1}{2}$	
$1\frac{3}{8}$	105·8	52·8	22·6	$13\frac{3}{4}$	$41\frac{1}{2}$	
$1\frac{1}{2}$	126·0	62·3	27·0	15	$49\frac{1}{2}$	

The greatest working load for studded link cables is one-half greater than that for close-link crane chains of the same diameter of iron.

The strength of chains varies as the square of the diameter of the iron in the link.

SOFTWOOD TIMBER. (F. A. Campbell.)

Kind.	Weight. Pounds per Cubic Foot.	Tensile. Pounds per Square Inch.	Compression.		Modulus of Rupture.	Modulus of Elasticity.	Shear. Pounds per Square Inch.
			Along Grain. Pounds per Square Inch.	Across Grain. Pounds per Square Inch.			
Red and yellow deal—(P. Silvestris)	35	5,000 to 10,000	5,000 to 6,000	600 to 1,000	7,000	1,800,000	300 500
White deal—(P. Abies)	...	12,000	7,000	...	...	...	300
American red pine—(P. Rubra)	36	10,000	6,000	...	7,000	1,800,000	...
American yellow pine—(P. Variabilis)	...	...	...	...	6,000–7,000	1,600,000	300–400
American pitch pine—(P. Resinosa)	50	8,000	6,500	...	9,000	1,200,000	...
American white pine—(P. Strobus)	30	...	5,000	600	6,500	1,600,000	450
Oregon—(Abies Douglasii)—	...	...	6,000	550	7,000	...	...
Kauri—(Dammara Australis)	38	10,000	6,000	...	9,000	...	...

AUSTRALIAN HARDWOOD TIMBER. (F. A. Campbell.)

Kind.	Weight. Lbs. per Cub. Ft.	Tensile. Lbs. per Sq. In.	Compression (along grain). Lbs. per Sq. In.	Modulus of Rupture.	Modulus of Elasticity.	Shear. Lbs. per Sq. In.
Ironbark—						
Red (E. Leucoxylon)	76	19,000	10,000	17,000	2,400,000	2,000
White (E. Crebra)	73	10,000	9,000	17,000	2,700,000	2,000
Grey (E. Crebra)	73	25,000	9,000	17,000	2,300,000	2,200
(E. Siderophloia)	...	...	...	14,000	...	...
Blackbutt— (E. Pilularis)	64	21,700	8,000	13,600	2,162,000	1,700
Blue gum— (E. Globulus)	63	20,000	7,700	13,100	2,038,000	..
Yellow box— (E. Melliodora)	63	..	...	12,300	1,900,000	...
Spotted gum— (E. Goniocalyx)	62	14,400	8,000	12,500	2,056,000	1,600
Stringy bark—						
(E. Macroryncha)	62½	22,000	7,700	11,600	928,000	...
(E. Piperita)	71	19,400	6,000	13,900	2,353,000	1,940
Woolybutt— (E. Longifolia)	63½	20,000	7,000	12,000	2,140,000	1,700
Red gum— (E. Rostrata)	62½	12,000	5,000	9,000	762,000	2,100
Jarrah— (E. Marginata)	62½	3,000	7,100	9,200	510,000	...
Blackwood— (Acacia Melanoxylon)	70½	14,800	6,800	10,200	1,908,000	2,000
Grey box— (E. Polyanthema)	73½	22,400	8,000	16,200	2,766,000	1,800
Tallowwood— (E. Microcorys)	77	16,100	7,500	15,200	2,287,000	1,800

CHEMISTRY, ASSAYING, ETC.

TABLE OF THE SYMBOLS AND ATOMIC WEIGHTS OF THE ELEMENTS.

Element.	Symbol.	Atomic Weight.	Element.	Symbol.	Atomic Weight.
Aluminium .	Al	27·1	Molybdenum .	Mo	96·0
Antimony .	Sb	120·2	Neodymium .	Nd	144·3
Argon. . .	A	39·9	Neon . . .	Ne	20·0
Arsenic . .	As	74·96	Nickel . . .	Ni	58·68
Barium . .	Ba	137·37	Nitrogen . .	N	14·01
Bismuth . .	Bi	208·0	Osmium . .	Os	190·9
Boron. . .	B	11·0	Oxygen . . .	O	16·00
Bromine . .	Br	79·92	Palladium . .	Pd	106·7
Cadmium .	Cd	112·40	Phosphorus .	P	31·0
Cæsium . .	Cs	132·81	Platinum . .	Pt	195·0
Calcium . .	Ca	40·09	Potassium . .	K	39·10
Carbon . .	C	12·00	Praseodymium	Pr	140·6
Cerium . .	Ce	140·25	Radium . . .	Ra	226·4
Chlorine . .	Cl	35·46	Rhodium . .	Rh	102·9
Chromium .	Cr	52·0	Rubidium . .	Rb	85·45
Cobalt. . .	Co	58·97	Ruthenium .	Ru	101·7
Columbium .	Cb	93·5	Samarium . .	Sa	150·4
Copper . .	Cu	63·57	Scandium . .	Sc	44·1
Dysprosium .	Dy	162·5	Selenium . .	Se	79·2
Erbium . .	Er	167·4	Silicon . . .	Si	28·3
Europium .	Eu	152·0	Silver . . .	Ag	107·88
Fluorine . .	F	19·0	Sodium . . .	Na	23·00
Gadolinium	Gd	157·3	Strontium . .	Sr	87·62
Gallium . .	Ga	69·9	Sulphur. . .	S	32·07
Germanium .	Ge	72·5	Tantalum . .	Ta	181·0
Glucinum .	Gl	9·1	Tellurium . .	Te	127·5
Gold . . .	Au	197·2	Terbium . .	Tb	159·2
Helium . .	He	4·0	Thallium . .	Tl	204·0
Hydrogen .	H	1·008	Thorium . .	Th	232·42
Indium . .	In	114·8	Thulium . .	Tm	168·5
Iodine . .	I	126·92	Tin	Sn	119·0
Iridium . .	Ir	193·1	Titanium . .	Ti	48·1
Iron . . .	Fe	55·85	Tungsten . .	W	184·0
Krypton . .	Kr	83·0	Uranium . .	U	238·5
Lanthanum .	La	139·0	Vanadium . .	V	51·2
Lead . . .	Pb	207·10	Xenon . . .	Xe	130·7
Lithium . .	Li	7·00	Ytterbium (Neoytterbium)	Yb	172·0
Lutecium .	Lu	174·0	Yttrium . . .	Y	89·0
Magnesium .	Mg	24·32	Zinc	Zn	65·37
Manganese .	Mn	54·93	Zirconium . .	Zr	90·6
Mercury . .	Hg	200·0			

NORMAL SOLUTIONS.

Normal solutions as used in volumetric analysis are so prepared that, one liter at 16 deg. C. shall contain the hydrogen equivalent of the active reagent weighed in grams (H = 1) : a decinormal solution (N/10) is one-tenth of the normal strength. Thus in the case of univalent substances, e.g. silver, iodine, hydrochloric acid, sodium, etc., the equivalent of the atomic (or in the case of salts, molecular) weights are identical: thus a normal solution of H Cl must contain 36·45 grams of the acid in a litre of fluid, and Na Ho 40 grams. In the case of bivalent substances, e.g. lead, calcium, sulphurous acid, oxalic acid, carbonates, etc., the equivalent is one-half the atomic (or in the case of salts, molecular) weight. Thus a normal solution of oxalic acid would be made by dissolving 63 grams of the crystallized acid in distilled water, and diluting the liquid to one litre. In the case of trivalent substances, e.g. phosphoric acid, a normal solution of sodium phosphate would be made by weighing $358 \div 3 = 119 \cdot 4$ grams of the salt, dissolving in distilled water, and diluting to one litre. One must remember that when preparing solutions for volumetric analysis, the value of a reagent as expressed by its equivalent hydrogen-weight must not always be regarded, but rather its particular reaction in any given analysis; for instance, tin is a quadrivalent metal, but when using stannous chloride as a reducing agent in the analysis of iron, the half and not the fourth of its molecular weight is required as shown by the equation $Fe_2 Cl_6 + Sn Cl_2 = 2 Fe Cl_2 + Sn Cl_4$. In like manner, with a solution of $Mn K O_4$ when used as an oxidizing agent, it is the available oxygen which has to be taken into account, therefore in making a normal solution one-fifth of its molecular weight $(158 \div 5)$ 31·6 grams must be contained in a litre. (F. Sutton.)

CHEMICAL ARITHMETIC. (Bayley.)

To find the Percentage Composition having the Formula given.—Multiply the atomic weight of the element by the number of the atoms of the element there are in the molecule; multiply the number thus obtained by 100 and divide by the molecular weight of the compound.

To find the Empirical Formula of a Body from its Percentage Composition.—Divide the percentage of each element by the atomic weight of that element to three places of decimals, and divide all the numbers thus obtained by the lowest; if the quotients are not whole numbers, reduce them to their simplest relation in whole numbers, and to these whole numbers prefix the symbol to which each refers.

To find the Weight of a Substance required to yield, liberate, or produce a given Weight of a Substance.—Write the equation expressing the chemical change: then—

Molecular weight of resulting substance × number of molecules involved.	:	Quantity of resulting substance given.	: :	Molecular weight of original substance × number of molecules involved.	:	Weight of original substance required.

TABLE FOR THE CALCULATION OF ANALYSIS.

Let w be the weight of the analysed substance, and a the weight of the determined constituent of the same; then the percentage $P = \frac{100 \times a}{w}$ or $\log. P = \log. a + 2 - \log. w$.

When the required constituent is weighed in a different combination than that in which it occurs in the analysed substance (*e.g.*, S of FeS_2 as $BaSO_4$), let f be the factor by which the determined compound must be multiplied; then $P = \frac{a \times 100 \times f}{w}$ or $\log. P = \log. a + \log. f + 2 - \log. w$.

Example.—1 grm. of iron pyrites yielded 20·5 grm. $BaSO_4$; what percentage of sulphur in the pyrites does that represent?

$$\frac{20{\cdot}5 \times 100 \times 0{\cdot}13748}{1} = 28{\cdot}18\ \%\ S.$$

TABLE FOR THE CALCULATION OF ANALYSIS (*continued*).

Found.	Sought.	Factor.	Log.
Aluminium			
Al^2O^3	Al^2	0·53279	1·72655
	$2AlCl^3$	2·60363	2·41558
Ammonia			
NH^4Cl	NH^3	0·31866	1·50333
	$NH^4.OH$	0·65511	1·81631
$2NH^4Cl$,	$(NH^4)^2O$	0·48689	1·68743
$PtCl^4$	$2(NH^3)$	0·07685	0·88562
	$(2NH^4.OH)$	0·15799	1·19862
	$(NH^4)^2O)$	0·11742	1·06973
	N^2	0·06329	0·80136
	$2NH^4Cl$	0·24116	1·38230
Pt	N^2	0·14409	1·15864
	$2(NH^3)$	0·17495	1·24290
	$2(NH^4Cl)$	0·54901	1·73958
$(NH^4)^2SO^4$	$2(NH^3)$	0·25804	1·41168
	$2(NH^4.OH)$	0·53050	1·72468
	$(NH^4)^2O$	0·39427	1·59579
	$2(NH^4Cl)$	0·80977	1·90836
Antimony			
Sb^2O^3	Sb^2	0·83596	1·92219
	Sb^2S^3	1·11647	2·06620
	Sb^2O^5	1·10936	2·04507
	Sb^2S^5	1·38279	2·14107
Sb^2O^5	Sb^2	0·75355	1·87711
	Sb^2O^3	0·90142	1·95493
	Sb^2S^3	1·04985	2·02113
	Sb^2S^5	1·24738	2·09600

Found.	Sought.	Factor.	Log.
Antimony			
$Na^2H^2Sb^2O^7$	Sb^2O^3	0·72301	1·85015
	Sb^2O^5	0·80208	1·90422
Sb^2S^3	Sb^2	0·71777	1·85599
	Sb^2O^3	0·85862	1·93380
	Sb^2O^5	0·95252	1·97887
	Sb^2S^5	1·18815	2·07487
Sb^2S^5	Sb^2	0·60411	1·78112
	Sb^2O^3	0·72265	1·85893
	Sb^2O^5	0·80168	1·90400
	Sb^2S^3	0·84164	1·92513
Arsenic			
As^2O^3	As^2	0·75780	1·87955
	As^2O^5	1·16147	2·06501
	As^2S^3	1·24312	2·09452
	As^2S^5	1·56667	2·19498
As^2O^5	As^2	0·65244	1·81454
	As^2O^3	0·86098	1·93499
	As^2S^3	1·07030	2·02950
	As^2S^5	1·34887	2·12997
As^2S^3	As^2	0·60959	1·78504
	As^2O^3	0·80443	1·90548
	As^2O^5	0·93432	1·97049
	As^2S^5	1·26028	2·10046
$2(MgNH^4AsO^4)+H^2O$	As^2	0·39490	1·59648
	As^2O^3	0·52112	1·71693
	As^2O^5	0·60526	1·78194
	As^2S^3	0·64781	1·81145

Found.	Sought.	Factor.	Log.
Arsenic			
	As^2S^5	0·81642	1·91191
$Mg^2As^2O^7$	As^2	0·48416	1·68499
	As^2O^3	0·63891	1·80544
	As^2O^5	0·74208	1·87045
	As^2S^3	0·79425	1·89996
	As^2S^5	1·00097	2·00042
$BiAsO^4$	As	0·21477	1·33198
$2BiAsO^4$	As^2O^3	0·28342	1·45243
	As^2O^5	0·32919	1·51744
	As^2S^3	0·35233	1·54695
	As^2S^5	0·44403	1·64741
Barium			
$BaSO^4$	Ba	0·55808	1·76944
	BaO	0·65669	1·81736
	$BaCl^2$	0·89218	1·95045
$BaCO^3$	Ba	0·69565	1·84239
	BaO	0·77681	1·89032
	$BaCl^2$	1·05538	2·02341
$BaCrO^4$	Ba	0·54063	1·73290
	BaO	0·60370	1·78082
	$BaCl^2$	0·82019	1·91391
$BaSiFl^6$	Ba	0·48962	1·68986
	BaO	0·54674	1·73778
	$BaFl^2$	0·62634	1·79681
$BaCl^2$	Ba	0·65915	1·81898
	BaO	0·73605	1·86691
$Ba(NO^3)^2$	Ba	0·52498	1·72015

TABLE FOR THE CALCULATION OF ANALYSIS (*continued*).

Found.	Sought.	Factor.	Log.
Barium			
	BaO	0·58623	1·76807
BaO	Ba	0·89552	1·95208
Bismuth			
Bi^2O^3	Bi^2	0·89767	1·95311
Bi^2S^3	Bi^2	0·81405	1·91065
	Bi^2O^3	0·90685	1·95754
$BiOCl$	Bi	0·80358	1·90503
$2BiOCl$	Bi^2O^2	0·89519	1·95191
	Bi^2S^3	0·98714	1·99438
$BiAsO^4$	Bi	0·60218	1·77972
$2BiAsO^4$	Bi^2O^3	0·67082	1·82660
	Bi^2S^3	0·73972	1·86907
Borium			
B^2O^3	B^2	0·31483	1·49807
$KBFl^4$	B	0·08700	0·93951
$2KBFl^4$	B^2O^3	0·27634	1·44144
Bromine			
$AgBr$	Br	0·42554	1·62894
	HBr	0·43088	1·63435
$2AgBr$	Br^2O^5	0·63844	1·80512
Cadmium			
CdO	Cd	0·87490	1·94195
CdS	Cd	0·77727	1·89057
	CdO	0·88842	1·94862
$Cd(NO^3)^2$	Cd	0·47413	1·67589

Found.	Sought.	Factor.	Log.
Cadmium			
	CdO	0·54193	1·73394
$CdSO^4$	Cd	0·53804	1·73081
	CdO	0·61498	1·78886
Calcium			
CaO	Ca	0·70961	1·85102
	$CaCl^2$	2·81385	2·44930
$CaSO^4$	Ca	0·28927	1·46131
	CaO	0·40765	1·61029
	$CaCl^2$	0·81397	1·91061
$CaCO^3$	Ca	0·39454	1·59609
	CaO	0·55599	1·74507
	$CaCl^2$	1·11273	2·04539
Carbonic Anhydride			
CO^2	C	0·27273	1·43573
$CaCO^3$	CO^2	0·44401	1·64739
$BaCO^3$	CO^2	0·22319	1·34868
Chlorine			
$AgCl$	Cl	0·24729	1·39321
	HCl	0·25428	1·40531
$2AgCl$	Cl^2O^5	0·52625	1·72119
Chromium			
Cr^2O^3	Cr^2	0·68640	1·83658
	$2CrO^3$	1·31370	2·11846
$BaCrO^4$	Cr	0·20708	1·31614

Found.	Sought.	Factor.	Log.
Chromium			
	CrO^3	0·39630	1·59802
$2BaCrO^4$	Cr^2O^3	0·30169	1·47956
$PbCrO^4$	Cr	0·16241	1·21061
	CrO^3	0·31081	1·49249
$2PbCrO^4$	Cr^2O^3	0·23661	1·37403
$K^2Cr^2O^7$	Cr^2	0·35574	1·55113
	Cr^2O^3	0·51826	1·71455
	$2CrO^3$	0·68079	1·83301
Cobalt			
Co	CoO	1·27235	2·10461
CoO	Co	0·78595	1·89539
$CoSO^4$	Co	0·37948	1·57919
	CoO	0·48284	1·68380
$Co(NO^2)^3$			
$3KNO^2$	Co	0·12985	1·11343
	CoO	0·16521	1·21804
Copper			
CuO	Cu	0·79864	1·90235
Cu^2S	Cu^2	0·79834	1·90218
	$2CuO$	0·99962	1·99984
	Cu^2O	0·89898	1·95375
Fluorine			
$CaFl^2$	Fl^2	0·49482	1·69445
	$2HFl$	0·52073	1·71661
$3CaFl^2$	H^2SiFl^6	0·62435	1·79543
$BaSiFl^6$	$6Fl$	0·41016	1·61296

TABLE FOR THE CALCULATION OF ANALYSIS (*continued*).

Found.	Sought.	Factor.	Log.	Found.	Sought.	Factor.	Log.	Found.	Sought.	Factor.	Log.
Fluorine				Iron				Lithium			
	6HFl	0·43164	1·63512	Fe^2O^3	Fe^2	0·70016	1·84519	Li^2CO^3	Li^2	0·18979	1·27828
	H^2SiFl^6	0·51754	1·71394		2FeO	0·90007	1·95427		Li^2O	0·40585	1·60836
	$SiFl^4$	0·37366	1·57247		2FeS	1·10070	2·04167		2LiCl	1·14742	2·05972
	$BaFl^2$	0·62634	1·79681	FeS	Fe	0·63609	1·80352	LiCl	Li	0·16541	1·21856
K^2SiFl^6	6Fl	0·51930	1·71542		FeO	0·81771	1·91260	2LiCl	Li^2O	0·35370	1·54864
	6HFl	0·54775	1·73858	2FeS	Fe^2O^3	0·90851	1·95833	Li^2O	2Li	0·46765	1·66992
	H^2SiFl^6	0·65525	1·81641	$Fe^2P^2O^8$	Fe^2	0·37094	1·56930		2LiCl	2·82722	2·45136
	$SiFl^4$	0·47308	1·67494		2FeO	0·47685	1·67838	Li^2SO^4	Li^2	0·12764	1·10599
	2KFl	0·52692	1·72174		Fe^2O^3	0·52980	1·72411		Li^2O	0·27294	1·43607
H^2SiFl^6	6Fl	0·79253	1·89902						2LiCl	0·77167	1·88743
	6HFl	0·83402	1·92118					Li^3PO^4	3Li	0·18156	1·25902
	$SiFl^4$	0·72199	1·85853	Lead					$3Li^2O$	0·38824	1·58910
	2HFl	0·27801	1·44406	PbO	Pb	0·92822	1·96765		3LiCl	1·09764	2·04046
					PbS	1·07205	2·03021				
Iodine					$PbSO^4$	1·35915	2·13326	Magnesium			
I^2O^5	I^2	0·76026	1·88096	PbS	Pb	0·86584	1·93744	MgO	Mg	0·60000	1·77815
	2HI	0·76627	1·88438		PbO	0·93280	1·96979	$Mg^2P^2O^7$	Mg^2	0·21614	1·33474
AgI	I	0·54029	1·73262		$PbSO^4$	1·26781	2·10305		2MgO	0·36036	1·55659
	HI	0·54456	1·73604	$PbCl^2$	Pb	0·74475	1·87201	$MgSO^4$	Mg	0·19990	1·30081
2AgI	I^2O^5	0·71067	1·85166		PbO	0·80234	1·90436		MgO	0·33350	1·52266
PdI^2	I^2	0·70439	1·84781	PbI^2	Pb	0·44922	1·65246				
	2HI	0·70996	1·85123		PbO	0·48396	1·68481	Manganese			
	I^2O^5	0·92652	1·96685	$PbSO^4$	Pb	0·68295	1·83439	MnO	Mn	0·77465	1·88899
FlI	I	0·38327	1·58351		PbO	0·73576	1·86673	Mn^2O^3	Mn^2	0·69596	1·84258
	HI	0·38630	1·58693		PbS	0·78876	1·89695		2MnO	0·89865	1·95359
2FlI	I^2O^5	0·50415	1·70255	$PbCrO^4$	Pb	0·63972	1·80599	Mn^3O^4	3Mn	0·72029	1·85751
PbI^2	I^2	0·55078	1·74098		PbO	0·68920	1·83834		3MnO	0·93007	1·96852
	2HI	0·55510	1·74437		PbS	0·73834	1·86855	MnS	Mn	0·63148	1·80036
	I^2O^5	0·72446	1·86001	Pb	PbO	1·07733	2·03235		MnO	0·81540	1·91137

TABLE FOR THE CALCULATION OF ANALYSIS (*continued*).

Found.	Sought.	Factor.	Log.
Manganese			
$MnSO^4$	Mn	0·36383	1·56090
	MnO	0·46980	1·67191
Mercury			
Hg	HgO	1·07987	2·03337
	HgS	1·15859	2·06348
2Hg	Hg^2O	1·03993	2·01700
	Hg^2Cl^2	1·17703	2·07079
HgO	Hg	0·92603	1·96662
	HgS	1·07425	2·03111
2HgO	Hg^2O	0·96301	1·98363
HgS	Hg	0·86202	1·93552
	HgO	0·93088	1·96889
Hg^2Cl^2	Hg^2	0·84960	1·92921
	2HgO	0·91746	1·96259
	Hg^2O	0·88353	1·94622
	2HgS	0·98559	1·99369
Molybdenum			
MoS^3	Mo	0·49963	1·69865
	MoO^2	0·66611	1·82355
MoO^2	Mo	0·75008	1·87511
Nickel			
NiO	Ni	0·78595	1·89539
$NiSO^4$	Ni	0·37948	1·57919
	NiO	0·48284	1·68380
Nitrogen			
$(NH^4)^2PtCl^6$	N^2	0·06330	0·80136

Found.	Sought.	Factor.	Log.
Nitrogen			
Pt	N^2	0·14409	1·15864
$BaSO^4$	N^2O^5	0·46350	1·66605
2Ag(CN)	2(CN)	0·19440	1·28870
Ag(CN)	HCN	0·20189	1·30511
Palladium			
PdI^2	Pd	0·29552	1·47059
Phosphorus			
P^2O^5	P^2	0·43692	1·64040
$Mg^2P^2O^7$	P^2	0·27953	1·44642
	P^2O^5	0·63977	1·80602
$Fe^2P^2O^8$	P^2	0·20544	1·31269
	P^2O^5	0·47021	1·67229
$2Ag^3PO^4$	P^2	0·07411	0·86985
	P^2O^5	0·16961	1·22945
$Ag^4P^2O^7$	P^2	0·10247	1·01059
	P^2O^5	0·23453	1·37019
$U^4P^2O^{11}$	P^2	0·08630	0·93602
	P^2O^5	0·19752	1·29562
Platinum			
$(NH^4)^2PtCl^6$	Pt	0·43926	1·64272
	$PtCl^4$	0·75884	1·88015
K^2PtCl^6	Pt	0·40117	1·60332
	$PtCl^4$	0·69766	1·84364
Tl^2PtCl^6	Pt	0·23893	1·37827
	$PtCl^4$	0·41276	1·61570

Found.	Sought.	Factor.	Log.
Potassium			
K^2O	K^2	0·83029	1·91923
KCl	K	0·52466	1·71988
2KCl	K^2O	0·63190	1·80065
K^2SO^4	K^2	0·44899	1·65224
	K^2O	0·54077	1·73301
	2KCl	0·85578	1·93236
KNO^3	K	0·38680	1·58749
	KCl	0·73724	1·86761
$2KNO^3$	K^2O	0·46587	1·66826
K^2PtCl^6	K^2	0·16107	1·20701
	K^2O	0·19399	1·28779
	2KCl	0·30771	1·48713
$KClO^4$	K	0·28239	1·45084
	KCl	0·53823	1·73097
$2KClO^4$	K^2O	0·34011	1·53161
$K^2Cr^2O^7$	K^2O	0·31921	1·50408
	2KCl	0·50516	1·70343
K^2SiFl^6	K^2	0·35382	1·54878
	K^2O	0·42614	1·62955
	2KFl	0·52692	1·72174
Silicon			
$SiFl^4$	SiO^2	0·57395	1·75887
SiO^2	Si	0·46729	1·66959
K^2SiFl^6	H^2SiFl^6	0·65525	1·81641
	SiO^2	0·27153	1·43381
	$SiFl^4$	0·47308	1·67494
$BaSiFl^6$	H^2SiFl^6	0·51754	1·71394
	SiO^2	0·21446	1·33135

TABLE FOR THE CALCULATION OF ANALYSIS (*continued*)

Found.	Sought.	Factor.	Log.
Silicon			
	$SiFl^4$	0·37366	1·57247
Silver			
AgCl	Ag	0·75271	1·87662
2AgCl	Ag^2O	0·80851	1·90768
AgBr	Ag	0·57446	1·75926
2AgBr	Ag^2O	0·61704	1·79032
AgI	Ag	0·45971	1·66248
2AgI	Ag^2O	0·49379	1·69354
Ag^3PO^4	3Ag	0·77309	1·88823
$2Ag^3PO^4$	$3Ag^2O$	0·83039	1·91928
$Ag^4P^2O^7$	4Ag	0·71265	1·85288
	$2Ag^2O$	0·76547	1·88393
AgCN	Ag	0·80560	1·90612
2AgCN	Ag^2O	0·86531	1·93717
Ag^2O	Ag^2	0·93100	1·96894
Sodium			
Na^2O	Na^2	0·74233	1·87060
NaCl	Na	0·39393	1·59542
2NaCl	Na^2O	0·53067	1·72482
Na^2SO^4	Na^2	0·32426	1·51089
	Na^2O	0·43681	1·64029
	2NaCl	0·82313	1·91547
$Na^2H^2Sb^2O^7$	Na^2	0·11390	1·05651
	Na^2O	0·15343	1·18591
	2NaCl	0·28913	1·46109
Na^2CO^3	Na^2	0·43442	1·63796
	Na^2O	0·58578	1·76736

Found.	Sought.	Factor.	Log.
Strontium			
SrO	Sr	0·84529	1·92701
$SrCl^2$	Sr	0·55211	1·74202
	SrO	0·65316	1·81502
$Sr(NO^3)^2$	Sr	0·41331	1·61628
	SrO	0·48896	1·68927
$SrSO^4$	Sr	0·47645	1·67802
	SrO	0·56366	1·75101
	$SrCl^2$	0·86297	1·93599
$SrCO^3$	Sr	0·59300	1·77305
	SrO	0·70153	1·84604
	$SrCl^2$	1·07406	2·03103
Sulphur			
$BaSO^4$	S	0·13748	1·13823
	SO^2	0·27470	1·43885
	SO^3	0·34331	1·53568
	H^2SO^4	0·42051	1·62378
	H^2S	0·14608	1·16458
As^2S^3	3S	0·39041	1·59152
	$3H^2S$	0·41483	1·68787
CdS	S	0·22273	1·34778
	H^2S	0·23666	1·37413
Thallium			
TlI	Tl	0·61673	1·79009
2TlI	Tl^2O	0·64090	1·80679
Tl^2PtCl^6	Tl^2	0·50033	1·69925

Found.	Sought.	Factor.	Log.
Thallium			
	Tl^2O	0·51993	1·71594
	2TlCl	0·58724	1·76881
Tin			
SnO^2	Sn	0·78680	1·89587
Titanium			
TiO^2	Ti	0·60060	1·77858
Uranium			
U^3O^8	3U	0·84938	1·92910
$U^2P^2O^{11}$	U^2	0·66901	1·82543
$K^2U^2O^7$	$2(UO^2)$	0·75800	1·87966
	U^2	0·71663	1·85530
Vanadium			
Vd^2O^5	Vd^2	0·56202	1·74975
Wolfram			
WoO^3	Wo	0·79351	1·89955
Zinc			
ZnO	Zn	0·80263	1·90451
ZnS	Zn	0·66990	1·82601
	ZnO	0·83464	1·92150
Zirconium			
ZrO^2	Zr	0·73820	1·86817

Blow-pipe Analysis.*

PRELIMINARY TESTS.

Exp. 1.—*Heat in a piece of hard glass tubing closed at one end.*

(*a*) Gas and vapour is given off which is :—

Colourless and Odourless.	Colourless and Smelling.	Coloured and Smelling.
Water (H_2O) of crystallisation, of hydration, or moisture. *Oxygen* (O) peroxides, nitrates, chlorates, bromates, and iodates. Recognized by a glowing chip burning brighter when inserted in the tube. *Carbonic anhydride* (CO_2) many carbonates and oxalates. *Carbonic oxide* (CO) oxalates and formates (the latter carbonize).	*Sulphurous anhydride* (SO_2) dithionic acid and other sulphur salts. *Sulphuretted hydrogen* (H_2S) thiosulphate salts and hydrous sulphides. *Ammonia* (NH_3) some ammonia salts.	*Nitrogen - tetroxide* (NO^2) reddish-brown ; most nitrates and nitrites. *Iodine* (I) violet; certain iodides and iodates. *Bromine* (Br) brown ; some bromides. *Chlorine* (Cl) greenish-yellow ; certain chlorides.

* Adapted from J. Landauer's "Systematischer Gang der Löthrohr-analyse."

(*b*) Sublimates.

White Sublimates.	Black or Grey Sublimates.	Coloured Sublimates.
Ammonic salts. *Mercurous chloride* (Hg_2Cl_2) sublimes without previous fusion. *Mercuric chloride* ($HgCl_2$) smelts before subliming. *Antimony-trioxide* (Sb_2O_3) fuses and sublimes in shining needles. *Tellurium dioxide* (TeO_2) fuses and sublimes to an amorphous mass. *Arsenic-trioxide* (As_2O_3) sublimes without smelting to octahedral crystals.	*Arsenic* (As) metallic arsenic and many arsenical combinations give a metallic reflection. *Amalgam* and many quicksilver combinations give metallic globules.	*Sulphur* (S) hot, yellowish-brown; cold, yellow. *Antimony-trisulphide* (Sb_2S_3) hot, black; cold, reddish-yellow. *Arsenic-trisulphide* (As_2S_3) hot, brownish-red; cold, reddish-yellow. *Mercuric-iodide* (HgI_2) yellow, on rubbing turns red. *Mercuric-sulphide* (HgS) black, on rubbing becomes red. *Selenium* (Se) reddish to black; powder dark red.

(*c*) Change of colour.

Oxide.	Hot.	Cold.
Zinc oxide (ZnO)	Yellow	White.
Stannic oxide (SnO_2)	Yellowish-brown	Light yellow to white.
Lead oxide (PbO)	Brownish-red	Yellow.
Bismuth oxide (Bi_2O_3)	Orange-yellow	Lemon-yellow.
Mercuric oxide (HgO)	Red to black	Red (volatile).
Ferric oxide (Fe_2O_3)	Red to black	Red (non-volatile).
Mercuric iodide (HgI_2)	Red to yellow	Red.

(*d*) Fusible.

Alkaline salts.

(*e*) Carbonises.

Organic substances.

(*f*) Phosphorescence.

Alkaline earths, earths, zinc oxide, tin oxide.

(*g*) Decrepitates.

Alkaline chlorides, and many minerals.

Exp. 2.—*Heat in a piece of hard glass tubing open at both ends.*

(*a*) Gas and vapour is given off.

Sulphurous anhydride (SO_2) known by its characteristic smell; sulphur and metallic sulphides.

Selenium dioxide (SeO_2) smells like rotten radishes; selenium and metallic selenides.

(*b*) Formation of sublimates.

Arsenic trioxide (As_2O_3) very volatile, a white sublimate is deposited some distance from the assay; arsenic and metallic arsenides.

Antimony trioxide (Sb_2O_3) white fumes, some volatilise and some sublime; antimony and antimony compounds.

Tellurium dioxide (TeO_2) white fumes sublime to colourless drops; tellurium and compounds of tellurium with metals.

Lead sulphate ($PbSO_4$)
Bismuth sulphate ($Bi_2(SO_4)^3$) } white, generally found below the assay; compounds of sulphur with lead: resp. bismuth.

Exp. 3.—*Heat on charcoal.*

(*a*) Fusibility.

Fusible.	Infusible.
Alkalies and some of the alkaline earthy salts. Antimony, lead, cadmium, tellurium, bismuth, zinc, tin (easily fusible). Copper, silver, gold (fusible with difficulty).	Salts of the earths and alkaline earthy metals, silica. Iron, cobalt, nickel, manganese, molybdenum, wolfram, platinum, palladium, iridium, rhodium and osmium.

(*b*) Detonates.

Nitrates and halogen salts.

(*c*) Swells up.

Expulsion of water, borates and alum.

(*d*) Colouring of the flame, reduction of metals, and formation of incrustations will be mentioned under the heading of characteristic examinations.

Characteristic Examinations.

Discovery of the bases.

Exp. 4.—*Heat the substance with soda on charcoal with the reducing flame.*

If one of the following group reactions takes place by itself, then the examination can be shortened in the following manner:—

(*a*) The substance gives an incrustation	Begin with Exp. 4, No. 1
(*b*) The substance gives a metallic bead without an incrustation	„ „ 4, „ 10
(*c*) The substance gives a grey or black residue	„ „ 5, „ 13
(*d*) The substance colours the flame, especially when moistened with HCl	„ „ 7, „ 32
(*e*) The substance leaves behind a white luminous residue . .	„ „ 8, „ 43
(*f*) The substance is completely volatile	„ „ 9, „ 52

The formation of hepar is an indication that sulphides or sulphates are present.

(1) *White incrustation.*—Very volatile; disappears with a light blue halo and propagates a garlic odour. *Arsenic.*

Special test.—When heated with cyanide of potassium and soda in a small glass tube closed at one end a steel-grey mirror is formed.

(2) *Reddish-brown incrustation.*—Variegated like the eye of a peacock's feather, driven off by O and R flame without a coloured halo. *Cadmium.*

Special test.—The scraped-off incrustation when heated with sodium thiosulphate ($Na_2S_2O_3$) in a glass tube closed at one end is coloured yellow.

(3) *Incrustation yellow when hot white when cold.*—Is luminous and not volatilized. *Zinc.*

Special test.—When heated with nitrate of cobalt solution it is coloured green. If Cd and Zn are both present the Cd incrustation is first formed, and later on that of the zinc.

(4) *Steel-grey incrustation.*—Disappears in the R flame with a blue colour, and gives off the smell of rotten radishes. *Selenium.*

(5) *White incrustation with a dark yellow to red edge.*—Disappears in the R flame with a green colour. *Tellurium.*

Special test.—If Te and Se are both present, transfer the incrustation to a test tube, moisten with a few drops of conc. H_2SO_4 and heat slightly, Te is soluble at once to a carmine red colour, while the dirty green colour of the Se first appears on heating more strongly.

(6) *Bluish-white incrustation.*—Volatile, driven off with the O. flame, and it disappears with a green colour in the R. flame.

Bead, white, brittle, and oxidizable. *Antimony.*

Special test.—The detached incrustation is dissolved in dilute HCl on platinum foil; when Zn is added the Sb is thrown down on the platinum and stains it black.

(7) *Incrustation orange when hot, lemon-yellow when cold.*—Driven off by O and R flame without colouring them.

Bead, reddish-white, brittle, and oxidizable. *Bismuth.*

Special test.—When treated on charcoal with a mixture of iodide of potassium and sulphur in the O flame a fine red incrustation of iodide of bismuth is formed.

(8) *Incrustation lemon-yellow when hot, sulphur-yellow when cold.*—Driven off by O and R flames, colours the R flame a fine blue.

Bead, white. malleable and oxidizable. *Lead.*

Special test.—Moisten the assay with HNO_3, evaporate the acid, add some H_2SO_4, and heat till white fumes are evolved; a white powder remains that is insoluble in H_2SO_4 acidulated water.

(9) *Incrustation yellow when hot, white when cold.*—Very small and found close to the assay, not volatile.

Bead, white, malleable and very oxidizable. *Tin.*

Special test.—Dissolve in HCl and precipitate the metallic tin as a grey spongy mass out of the acid solution by means of metallic zinc; this will not cling to platinum as Sb does.

(10) *Bead white, malleable, and very bright.*—In the strong O flame, a reddish-brown incrustation is formed; in the presence of Pb or Sb it becomes carmine-red. *Silver.*

Special test.—Dissolve in HNO_3; on the addition of HCl a white curdy precipitate of AgCl is thrown down.

(11) *Bead yellow.*—Very bright, malleable, and not oxidizable. *Gold.*

Special test.—When dissolved in aq. regia, and $SnCl_2$ is added, purple of Cassius is formed.

(12) *Bead red.*—Malleable and oxidizable. *Copper.*
Special test.—See Nos. 13 and 39.

Remarks.

As a grey, infusible powder remaining behind, we have iron, nickel, cobalt (magnetic), molybdenum, wolfram, and the metals of the platinum group. The first-named bodies can be tested by borax in Exp. 5, but the platinum metals cannot be well tested by blowpipe reactions. Some combinations of the metals with Cl, I, Br and S, form white, not very characteristic incrustations without reduction of the metal: these incrustations must not be mistaken for the above reactions. The substances which give these incrustations will be otherwise determined in the course of these tests.

Exp. 5.—*The assay is dissolved in a borax bead on platinum wire.*

(*a*) The bead is coloured by the O or R flame. No. 13.
(*b*) The bead is not coloured by either flame. Ex. 7, No. 32.

The colour of the bead is

In the Oxidizing Flame.		In the Reducing Flame.		
Hot.	Cold.	Hot.	Cold.	
(13) Green	Bluish-green.	Colourless	Brown	*Copper.*
(14) Blue	Blue	Blue	Blue	*Cobalt.*
(15) Violet to black	Reddish-violet	Colourless	Rose-red	*Manganese.*
(16) Violet	Reddish-brown	Yellowish-grey	Yellowish-grey	*Nickel.*
(17) Red to yellow	Colourless	Green	Green	*Iron.*
(18) Brownish-red to yellow	Colourless	Reddish-yellow	Green	*Uranium.*
(19) Yellow	Colourless l.q.opaque	Brown	Brown and opaque	*Molybdenum.*
(20) Brownish red to reddish-yellow	Grass-green	Green	Emerald-green	*Chromium.*
(21) Red	Colourless to yellow	Colourless	Colourless	*Cerium.*
(22) Yellow	Greenish-yellow	Brownish	Emerald-green	*Vanadium.*
(23) Yellow	Colourless to yellow	Yellow	Yellowish-brown	*Wolfram.*
(24) Yellow	Colourless	Yellow to brown	Violet	*Titanium.*

13*. Special test.—When heated with microcosmic salt and tin in the reducing flame, the bead becomes red; if it is black, roast it on charcoal and get rid of Sb and Bi with boric acid in the O flame.

14*. Special test.—The metal reduced on charcoal if rubbed on paper and treated with HNO_3 forms a red solution, on adding HCl and drying a green spot is developed, which on moistening with H_2O disappears.

15*. Special test.—Fusing with soda and nitre on platinum foil gives a green mass.

16*. Special test.—If the metal reduced on charcoal is rubbed on paper and treated with HNO_3, a green solution is formed, which on the addition of Na_2Co_3 gives an apple-green spot.

17*. Special test.—Rub the metal reduced on charcoal on a piece of paper, treat with HNO_3 and a drop of HCl; when warmed over a flame a yellow spot is left; if moistened with potassium ferrocyanide (K_4FeCy_6) it turns a blue colour.

18*. Special test.—The microcosmic salt bead is in the O. flame, yellow when hot, yellowish-green when cold; in the R. flame a dirty green when hot, and a fine green when cold (distinction from Fe).

Insoluble combinations of uranium are smelted on platinum with $HKSO_4$, and the fused mass rubbed up with Na_2CO_3 moistened and the liquid absorbed by paper, which, when moistened with acetic acid, gives a reddish-brown spot with K_4FeCy_6.

19*. Special test.—By digesting with H_2SO_4 on platinum foil, the MoO_3 colours the acid a deep blue on the addition of alcohol or by breathing on it.

20*. Special test.—By smelting with soda and nitre on platinum foil a yellow mass is obtained.

21*. Special test.—Cannot be well determined by the blow-pipe.

22*. Special test.—Fuse with soda and saltpetre, dissolve in water, acidulate with acetic acid, add $AgNO_3$, which gives a yellow precipitate.

23*. Special test.—The microcosmic salt bead is colourless in the O. flame both hot and cold; in the R. flame it is a dirty green when hot, and blue when cold; in the presence of iron it is a blood red. (See No. 27.)

24*. Special test.—The microcosmic salt bead is colourless both when hot and cold in the O. flame; but in the R. flame it is yellow when hot, and violet when cold; in the presence of iron it is blood-red. (See No. 30.)

(25.) When more than one coloured oxide is present, double reactions take place, for instance :—

In the Oxidizing Flame.		In the Reducing Flame.		
Hot.	Cold.	Hot.	Cold.	
Violet to blood-red .	Brownish-violet .	Yellow . .	Bottle-green	*Mn and Fe.*
Plum-coloured	Plum-coloured	Bluish-green	Blue . .	*Mn, Fe and Co.*
Green . .	Greyish-blue	Bluish-green	Green . .	*Mn, Fe, Co, and Ni.*
Yellowish-green	Green . .	Greenish-blue	Blue . .	*Fe, Co, and little Ni.*
Violet-brown	Brown . .	Blue . .	Blue . .	*Co and much Ni.*
Green. .	Light green, blue or yellow, according to quantity .	. . .	. . .	*Fe and Co. Fe and Cu. Fe and Ni.*

25*. Special test.—Several borax beads, with some of the assay dissolved in them, are collected and reduced on charcoal, with the addition of lead. After a few blasts separate the borax (*a*) from the lead (*b*).

(*a*) Dissolve some of the old borax slag in fresh borax in a platinum wire loop.

(*α*) The bead is blue. *Cobalt.*

(*β*) The bead in the O. flame is green when hot, blue when cold. *Iron and Cobalt.*

(*γ*) In the O. flame violet to blood-red when hot, brownish-violet when cold; in the R. flame yellow when hot, bottle-green when cold; when reduced on charcoal with tin gives a vitriol-green colour. *Manganese and Iron.*

(δ) In the O. flame the bead is plum-colour both hot and cold; in the R. flame is bluish-green when hot, and blue when cold. *Manganese, Iron and Cobalt.*

(*b*) Drive off the lead from the lead button with boric acid on charcoal in the O. flame, and dissolve the residue in microcosmic salt.

(α) The bead in the O. flame is blue when cold; with tin on charcoal it is reduced to a red colour. *Copper.*

(β) The bead in the O. flame is yellow when cold. *Nickel.*

(γ) The bead in the O. flame is green when cold. *Copper and Nickel.*

Exp. 6.—*Decompose the substance with bi-sulphate of potash, treat with HCl, and add a strip of zinc.**

The solution is coloured :—

(26) Blue, then green, and finally blackish-brown. (No. 19.) *Molybdic acid.*

(27) Blue, then copper-red. (No. 23.) *Tungstic acid.*

(28) Blue, then green, and finally violet. (No. 22.) *Vanadic acid.*

(29) Green. (No. 20.) *Chromic acid.*

(30) Violet. (No. 24.) *Titanic acid.*

(31) Blue, in strongly acid solutions brown. *Niobic acid.*

Exp. 7.—*The substance, held in clean platinum forceps or wire, is placed in the non-luminous flame.*

(*a*) The flame is coloured (especially after moistening it with HCl or H_2SO_4). No. 32.

(*b*) The flame is not coloured. Exp. 8, No. 43.

* Exp. 6 can be omitted when wolfram, vanadium, titanium, and niobium are not sought.

Testing for bases.

The colour of the flame is :—

	By Itself.	Through Blue Glass.	Through Green Glass.		
	(32) Violet . .	Reddish-violet .	Bluish-green .	*Potassium.*	
After moistening with H_2SO_4 bring substance into the flame for a short time only,	(33) Orange . .	Reddish-violet .	Orange-yellow.	*Potassium and sodium.*	
	(34) Orange .	Invisible or weak blue .	Orange-yellow.	*Sodium.*	
	(35) Carmine-red.	Violet-red . .	Invisible . .	*Lithium.*	
Moisten again with H_2SO_4, dry, and then use the greatest heat.	(36) Yellowish-green .	Bluish-green . .	Green . .	*Barium.*	Ba, Ca, and Sr can be recognized when together by noting the different coloured jets after the assay, moistened with HCl, has been brought into the flame.
	(37) Yellowish-red	Greenish-grey .	Siskin-green .	*Calcium.*	
	(38) Carmine-red.	Purple . . .	Weak yellow .	*Strontium.*	

(39) Green ; after moistening with HCl, blue. *Copper.*

Testing for acids.

(40) Yellowish-green, similar to the barium flame. *Molybdic acid.*

Special test.—Gives with borax the reaction of No. 19.

(41) Yellowish-green (the salt is moistened with H_2SO_4). *Phosphoric acid.*

Special test.—When heated with Mg in a closed tube, and moistened with water, it smells of phosphoretted hydrogen.

(42) Fine green (the salt is moistened with H_2SO_4). *Boric acid.*

Special test.—Heat on platinum with $CaFl_2$ and $HKSO_4$, when the intense green flame of boric fluoride is obtained.

Remarks.

HCl and HNO_3 also produce green-coloured flames, but they are weak and rapidly disappear.

The flame colourations of the already recognised elements, As, Sb, Pb (blue), Zn (greenish-white), are removed by the employment of conc. H_2SO_4.

Exp. 8.—*Moisten the substance with cobalt solution on charcoal, and heat strongly.*

(43) Blue infusible mass. *Alumina.*

Special test.—Does not colour the flame as No. 41, and does not give a Si-skeleton with microcosmic salt.

(44) Blue infusible mass. *Earthy phosphates.*

Special test.—Gives a yellowish-green coloured flame: see No. 41.

(45) Blue infusible mass. *Earthy silicates.*

Special test.—Gives a Si-skeleton in the microcosmic salt bead.

(46) Blue glass. *Alkaline borates.*

Special test.—Gives a fine green-coloured flame : see No. 42.

(47) Blue glass. *Alkaline phosphates.*

Special test.—Gives a yellowish-green flame : see No. 41.

(48) Blue glass. *Alkaline silicates.*

Special test.—In the microcosmic salt bead gives a Si-skeleton.

(49) Flesh-coloured mass. *Magnesia.*

(50) Violet mass. *Zirconia.*

(51) Green mass. *Zinc oxide*, *tin oxide*, *antimony oxide*, *titanic acid* (already found).

Exp. 9.—*Heat the substance with soda in a glass tube closed at one end.*

(52) Metallic sublimate, which, when rubbed, unites into globules. *Quicksilver.*

Special test.—Heat with $Na_2S_2O_3$ in a closed tube, black HgS is formed.

(53) Odour of NH_3. *Ammonia.*

Special test.—With HCl fumes, forms a white cloud of AmCl.

Discovery of the acids.

Exp. 10.—*Heat the substance with bisulphate of potash in a tube closed at one end.*

(*a*) It forms a coloured gas. No. 54.
(*b*) It forms a colourless, smelling gas. No. 60.
(*c*) It forms a colourless and odourless gas. No. 68.
(*d*) It gives no reaction. Exp. 11, No. 71.

(54) Red fumes, with a smell of nitrous acid. *Nitric or nitrous acid.*

Special test.—If a strip of paper, saturated with a solution of $FeSO_4$, is pushed in the tube, it is coloured brown.

Nitrates deflagrate with an explosion, and flame when heated on platinum foil with KCy.

(55) Yellowish-green gas, which smells of chlorine. *Chloric acid.*

Special test.—The substance deflagrates on charcoal.

(56) Violet fumes, turns starch-paste blue. *Iodine.*

Special test.—The substance, together with oxide of copper in a microcosmic salt bead, colours the flame a pure green.

(57) The previous reaction takes place on the addition of $FeSO_4$. *Iodic acid.*

Special test.—The substance deflagrates on charcoal.

(58) Red-brown fumes, colours damp starch paper yellowish-brown. *Bromine.*

Special test.—The substance, together with oxide of copper in a microcosmic salt bead, colours the flame a greenish-blue.

(59) The same reaction. *Bromic acid.*

Special test.—The substance deflagrates on charcoal.

(60) Fumes, which, with NH_3, form white clouds, and have the smell of *Hydrochloric acid.*

Special test.—The substance, together with oxide of copper in a microcosmic salt bead, colours the flame an intense blue.

(61) Strong-smelling pungent gas, which etches glass. *Hydrofluoric acid.*

Special test.—Heat the salt in a borax bead with bisulphate of potash; the flame is coloured green.

(62) Smell of sulphuretted hydrogen. *Sulphuretted hydrogen.*

Special test.—When heated in an inclined glass tube open at both ends, metallic sulphides give a smell of SO_2, and the fumes turn blue litmus paper red.

(63) Smell of burning sulphur ; no separation of sulphur. *Sulphurous acid.*

(64) The same reaction, but with the separation out of sulphur. *Thiosulphuric acid.*

(65) A pungent-smelling gas that brings tears to the eyes and makes lime-water cloudy. *Cyanic acid.*

(66) Smell of vinegar. *Acetic acid.*

(67) Smell of almonds. *Hydrocyanic acid*

(68) A gas is driven off that makes lime-water turbid. *Carbonic acid.*

(69) The gas burns with a blue flame. *Carbonic oxide.*

(70) The substance is carbonised. *Organic acids.*

Exp. 11.—*Heat the substance, that forms a hepar with soda on charcoal, with caustic potash on platinum foil ; place the whole in a vessel of water with a clean silver coin.*

(71) The coin is not browned. *Sulphuric acid.*

Special test.—To recognise sulphuric acid in the presence of sulphides (No. 62), dissolve the substance in water acidulated with HNO_3, and precipitate the H_2SO_4 with $BaCl_2$. Insoluble sulphates are first boiled in a solution of carbonate of soda, filtered and acidulated.

The following have already been found.

(72) Phosphoric acid (No. 41), boric acid (No. 42), silicic acid (No. 45).

ASSAYS.

Gold and Silver.

Grind the ore to pass through an 80 mesh sieve. If metallics remain behind, either dissolve in acid, dilute, sprinkle over sample, and dry at 100 deg. C., or else take the proportion of metallics to the whole and assay separately.

Scorification Assay.—Suitable for rich silver ores or ores that contain much copper, which would be reduced in the pot assay. Granulated lead may be prepared by taking silver-free red-lead in the proportion of 300 grams to 15 grams of charcoal, and reducing to lead in a clay crucible. Pour into a wooden box that has been coated with black-lead ; keep the molten lead just moving till solidification begins, then shake violently. The lead will break into fine particles, which can be separated from the larger pieces by sieving. Take 5 grams (or 0·2 of an assay ton), mix with 30–60 grams of granulated lead, place in a scorifier, cover with a little borax-glass, and heat in a hot muffle-furnace till the slag covers the lead completely ; then add 0·5 gram of powdered charcoal to clean the slag, and when the lead thus formed disappears, pour into a mould, allow to cool, break off slag, clean and square button by hammering, cupel, weigh, add silver if necessary, part, weigh again, and calculate. Silver has to be added when the amount already present is less than 2½ times the amount of gold, as otherwise the parting is not complete. The silver may be added by recupelling or by fusion under a blowpipe on charcoal or a cupel.

Parting is performed by brushing the adherent bone-ash from the lead, flattening with a hammer, first treating with dilute nitric acid, 1 to 2, in a porcelain crucible, then with stronger acid, 1 to 1, pouring off and washing with water. The parted gold should be heated to redness before weighing. If much silver is present, weaker acid should be used to prevent the gold from breaking up into very fine particles, when it is liable to be poured off with the acid or wash-water. When making up parting acids, a few drops of silver nitrate should be added in order to precipitate any chlorides present in the water. The silver chloride thus formed may be allowed to settle.

Pot Assay. Roasting.—If the ore is a heavy sulphide, arsenide, or antimonide, roast sweet in a muffle surface, stirring constantly to prevent clinkering. Should the ore be very fusible, mix a little clean fine sand with the assay. If As or Sb are present, re-roast with the addition of a little C to decompose the arsenates and antimonates that are formed. Roasting in the pot to be used for the subsequent fusing is sometimes performed, chiefly for antimonides, nitre being added.

Fusion.—Mix 50 grams (or an assay ton) of the ore with red-lead or litharge and charcoal so as to form lead, which will dissolve and settle with the gold and silver, also carbonate of soda and borax to flux the silica and metallic oxides respectively. The amounts of the fluxes to be added will vary with the nature of the ore. The following typical charges may be taken as examples in which A is ore with a siliceous gangue, B with a basic (iron oxide) gangue, C pyrites ore without roasting :—

	A	B	C
Ore	50 grams	50 grams	50 grams
Red-lead	40 ,,	40 ,,	60 ,,
Charcoal	1½ ,,	2–3 ,,	—
Borax	—	10–20 ,,	15–25 ,,
Sodium Carbonate	60 ,,	30–45 ,,	30–40 ,,
	—	—	Hoop-iron or nails.

Place the pot containing the charge in a wind furnace, heat till the mass becomes pasty, keep at this stage for about ten minutes, then raise the temperature, and when the mass is fluid and all action has ceased, pour into a black-leaded mould, allow to cool, detach the slag, cupel, weigh bead and part. If button is brittle due to the presence of S, As, Sb, or Zn, if hard due to Cu or Sb, or if too large, scorify before cupelling. When assaying poor ore or tailings, scorify two or more buttons together till of a convenient size to cupel.

Cupellation.—Place a clean dry cupel, which must weigh more than the lead button to be treated, in a muffle. When the cupel is red-hot place the lead button in it, and allow the action to continue till all the lead has been oxidized and absorbed by the cupel. The temperature, which should be increased towards the finish of the cupellation, is right when the fumes from the assay do not creep over the cupel or shoot straight up, but rise slightly and are carried by the draught approximately parallel to the roof of the muffle. A large silver bead is apt to spit on cooling; this can be avoided by slow cooling, best by covering with another cupel, or by removing from the muffle and, at the moment of complete solidification, quenching with a jet of cold water.

Bullion Assay.—After smelting the bullion so as to make its composition as uniform as possible, a sample may be taken by drilling, but if very impure it is better to take a dip sample from the molten mass in a charcoal or clay spoon. Weigh 0·5 gram of the sample accurately, cupel with 8 grams of lead foil, clean bead, weigh and part, wash, dry, ignite, and weigh again. This gives the approximate value of the bullion. The difference between the weight of bullion taken, and the gold–silver bead being considered as base metal; the difference between the gold and silver bead and the parted gold being taken as silver. Make a "check" by weighing pure gold, silver, and copper to form 0·5 gram of alloy of the composition of the bullion found by the trial assay and cupel, with two lots of 0·5 gram of the bullion in separate cupels each with 8 grams of lead foil. By comparing the weight of the assay after cupelling with that of the check, the loss of gold and silver in the bullion due to cupellation may be ascertained. After parting, the loss or apparent gain of gold on the "check," known as "surcharge," and which should not exceed 0·0003 gram, will show the amount to be added or deducted to the gold weights to give the true amount present in the bullion. The true silver content is found by adding the cupellation loss to the ascertained weight of the bead, and deducting the corrected fine gold. The difference between the combined fine gold and silver and the weight of bullion taken is counted as impurities. Of course the weight of any silver added in order to form an alloy capable of being parted, must be deducted from the total silver found. Before parting, the button should be hammered flat, rolled into a "fillet" ⅜ in. long annealed, then coiled into a "cornet" having the original bottom of the button on the outside.

Gold in Blister Copper.—Four lots of ¼ assay-ton of the borings are weighed and placed in 3 inch scorifiers, mixed with 60 grams granulated test-lead, and covered with 30 grams of the same; a little silica and borax glass may also be added. Scorify twice, adding fresh lead the second time, then combine two buttons and continue scorifying with fresh addition of lead till all the copper is removed. The slags should be saved, and either scorified after mixing with powdered charcoal or run down in a crucible. The buttons from the slag and assay should be scorified together till of convenient size, then cupelled, parted, and the gold determined in the usual manner. As an extra precaution, the button from the blister copper may be cupelled first, and then the cupel broken up and run down with the slags, the gold thus obtained being added to the first result.

TABLE FOR CONVERTING PERCENTAGES INTO TROY WEIGHT PER STATUTE TON.

Percentage.	Per Ton.	Percentage.	Per Ton.	Percentage.	Per Ton.
	oz. dwt. gr.		oz. dwt. gr.		oz. dwt. gr.
0·0001	0 0 15·68	0·008	2 12 6·4	0·5	163 6 16
0·0002	0 1 7·36	0·009	2 18 19·2	0·6	196 0 0
0·0003	0 1 23·04	0·01	3 5 8·0	0·7	228 13 8
0·0004	0 2 14·72	0·02	6 10 16·0	0·8	261 6 16
0·0005	0 3 6·40	0·03	9 16 0·0	0·9	294 0 0
0·0006	0 3 22·08	0·04	13 1 8·0	1·0	326 13 8
0·0007	0 4 13·76	0·05	16 6 16·0	2·0	653 6 16
0·0008	0 5 5·44	0·06	19 12 0	3·0	980 0 0
0·0009	0 5 21·12	0·07	22 17 8	4·0	1,306 13 8
0·001	0 6 12·8	0·08	26 2 16	5·0	1,633 6 16
0·002	0 13 1·6	0·09	29 8 0	6·0	1,960 0 0
0·003	0 19 14·4	0·1	32 13 8	7·0	2,286 13 8
0·004	1 6 3·2	0·2	65 6 16	8·0	2,613 6 16
0·005	1 12 16·0	0·3	98 0 0	9·0	2,940 0 0
0·006	1 19 4·8	0·4	130 13 8	10·0	3,266 13 8
0·007	2 5 17·6				

Example.—500 grs. of ore gave 0·044 grs. gold, what is the yield per ton?

One hundred grs. of the ore will give 0·044 ÷ 5 = 0·0088 grs.; and,

	Per cent.		oz.	dwt.	gr.
According to table	0·008	=	2	12	6·4
,, ,,	0·0008	=	0	5	5·44
So	0·0088	=	2	17	11·84 per ton.

TABLE SHOWING THE QUANTITY OF FINE GOLD IN ONE OUNCE OF ANY ALLOY TO ONE-EIGHTH OF A CARAT AND THE MINT VALUE OF THE GOLD IN ONE OUNCE OF EACH ALLOY.

Fine Gold.			Carat Gold.			Sterling Value.		
Oz.	dwt.	gr.	Carats.	grs.	eighths.	£	s.	*d.*
1	0	0	24	0	0	4	4	11·454
0	19	4	23	0	0	4	1	4·977
0	18	8	22	0	0	3	17	10·500
0	17	12	21	0	0	3	14	4·023
0	16	16	20	0	0	3	10	9·545
0	15	20	19	0	0	3	7	3·068
0	15	0	18	0	0	3	3	8·591
0	14	4	17	0	0	3	0	2·113
0	13	8	16	0	0	2	16	7·636
0	12	12	15	0	0	2	13	1·159
0	11	16	14	0	0	2	9	6·682
0	10	20	13	0	0	2	6	0·204
0	10	0	12	0	0	2	2	5·727
0	9	4	11	0	0	1	18	11·250
0	8	8	10	0	0	1	15	4·773
0	7	12	9	0	0	1	11	10·295
0	6	16	8	0	0	1	8	3·818
0	5	20	7	0	0	1	4	9·341
0	5	0	6	0	0	1	1	2·863
0	4	4	5	0	0	0	17	8·386
0	3	8	4	0	0	0	14	1·909
0	2	12	3	0	0	0	10	7·432
0	1	16	2	0	0	0	7	0·954
0	0	20	1	0	0	0	3	6·477
0	0	15	0	3	0	0	2	7·858
0	0	10	0	2	0	0	1	9·239
0	0	5	0	1	0	0	0	10·619
0	0	4·375	0	0	7	0	0	9·292
0	0	3·750	0	0	6	0	0	7·964
0	0	3·125	0	0	5	0	0	6·637
0	0	2·500	0	0	4	0	0	5·309
0	0	1·875	0	0	3	0	0	3·982
0	0	1·250	0	0	2	0	0	2·655
0	0	0·625	0	0	1	0	0	1·327

	£	s.	*d.*
1 oz. pure gold is worth	4	4	$11\frac{1}{2}$
1 dwt. " "	0	4	3
1 gr. " "	0	0	2

Copper Assay.

THE CYANIDE METHOD.—This is the simplest method, and generally accurate enough for mine work.

Standard Solution.—Weigh pure potassium cyanide and dissolve in water in the ratio of 40 grams of K Cy to a litre of water. The solution should be kept in a dark stoppered bottle, and not too much made at a time as it becomes weaker on standing. It must always be re-standardised at intervals of about a week.

Standardising.—Weigh exactly three lots of 0·3 gram of pure electro-copper; if a little too heavy may fetch the copper to the exact amount by rubbing on a fine file. Dissolve in nitric acid, heat to drive off all nitrous fumes, cool, dilute, neutralize with ammonia, add 5 c.c. of ammonia in excess, then dilute to 500 c.c. From a burette run in potassium cyanide solution into the copper solution, a little at a time, till the blue colour shows signs of fading: then proceed slowly, waiting between each fresh addition of cyanide till the last trace of blue colour disappears on standing.

The Assay.—Take from 0·5 gram to 5·0 grams, depending on the richness of the ore, and dissolve in aqua regia or nitric acid, adding a little sulphuric acid towards the end of the action, then dilute, add ammonia, and proceed as during standardisation. If a heavy precipitation of iron is formed, it should not be removed by filtration but allowed to settle, or a little of the liquid filtered into a test-tube, and the colour compared with that of a test-tube containing water.

The above method is only suitable for fairly pure ores. A more satisfactory procedure is to boil down with sulphuric acid after dissolving the ore, then to dilute and boil with a strip of aluminium foil in the beaker. This precipitates the copper, which may be separated by filtering off the liquid, dissolving in nitric acid, titrating as in the case of a standard.

THE IODIDE METHOD.—The copper is determined by titration with sodium thiosulphate (hypo) after the addition of potassium iodide.

Standard Solutions.—Sodium thiosulphate 39·18 grams per litre. Potassium iodide 75 grams in 500 c.c. A freshly made starch solution.

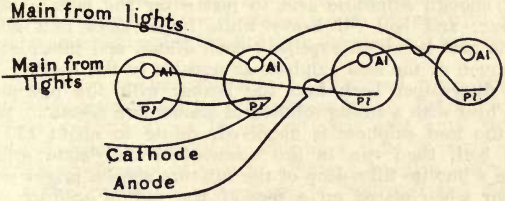
Standardising.—Three lots of 0·3 gram of pure copper are dissolved in the least possible quantity of nitric acid, and carefully heated till all nitrous fumes are expelled. After diluting to about 50 c.c., sodium carbonate or ammonia is added carefully till just neutral, then a drop or two of acetic acid to re-dissolve the small precipitate formed. Twenty c.c. of the iodide solution are added, and the sodium thiosulphate solution run in from a burette till the brown colour due to free iodide becomes faint, then starch is added, and the titration continued till the blue colour disappears and the assay is quite white.

The Assay.—Alloys with Cu and Zn may be treated direct by this method, but the copper must be separated from nearly all ores by aluminium or some suitable method, and then treated as in standardising.

THE ELECTROLYTIC METHOD.—The copper in blister may be determined by the Iodide method, but the following is that most generally used for accurate work.

The Assay.—Twenty grams of the ground borings are treated with a mixture of 200 c.c. water, 20 c.c. H_2SO_4, and 60 c.c. HNO_3 till solution is complete. Sodium chloride solution is then added in sufficient quantity to precipitate all the silver present, and leave only a small excess of common salt. Boil till all nitrous fumes are expelled, then dilute to a litre at room temperature, keeping the solution well agitated. Filter part through a dry filter; take two lots of 50 c.c. each (= 1 gram borings), place in a beaker, dilute to 125 c.c., and electrolyse, using a current of 0·3 amp. overnight. The increase in the weight of the cathodes multiplied by 100 gives the copper per cent.

The ordinary lighting circuit may be used for electrolytic copper assays if D.C., but if A.C. a rectifier must be used. This can be made by placing a saturated solution of ammonium phosphate in four small beakers, and using rods of aluminium for anodes and strips of sheet lead for cathodes. The current is led from a small switchboard, fitted with lamp connections to the rectifiers as shown, Figure, and from the rectifiers to the terminals to which the cones on which the copper is deposited are attached. With a 100 volt circuit one lamp does for two 1 gram assays; two lamps in parallel for 4 assays, and so on.



Lead Assay.

DRY METHOD.—To be used for fairly pure, rich ores only. Otherwise use the wet process. The results are always low owing to the formation of a double sulphide of lead and iron not decomposed in the process. Fuse a weighed amount of the crushed ore in a crucible in a wind furnace with one of the following charges, depending on the nature of the gangue, till all action ceases, then pour into a mould, allow to cool, detach the button, hammer, clean, and weigh. The fusion should be begun at a low temperature and raised towards the end of the operation, which will take about half an hour.

	A.	B.	C.
Ore	30 grams	30 grams	30 grams
Carbonate of Soda .	30 ,,	35 ,,	35 ,,
Argol of Flour . .	3 ,,	3 ,,	5 ,,
Borax	—	5 ,,	10 ,,

Unless performed in an iron pot, hoop iron or nails should be put in with the charge and withdrawn just before pouring.

A. For pure Galena. B. For less pure Galena with base metals present. The borax may be used as a cover, and, if arsenic is present, as shown by the presence of a hard metallic speiss on the lead button, the argol should be reduced in quantity, and the finishing temperature raised a little higher than before. C. For oxidised ores.

WET ASSAY. AMMONIUM MOLYBDATE METHOD.—This process consists of dissolving the lead in nitric acid and separating it as sulphate, dissolving the precipitate in ammonium acetate and titrating with a standard solution of ammonium molybdate, using a solution of tannin as indicator on a spot plate.

Standard Solution.—The ammonium molybdate solution is made by dissolving the finely powdered salt in water in the proportion of 10 grams to the litre. The indicator solution should be freshly made by dissolving 0·1 gram of tannin in 30 c.c. of water.

Standardising.—To determine the lead value of the ammonium molybdate, take three lots of 0·3 gram of pure lead, and dissolve in dilute nitric acid. When solution is complete add enough sulphuric acid to just cover the bottom of the beaker, and boil till heavy white fumes show that all the nitric acid has been expelled; cool, dilute, and filter, leaving as much of the lead sulphate as possible in the beaker. Put the filter-paper back into the beaker with the precipitate, and heat with a strong solution of ammonium acetate. When all the lead sulphate is dissolved, dilute to about 150 c.c. and boil, then run in the ammonium molybdate solution from a burette till a drop of the mixture gives a bright yellow colour when placed on a spot of the tannin solution on a plate or white tile. The three titrations should agree closely, and their average will show how many c.c. of the molybdate solution are equal to 0·3 gram of lead, and by calculation how much lead each c.c. of the solution is equal to.

The Assay.—Take 0·5 gram of ore and dissolve in nitric acid, evaporate down with sulphuric acid, dilute, boil, filter, wash with dilute sulphuric, dissolve the lead sulphate in ammonium acetate, and titrate as in standardising. The number of c.c. used to give the yellow colour, multiplied by the lead value of each c.c., shows the amount of lead in the 0·5 gram of ore taken, and that result multiplied by 200 gives the percentage of lead.

Zinc Assay.

POTASSIUM FERRO-CYANIDE METHOD.—*Standard Solution.*—Dissolve 41·25 grams of potassium ferro-cyanide in 1 litre of water. The test solution is made by dissolving 1 gram of uranium acetate in 30 c.c. of water.

Standardising.—Weigh out 0·5 gram of pure zinc, dissolve in hydrochloric acid, boil, and then run in the standard solution from a burette till a drop of the mixture gives a bright brown colour with a drop of the uranium acetate solution on a spot plate.

The Assay.—Weigh out 1 gram of the finely powdered ore, and dissolve in hydrochloric acid with the addition of a few drops of nitric acid towards the end of the action. Add a few drops of sulphuric acid and evaporate down to fuming to precipitate lead. Cool, dilute with weak hydrochloric acid, and pass sulphuretted hydrogen gas through it till all the metals of Group II are precipitated. Boil, filter, boil the filtrate till free from sulphuretted hydrogen, oxidise by adding nitric acid, care being taken not to add excess, boil, cool, and precipitate iron by ammonia. Filter, dissolve the precipitate in hydrochloric acid, re-precipitate with ammonia, filter, and add the second filtrate to the first. If much iron is present, a third precipitation will be necessary to remove all the zinc from the iron. To the mixed filtrates add bromine water and boil, adding more ammonia if necessary, filter, wash precipitate with water, acidify filtrate with hydrochloric acid, boil and titrate hot with the standard ferro-cyanide solution.

Alternative method for zinc, chiefly used when lead has not to be determined in the same sample. Treat 0·5 gram of the ore with about 10 c.c. of nitric acid until the first violent action ceases, then add from time to time a few crystals of chlorate of potash. When all action has ceased, the vessel, preferably a casserole, is uncovered and taken to complete dryness. To the dry mass is then added 7 grams of solid ammonium chloride, 20 c.c. of ammonia, and 25 c.c. of hot water in succession. The mixture is well stirred, boiled for about one minute, and filtered. If much precipitate is present it is re-treated with nitric acid and potassium chlorate to remove the last trace of zinc. The mixed filtrates are acidified with hydrochloric acid; copper, if present, is separated by boiling with granulated lead, which need not be removed, and the titration performed as before.

Tin Assay.

Preparation of the Sample.—Crush fine and weigh enough ore to leave about 10 grams of tin oxide as concentrates after panning. Pan carefully from one dish to another; if sulphides or arsenides are present wash and pan again or treat with acid. If wolfram is present, treat with aqua regia for half an hour, decant, wash, dissolve tungstic acid in ammonia, decant, wash, and dry.

Cyanide of Potassium Method.—Having weighed the concentrate prepared as above, take about three times as much potassium cyanide and mix with a little powdered charcoal, place in a small hot Cornish crucible, then add the tin oxide and heat at a bright yellow heat for about twenty minutes. Pour into a mould, allow to cool, dissolve the slag in water, weigh the tin button or buttons, noting if any undecomposed ore is left. The tin button may be examined for purity by fracture or analysis.

Slags.

Properly chilled slag, if not too high in silica (i.e. 40–45 %) may be completely dissolved in HCl after crushing to pass through a 100 mesh screen. Other slags will have to be fused with alkalies for analysis.

Determination of Copper by Colour.—Two grams of the slag are placed in a small beaker, and 50 c.c. of hot water added together with 15 c.c. HCl, and the mixture stirred vigorously. Practically everything dissolves, with the exception of copper sulphide and a little matte. After filtering, the residue is ignited, dissolved in 5 c.c. HNO_3, boiled till red fumes cease to come off, diluted, made alkaline with 20 c.c. Am Ho, boiled, and either filtered or decanted into a colormetric tube. The amount of standard copper solution required to give the same depth of colour to an equal volume in another colour-tube shows the amount of copper present in the slag.

Determination of Iron.—Half a gram of slag is placed in a beaker, and 25 c.c. of boiling water added; the mixture is then placed on a hot plate and well stirred while 20 c.c. of strong HCl is added. After boiling for a few minutes to remove H_2S, a few drops of stannous chloride solution are added to reduce all iron present to the ferrous condition, as shown by the solution becoming colourless, and then it is quickly cooled. When cold 20 c.c. of a strong solution of mercuric chloride are added, and a standard solution of potassium dichromate run in from a burette till a drop of the mixture gives no blue colour on adding to a drop of dilute potassium ferro-cyanide on a spot plate. The standard potassium dichromate contains 4·392 grams per litre, and is standardised by dissolving pure iron wire in hydrochloric acid, reducing with stannous chloride and adding mercuric chloride as above.

Determination of Silica.—Half a gram of slag after dissolving as before is taken to dryness, then heated till all hydrochloric acid fumes have disappeared. After cooling, the residue is moistened with 5 c.c. of hydrochloric acid and a few drops of nitric acid, diluted with hot water, filtered, and the residue, which is silica, ignited and weighed.

Determination of Lime.—To the filtrate from the silica, ammonia is added till it is alkaline, then solid oxalic acid till the precipitated ferric hydrate has been dissolved. A faint permanent precipitate is produced by adding more ammonia, and again dissolved by the careful addition of small quantities of oxalic acid. Boil and filter. The precipitate, which is calcium oxalate, together with the filter paper, is placed in a beaker of hot dilute H_2SO_4, and titrated with standard potassium permanganate. The permanganate solution containing 5·991 $KMnO_4$ per litre may be standardised by oxalic acid, in which case the amount of oxalic acid taken multiplied by 0·444 gives the equivalent weight of lime; or if standardised with metallic iron the iron value of the solution divided by two gives the lime value.

Water.

It is usual to combine the acids and bases found in water analysis as follows, though it may be necessary to make modifications in special cases.

Combine Cl first with Na, and if any excess with Ca and Mg.

If Na is in excess of Cl combine as Na_2O with SO_3. If SO_3 is insufficient, calculate excess of Na_2O to Na_2CO_3.

If SO_3 is in excess combine first with CaO and then with MgO.

Calculate excess of CaO or MgO to $CaCO_3$ and $MgCO_3$.

Calculate Fe_2O_3 to $FeSO_4$ if any SO_3 remains after satisfying the other bases, otherwise to $FeCO_3$.

AIR.

Pure outside air is a mixture of :—

Oxygen	20·93%	by volume.
Carbon dioxide	0·03	,, ,,
Nitrogen, including 0·94 Argon .	79·04	,, ,,

The CO_2 may vary in the lower strata of air from 0·025 to 0·035%.

The allowable amount of CO_2 in mine air is 0·3% by volume.

The O should not be decreased to less than 20% by volume.

At a temperature over 85° F., when the air is saturated with moisture, it is not possible to do continuous hard bodily labour.

To take a sample of air.—Secure a suitable bottle, say a Winchester quart, clean and dry thoroughly. In its neck fit a rubber stopper provided with two holes. Insert a short piece of glass tubing into one hole and a long piece which reaches to the bottom of the bottle into the other; the outer end of the latter is connected to the nozzle of a small pair of bellows by a rubber tube. When the atmosphere to be tested is reached work the bellows steadily for three minutes, by which time the original air in the bottle will be replaced. Take out the rubber stopper, replace it by a well-ground and vaselined glass stopper, lute it with candle grease, and tie it down with string.

Apparatus.—The most suitable apparatus to use is Haldane's larger apparatus for gas analysis. About 20 c.c. of air is required for each test; the gas burette is graduated to 0·1 c.c., but can be read to 0·05. The reagents required are a solution of about 20% KHO to absorb the CO_2, and an alkaline pyrogallic solution made by dissolving 10 grm. pyrogallic acid in 100 c.c. of a nearly saturated solution of KHO (sp. gr. 1·55) to absorb the oxygen. These solutions placed in their pipettes will serve for several analyses, as they do not deteriorate with standing, but are changed when absorption of gases becomes sluggish. CO and CH_4 are burnt in a combustion pipette by means of an electric current which heats a platinum wire, forming respectively CO_2 and $CO_2 + H_2O$.

Small quantities of nitrous fumes may be recognized by exposing a strip of paper moistened with a solution of starch and a little iodide of potassium slightly acidified: this will turn blue.

TESTING CYANIDE SOLUTIONS.

Gold.—Of the many methods for determining the gold in cyanide solutions the following are those most generally used, all of which give satisfactory results. The amount of solution taken varies with the richness of the solution, also according to whether the amount of gold is compared to weight or volume of solution.

Method 1.—A known amount of solution is evaporated to dryness in a dish made of test lead, the dish and contents are then folded up and cupelled, the resulting bead being parted, if necessary, and weighed.

Method 2. — Litharge is mixed with the solution before evaporating in a porcelain dish, the dry residue is then fluxed in a crucible so as to produce a lead button, which is treated for gold in the ordinary way.

Method 3.—To a measured quantity of solution silver nitrate is added till no more precipitate is formed. This precipitate, which contains the gold, is mixed with litharge, soda, argol, and glass, and melted in a crucible to give a lead button, from which the gold is extracted as before.

Method 4.—A known quantity of solution is boiled with zinc turnings, then a solution of lead acetate and hydrochloric acid are added, and the boiling continued till all zinc has dissolved, and a spongy mass of lead is left. This lead is dried and cupelled to obtain the gold.

Available Cyanide. — This is determined by titrating a measured quantity of the solution against standard silver nitrate, using potassium iodide as an internal indicator. A faint permanent yellow precipitate shows the end of the reaction. The standard silver nitrate solution is made by dissolving 13·076 grams of pure silver nitrate crystals per litre of water, then if 10 c.c. of the cyanide solution are taken, each c.c. of silver solution used represents 0·1 % of potassium cyanide.

Total Cyanide.—The estimation is performed in the same manner as the preceding with the exception that the cyanide solution is made alkaline by the addition of excess sodium hydrate before titrating.

TABLE FOR STANDARDISING SUMP SOLUTIONS.

Tons of Water.

Strength of Cyanide Solution.	1 lbs.	1 oz.	2 lbs.	2 oz.	3 lbs.	3 oz.	4 lbs.	4 oz.	5 lbs.	5 oz.	6 lbs.	6 oz.	7 lbs.	7 oz.	8 lbs.	8 oz.	9 lbs.	9 oz.	10 lbs.	10 oz.
·01	0	3	0	6	0	8	0	13	1	0	1	3	1	6	1	8	1	13	2	0
·02	0	6	0	13	1	3	1	8	2	0	2	6	2	13	3	3	3	8	4	0
·03	0	8	1	3	1	13	2	6	3	0	3	8	4	3	4	13	5	6	6	0
·04	0	13	1	8	2	6	3	3	4	0	4	13	5	8	6	6	7	3	8	0
·05	1	0	2	0	3	0	4	0	5	0	6	0	7	0	8	0	9	0	10	0
·06	1	3	2	6	3	8	4	13	6	0	7	3	8	6	9	8	10	13	12	0
·07	1	6	2	13	4	3	5	8	7	0	8	6	9	13	11	3	12	8	14	0
·08	1	8	3	3	4	13	6	6	8	0	9	8	11	3	12	13	14	6	16	0
·09	1	13	3	8	5	6	7	3	9	0	10	13	12	8	14	6	16	3	18	0
·10	2	0	4	0	6	0	8	0	10	0	12	0	14	0	16	0	18	0	20	0
·11	2	3	4	6	6	8	8	13	11	0	13	3	15	6	17	8	19	13	22	0
·12	2	6	4	13	7	3	9	8	12	0	14	6	16	13	19	3	21	8	24	0
·13	2	8	5	3	7	13	10	6	13	0	15	8	17	3	20	13	23	6	26	0
·14	2	13	5	8	8	6	11	3	14	0	16	13	19	8	22	6	25	3	28	0
·15	3	0	6	0	9	0	12	0	15	0	18	0	21	0	24	0	27	0	30	0
·16	3	3	6	6	9	8	12	13	16	0	19	3	22	6	25	8	28	13	32	0
·17	3	6	6	13	10	3	13	8	17	0	20	6	23	13	27	3	30	8	34	0
·18	3	8	7	3	10	13	14	6	18	0	21	8	25	3	28	13	32	6	36	0
·19	3	13	7	8	11	6	15	3	19	0	22	13	26	8	30	6	34	3	38	0
·20	4	0	8	0	12	0	16	0	20	0	24	0	28	0	32	0	36	0	40	0
·21	4	3	8	6	12	8	16	13	21	0	25	3	29	6	33	8	37	13	42	0
·22	4	6	8	13	13	3	17	8	22	0	26	6	30	13	35	3	39	8	44	0
·23	4	8	9	3	13	13	18	6	23	0	27	8	32	3	36	13	41	6	46	0
·24	4	13	9	8	14	6	19	3	24	0	28	13	33	8	38	6	43	3	48	0
·25	5	0	10	0	15	0	20	0	25	0	30	0	35	0	40	0	45	0	50	0

EXAMPLE.—Find the number of pounds of cyanide necessary to add to 3 tons of water to make its strength 0·12%. Answer—7 lbs. 3 oz.

THE INSTITUTION OF MINING AND METALLURGY STANDARD SCREENS FOR LABORATORY USE.

"I.M.M." SERIES.

Wire Diameter.	Apertures.		Mesh, per Linear inch.	% Screening Area.
Decimal of an in.	in.	mm.		
·0100	0·1000	2·540	5	25·00
·0630	0·0620	1·574	8	24·60
·0500	0·0500	1·270	10	25·00
·0417	0·0416	1·056	12	24·92
·0313	0·0312	0·792	16	24·92
·0250	0·0250	0·635	20	25·00
·0167	0·0166	0·421	30	24·80
·0125	0·0125	0·317	40	25·00
·0100	0·0100	0·254	50	25·00
·0083	0·0083	0·211	60	24·80
·0071	0·0071	0·180	70	24·70
·0063	0·0062	0·157	80	24·60
·0055	0·0055	0·139	90	24·50
·0050	0·0050	0·127	100	25·00
·0041	0·0042	0·107	120	25·40
·0033	0·0033	0·084	150	24·50
·0025	0·0025	0·063	200	25·00

Sizing Tests and Grading Analysis.

A sizing test gives the engineer an idea of the percentage of different-sized material produced by various fine-crushing machinery, and the analysis of the different grades enables him to ascertain which sizes carry payable values.

TABLE FOR THE CONVERSION OF PERCENTAGE INTO CWTS. AND LBS. PER TON AND INTO LBS. PER CWT.

Per Cent.	Per Ton.		Per Cwt.	Per Cent.	Per Ton.		Per Cwt.
	Cwt.	Lbs.	Lbs.		Cwt.	Lbs.	Lbs.
1	...	22·4	1·12	40	8	0·0	44·80
2	...	44·8	2·24	41	8	22·4	45·92
3	...	67·2	3·36	42	8	44·8	47·04
4	...	89·6	4·48	43	8	67·2	48·16
5	1	0·0	5·60	44	8	89·6	49·28
6	1	22·4	6·72	45	9	0·0	50·40
7	1	44·8	7·84	46	9	22·4	51·52
8	1	67·2	8·96	47	9	44·8	52·64
9	1	89·6	10·08	48	9	67·2	53·76
10	2	0·0	11·20	49	9	89·6	54·88
11	2	22·4	12·32	50	10	0·0	56·00
12	2	44·8	13·44	51	10	22·4	57·12
13	2	67·2	14·56	52	10	44·8	58·24
14	2	89·6	15·68	53	10	67·2	59·36
15	3	0·0	16·80	54	10	89·6	60·48
16	3	22·4	17·92	55	11	0·0	61·60
17	3	44·8	19·04	56	11	22·4	62·72
18	3	67·2	20·16	57	11	44·8	63·84
19	3	89·6	21·28	58	11	67·2	64·96
20	4	0·0	22·40	59	11	89·6	66·08
21	4	22·4	23·52	60	12	0·0	67·20
22	4	44·8	24·64	61	12	22·4	68·32
23	4	67·2	25·76	62	12	44·8	69·44
24	4	89·6	26·88	63	12	67·2	70·56
25	5	0·0	28·00	64	12	89·6	71·68
26	5	22·4	29·12	65	13	0·0	72·80
27	5	44·8	30·24	66	13	22·4	73·92
28	5	67·2	31·36	67	13	44·8	75·04
29	5	89·6	32·48	68	13	67·2	76·16
30	6	0·0	33·60	69	13	89·6	77·28
31	6	22·4	34·72	70	14	0·0	78·40
32	6	44·8	35·84	71	14	22·4	79·52
33	6	67·2	36·96	72	14	44·8	80·64
34	6	89·6	38·08	73	14	67·2	81·76
35	7	0·0	39·20	74	14	89·6	82·88
36	7	22·4	40·32	75	15	0·0	84·00
37	7	44·8	41·44	76	15	22·4	85·12
38	7	67·2	42·56	77	15	44·8	86·24
39	7	89·6	43·68	78	15	67·2	87·36

TABLE FOR THE CONVERSION OF PERCENTAGE INTO CWTS. AND LBS. PER TON AND INTO LBS. PER CWT. (*continued*).

Per Cent.	Per Ton.		Per Cwt.	Per Cent.	Per Ton.		Per Cwt.
	Cwt.	Lbs.	Lbs.		Cwt.	Lbs.	Lbs.
79	15	89·6	88·48	90	18	0·0	100·80
80	16	0·0	89·60	91	18	22·4	101·92
81	16	22·4	90·72	92	18	44·8	103·04
82	16	44·8	91·84	93	18	67·2	104·16
83	16	67·2	92·96	94	18	89·6	105·28
84	16	89·6	94·08	95	19	0·0	106·40
85	17	0·0	95·20	96	19	22·4	107·52
86	17	22·4	96·32	97	19	44·8	108·64
87	17	44·8	97·44	98	19	67·2	109·76
88	17	67·2	98·56	99	19	89·6	110·88
89	17	89·6	99·68	100	20	0·0	112·00

Example.—A lead ore contains 60 per cent. of lead, how much is that per ton?

Opposite 60 per cent. see 12 cwt. per ton.

Assay of Fuel.

1. *External appearance.*—Porosity, compactness, fracture, size, shape, cleavage, &c.

2. *Moisture.*—Weight 5 grm. powdered fuel into a watch glass; heat over a water bath at 212° F. for about an hour; allow to cool in a dessicator; weigh. Repeat the heating till the weight is constant: the loss is hygroscopic moisture.

3. *Specific Gravity.*—Place a coarse homogeneous fragment of the fuel in a sling of silk thread; suspend it from one of the pans of a balance and weigh it in air, having previously cleaned it from any dust. Thoroughly soak the fuel in distilled water, for about 12 hours; brush off any adhering air bubbles, and weigh in water.

$$\text{Spc. Grv.} = \frac{\text{weight of coal in air}}{\text{diff. of wt. in air and in water.}}$$

4. *Volatile hydrocarbons.*—Weigh out 5 grm. of the fuel; place it in a covered porcelain crucible and heat gradually in a muffle furnace, till the flame that shows on the top disappears; then raise the temperature to red heat for a minute or two; allow to cool and weigh. The loss equals the volatile hydrocurbons plus the moisture, and is returned in percent.

5. *Coke or Charcoal.*—This is the residue left after driving off the volatile hydrocarbons.

6. *Ash.*—Powder the coke fine, and heat it in a muffle furnace with free access of air, till all the black portion has disappeared; allow to cool, then weigh. Note the colour of the ash, also its condition, whether pulverulent clinkered, &c.

7. *Fixed carbon.*—This is found by the difference between the weight of the coke, and that of the ash, minus half the sulphur in the coal, which is retained by the coke.

8. *Sulphur.*—This may be hurtful when driven off by heat; or harmless when it remains in the ash: the two together form the total sulphur.

For the total sulphur, mix 1 grm. finely powdered coal with 7—8 grm. Nitre, 4 grm. carbonate of potash or soda, and 16 grm. sodic chloride, all of which must be pure. Fuse gently in a platinum crucible, placed in a muffle furnace until thoroughly white and fluid, allow to cool, by placing it on a cold iron; dissolve out with hot water slightly acidulated with Hydrochloric acid. Heat nearly to boiling, then add a solution of baric chloride in moderate excess; allow to settle at a gentle heat; decant through a filter paper, wash the precipitate in the beaker till free from chlorine, finally transfer the precipitate to the filter paper, dry, ignite precipitate at a moderate red heat apart from the filter paper, weigh.

The percentage of sulphur =

$$\frac{\text{Wt. of Ba SO}_4\text{ ppt.} - \text{wt. filter ash} \times 13{\cdot}7}{100}$$

For the harmless sulphur boil 5 grm. finely powdered coal in a solution containing about 5 grm. pure sodium or potassium carbonate. Filter: acidify with HCl; add $BaCl_2$; allow to settle; dry; incinerate; weigh as $BaSO_4$, and calculate as above. The difference between this and the total sulphur gives the percentage of hurtful sulphur.

9. *Other peculiarities of Fuels.*—Notice whether—(*a.*) It is easily inflammable. (*b.*) Any smell is evolved during combustion. (*c.*) It is good for coking. (*d.*) It burns with a large or small flame, smoky or luminous. (*e.*) It burns quietly or with decrepitation. (*f.*) The resulting coke burns for a long time or easily goes out.

10. *Absolute heating power.*—Berthier's method. Weigh 1 grm. finely powdered dry coal, mix thoroughly with 40—50 grm. pure PbO; place in a clay crucible, add a layer of 30 grm. more PbO, and then a cover of borax glass; lute on a lid: heat gradually till fused, then raise to red heat for 10 minutes; tap the crucible to collect all the lead to the bottom, and allow to cool, then break out the reduced lead.

To find the number of calories or heat units, multiply the weight of lead reduced by 237·6.

11. *Specific heating power.*—Multiply the absolute heating power by the specific gravity.

Tests for Common Impurities found in Mine Waters.

The usual impurities found in mine water are lime, magnesia, potash, soda, iron, copper, sulphuric acid, hydrochloric acid, carbonic acid, and sulphuretted hydrogen.

Test for Hard or Soft Water.—Dissolve a small quantity of soap in alcohol, let a few drops fall into a glass of water. If it curdles it is hard, if it remains clear it may be considered soft. Hard water may contain carbonic acid, carbonate of lime, carbonate of iron, sulphate of lime, &c. If soft it may contain alkalies.

Test for Acid.—If blue litmus paper turns red when moistened with the water, it contains a free acid.

Test for Carbonic Acid.—If a precipitate occurs when clear lime water is added, carbonic acid is present. If on evaporating the water to dryness, the residue effervesces, a carbonate is present.

Test for Sulphuric Acid.—If a solution of chloride of barium gives a white precipitate which is not redissolved by pure nitric acid, sulphuric acid is present.

Test for a Chloride.—If water turns turbid on the addition of a drop of nitrate of silver, a chloride is present, probably a chloride of lime, soda, or magnesia.

Test for Sulphuretted Hydrogen.—Place a bright silver coin in the water, if it gets a brown or black coating it indicates sulphuretted hydrogen.

Test for Alkalies or Alkaline Earthy Matters.—If red litmus paper turns blue when moistened with the water, an alkali or alkaline earth is present.

Test for Lime.—Neutralise the water if acid with ammonia, and add oxalate of ammonia; a white precipitate indicates lime.

Test for Magnesia.—After the last solution has stood for some hours, to allow all the lime to settle, filter off, evaporate down to $\frac{1}{20}$th its bulk and add a few drops of phosphate of soda; stir well, the formation of a white precipitate after a little while indicates magnesia.

Test for Iron.—Add a few drops of yellow prussiate of potash to a glass of the water, it will immediately become of a blue colour if iron is present.

Test for Copper.—A polished piece of iron immersed in the water for a few minutes will have any copper present precipitated on it. Ammonia added to water containing copper in solution turns it blue.

Adulteration of Oils, Lard, and Tallow.

Fats and oils are subject to adulteration and falsification, particularly those of great commercial value, and generally with fats and oils of lower prices. By exposure to the air they absorb oxygen and become rancid; some oils dry into a kind of varnish, and are called drying oils. The fats are adulterated with foreign substances to increase their weight. We cannot here go into a general analysis of all these important materials, but will examine such as are in common use and most liable to sophistication.

Olive Oil.—Olive oil for the manufacture of soaps is ordinarily adulterated with cole-seed oil, cotton-seed oil, and poppy oil. These mixtures are sometimes disguised by colouring them green with indigo, so as to create the impression that green olive oil is present. The adulteration with black poppy oil is the most frequent, not only on account of the cheapness of this oil, but also on account of its sweet taste, and its odour being but little pronounced.

Oil of Sweet Almonds.—The oil of sweet almonds is principally falsified with poppy oil and with sesame oil. Several processes have been proposed for detecting this falsification. Oil of sweet almonds becomes cloudy at 20° C. (4° below 0° F.), and solidifies at 25° C. (13° below 0° F.), while poppy oil begins to solidify between 3·9° C. (39° F.), and 6° C. (42·8° F.). One part of aqua ammonia, mixed with nine parts of oil of sweet almonds, forms a white soft soap, very smooth and homogeneous if the oil be pure; on the contrary, it is clotted if it contains more than one-fifth of poppy oil.

Rapeseed Oil.—This oil is falsified with linseed, mustard, and whale oils, oleic acid, &c. Ammonia with pure oil gives a milk-white soap; and a yellowish-white soap when the mustard and whale oils are present. Gaseous chlorine colours rapeseed oil brown, when it contains whale oil; if pure it remains colourless.

Sesame Oil.—This oil is ordinarily mixed with earth-nut oil.

Linseed Oil.—This oil is falsified with hemp seed, and especially with fish oil. Pure linseed oil treated by hyponitric acid becomes pale pink; by ammonia, dark yellow, and gives a thick and homogeneous soap.

Black Poppy Oil.—This oil is often mixed with sesame and beech-nut oils. The pure oil is coloured a light yellow with hyponitric acid, while beech oil acquires a pink colour.

Ammonia colours it a light yellow; the consistency is slightly thick, and the soap is a little granular.

Hempseed Oil.—The adulteration of this oil is always done with linseed oil. The pure oil treated by ammonia becomes yellow, thick, and granular.

Castor Oil.—This oil is generally mixed with black poppy oil. The adulteration is easy to detect with alcohol at 95° B.; a certain quantity of oil agitated with this liquid is dissolved, and leaves the foreign oil as a residuum.

Neat's Foot Oil.—This oil is without doubt the most adulterated oil found in commerce. It is mixed with whale, black poppy oil, and olein.

Oleic Acid.—This acid is often mixed with resin oil. The pure acid, treated with an acid solution of nitrate of mercury, yields a pale straw-coloured foam; the resin oil yields a very dark orange foam.

Palm Oil.—This oil has been mixed with or manufactured entirely of yellow wax, lard, mutton suet, coloured with turmeric, and aromatised with powdered orris root, without any genuine palm oil. By treating the suspected oil with ether, all the fatty bodies are dissolved; the turmeric and orris root remain insoluble. By saponification the mixed or artificial oil takes a reddish shade, due to the action of the alkali on turmeric. Sometimes powdered resin has been mixed with it; this falsification is easily detected by treating the oil with alcohol: the resin is dissolved while the oil remains insoluble.

Cocoanut Oil.—The commercial oil is often adulterated with mutton suet, beef marrow, or other animal greases, sometimes also with the oil of sweet almonds and wax. The oil falsified by these substances does not completely dissolve in cold ether. The ethereal solution is muddy like that given by pure butter. The oil thus falsified has a taste and an odour less agreeable, a colour rather greyish than yellowish, and has less consistency. The melting point is the best method of ascertaining the purity. Adulterated with greases or tallows the oil melts at 26° to 28° C. (78·8° to 82·4° F.); with oil of sweet almonds it melts at 23° C. (73·4° F.)

Lard.—Alterations.—Lard exposed to the air in jars not well closed becomes rancid and turns yellow. If kept in copper vessels, or in earthen jars glazed with sulphide of lead, it may, by contact with the air, attack the copper or the glazing, and then contain stearate and oleate of copper or lead. The copper is detected by pouring on the grease a few drops of ammonia, which immediately becomes blue. A red colouration is given by a solution of yellow prussiate of potash. Lead is detected by burning the lard, and carefully examining the residuum to see if there are any metallic globules. The residuum is then treated by nitric acid, which dissolves the metal. Filter, and to the filtrate add sulphuric acid, which gives a white precipitate. Lard may also contain an excess of water, which is ascertained by pressing and softening it with a wooden spatula ; the water oozes from it in the form of drops. By melting it at a low temperature the water separates from the grease. The principal adulterations of lard are the addition of common salt, the admixture of a grease of inferior quality, or that of a kind of grease obtained by the cooking of pork meat. Plaster of Paris is sometimes added. The addition of salt is easily detected by digesting the lard with hot distilled water. The salt in the water is abundantly precipitated with nitrate of silver. The precipitate is white, soluble in ammonia, and insoluble in nitric acid ; it becomes black when exposed to the light. Plaster of Paris is detected by melting in warm water the suspected lard. If it contains plaster, this falls to the bottom in the form of a white powder. The inferior greases are often very difficult of detection ; they are ascertained by the less white colour of the lard, and by a taste entirely different. The greases from the cooking of pork meat give to the lard a greyish colour, a soft consistency, a salted and disagreeable taste.

Tallows.—Tallows are generally adulterated with greases of inferior quality. Water is also incorporated in them by a long beating. Cooked and mashed potatoes have been also introduced into them. Fecula, kaolin, white marble, and sulphate of baryta, are also added to tallows. The principal adulteration is the addition of bone tallow ; properly speaking, it is not a falsification, it is only a change in the quality of the product. The mineral matters, the fecula, and the cooked potatoes are easily ascertained by disolving the tallow in ether or sulphide of carbon. All the foreign substances remain insoluble, and their nature is then easily determined. Iodine water, or the alcoholic tincture of iodine, will colour blue the insoluble residuum if it contains fecula. This fecula can be determined in the tallow by triturating the grease with iodine water and adding a few drops of sulphuric acid. The blue colour will appear immediately if there be fecula. For the mineral substances there is a process as simple as the above to ascertain their presence in tallow. It is to melt the tallow in twice its weight of water ; the foreign substances are precipitated, and the grease floats on the surface. Instead of using ordinary water, the tallow may also be boiled for a few minutes with two parts acidulated water for one part of tallow. The whole is allowed to rest in a test glass, or in a funnel placed over a water bath, kept at a temperature of about 40° C. (104° F.), so as to prevent the too rapid cooling of the tallow, and to give time to the impurities to separate and deposit. Iodine added in this last treatment will disclose the presence of fecula or starch. To ascertain the presence of water, knead dried powdered sulphate of copper with the tallow (half its volume of the powder). If there be much water, the mixture will take a blue colour if the tallow is white, and greenish if the grease is yellowish. As for the quantity of water added, the only way to ascertain it is by drying a sample in an oven.

Physical Properties of Oils.—Fixed oils, at the ordinary temperature, are nearly always liquid; some, however, such as palm oil, cocoa-nut oil, &c., are more or less consistent. They are also more or less mucilaginous, with a feeble taste, sometimes disagreeable. Some are colourless, but generally they have a slight yellow tint; some are of a greenish-yellow colour, and this colour is due to a peculiar principle they hold in solution. Their specific gravity is less than that of water, all floating on this liquid, but it varies.*

SLAGS.

Formulæ for silicates of bases having the composition RO; e.g. CaO, MgO, BaO, FeO, MnO, and ZnO.

		Oxygen Ratio.
Subsilicate	$4\,RO + SiO_2 = R_4SiO_6$	2 in base : 1 in acid
Monosilicate	$2\,RO + SiO_2 = R_2SiO_4$	1 ,, : 1 ,,
Bisilicate	$RO + SiO_2 = RSiO_3$	1 ,, : 2 ,,
Trisilicate	$2\,RO + 3\,SiO_2 = R_2Si_3O_8$	1 ,, : 3 ,,
Sesquisilicate	$4\,RO + 3\,SiO_2 = R_4Si_3O_{10}$	2 ,, : 3 ,,

Formulæ for silicates of bases having the composition R_2O_3; e.g. Al_2O_3, Fe_2O_3, Mn_2O_3.

		Oxygen Ratio.
Subsilicate	$4\,R_2O_3 + 3\,SiO_2 = R_8Si_3O_{18}$	2 in base : 1 in acid
Monosilicate	$2\,R_2O_3 + 3\,SiO_2 = R_4Si_3O_{12}$	1 ,, : 1 ,,
Bisilicate	$R_2O_3 + 3\,SiO_2 = R_2Si_3O_9$	1 ,, : 2 ,,
Trisilicate	$2\,R_2O_3 + 9\,SiO_2 = R_4Si_9O_{24}$	1 ,, : 3 ,,
Sesquisilicate	$4\,R_2O_3 + 9\,SiO_2 = R_8Si_9O_{30}$	2 ,, : 3 ,,

Each sesquisilicate can be broken up into a monosilicate and a bisilicate; for instance:—

$$R_4Si_3O_{10} = R_2SiO_4 + 2\,(RSiO_3)$$
$$R_8Si_9O_{30} = R_4Si_3O_{12} + 2\,(R_2Si_3O_9)$$

If a silicate contains but one base it is called monobasic, but if two or more a double silicate or multibasic silicate.

Subsilicates are easily fusible, flow thinly, but consolidate quickly and break up in doing so. Their colour is usually dark, and they have a high specific gravity: formed mostly during the refining of metals. Subsilicates are only used for special purposes, e.g. when it is cheaper to lose some of the metal in the slag than go to the expense of flux and the necessary fuel to melt a larger quantity of more siliceous slag.

Monosilicates are not so readily fusible as the former, neither are they so thinly fluid, but they cool quickly and form crumbly pieces that don't hold together. Specific gravity 4·2 to 3·6.

Monosilicates eat into the furnace lining when not kept sufficiently cool, and on account of solidifying easily they entangle globules of metal. They also form deposits in the furnace, and if heated too strongly reduce iron, causing sows, thus shortening the life of the campaign. Monosilicates dissolve simple metallic sulphides of Fe, Zn, Ca, etc.

A monosilicate is used when converting copper matte.

Slags used in smelting lead ores are usually monosilicates, the bisilicates not being suitable as they carry away too much lead as a silicate; they are also more viscous, and cause irregularities in the working of the furnace. The monosilicate, however, requires more base for fluxing the silica, and is, therefore, not always economical, so other slags are aimed at having oxygen ratios of 2 to 3, 4 to 5, and so forth.

Sesquisilicates are a mixture of a monosilicate with a bisilicate. It has a low melting-point, and runs smoothly without forming a thick crust over its surface. Its specific gravity allows a complete and rapid settlement of the matte.

Bisilicates are still more difficult to fuse, flow thickly, and can be drawn out into threads. They cool slowly. Specific gravity 3 to 3·5.

Bisilicates are often made because they are not too difficult to fuse, and do not corrode the acid lining of furnaces so easily as more basic slags, and on account of cooling slower do not deposit so readily in the furnace, besides giving time for the metal to settle through it.

In copper smelting generally aim for a bisilicate slag from the ore, but it may be necessary to vary this in order to obtain the required grade of matte, since this may be raised or lowered by adding more or less silica to flux off the iron that would otherwise pass into the matte. If the ore reduces with difficulty, flux it in such a manner as to give the metals time to reduce before the slag separates out. When concentrating a matte, make a sesquisilicate slag; it works slower, giving the matte time to roast.

In blast furnace work, if too high a copper matte is not formed, the slag may be sufficiently poor to be discarded, and the gases, which escape at a temperature of about 300 C., are relatively free from metals. The slag from copper convertors is so foul that it has to be re-treated, and convertor gases escape at a temperature of about 1,500 C., which carry away large quantities of metals. The volatilization losses of Au and Ag from a convertor may be increased by the long period required to blow too low a grade of matte.

Trisilicates flow slowly, cool gradually, and can also be drawn out into threads ; they are porcelain-like in appearance. They require a very great temperature to form them, and are seldom used. Specific gravity 2·94 to 2·57.

The choice of a slag depends on the object of the operation, the composition of the materials at hand, taking their cost into consideration, and the cleanliness of the slag. One wants to use the least possible amount of fluxes and fuel. An unnecessary amount of flux increases the quantity of slag and the loss of metals in it. Besides the heat-producing substances in a fuel, one must consider the ash which has to be slagged off, likewise impurities in the fluxes used. Many of the difficulties met with in smelting are due to an excess of fuel, e.g. the reduction of iron which forms sows and shortens the life of a campaign.

The monobasic silicates generally require more heat to form than double or multibasic silicates, and of the compound silicates those composed of monoxide bases are more difficult to fuse than a mixture of monoxide and sesquioxide bases.

Of the monobasic silicates those of—

Iron and Manganese require .	1789° C. to 1832° C.
Lime	2100° C. ,, 2150° C.
Baryta	2100° C. ,, 2200° C.
Magnesia	2200° C. ,, 2250° C.
Alumina	2300° C. ,, 2400° C.

Of double silicates those of—

Lime and Alumina	form at	from	1918° C. to 1950° C.
Lime and Magnesia	,,	,,	2000° C.
Baryta and Alumina	,,	,,	2050° C.
Baryta and Lime	,,	,,	2100° C.

Slags already formed fuse at a lower temperature than that required for their formation.

Slag calculations are based on the ratio of the O in the bases to that of the silica.

When calculating a slag to contain Ba O or Mg O it simplifies matters to bring these substances to their equivalent of Ca O. This is done by multiplying the percentage of Ba O by 0·368, and the percentage of Mg O by 1·4.

$$\text{Molecular weight of } \frac{\text{Ca O}\ 56}{\text{,,}\quad \text{Ba O}\ 152} = 0·368. \qquad \frac{\text{Ca O}\ 56}{\text{Mg O}\ 40} = 1·4.$$

In like manner Mn O is calculated to its equivalent of Fe O.

The volatilization of sulphur in ordinary copper smelting may be as much as 75 %, leaving 25 % active sulphur.

The following type slags are taken from the private notebook of H. C. Bellinger. A slag is called whole, half, or quarter, according to the ratio of Fe O + Mn O to the Ca O + Mg O + Ba O.

Lead Slag and Eiler's Pueblo Slag and Leadville.

One-quarter slag % Fe O : % Ca O :: 4 : 1
One-half slag % Fe O : % Ca O :: 2 : 1

$$x = \text{Fe O} \qquad x+y=1 \qquad \text{Fe O} = 72$$
$$y = \text{Ca O} \qquad\qquad\qquad \text{Ca O} = 56$$

For quarter slag $x \text{ Fe O} = 4y \text{ Ca O}$
For half slag $x \text{ Fe O} = 2y \text{ Ca O}$

Quarter slag.

$$x+y=1$$
$$\frac{x}{7}-\frac{4y}{9}=0$$
$$x : 4y = \frac{1}{72} : \frac{1}{56}$$
$$\frac{x}{56}=\frac{4y}{72} \text{ whence } x = \frac{28y}{9}$$
$$x+y=1, \text{so } \frac{28y}{9}+y=1$$
$$28\,y+9\,y=9 \qquad x=\frac{28}{37}$$
$$37\,y = 9$$
$$y=\frac{9}{37} \qquad y=\frac{9}{37}$$

For quarter slag.
$$\text{RO} = \frac{28}{37}\text{ Fe O} + \frac{9}{37}\text{ Ca O}.$$

Half slag.

$$x+y=1 \qquad x=\frac{14}{23}$$
$$\frac{x}{7}-\frac{2y}{9}=0 \qquad y=\frac{9}{23}$$

For half slag.
$$\text{RO} = \frac{14}{23}\text{ Fe O} + \frac{9}{23}\text{ Ca O}.$$

Examples.

(1) *Subsilicate.* $3\,RO + SiO_2$

Quarter slag.

$$3\left(\frac{28}{37}\,FeO + \frac{9}{37}\,CaO\right) + SiO_2 = 3\left(\frac{28}{37}\times 72 + \frac{9}{37}\times 56\right)$$
$$+ (28+32) = 3\,(54{\cdot}487 + 13{\cdot}622) + 60 = 3\,(68{\cdot}11) + 60 = 264{\cdot}33$$

$$\frac{3\times 54{\cdot}49}{264{\cdot}33} = 61{\cdot}84\%\ FeO$$

$$\frac{3\times 13{\cdot}62}{264{\cdot}33} = 15{\cdot}46\%\ CaO$$

$$\frac{60}{264{\cdot}33} = \frac{22{\cdot}70\%\ SiO_2}{100{\cdot}00}$$

Half slag.

$$3\left(\frac{14}{23}\,FeO + \frac{9}{23}\,CaO\right) + SiO_2 = 3\,(43{\cdot}826 + 21{\cdot}913) + 60 =$$
$$257{\cdot}22$$

$$\left.\begin{matrix}131{\cdot}49\\65{\cdot}73\\60{\cdot}00\end{matrix}\right\} = \begin{matrix}51{\cdot}12\%\ FeO\\25{\cdot}55\%\ CaO\\23{\cdot}33\%\ SiO_2\end{matrix}$$

$$\overline{257{\cdot}22}\qquad\overline{100{\cdot}00}$$

(2) *2 Mono and 1 Bisilicate* $2\,(2\,RO + SiO_2) + (RO + SiO_2)$

Quarter slag.

$$5\,RO + 3\,SiO_2 = 5\left(\frac{28}{37}\,FeO + \frac{9}{37}\,CaO\right) + 3\,SiO_2 = 5\,(54{\cdot}487$$
$$+ 13{\cdot}622) + 180$$

$$\left.\begin{matrix}180{\cdot}00\\272{\cdot}45\\68{\cdot}10\end{matrix}\right\} = \begin{matrix}34{\cdot}58\%\ SiO_2\\52{\cdot}34\%\ FeO\\13{\cdot}08\%\ CaO\end{matrix}$$

$$\overline{520{\cdot}55}\qquad\overline{100{\cdot}00}$$

Half slag.

$$5\,RO + 3\,SiO_2 = 5\left(\frac{14}{23}\,FeO + \frac{9}{23}\,CaO\right) + 3\,SiO_2 = 5\,(43{\cdot}826$$
$$+ 21{\cdot}913) + 180$$

$$\left.\begin{matrix}180{\cdot}00\\219{\cdot}15\\109{\cdot}56\end{matrix}\right\} = \begin{matrix}35{\cdot}38\%\ SiO_2\\43{\cdot}08\%\ FeO\\21{\cdot}54\%\ CaO\end{matrix}$$

$$\overline{508{\cdot}71}\qquad\overline{100{\cdot}00}$$

(3) *2 Mono and 1 Bisilicate.*

2 parts by weight of Monosilicate ($2\,RO + SiO_2$).
1 part ,, Bisilicate ($RO + SiO_2$).

Quarter Slag.

$$\frac{(2 \times 30{\cdot}58) + 46{\cdot}83}{3} = \frac{107{\cdot}99}{3} = 36{\cdot}0\ \%\ SiO.$$

$$\frac{(2 \times 55{\cdot}54) + 42{\cdot}54}{3} = \frac{153{\cdot}61}{3} = 51{\cdot}2\ \%\ FeO.$$

$$\frac{(2 \times 13{\cdot}08) + 10{\cdot}63}{3} = \frac{38{\cdot}39}{3} = 12{\cdot}8\ \%\ CaO.$$

$$100{\cdot}00$$

Half Slag.

$$\left.\begin{array}{l} \dfrac{(2 \times 31{\cdot}33) + 47{\cdot}11}{3} = 36{\cdot}8\ \%\ SiO_2 \\ \dfrac{(2 \times 45{\cdot}78) + 34{\cdot}86}{3} = 42{\cdot}1\ \%\ FeO \\ \dfrac{(2 \times 22{\cdot}89) + 17{\cdot}43}{3} = 21{\cdot}1\ \%\ CaO \\ \qquad\qquad 100{\cdot}00 \end{array}\right\} \text{Contrast with results above.}$$

Example of Pueblo and Leadville Lead Slag.

$$\left.\begin{array}{l} 36{\cdot}00\ \%\ SiO_2 \\ 50{\cdot}00\ \%\ FeO \\ 12{\cdot}50\ \%\ CaO \\ 1{\cdot}50\ \%\ RO \end{array}\right\} \text{One-quarter.} \qquad \left.\begin{array}{l} 36\ \%\ SiO_2 \\ 40\ \%\ FeO \\ 20\ \%\ CaO \\ 4\ \%\ RO \end{array}\right\} \text{One-half.}$$

Quarter Slag.

$$36{\cdot}0\ \%\ SiO_2 = 36 \times \frac{32}{60} = 19{\cdot}20$$

$$\left.\begin{array}{l} 51{\cdot}2\ \%\ FeO = 51{\cdot}2 \times \dfrac{16}{72} = 11{\cdot}38 \\ 12{\cdot}8\ \%\ CaO = 12{\cdot}8 \times \dfrac{16}{56} = 3{\cdot}66 \end{array}\right\} \begin{array}{c} 15{\cdot}04 : 19{\cdot}20 \\ 3 : 4 \end{array}$$

Half Slag.

$$36{\cdot}0\ \%\ SiO_2 = 36 \times \frac{32}{60} = 19{\cdot}20$$

$$\left.\begin{array}{l} 42{\cdot}66\ \%\ FeO = 42{\cdot}66 \times \dfrac{16}{72} = 9{\cdot}48 \\ 21{\cdot}33\ \%\ CaO = 21{\cdot}33 \times \dfrac{16}{56} = 6{\cdot}10 \end{array}\right\} \begin{array}{c} 15{\cdot}58 : 19{\cdot}20 \\ 3 \quad 4 \end{array}$$

Class of Slag.	Formula.	xFeO = $4y$ CaO.			xFeO = $2y$ CaO.		
		SiO_2	FeO	CaO	SiO_2	FeO	CaO
Subsilicate . . .	3 RO+ SiO_2	22·70	61·84	15·46	23·33	51·12	25·55
Monosilicate . .	2 RO+ SiO_2	30·58	55·54	13·88	31·33	45·78	22·89
Sesquisilicate . .	4 RO+3 SiO_2	39·78	48·17	12·05	40·64	39·58	19·78
Bisilicate . . .	RO+ SiO_2	46·83	42·53	10·64	47·71	34·86	17·43
Trisilicate . . .	2 RO+3 SiO_2	56·92	34·46	8·62	57·79	28·14	14·07
2 Mono and 1 Bisilicate	5 RO+3 SiO_2	34·58	52·34	13·08	35·38	43·08	21·54
3 Mono and 2 Bisilicate	8 RO+5 SiO_2	35·50	51·60	12·90	36·32	42·45	21·23
1 Mono and 1 Sesquisilicate	3 RO+2 SiO_2	37·00	50·40	12·60	37·83	41·45	20·72
1 Mono and 2 Sesquisilicate	10 RO+7 SiO_2	38·14	49·49	12·37	38·99	40·67	20·34

Type.	x.	y.	Slag formula 5 R O + 3 SiO_2.		
			SiO_2.	FeO.	CaO.
1 : 4	$\frac{28}{37}$	$\frac{9}{37}$	34·6	52·3	13·1
3 : 11	$\frac{77}{104}$	$\frac{27}{104}$	34·7	51·3	14·0
2 : 7	$\frac{49}{67}$	$\frac{18}{67}$	34·7	50·8	14·5
3 : 10	$\frac{70}{97}$	$\frac{27}{97}$	34·8	50·2	15·0
1 : 3	$\frac{7}{10}$	$\frac{3}{10}$	34·9	48·8	16·3
3 : 8	$\frac{56}{83}$	$\frac{27}{83}$	35·0	47·3	17·7
2 : 5	$\frac{35}{53}$	$\frac{18}{53}$	35·1	46·3	18·5
3 : 7	$\frac{49}{76}$	$\frac{27}{76}$	35·2	45·4	19·5
1 : 2	$\frac{14}{23}$	$\frac{9}{23}$	35·4	43·1	21·5
3 : 5	$\frac{35}{62}$	$\frac{27}{62}$	35·6	40·2	24·2
2 : 3	$\frac{7}{13}$	$\frac{6}{13}$	35·8	38·5	25·7

Slags by A. Raht.

Type.	SiO_2.	FeO.	CaO.	RO.
½ with 14 RO	35·43	33·31	17·26	14·00
½ ,, 12 RO	35·43	34·60	18·00	12·00
½ ,, 10 RO	35·43	35·93	18·63	10·00
½ ,, 6 RO	37·5	44·9	11·6	6·0
½ ,, 4 RO	36·0	40·0	20·0	4·0
½ ,, 17 RO 1 mono and 1 sesqui.	35·98	31·35	15·68	17·00

One-half Slag used in E. Helena on account of lack of Siliceous Ores.

$3 (FeO) 2 SiO_2 + (CaO) 2 SiO_2$. That is at 18 R O.

31·38	SiO_2 =	100	= 1·2116
33·32	FeO =	82·53	= 1·000
17·28	CaO =	55	= 0·667
81·98			2·8786
18·02			
100·00			

Lime is generally added in the form of limestone ; it is used to remove silica ; it cleans the slag and lessens its specific gravity, allowing the matte to settle more perfectly. About 15 % Ca O gives the best results for copper ore smelting when plenty of iron is available. A high lime slag makes it low in lead, except when the presence of zinc interferes and requires more iron. When required to slag off a small amount of sulphur, as in iron smelting, it may be got rid of as sulphide of calcium or barium. The sulphur may be considered as equal to half its own amount of silica—really 28 to 60.

Magnesia is generally added in the form of dolomite. Magnesia has 1·4 times the fluxing power of lime, and gives little trouble when used alone under 8 %, but in the presence of Zn or Al_2O_3 is objectionable. It makes the slag less fluid, and when high magnesia slags are formed must have at least 20% iron.

Baryta is used as heavy spar, it makes a slag fluid but heavy ; some of it enters the matte as Ba S. Matte does not separate well from slags carrying barium.

Zinc decreases the fluidity of the slag and requires more fuel ; by entering the matte it decreases its specific gravity and makes it more difficult to settle. Being volatile zinc causes a loss of silver and forms accretions ; 10 % Zn is the maximum limit that should be present in a charge.

Alumina tends to purify a slag, but if over 10 % is apt to make the slag sticky. Used in the form of clay-slate or alumina-bearing rocks ; employed when smelting ores rich in lime. Aluminous slags are generally slow running, and require a high heat to make them flow properly.

Iron and Manganese, in the form of oxide or carbonate, are used to flux siliceous ores.

Silica as quartz and natural silicates is used for removing excess of bases.

A wide range in the composition of slags is allowable in copper smelting, depending on the class of smelting employed; yet the proportion of silica to iron and lime will be found to correspond approximately to definite silicates.

One must determine whether it is cheaper to use a lime or iron flux, and whether conditions are such that it is better to make a concentrating or converting matte. If the matte is lower than, say, 35% copper, it is generally better to concentrate it by re-smelting, which serves at the same time to reduce the amount of As, Sb, Pb, and Zn present. Matte suitable for converting generally ranges between 35% and 60% of copper; if too high it is apt to chill when being transported from the furnace to the converter, and the ore slag is liable to be too rich in copper.

The size of a charge depends on a combination of circumstances, e.g. the size of the furnace and the relative amounts of the various ores to be smelted.

Draw up a table as shown, noting the assays of the various ingredients in their proper column. Take the greatest weight from the chief ore, and proportion the other constituents according to their production, or, if that is capable of regulation, according to the probable requirements for matte and slag formation. It does not matter whether the total weights exceed or are less than that required for the charge, for they can be adjusted later when the relative proportions of the ores and fluxes have been ascertained. If several ores are to be smelted, blend those of small bulk to make a mixture so that there are only two classes of ore to deal with. If desired to blend two ores, one containing 30% and the other 45%, in order to get a blende of 35%, then—

$$\begin{matrix} 45-30=15 \\ 35-30=\ \ 5 \end{matrix}; \quad \frac{5 \times 100}{15} = 33{\cdot}33 \text{ pts. by weight of the } 45\% \text{ ore.}$$

The proportion of the 30% ore required is $100 - 33{\cdot}33 = 66{\cdot}67$ parts.

From the quantities assumed in the trial calculations and the assays, calculate the number of lbs. of each constituent, and add those of the same kind together.

The proportion of sulphur burnt off varies with the furnace, the ore, the length of time the charge is in the furnace, the flux, and the pressure of the blast. Of the sulphur that is left most passes into the matte while about 1% goes into the slag. The amount of sulphur retained for the matte will determine the matte fall. The usual matte fall is from 10 : 1 to 15 : 1. Let us assume in our particular case that there is a loss of 70% of the sulphur in the ore and concentrates by volatilization and in the slag, then 70% of 156 lbs. equals

CHARGE CALCULATION.

Trial Method.

Material.	Total wt. in lbs. dry.	Moisture.	Total wt. lbs. wet.	Fe+Mn %	Fe+Mn lbs.	Si O2 %	Si O2 lbs.	S %	S lbs.	CaO+MgO %	CaO+MgO lbs.	Cu %	Cu lbs.
Ore. . . .	1000	3	Fill this in after correcting for moisture.	27	270	31	310	10	100	...	...	4	40
Concentrates	200	4		30	60	13	26	28	56	...	...	12	24
-									156				
Old Slag . .	250	...		33	82·5	30	75	5	12·5	...	...	7	17·5
Limestone .	100	1		...	...	7	7	...	...	47	47	...	...
Ironstone .	70	1		61	42·7	9	6·3	...	...	...	...	...	...
	1620												
Coke 8% . .	130			1·2	1·5	10	13	1	1·3	2	2·6	...	...
					456·7		437·3		13·8		49·6		81·5

Desired Composition of Slag.

SiO_2	42%
FeO	45%
CaO	4%
Other components	9%
	100

Matte.

S.	60·80	units
Fe	104·02	„
Cu	78·38	„
	243·20	„

Assume this to be 95% of total matte, which would then be 256 lbs. of 30·6% Cu.

	lbs.
Total S in ore and conc. . .	156
Less 70% vol. and in slag .	109
	47
S in old slag and coke ash .	13·8
S available for matte . . .	60·8
Ratio between S and Fe+Cu in matte	3
Fe+Cu in matte	182·4

Slag formed 42 : 100 :: 437·3 = 1041

If loss of Cu in slag is 0·3%, then

$$\frac{1041 \times 0{\cdot}3}{100} = 3{\cdot}123 \text{ lbs. Cu.}$$

Slag.

SiO_2 437·3 = 233·2 acid units oxygen
FeO 453·4 = 100·7 basic „ „
CaO 49·6 = 14·1 „ „ „

940·3 or ratio.

	lbs.
Total Cu. .	81·50
Lost in slag	3·12
Cu available for matte	78·38
Fe+Cu in matte . .	182·40
Fe in matte	104·02
Total Fe .	456·70
Required for matte . .	104·02
Available for slag .	352·68

$$352{\cdot}68 \times \frac{9}{7} = 453{\cdot}4 \text{ FeO}$$

Matte-fall.

$$\frac{256 \times 100}{1620} = 15{\cdot}8\%$$

BU : AU as 114·8 : 233·2 = 1 : 2·03 or approx. R O SiO_2

109 lbs., leaving 47 lbs. sulphur available for matte making, plus 13·8 lbs. in the slag and coke ash, from which there was little or no loss, making 60·8 lbs. altogether.

Cu_2	126 =	51·2%	} 74%	$\frac{74}{26}\ \frac{Fe+Cu}{S}=3$
Fe	56 =	22·8		
S_2	64 =	26·0	26%	
	246	100·0		

The matte formed may or may not have the above composition, and actually all the copper in the matte is not combined as Cu_2S, but for the present we will take it that the sulphur constitutes about one-quarter the weight of the matte, so multiplying the matte-making sulphur by 3 will give the amount of Fe + Cu in the matte, viz. 182·4 lbs.

To determine the quantity of slag formed :—

As SiO_2 in assumed slag : 100 :: lbs. SiO_2 in charge : weight of slag
42 : 100 :: 437·3 : 1041

Assume the loss of copper in the slag to be 0·3%, then $\frac{1041 \times 0{\cdot}3}{100} = 3{\cdot}123$ lbs. Cu. Deduct this from the 81·5 lbs. in the charge, we then have 78·38 lbs. copper available for matte making. Deducting the 78·38 lbs. copper from the 182·4 lbs. combined Fe and Cu leaves 104·021 lbs. in the matte. If we consider the Fe, Cu, and S to form 95% of the total matte, we have 256 lbs. matte containing 30·6% Cu.

Note down the composition of the slag it is desired to make. If the available sulphur makes too low a matte, we may have to abandon the slag originally desired and increase the SiO_2 of the slag in order to reduce the S in the matte by smelting slower. This increase of SiO_2 can only go on to a stage when the slag becomes uneconomical.

The balance of the Fe not required by the matte passes into the slag, and is calculated as its equivalent of FeO.

Fe : FeO :: 56 : 72 $\frac{72}{56}=\frac{9}{7}$; therefore, to convert Fe to FeO multiply the Fe by $\frac{9}{7}$

The CaO in limestone, allowing for reasonable impurities, is approximately 50%, therefore the required amount of lime has to be multiplied by 2 to bring it to limestone.

The combined weights of SiO_2, FeO, and CaO in the slag amounts to 940·3, but these constituents only form 91%

of the desired slag, so the total weight of the slag will be 91 : 940·3 :: 100 : 1033.

Total wt. of slag : total wt. of constituent :: 100 : theoretical % of constituent.

1033	:	437·3	:: 100 :	42·3% SiO_2
1033	:	453·4	:: 100 :	43·9% FeO
1033	:	49·6	:: 100 :	4·8% CaO
		940·3		91·0

If the theoretical result comes within 2% of the desired slag, that is considered near enough, owing to variations in the ores, imperfect weighing, and other irregularities. If over 2% another trial calculation must be made with other figures.

The matte fall is—

Weight of charge	:	weight of matte	:: 100 : x
1620	:	256	:: 100 : 15·8

Supposing the ore, concentrates, and old slags available form the commercial basis of the charge, and it is desired to use only a limestone flux, there would be no occasion to make a trial calculation, but the required amount of limestone could be obtained by a straight out calculation. A bisilicate slag requires to have twice the percentage of O on the silica or acid side as on the base side.

Si 28	Ca 40	Fe 56 ;	72 : 60 :: 1 : 0·833 FeO factor.
O_2 32	O 16	O 16 ;	56 : 60 :: 1 : 1·07 CaO factor.
60	56	72	

The available Fe for slag is $414 - 104 = 310 \times \frac{9}{7} = 398{\cdot}6$ FeO; multiply this by the factor 0·833 = 332·03 SiO_2 satisfied.

The SiO_2 less that in the limestone and ironstone as shown in the table is 424 lbs., deduct 332·03 satisfied by the FeO, this leaves 91·97 unsatisfied. To find the amount of CaO necessary to form a bisilicate, divide the SiO_2 in the limestone by 1·07, in our case 7% equals 6·5. Subtract this from the 47% CaO in the limestone, which leaves 40·5% CaO available. The 91·97 lbs. SiO_2 to be fluxed with CaO is divided by the factor 1·07, which gives 85. As the available CaO in the limestone is 40·5%, then—

40·5 : 85 :: 100 : 209·9 lbs. limestone in the charge.

TABLE A. For ascertaining the necessary amounts of Bases to convert given amounts of SiO_2 into slag.		Table B. For ascertaining the necessary amounts of SiO_2 to convert given amounts of bases into slag.	
One part by weight of SiO_2 requires—	Parts by weight of bases.	One part by weight of base requires—	Parts by weight of silica.
For Monosilicates—		For Monosilicates—	
CaO	1·86	CaO	0·535
MgO	1·33	MgO	0·750
Al_2O_3	1·14	Al_2O_3	0·873
FeO	2·40	FeO	0·416
MnO	2·36	MnO.	0·422
For Bisilicates—		For Bisilicates—	
CaO	0·93	CaO	1·070
MgO	0·66	MgO.	1·500
Al_2O_3	0·57	Al_2O_3	1·747
FeO	1·20	FeO	0·833
MnO	1·18	MnO.	0·845
For Sesquisilicates—		For Sesquisilicates—	
CaO	1·24	CaO	0·803
MgO	0·88	MgO.	1·125
Al_2O_3	0·76	Al_2O_3	1·310
FeO	1·60	FeO	0·625
MnO	1·57	MnO.	0·633
Ratio of molecular weight of bases to that of SiO_2; $\frac{2\,CaO\ 112}{SiO_2\ 60} = 1·86$		Ratio of molecular weight of SiO_2 to that of the base $\frac{SiO_2\ 60}{2\,CaO\ 112} = 0·5357$	

The use of these tables saves much calculation. If the slag-forming bases are multiplied by their corresponding factors in table B, and the amounts of SiO_2 so formed added up, this can be deducted from the amount of SiO_2 in the ore should that be in excess, in which case the balance of SiO_2

must be multiplied by the factor of the base in table A with which it is intended to flux it. If the flux is lime, then as the lime is generally added in the form of limestone, $\frac{CaCO_3}{CaO}\ \frac{100}{56} = 1{\cdot}785$, the amount of lime required must be multiplied by 1·785 in order to ascertain the necessary amount of limestone.

Graphic Method.

On squared paper draw two lines at right angles to each other and divide them into equal parts, making zero the point of intersection. Let the horizontal line represent the bases, and the vertical the SiO_2 of a monosilicate. From the point where the two lines meet, draw lines to represent different bases required in the formation of a slag at such an angle that the Al_2O_3 line cuts the horizontal line opposite 10 SiO_2 at 11·3, the MgO at 13·3, the CaO, Fe, and Mn at 18·6, FeO and MnO at 24, and BaO at 50·7. For convenience in calculating the fluxes required, lines for Fe_2O_3 cutting the 10 SiO_2 line at 26·6, and $CaCO_3$ at 33·3 are added. The atomic weights of Fe and Mn being so close to the molecular weights of CaO, the same line does for all of them.

The above distances are determined as follows:—

$2CaO\,SiO_2$
Monosilicate of lime

$$\left.\begin{array}{l}\left.\begin{array}{ll} Ca_2 & 80 \\ O_2 & 32 \end{array}\right\} 112 \\ \left.\begin{array}{ll} Si & 28 \\ O_2 & 32 \end{array}\right\} 60 \end{array}\right\} 60 : 112 :: 10 : 18{\cdot}6$$

Likewise $2MgO\,.\,SiO_2 = 60 : 80 :: 10 : 13{\cdot}2$
$2FeO\,.\,SiO_2 = 60 : 144 :: 10 : 24$
$2BaO\,.\,SiO_2 = 60 : 304 :: 10 : 50{\cdot}7$
$2Al_2O_3\,.\,3SiO_2 = 180 : 204 :: 10 : 11{\cdot}3$

Alumina having the composition R_2O_3 requires 3 SiO_2 to form a monosilicate.

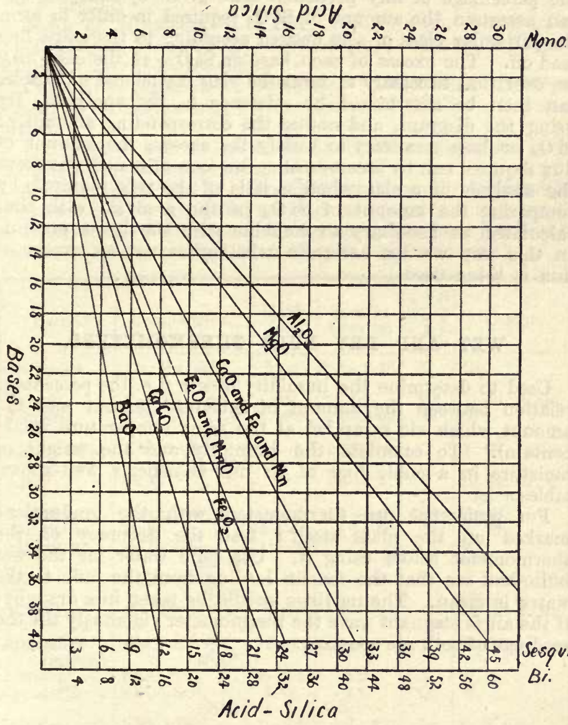
Fe_2O_3 is equal to 2 FeO from a slag-making point of view; therefore, as the molecular weight of Fe_2O_3 is 160,

$$60 : 160 :: 10 : 26{\cdot}6$$

and as 2 $CaCO_3$ is equal to 2 CaO, and the molecular weight of 2 $CaCO_3$ is 200, then—

$$60 : 200 :: 10 : 33{\cdot}3$$

Two vertical lines should be drawn parallel to the monosilicate line, one divided into double the number of spaces in the same distance as the monosilicate line to represent bisilicates, the other into one and a half the number of spaces to represent



Acid Silica
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
Mono.
Bases
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
Al2O3
MgO
CaO and Fe2 and Mn
FeO and MnO
Fe2O3
CaO
BaO
Sesqui
Bi.
3 6 9 12 15 18 21 24 27 30 33 36 39 42 45
4 8 12 16 20 24 28 32 36 40 44 48 52 56 60
Acid-Silica

the sesquisilicates. All sesquisilicates may be resolved into a monosilicate and a bisilicate, for instance $R_4\,Si_3\,O_{10} = R_2\,Si\,O_4 + 2(R\,Si\,O_3)$, and $R_8\,Si_9\,O_{30} = R_4\,Si_3\,O_{12} + 2(R_2\,Si_3\,O_9)$.

To use the diagram it is advisable to employ set squares. By following the horizontal line cut by each base-line above the percentage of any particular base given by analysis, one can ascertain the amount of $Si\,O_2$ required in order to form the particular class of slag desired according to the silica line read off. The excess of each base or $Si\,O_2$, as the case may be, over that necessary to form the slag considered advisable, can then be ascertained by reference to the analysis. By using the diagram, and noting the corresponding amount of $Si\,O_2$ or base necessary to satisfy the excess, the amount of flux required can be ascertained. One can also find out from the analysis of a slag whether it is of the type required, by comparing the amount of $Si\,O_2$ in the analysis with that calculated as necessary to combine with the bases present. In this way we can ascertain whether or not an excess of flux is being used.

WET AND DRY BULB THERMOMETERS.

Used to determine the humidity of air (i.e. the percentage relation between the amount of moisture present and the amount which air saturated at the same temperature would contain). To calculate the humidity and the weight of moisture in a cubic foot of air use Glaisher's well-known tables.

For preference use thermometers with the graduations marked on the glass itself: test the accuracy of the thermometer before using it. Use pure water for the wet bulb, and see that the muslin leading from the bulb to the water is clean. The readings should be taken in a draught: if the air is stagnant wave the thermometer vigorously till the readings of both are constant.

List of Minerals, giving their Composition, Hardness, Specific Gravity, Crystalline System, and Colour.

C. = colourless, W. = white, R. = red, Bl. = blue, Y. = yellow, Ge. = green, Br. = brown, B. = black, V. = violet, Gr. = grey, Or. = orange.

Scale of Hardness.—1 = Talc, 2 = Gypsum, 3 = Calcite, 4 = Fluorspar, 5 = Apatite, = Orthoclase, 7 = Quartz, 8 = Topaz, 9 = Corundum, 10 = Diamond.

Crystalline Systems.—I Isometric, II Tetragonal, III Hexagonal, IV Orthorhombic, V Monoclinic, VI Triclinic, O Amorphous.

The inclined hemihedral forms for I—IV are indicated by ×, the parallel hemihedral forms by π.

Scale of Fusibility (v. Kobell).—1 Antimonite, 2 Natrolite, 3 Alamandite, 4 Actinolite, 5 Orthoclase (smelts only in small splinters in the hottest part of the blowpipe flame), 6 Bronzite (only the sharp edges of small splinters fuse round).

Name.	Composition.	Hardness.	Specific Gravity.	Crystalline System.	Colour.
Actinolite	(Ca, Mg, Fe) SiO^3	5—6	3·02—3·16	V	Ge.
Adamite	$Zn^2(OH)AsO^4$	3·5	4·3	V ?	Y. Bl. R. Ge.
Adularia	$K^2O, Al^2O^3, 6SiO^2$	6—6·5	2·5—2·69	V	C.
Agalmatolite	$K^2O, 3Al^2O^3, 9SiO^2, 3H^2O$	2·5—3	2·75—2·9	O	Y. Gr. R. Ge.
Agate	SiO^2	7	2·5—2·8	O	R. Ge. Gr. C. Br. W.
Aikinite	$Pb^2Cu^2Bi^2S^6$	2—2·5	6·1—6·8	IV	Gr. B.
Alabandite	MnS	3·5—4	3·9—4	I	B. Br.
Alabaster	$CaO, SO^3 + 2H^2O$	1·5—2	2·4	O	W.
Albite	$Na^2O, Al^2O^3, 6SiO^2$	6—7	2·5—2·64	VI	C. Gr. Ge. Bl. R.
Allophane	$Al^2SiO^5, 5H^2O$	3	1·8—1·9	O	Bl. Ge. Y. Br. C.
Almandite (garnet)	$3FeO, Al^2O^3, 3SiO^2$	6·5—7·5	3—4·3	I	R. RBr.
Altraite	PbTe	3—3·5	8·2	I	W. Y.
Aluminite	$Al^2O^3, SO^3, 9H^2O$	1—2	1·6	O	W.
Alunite	$K^2O, Al^2O^3, 4SO^3, 24aq.$	2—2·5	1·7—2	Iπ	C. Y. Gr.
Amalgam	Ag+Hg	3—3·5	13·7—14·1	I	W. (silver).
Amazon stone (orthoclase)	$K^2O, Al^2O^3, 6SiO^2$	6—6·5	2·4—2·6	V	Ge.
Amber (succinite)	Fossil resin	2—2·5	1·0	O	W. Y. Br. R.

LIST OF MINERALS (*continued*).

Name.	Composition.	Hardness.	Specific Gravity.	Crystalline System.	Colour.
Amblygonite	Al^2O^3, P^2O^5 2(LiF, LiOH)	6	3·05—3·1	VI	W. Gr. Ge.
Ambrite	C, O, H	2	1·034	...	Y. Gr. Ge.
Amethyst (quartz)	SiO^2	7	2·64—2·66	III	Bl. V.
Amphibole	SiO^2(Ca, Mg, Fe, Mn, Na^2, K^2, H^2)O	5—6	2·9—3·4	V	C. Ge. B.
Analcime (analcite)	Na^2O, Al^2O^3, $4SiO^2$, $2H^2O$	5—5·55	2·29	I	C. W. R. Gr. Ge. Y.
Anatase (octahedrite)	TiO^2	5·5—6	3·8—3·9	II	C. Br. B. Bl. Ge. Y.
Andalusite	Al^2O^3, SiO^2	7·5	3—3·2	IV	Gr. R. Br. W. V. Ge
Andesine (andesite)	$(CaNa^2)O$, Al^2O^3, $4SiO^2$	5—6	2·65—2·74	VI	C. Y. Gr. W. Ge. R.
Andradite (garnet)	$Ca^3Fe^2Si^3O^{12}$	6·5—7·5	3·6—4	I	W. Y. Gr. R. Br. Ge. B.
Anglesite	PbO, SO^3	2·7—3	6—6·37	IV	C. Y. Ge. Gr. Br. W. Bl.
Anhydrite	CaO, SO^3	3—3·5	2·8—2·98	IV	C. W. Gr. Bl. R.
Annabergite	3NiO, As^2O^5+ $8H^2O$	2—2·5	3—3·1	V	Ge. W.
Anorthite	CaO, Al^2O^3, $2SiO^2$	6—7	2·6—2·78	VI	W. Gr. R. C.
Anthophyllite	(Mg, Fe)O, SiO^2	5·5	3·18—3·22	IV	Br. Gr. Ge. Y.
Anthracite	C (95°/。)	2—2·5	1·3—1·75	O	B.
Antimonite (stibnite)	Sb^2S^3	2	4·5	IV	Gr. B.
Antimony (native)	Sb (Ag, As, Fe)	3—3·5	6·6	III×	W. Gr.
Apatite	$3Ca^3P^2O^8$+ $CaCl^2(CaF^2)$	5	2·9—3·2	IIIπ	C. Ge. Bl. Y. V. W. R. Gr. Br.
Apophyllite	$4(H^2CaSi^2O^6$+ aq)+KF	4·5—5	2·3—2·4	II	C. R. Gr. Ge. Y.
Aquamarine	Al^2O^3, 3BeO, $6SiO^2$	7·5—8	2·6—2·7	III	Bl-Ge.
Aragonite	$CaOCO^2$	3·5—4	2·95	IV	C. W. Y. Gr. Ge. V.
Argentite	Ag^2S	2—2·5	7·1—7·36	I	Gr.
Arkansite (brookite)	TiO_2	5·5—6	4	IV ?	Br. Y. R. B. Gr.
Arsenic (native)	As (traces of Sb, Ag, Fe, and Au)	3·5	5·9	III×	W. Gr. B.
Arsenolite	As^2O^3	1·5	3·7	I	C. W.
Asbestos (amianthus)	(Mg, Ca)O, SiO^2	5	3·02—3·1	V	W. Ge. Br.
Asphaltum	C (76 °/。) H, O	1—2	1—1·7	O	Br. B.

LIST OF MINERALS (*continued*).

Name.	Composition.	Hardness.	Specific Gravity.	Crystalline System.	Colour.
Atacamite	$3CuO, CuCl^2, 3 H^2O$	3—3·5	4—3·7	IV	Ge.
Augite (pyroxene)	$(Ca, Mg, Fe)O, SiO^2$	5—6	3·2—3·5	V	B. Gr. Ge. Br.
Aurichalcite.	$2CuO, 3ZnO, 2CO^2, 3H^2O$	2	...	?	Ge.
Autunite (uranite)	$CaU^2P^2O^{12}+10aq$	2—2·3	3—3·2	IV	Y.
Aventurine	Partly quartz, partly felspar	...	...	...	Y. R. Br. Gr.
Axinite	$(CaO, Al^2O^3), SiO^2, Bo^2O^3$	6·5—7	3·3	VI	C. Br. V. Gr.
Azurite	$CuO, H^2O, 2(CuO, CO^2)$	3·5—4·2	3·5—3·8	V	Bl.
Babingtonite	$9(CaFeMn)SiO^3 + Fe^2Si^3O^9$	5·5—6	3·4	VI	B.
Barytes (heavy spar)	BaO, SO^3.	2·5—3·5	4·4—4·7	IV	C. Y. Gr. Bl. R. Br.
Barytocalcite	$BaOCO^2, CaOCO^2$	4	3·6	V	W. Gr. Y. Ge.
Basanite (touchstone)	SiO^2 impure with Fe, &c.	7	2·8	O	B.
Beauxite	$Al^2(Fe^2)O^3+2aq$ $4H^2O$	...	2·5	O	W. Br.
Beryl	$3BeO, Al^2O^3, 6SiO^2$	7·5—8	2·67—2·7	III	Ge. Y. Bl. W.
Bieberite (cobalt vitriol)	CoO, SO^3+7H^2O	...	1·9	V	R.
Biotite	$K^4SiO^4,(Fe[Mg])^2 SiO^4+(Al[Fe])^2 Si^3O^{12}$	2·5—3	2·7—3·1	V	Ge. Br. B. Gr.
Bismite (bismuth ochre)	Bi^2O^3	Soft	4·3—4·7	?	Gr. Y. Ge.
Bismuth (native)	Bi (As, S, Te)	2—2·5	9·7	III×	W. R.
Bismuthinite	Bi^2S^3	2·0	6·4—7·2	IV	W. Gr. Y.
Bismutite	Bi^2O^3, CO^2	4—4·5	6·8—6·9	?	Gr. Ge. Y. W.
Blende (sphalerite)	ZnS	3·5—4	3·9—4·2	I×	Y. Br. Ge. B. R.
Blödite	$Na^2O, MgO, 2SO^3, 4H_2O$	2·5—3·5	2·25	V	C. Ge. Gr. R.
Bole (halloysite)	Ferruginous clay	1—2	2—2·5	O	Br. Y. R.
Boracite	$Mg^7Bo^{16}O^{30}Cl^2$	7	2·97	I×	C. Gr. Ge. Y.
Borax (tinkal)	$Na^2Bo^4O^7, 10H^2O$	2—2·5	1·71	V	C. W. Gr. Bl. Ge.
Bornite (erubescite)	$3Cu^2S, Fe^2S^3$	3	4·4—5·5	I	R. Br.
Boulangerite	$3PbS+Sb^2S^3$	2·5—3	5·7—6	O	Gr.
Bournonite.	$Sb^2S^3, 2PbS, Cu^2S$	2·5—3	5·7—5·87	IV	Gr.

LIST OF MINERALS (*continued*).

Name.	Composition.	Hardness.	Specific Gravity.	Crystalline System.	Colour.
Braunite	Mn^2O^3	6—6·5	4·7—4·9	II	Br. B.
Bredbergite (garnet)	$(CaMg)^3Fe^2Si^3O^{12}$	6·5—7·5	3·2—4·3	I	...
Breithauptite	NiSb	5	7·5—7·6	III	R.
Bronzite (enstatite)	MgO, SiO^2	5·5	3·12—3·3	IV	Br. Y. Gr. Ge.
Brookite (arkansite)	TiO^2.	5·5—6	4	IV?	Br. Y. R. B. Gr.
Brown coal (lignite)	C 55—75°/o	...	1·2—1·4	O	Br. B.
Brucite	MgO,H^2O	2·5	2·35	III×	C. Ge. Gr. Bl.
Cacholong (opal)	SiO^2+3—9 aq	5—6	2	O	W. Bl. Y. R.
Cacoxenite	$2Fe^2O^3$, P^2O^5, $12H^2O$	...	2·3	V. or VI	Y.
Cairngorm (quartz)	SiO^2.	7	2·5—2·8	III	Y. Br. B.
Calamine	2ZnO, SiO^2, H^2O	4·5—5	3·1—3·9	IV	C. W. Ge. Y. R. Br. Gr. Bl.
Calcite	CaO, CO^2.	2·5—3	2·723	III×	C. Ge. Gr. Br. R. Bl. V. Y. B.
Caledonite	$5PbSO^4 + 3H^2CuO^2 + 2H^2PbO^2$	2·5—3	6·4	V	Gr.
Calomel	Hg^2Cl^2	1—2	6·5	II	W. Gr. Br.
Cancrinite (nepheline)	$(NaK)^2O$, Al^2O^3, $2SiO^2$	5—6	2·45	III	Gr. Bl. R. Ge. Y. W.
Carnallite	KCl, $MgCl^2$, $6H^2O$	...	1·618	IV	C. R.
Carnelian	SiO^2 with Fe^2O^3	7	2·65	O	R. Br.
Cassiterite	SnO^2 (up to 9°/o Fe^2O^3)	6—7	6·4—7·1	II	Y. Br. Gr. R. B.
Cats-eye	SiO^2.	7	2·6	O	Gr.
Celestine	SrO, SO^3	3—3·5	3·96	IV	C. W. R. Bl.
Cerargyrite	AgCl	1—1·5	5·6	I	Ge. Gr. V. W.
Cerite	2(Ce, La, Di) O, SiO^2, H^2O	5·5	4·9—5	IV	Br. R.
Cerussite	PbO, CO^2	3—3·5	6·4	IV	C. W. Gr. B. Br.
Cervantite	SbO^2	4—5	4·08	IV	Y.
Chabazite	CaO, Al^2O^3, $4SiO^2$, $6H^2O$	4—5	2	III×	C. R.
Chalcanthite	CuO, SO^3, $5H^2O$	2·5	2·2	VI	Bl.
Chalcedony (quartz)	SiO^2.	7	2·65	O	W. Gr. B. Y. Ge. R. Bl. Br.
Chalcopyrite (copper pyrites)	Cu^2S, Fe^2S^3.	3·5—4	4·1—4·3	II×	Y.

LIST OF MINERALS (*continued*).

Name.	Composition.	Hardness.	Specific Gravity.	Crystalline System.	Colour.
Chalcocite (copper glance)	Cu^2S . .	2·5—3	5·5—5·8	IV	Gr.
Chalcostibite	Cu^2S, Sb^2S^3. .	3·5	4·7	IV	Gr. B.
Chalybite (siderite)	FeO, CO^2. .	3·5—4·5	3·7—3·9	III×	C. Gr. R.
Chiastolite (andalusite)	Al^2O^3, SiO^2. .	5—5·5	2·9—3	IV	W. Gr. Y. R.
Chlorite .	$8MgO, Al^2O^3, 5SiO^2, 7H^2O$	1—1·5	2·8	III	Ge.
Chondrodite.	$5MgO, 2SiO^2$, or $4MgO, MgFl^2, 2SiO^2$	6—6·5	3·17—3·23	V	Y. R. Br. Ge. Gr. B.
Chromite .	$FeCr^2O^4$ . .	5·5	4·3—4·5	I	B.
Chrysoberyl.	BeO, Al^2O^3 . .	8·5	3·65—3·8	IV	Ge.
Chrysocolla .	$CuO, SiO^2, 2H^2O$	2—4	2—2·3	O	Ge. Br. Bl. B.
Chrysolite (olivine or peridot)	$2MgO, SiO^2$.	6—7	3·1—3·5	IV	Y. Gr. Ge. Br.
Chrysoprase (chalcedony)	SiO^2	7	2·65	O	Ge.
Cinnabar	HgS. . . .	2—2·5	8·99	III	R. Gr.
Clausthalite .	$PbSe$ . . .	2·5—3	7·6—8·8	I	Gr.
Clinochlore (ripidolite)	$5Mg(Fe)O, Al^2O^3, 3SiO^2+4H^2O$	2—2·5	2·65—2·78	V	Ge. B. Bl. R.
Clinoclasite .	$6CuO, As^2O^5, 3H^2O$	2·5—3	4·1—4·4	V	Ge. B.
Coal (mineral)	$C(+O+H+N)$ 74—96°/₀C.	0·5—2·5	1—1·8	O	B.
Cobaltite (glance cobalt)	CoS^2+CoAs^2 .	5·5	6—6·3	Iπ	R. W. Gr.
Collyrite .	$2Al^2O^3, SiO^2, 8H^2O$	1·2	2	O	W.
Columbite (niobite)	$FeO(Nb, Ta)^2O^5$	6	5·4—6·4	IV	Br. Gr. B.
Copiapite .	$2Fe^2O^3, 5SO^3, 12H^2O$	1·5	2·14	III	Y.
Copper (native)	Cu	2·5—3	8·8	I	R.
Copper glance	Cu^2S . . .	2·5—3	5·5—5·8	IV	Gr.
Copper nickel	$NiAs$ . . .	5—5·5	7·33—7·6	III	R. Gr.
Copper pyrites	Cu^2S, Fe^2S^3. .	3·5—4	4·1—4·3	II×	Y.
Copper vitriol (chalcanthite)	$CuO, SO^3, 5H^2O$	2·5	2·2	VI	Bl.
Coquimbite .	$(FeAl)^2O^3, 3SO^3, 9H^2O$	2—2·5	2—2·1	III	C. W. Bl. Ge. V.
Cordierite (iolite)	$3MgO, 3Al^2O^3, 8SiO^2$	7—7·5	2·6—2·7	IV	W. Br. Y. Gr. Bl.

LIST OF MINERALS (*continued*).

Name.	Composition.	Hardness.	Specific Gravity.	Crystalline System.	Colour.
Corundum (emerald, sapphire, ruby)	Al^2O^3	9	3·9—4·2	III×	C. W. Gr. Y. Br. Bl. R.
Cotunnite	$PbCl^2$	2	5·2	IV	W.
Covellite (indigo copper)	CuS	1·5—2	3·8—3·9	III	Bl. B.
Crocoisite	PbO, CrO^3	2·5—3	5·9—6·1	V	R.
Cryolite	Al^2Fl^6, 6NaFl	2·5	2·9—3	VI	W. Gr. B. R. Br.
Cuprite	Cu^2O	3·5—4	5·7—6·1	I	R.
Cyanite (disthene)	Al^2O^3, SiO^2	5—7	3·4—3·68	VI	B. Bl. W. Gr. Ge.
Danburite	CaO, B^2O^3, $2SiO^2$	7	2·95	IV	Y.
Datolite	2CaO. $2SiO^2$, Bo^2O^3, H^2O	5—5·5	2·8—3	V	W. Gr. Ge. Y. R. V.
Descloizite	4(Pb, Zn)O, V^2O^5, H^2O	3·5	5·8	IV	Ge. B.
Desmine (stilbite)	CaO, Al^2O^3, $6SiO^2$, $6H^2O$	3·5—4	2·1	IV	W. C. Y. Br. R.
Diallage	(Ca, Mg, Fe)O, SiO^2	4	3·2—3·3	V	Ge. Br.
Dialogite	Mn(Ca)O, CO^2	3·5—4·5	3·4—3·7	III	R. W. Y. Br.
Diamond	C	10	3·5	I×	C. R. Y. Bl. B. Br. Ge.
Diaspore	Al^2O^3, H^2O	6·5—7	3·3—3·5	IV	Gr. Ge. Y. R. W. Br.
Dichroite (cordierite)	3MgO, $3Al^2O^3$, $8SiO^2$	7—7·5	2·6—2·7	IV	C. W. Br. Y. Gr. Bl.
Diopside (pyroxene)	(Ca, Mg)O, SiO^2	5—6	3·2—3·38	V	C. Y. Gr. Ge.
Dioptase	CuO, SiO^2, H^2O	5	3·27—3·348	III×	Ge.
Disthene (cyanite)	Al^2O^3, SiO^2	5—7·2	3·4—3·68	VI	Ge. Bl. W.
Dolomite	CaO, MgO, $2CO^2$	3·5—4	2·8—2·9	III×	C. Gr. Ge. R. Br. B.
Dufrenite	$2Fe^2O^3$, P^2O^5, $3H^2O$	3·5—4	3·3—3·5	IV	Ge. B. Y. Br.
Dufrenoysite	2PbS, As^2S^3	3	5·57	IV	Gr.
Durangite	Al^2O^3, As^2O^5, 2NaFl	5	3·9—4	V	R. Y.
Dyscrasite	Ag^4Sb or Ag^6Sb	3·5—4	9·4—9·8	IV	W. Gr.
Elaterite	C^nH^{2n}	Soft	0·8—1·23	O	B. Br. R. Y.
Electrum	Au+Ag	2·5—3	13—15·5	I	Y. W.
Emerald	Al^2O^3	9	3·9—4·2	III×	Ge.
Emplectite	Cu^2S, Bi^2S^3	2	5·1—5·26	IV	W. Gr.

LIST OF MINERALS (*continued*).

Name.	Composition.	Hardness.	Specific Gravity.	Crystalline System.	Colour.
Enstatite . .	MgO, SiO^2 .	5·5	3·1—3·3	IV	C. W. Ge. Y. Gr. Br.
Epidote .	$3Al^2O^3, 4CaO, 6SiO^2, H^2O$	6—7	3·5	V	Gr. Br. B. R. Y. Ge.
Epistilbite .	$CaO, Al^2O^3, 6SiO^2, 5H^2O$	4—5	2·2—2·36	IV	W. Bl.
Epsomite .	$MgSO^4, 7H^2O$.	2—2·5	1·7	IV×	C. W. Gr.
Erubescite (purple copper ore)	$3Cu^2S, Fe^2S^3$	3	4·4—5·5	I	R. Br.
Erythrite (cobalt bloom)	$3CoO, As^2O^5, 8H^2O$	1·5—2·5	3	V	R. Gr.
Euchroite .	$4CuO, As^2O^5, 7H^2O$	3·5—4	3·4	IV	Ge.
Euclase .	$2BeO, Al^2O^3, 2SiO^2, H^2O$	7·5	3·1	V	C. Gr. B.
Eudialyte ..	$2Na^2O^{12}, CaO, 6(SiZn)O^2$?	5—5·5	2·8—3	III×	R. Br.
Eulytite ..	$2Bi^2O^3, 3SiO^2$.	4·5—5	6·106	I	Br. Gr. Y. W.
Euxenite . .	$4R_2O_3, 3TiO^2, 3Nb^2O^5$ (R= Y, Er, U, Ce, Fe)	6·5	4·6—5	IV	Br. B.
Fahlerz . .	$4Cu^2$ (Fe, Zn, Pb, Hg, Ag^2) S + Sb^2 (As, Bi)S^3(Cu^2, Fe, Zn, Pb, Hg. Ag^2)S, Sb(As)^2 S^3	3—4·5	4·5—5·1	I	Gr. B.
Fahlunite .	Variable . .	3·5—5	2·6—2·8	?	Gr. Ge. Br. B.
Fassaite (pyroxene augite)	$RSiO^3$, (R=Ca, Mg, Fe, Mn)	6	3·25—3·5	V	Ge. B.
Fayalite (olivine)	2Fe(Mn, Ca, Mg)O, SiO^2	6	4—4·15	IV	Ge. Br. B.
Felspar (anorthite, albite, andesite, labradorite, microcline, oligoclase, orthoclase)					
Fergusonite .	$R^3Q^2O^8$ (R=Y, Ce, W, Fe Ca; Q=Nb, Ta)	5·5—6	5·8	II	B.
Fibrolite (sillimanite)	Al^2O^3, SiO^2 . .	6—7	3·23	V	Gr. Br. Ge.
Fichtelite .	C^nH^{2n-4} . .	1	...	V	Br. W.

LIST OF MINERALS (*continued*).

Name.	Composition.	Hardness.	Specific Gravity.	Crystalline System.	Colour.
Flint (quartz)	SiO^2 . . .	7	2·63	O	Gr. Br. B. Bl. R. Y.
Fluorspar (fluorite)	$CaFl^2$ . .	4	3·18	I	C. V. Ge. Bl. Y. R.
Fowlerite .	(Mn, Fe, Zn, Mg, Ca)O, SiO^2	4—5	3·4	VI	Br. R. V.
Franklinite .	(Fe, Zn, Mn) Fe^2O^4	5·5—6·5	5·06	I	B.
Freibergite .	$(Ag, Cu)^8, Sb^2S^7 + (Fe, Zn)^4, Sb^2S^7$	3—4	4·8—5	I×	Gr. B.
Fuchsite . .	...	2—2·5	2·75	V	Ge.
Gadolinite .	3(Y, La, Fe, Be)O, SiO^2	6·5—7	4·2—4·35	V	B. Ge.
Gahnite .	ZnO, Al^2O^3 .	7·5—8	4—4·6	I	Gr. Bl. B.
Galena . .	PbS . . .	2·5—2·7	7·2—7·7	I	Gr.
Garnet (almandite, melanite, grossularite, &c.)	$3RO, R^2O^3, 3SiO^2$ R = Ca, Fe, Mg, Mn; $R^2 = Al^2, F^2. Cr^2$	6·5—7·5	3·1—4·3	I	B. Ge. Y. R. Br. W.
Gaylussite .	Na^2O, CaO, $2CO^2, 5H^2O$	2—3	1·99	V	C. Y.
Genthite . .	$H^4(Ni, Mg)^4 Si^3O^{12}$	3—4	2·4	O	Ge. Y.
Gersdorffite .	$NiS^2 + NiAs^2$.	5·5	5·6—6·9	I	W. Gr.
Geyserite (opal)	SiO^2+Aq. .	5	2	O	Gr.
Gibbsite .	$Al^2O^3, 3H^2O$.	2·5—3·5	2·35	V	C. W. Gr. Ge. R.
Gismondite .	CaO, Al^2O^3, $2SiO^2 + 4H^2O$	5	2·26	II	Gr. R.
Glauberite .	$Na^2O, CaO, 2SO^3$	2·5—3	2·64—2·85	V	C. R. Y. Gr.
Glaubersalt (mirabilite)	$Na^2O, SO^3, 10H^2O$	1·5—2	1·4—1·5	V	C.
Gold . .	Au (Ag, Cu, Fe, Pb)	2·5—3	15·6—19·5	I	Y.
Goslarite . .	ZnO, SO^3+ $7H^2O$	2—2·5	1·9—2·1	IV×	W. C.
Göthite .	Fe^2O^3, H^2O . .	5—5·5	4—4·4	IV	Br. Y. R.
Graphite (plumbago)	C. often associated with SiO^2, CaO, Fe^2O^3, &c.	0·5—2	2·1—2·2	III	Gr. B.
Greenockite .	CdS . . .	3—3·5	4·8—4·9	III	Y.
Grossularite (garnet)	$Ca^3Al^2Si^3O^{12}$.	6·5—7·5	3·1—3·7	I	Ge. Br. W.
Gypsum (satin spar)	CaO, SO^3, $2H^2O$	1·5—2	2·33	V	C. Y. Br. W. R. Gr. Bl.

LIST OF MINERALS (*continued*).

Name.	Composition.	Hardness.	Specific Gravity.	Crystalline System.	Colour.
Haidingerite.	$2CaO, As^2O^5, 2H^2O$	2—2·5	2·8—2·9	IV	C. W.
Halite (rock salt)	$NaCl$ . .	2—2·5	2·25	I	Gr. R. Bl. W. Y.
Halloysite .	$Al^2O^3, 2SiO^2, 4H^2O$	1·5—2·5	1·9—2·1	O	W. Bl. Y. Gr. Ge.
Harmotome .	$BaO, Al^2O^3, 5SiO^2, 5H^2O$	4·5	2·45	V	C. W. Br. Gr. R. Y.
Hauerite . .	MnS^2 . .	4	3·46	Iπ	Br. B.
Hausmannite	Mn^3O^4 . . .	5—5·5	4·7—4·9	II	Br. B.
Haüynite .	$2Na^2(Ca)Al^2Si^2O^8+CaSO^4$	5·5—6	2·4—2·5	I	Bl. Gr.
Heavy spar (barytes)	BaO, SO^3 . .	2·5—3·5	4·3—4·7	IV	C. Y. Gr. Bl. R. Br.
Heliotrope (bloodstone)	Chalcedony . .	7	2·65	O	Ge. with R. spots.
Helvite .	$(Be, Mn, Fe)O, SiO^2, MnS$	6—6·5	3·1—3·3	I×	Y. Br. Gr.
Hematite (specular iron)	Fe^2O^3 . .	5·5—6·5	4·5—5·28	III×	Gr. R. B.
Hessite . .	Ag^2Te . . .	2—3·5	8·13—8·6	IV	Gr.
Heulandite (stilbite)	$CaO, Al^2O^3, 6SiO^2, 5H^2O$	3·5—4	2·2	V	C. R. Gr. Br.
Hornblende (amphibole)	$(Ca, Mg, Fe O, SiO^2$	5—6	2·9—3·4	V	Ge. B. C.
Hornsilver (cerargyrite)	$AgCl$ . .	1—1·5	5·5	I	Ge. Gr. W. V.
Hornstone (chert)	SiO^2 . . .	7	2·65	Compact	Ge. Y. Gr. R. Br.
Huantajayite	$(Na, Ag)Cl$.	...	...	I	W.
Hübnerite .	MnO, WO^3 . .	4·5	7·14	V	Br.
Humite .	$4MgO, MgFl^2, SiO^2$	6—6·5	3·01—3·23	IV	Y. R. Br. W.
Hyacinth (zircon)	ZrO^2+SiO^2 . .	7·5	4—4·7	II	C. Y. Gr. Ge. Br. R.
Hyalite(opal)	SiO^2+Aq . .	6	2·15—2·18	O	C.
Hyalophane .	$K^2O, Al^2O^3, 6SiO^2 + BaO, Al^2O^3, 2SiO^2$.	6—6·5	2·8	V	W. C. R.
Hyalosiderite (olivine)	$4MgO, 2FeO, 3SiO^2$	6—6·5	3·5	IV	Ge. Y. Br.
Hydromagnesite	$4MgO, 3CO^2, 4H^2O$	3·5	2·15	V	W.
Hydrozincite	$ZnOCO^2, 2ZnO, H^2O$	2—2·5	3·6—3·8	?	W. Gr. Y.
Hypersthene	$(Mg, Fe)O, SiO^2$	5—6	3·4	IV	Br. Gr. Ge. B.
Idocrase (vesuvianite)	$2(Al^2Ca^3) O^3, 3SiO^2$	6·5	3·3—3·45	II	Ge. Br. Bl.
Idrialite .	C^nH^{2n-12} . .	1—1·5	1·4—1·6	O	Br. B. R.

LIST OF MINERALS (*continued*).

Name.	Composition.	Hardness.	Specific Gravity.	Crystalline System.	Colour.
Ilmenite (titanic iron)	FeO, TiO^2 . .	5—6	4·5—5	III×	B. Br. R.
Ilvaite . .	$H^2Ca^2Fe^6Si^4O^{18}$	5·5—6	3·7—4·2	IV	B.
Iolite . .	$3MgO, 3Al^2O^3, 8SiO^2$	7—7·5	2·6—2·7	IV	W. Br. Y. Gr. Bl.
Iridium .	Ir(Pt, Cu) .	6	22·6	I	W.
Iridosmine .	Ir+Os (Rh, Fe, Pd)	6—7	19—21·12	III×	W. Gr.
Jamesonite .	$2PbS, Sb^2S^3$.	2—3	5·5—5·8	IV	Gr.
Jasper (quartz)	$SiO^2(Fe^2O^3)$. .	7	2·65	O	R. Y. Br. Ge. B.
Jeffersonite .	Ca(Fe, Mn, Zn, Mg)O, SiO^2	4·5	3·5	VI	Ge. Br. B.
Kainite .	$KCl, MgO, SO^3, 3H^2O$	2·5	2·13—2·2	V	C. Gr. Y.
Kaluszite (syngenite)	$K^2O, SO^3+CaO, SO^3+H^2O$	2·5	2·6	V	C.
Kaolinite .	$Al^2O^3, 2SiO^2, 2H^2O$	1—2·5	2·4—2·6	IV	W. Gr. Y. Br. Bl. R.
Kermesite .	Sb^2S^2O . .	1—1·5	4·5	V	R.
Kieserite . .	MgO, SO^3, H^2O	3	2·51—2·57	V	C. W. Gr. Y.
Labradorite .	$CaO, Al^2O^3, 3SiO^2$	6	2·67—2·76	VI	C. W. Br. Gr. Ge. Bl.
Lanarkite .	PbO, SO^3, PbO^2	2—2·5	6·3—6·4	V	Ge. Y.
Lanthanite .	$LaO, CO^2, 3H^2O$	2·5—3	2·6	IV	W. Gr. Y.
Lapis lazuli .	Varies, $Al^2O^3+NO^2O+CaO+SO^2+SiO^2$	5·5	2·4	I	Bl.
Lazulite .	(Mg, Fe)O, $Al^2O^3P^2O^3, H^2O$	5—6	3·1	V	Bl.
Leadhillite .	$PbO, SO^3, 2(PbO, CO^2), PbO, H^2O$	2·5	6·26—6·4	IV	Y. W. Ge. Gr. Br.
Lepidolite .	(Al, K, Li), Fl, SiO^2	2·5—4	2·84—3	IV	R. V. Y. W.
Lepidomelane	$2(Fe, Mg, K^2)OAl^2O^3, SiO^2$	3	3	V	Ge. B.
Leucite .	$K^2O, Al^2O^3, 4SiO^2$	5·5—6	2·45—2·5	II	C. Gr. W.
Leucophanite	$5(CaBe)O, 5SiO^2, 2NaFl$	3·5—4	2·97	IV	Ge. Br. Y.
Leucopyrite .	Fe^2As^3 . .	5—5·5	6·8—8·7	IV	W. Gr.
Libethenite .	$4CuO, P^2O^5, H^2O$	4	3·6—3·8	IV	Ge.
Lievrite (ilvaite)	$H^2Ca^2Fe^6Si^4O^{18}$	5·5—6	3·7—4·2	IV	B.
Lignite. .	60—70°/₀C.; H. O, and ash	...	1·2—1·3	O	Br. B.
Limonite . .	$2Fe^2O^3, 3H^2O$.	5—5·5	3·6—4	O	Br. Y. B.

LIST OF MINERALS (*continued*).

Name.	Composition.	Hardness.	Specific Gravity.	Crystalline System.	Colour.
Linarite .	(PbCu)O, SO^3+ (PbCu)O, H^2O	2·5	5·3—5·45	V	Bl.
Liroconite .	$Cu^3(Al^2)As^2(P^2)O^8$ + $H^6(Cu^3, Al^2)O^6$+9Aq	2—2·5	2·8—2·9	V	Bl. Ge.
Lithomarge .	Clay . . .	2—2·5	2·3—2·6	O	W. Y. Gr. R.
Löweite . .	2(MgOSO^3, Na^2 OSO^3), 5H^{2}O	2·5—3	2·37	II	W. R. Y.
Lydian stone	SiO^2 impure with Fe, &c.	7	2·8	O	B.
Magnesite .	MgO, CO^2 .	3·5—4·5	2·9—3·1	III×	W. Y.
Magnetite .	Fe^{3}O^4 . .	5·5—6·5	4·9—5·2	I	B.
Malachite .	2CuO, CO^2, H^{2}O	3·5—4	3·7—4	V	Ge.
Manganite .	Mn^{2}O^3, H^{2}O .	4	4·2—4·4	IV	Gr. B.
Marble (calcite)	CaO, CO^2 . .	2·5—3·5	2·5—2·8	O	W.Gr. Bl. Ge. Y. R. B.
Marcasite .	FeS^2 . .	6—6·5	4·6—4·8	IV	Y. Gr.
Margarite .	CaO, Al^{2}O^3, SiO^2,H^{2}O	3·5—4·5	2·9—3	V	W. Gr. Y. R.
Mascagnite .	(NH^{4}O)^{2}SO^3, H^{2}O	2—2·5	1·7—1·8	IV	C. W. Y.
Meerschaum (sepiolite)	2MgO, 3SiO^2+ 2aq.	2—2·5	0·98—1·2	O	W. Gr. Y. R.
Meionite .	6CaO,4Al^{2}O^3, 9SiO^2	5·5—6	2·6—2·74	II	C. W.
Melanite (garnet)	Ca^{3}Fe^{2}Si^{3}O^{12} .	6·5—7	3·5	I	B.
Melanterite (iron vitriol)	FeO, SO^3+ 7H^{2}O	2	1·8—1·9	V	Ge. Y.
Melilite .	2Al^2 (Fe^2) O^3, 12CaO, Mg, 9SiO^2	5—6	2·9	II	C. W. Y. Br. Gr.
Mellite . .	C^6(CO^2)^{6}Al^{2}O^3, 18H^{2}O	2—2·5	1·55—1·6	II	Y. R. Br. W.
Menaccanite (ilmenite)	FeO, TiO^2 .	5—6	4·5—5	III×	B. Br. R.
Mendipite .	Pb^{3}O^{2}Cl^2= (2PbO, PbCl^2)	2·5—3	7—7·1	IV	W. Y.
Mesitite . .	2MgO, CO^2+ FeO, CO^2	4—5	3·3	III×	W. Br. Y.
Mesolite .	CaO, Na^{2}O,2Al^2 O^3,3SiO^2,3H^{2}O	5	2·2—2·4	V or VI	C. W. Y.
Mesotype (natrolite)	Al^{2}O^3, Na^{2}O, 3SiO^2, 2H^{2}O	5—5·5	2·17—2·2	IV	C. W. Y. Gr. R.
Miargyrite .	AgSbS^2 . .	2—2·5	5·2—5·4	V	Gr. B.
Microcline .	K^{2}O, Al^{2}O^3, 6SiO^2	6	2·54	VI	W. R. Br.
Millerite .	NiS . . .	3—3·5	4·6—5·6	III×	Y.
Mimetite . .	3(3PbO,As^{2}O^5) PbCl^2	3·5	7·2—7·25	III	C. Y. Gr. Br.
Minium .	Pb^{3}O^4 . .	2—3	4·6	O	R. Y.

LIST OF MINERALS (*continued*).

Name.	Composition.	Hardness.	Specific Gravity.	Crystalline System.	Colour.
Mirabilite (glauber salt)	$Na^2O, SO^3, 10H^2O$	1·5—2	1·4—1·5	V	C.
Mispickel (arsenical pyrites)	FeS^2+FeAs^2 .	5·5—6	6—6·4	IV	W. Gr.
Molybdenite.	MoS^2 . .	1—1·5	4·4—4·8	III?	Gr.
Molybdite .	MoO^3 . . .	1—2	4·5	IV	Y.
Monazite . .	$(Ce, La, Di, Th)^3 (PO^4)^2$	5—5·5	4·9—5·2	V	Br. R. Y.
Monticellite.	$2(Ca, Mg, Fe)O, SiO^2$	5—5·5	3·1	V	C. Gr.
Morenosite (nickel vitriol)	$NiOSO^3+7H^2O$	2—2·25	2	IV	Ge.
Mosandrite .	$3CaO, 2(Ce, La, Di)^2O^35(SiO^2, TiO^2)$	4	3	IV	Br. R. Gr.
Nagyagite .	$PbTe+AuTe$.	1—1·5	6·8—7·2	II	Gr.
Naphtha (rock oil)	C^nH^{2n+2} . .	...	0·7	O	C.
Natrolite (mesotype)	$Al^2O^3, Na^2O, 3SiO^2, 2H^2O$	5—5·5	2·17—2·2	IV	C. W. Y. Gr. R.
Naumannite.	Ag^2Se . .	2·5	8	I	B.
Nephelite .	$4Na^2O, 4Al^2O^3, 9SiO^2$	5·5—6	2·56—2·6	III×	Gr. C. W. Y. Ge. Br. R.
Nephrite . .	$(Ca, Mg, Fe)O, Al^2O^3, SiO^2$	6·5	2·9—3·1	V	W. Gr. Ge.
Niccolite (copper nickel)	$NiAs$ . .	5—5·5	7·33—7·6	III	R. Gr.
Niobite (columbite)	$FeO(Nb, Ta)^2O^5$	6	5·4—6·4	IV	Br. B. Gr.
Nitre . .	Na^2O, N^2O^5 .	1·5—2	2·1—2·3	IV	C. Gr. Y. R.
Nosean (haüyn)	$Na^2O, Al^2O^3, 2SiO^2+Na^2O, SO^3$	5·5	2·28—2·4	I	Y. Ge. B. Br.
Octahedrite (anatase)	TiO^2. . .	5·5—6	3·8—3·9	II	C. Br. B. Bl. Ge. Y.
Oligoclase .	$Na^2O, Al^2O^3, 6SiO^2 + CaO, Al^2O^3, 2SiO^2$	6—7	2·63—2·73	VI	C. Ge. R. Gr.
Olivine (chrysolite)	$2MgO, SiO^2$.	6—7	3·3—3·5	IV	Gr. Ge. Y. Br. R.
Olivenite . .	$AsO^4Cu, CuOH$	3	4·1—4·4	IV	Ge. Y. Br.
Ouvarovite .	$Ca^3Cr^2Si^3O^{12}$.	7·5	3·4—3·5	I	Ge.
Onyx . .	SiO^2. . .	7	2·65	O	Gr. W. B. Br.
Opal (precious, fire, common, wood, &c.)	$SiO^2, 10H^2O$.	5·5—6·5	1·9—2·3	O	C. Y. Gr. R. Br. Ge.
Orpiment .	As^2S^3 . .	1·5—2	3·48	IV	

LIST OF MINERALS (*continued*).

Name.	Composition.	Hard-ness.	Specific Gravity.	Crys-talline System.	Colour.
Orthite . .	$(Al^2,Fe^2,Ce^2)O^3$, $2(CaFe)O$, $3SiO^2$	4—6	3·1—4	V	B.
Orthoclase (felspar)	K^2O, Al^2O^3, $6SiO^2$	6—6·5	2·4—2·7	V	C. R. Gr. Ge.
Ozocerite . .	C^nH^{2n} . .	1	0·85—0·9	O	W. Y. Br. B. C. Ge.
Palladium (native)	Pd(PtIr) . .	4·5—5	11·3—11·8	I	Gr.
Paragonite .	Na^2O, Al^2O^3, $2SiO^2$	2·5—3	2·78	O	W. Gr. Y. Ge.
Pectolite . .	Na^2O, $4CaO$, $6SiO^2$+Aq.	5	2·8	V	W. Gr.
Periclase .	MgO . .	6	3·67	I	Gr.
Pericline (albite)	Na^2O, Al^2O^3, $6SiO^2$	6—6·5	2·6—2·64	VI	W.
Peridot (chrysolite, olivene)	$2MgO$, SiO^2 .	6—7	3·3—3·5	IV	Gr. Ge. Y. Br.
Perofskite . .	(Ca, Fe)O, TiO^2	5·5	4	I	R. Y. B.
Petalite . .	Al^2O^3, $Li^2(Na^2$, Ca)O, SiO^2	6—6·5	2·4—2·5	V	W. R. Gr. Ge.
Petroleum (mineral oil)	C^nH^{2n+2} . .	...	0·7—0·9	O	C. Y. Br.
Pharmacolite	$2CaO$, As^2O^5, H^2O+5H^2O	2—2·5	2·6—2·7	V	W. Gr. R.
Pharmacosiderite	$3Fe^2As^2O^3$+ $H^6Fe^2O^6$	2·5	2·9—3	I×	Ge. Br. Y. R.
Phenacite .	$2BeO$, SiO^2 . .	7·5—8	3	III	C. Y.
Phillipsite .	CaO, Al^2O^3, $4SiO^2$, $4H^2O$	4—4·5	2·2	V	C. W. R.
Phosgenite .	PbO, CO^2, $PbCl^2$	2·5—3	·6—6·3	II	W. Y. Gr.
Phosphorite (earthy apatite)	$3Ca^3P^2O^8$+ $CaF(Cl)^2$	5	3·15	O	W. Gr. Y.
Piauzite .	Fossil resin . .	1·5	1·2	O	Br. B.
Pimelite . .	(Al, Ni)^{2}O^3, MgO, SiO^2	2·5	2·2—2·7	O	Ge.
Pisanite (iron copper vitriol)	(FeO, CuO)SO^3 +7aq.	...	...	VI	Bl.
Pistazite (epidote)	$3Al^2O^3$, $4CaO$, $6SiO^2+H^2O$	6—7	3·3—3·5	V	Ge. Y. B.
Pitchblende (uraninite)	U^3O^4(Pb, Fe, Ag, Ca, Mg, Bi, SiO^2, &c.)	3—6	4·8—8		B.
Plagionite .	$4PbS$, $3Sb^2S^3$.	2·5	5·4	V	Gr.
Platinum (native)	Pt(Fe, Ir, Rh, Pd, Os, Cu)	4—4·5	16—19	I	Gr.
Platiniridium	Pt+Ir(Rh, Fe, Cu, Pd)	6—7	22·6—23	I	W. Gr.

LIST OF MINERALS (*continued*).

Name.	Composition.	Hardness.	Specific Gravity.	Crystalline System.	Colour.
Plattnerite	PbO^2	...	9·4—9·45	III	B.
Pleonaste (spinel)	MgO, Al^2O^3	8	3·5—4·1	I	Ge. Br. B. R. Bl. Y.
Polianite	MnO^2	6·5—7	4·8—5	IV	Gr.
Pollucite (pollux)	$Cs^2O, Al^2O^3, 5SiO^2, H^2O$	5·5—6·5	2·9	I	C.
Polybasite	$(Sb, As)^2S^3, 9(Ag^2, Cu^2)S$	2—3	6·21	IV	B.
Polycrase	$4RTiO^3 + RNb^2O^6 + 2H^2O$ [R = Y, Er, Ce, (U, Fe)]	5·5	5—5·1	IV	B. Br.
Polyhalite	$(Ca, K^2, Mg)O SO^3, 2H^2O$	2·5—3	2·77	V ?	R. Y.
Prase	SiO^2	7	2·62	O	Ge.
Praseolite	Decomposed cordierite	3·5	2·75	IV	Ge.
Prehnite	$Al^2O^3, 2CaO, 3SiO^2, H^2O$	6—6·5	2·8—2·9	IV	Ge. Gr. W.
Proustite	$3Ag^2S + As^2S^3$	2—2·5	5·4—5·56	III×	R.
Psilomelane	$RO + 4MnO^2$ R = K^2, Mn or Ba	5—6	3·7—4·7	O	B. Gr.
Pucherite	Bi^2O^3, V^2O^5	6	6·25	IV	R. Br.
Pyrargyrite	Ag^3SbS^3	2—2·5	5·7—5·9	III×	R. Gr.
Pyrites (iron pyrites)	FeS^2	6—6·5	4·8—5·2	Iπ	Y.
Pyrochlore	$Nb^2O^5 + TiO^2 + ThO^2 + CaO + CeO + FeO(UO^2) + F + HgO + Na^2O + H^2O$	5—5·5	4·3	I	Br. R.
Pyrolusite	MnO^2	2—2·5	4·82	IV	B. Gr.
Pyromorphite	$3(PbO)^3P^2O^5 + PbCl^2$	3·5—4	6·5—7	IIIπ	Ge. Br. Y. Gr. W.
Pyrope (garnet)	$(Mg, Ca, Fe, Mn)^3Al^2Si^3O^{12}$	6·5—7·5	3·5—4	I	R.
Pyrophillite (agalmatolite)	$Al^2O^3, 3SiO^2 +$ aq.	1—2	2·8—2·9	IV	Gr. Ge. Br. Y
Pyrrhotite (magnetic pyrites)	Fe^nS^{n+1} (generally Fe^7S^8)	3·5—4·5	4·4—4·6	III	Br. Y. R.
Pyroxene (augite, diallage)	$(Ca, Mg, Fe, Mn)OSiO^2$	5—6	3·2—3·5	V	C. Ge. Gr B.
Quartz (smoky, rose, amethystine, milky, rock crystal, false topaz, &c.)	SiO^2	7	2·5—2·8	III	C. Y. V. Gr. B. R.

LIST OF MINERALS (*continued*).

Name.	Composition.	Hardness.	Specific Gravity.	Crystalline System.	Colour.
Rammelsbergite	(Ni, Co, Fe)As^2	5·5	7·1—7·2	IV	W.
Realgar .	AsS . . .	1·5—2	3·4—3·6	V	R. Y.
Retinite . .	Fossil resin .	1·5	1·01—1·5	O	Br. Y.
Rhodochrosite	Mn(Ca)O, CO^2.	3·5—4·5	3·4—3·7	III×	R. W. Y. Br.
Rhodonite .	MnO, SiO^2 . .	5·5—6·5	3·4—3·7	VI	R. Br.
Ripidolite (clinochlore)	6Mg(Fe)O, Al^2O^3, $3SiO^2$ + $4H^2O$	2—2·5	2·65—2·78	V	Ge. R.
Rocksalt (halite)	NaCl . .	2—2·5	2·25	I	Gr. R. Bl. W. Y.
Roselite .	$(CoCa)^3 (AsO^4)^2$, $2H^2O$	3·5	3·58	VI	R.
Ruby . .	Al^2O^3 . .	9	3·9—4·1	III×	R.
Rutile . .	TiO^2 . . .	6—6·5	4·18—4·25	II	Br. B. R. Y. Bl. V. Ge.
Sal ammoniac	NH^4Cl . .	1·5—2	1·52		W. Y. R. Br.
Samarskite .	UO^3, Cb^2O^5, Ta^2O^5, WO^3, SnO^2, ZrO^2, ThO^2 (Fe, Cu, Mg, Ce, Ca, Y)O	5·5—6	5·6—5·75	IV	B.
Sanidin .	K^2O, Al^2O^3, $6SiO^2$	6—6·5	2·5—2·6	V	Gr. W.
Sapphire (corundum)	Al^2O^3 . . .	9	3·9—4·16	III×	Bl.
Sarcolite . .	Al^2O^3, Na^2O, CaO, SiO^2	6	2·5—2·9	II	R.
Sartorite .	PbS, As^2S^3 .	3	5·39	IV	Gr.
Sassolite . .	Bo^2O^3, $3H^2O$.	1	1·48	VI	C. Y. Gr.
Satinspar .	CaO, SO^3, $2H^2O$	1·5—2	2·33	V	C. Y. Br. R. Gr. Bl.
Scapolite (wernerite)	Al^2O^3, CaO, $2SiO^2$	5—6	2·6—2·8	II	C. W. Ge. Gr. B. R.
Scheelite . .	CaO, WO^3 .	4·5—5	5·9—6	II×	C. Y. R. Br. Ge.
Schillerspar (decomposed bronzite)	3MgO, $2SiO^2$, $2H^2O$	3·5—4	2·6—2·8	O	Gr. Br. Y.
Scolecite .	CaO, Al^2O^3, $3SiO^2$, $3H^2O$	5—5·5	2·2	V	C.
Scorodite . .	Fe^2O^3, As^2O^5, $4H^2O$	3·5—4	3·1—3·3	IV	Ge. Br.
Selenite .	CaO, SO^3, $2H^2O$	1·5—2	2·33	V	C.
Senarmonite.	Sb^2O^3 . .	2·5—4	2·5—2·6	IV?	Gr. Br. Y.
Sepiolite (meerschaum)	2MgO, $3SiO^2$+ 2Aq	2—2·5	0·98—1·2	O	W. Gr. Y. R.
Serpentine .	3MgO, $2SiO^2$, 2—$3H^2O$	2·5—4	2·5—2·6	IV?	Ge. Br. Y.

LIST OF MINERALS (*continued*).

Name.	Composition.	Hardness.	Specific Gravity.	Crystalline System.	Colour.
Siderite (chalybite)	FeO, CO^2 .	3·5—4·5	3·7—3·9	III×	C. Gr. R.
Sillimanite (fibrolite)	Al^2O^3, SiO^2 .	6—7	3·23	IV	Gr. Br. Ge.
Silver native	Ag(Au, Cu, As, Sb, Bi, Pt, Hg)	2·5—3	10·1—11·1	I	W. Gr.
Silver glance (argentite)	Ag^2S . .	2—2·5	7·19—7·36	I	Gr.
Skutterudite	$CoAs^3$ . . .	5·5—6	6·8	I	W. Gr.
Smaltine . .	$(Co, Fe, Ni)As^2$	5·5—6	6·4—7·2	Iπ	Gr. W.
Smithsonite .	ZnO, CO^2 . .	5	4—4·5	III×	Ge. Gr. Br. W.
Sodalite . .	$3Na^2O. 3Al^2O^3, 6SiO^2, 2NaCl$	5·5—6	2·1—2·4	I	C. Gr. Ge. Y. R. B. W.
Sphne (titanite)	CaO, SiO^2, TiO^2	5—5·5	3·4—3·56	V	Gr. Br. Y. Ge. B.
Spessartite .	$(MnFe)^3Al^2Si^3O^{12}$	6·5—7·5	3·7—4·4	I	R.
Spinel (pleonaste)	MgO, Al^2O^3 .	8	3·5—4·1	I	R. Bl. Ge. Y. Br. B.
Spodumene .	$3(Li^2,Na^2,Ca)O, 4Al^2O^3, 6SiO^2$	6·5—7	3·1	V	Ge. Gr.
Stannite . .	Cu^2S, FeS, SnS^2	4	4·3—4·5	I×	Gr. Y.
Staurolite .	$4(Fe, Mg)O, 8Al^2O^3, 7SiO^2$	7—7·5	3·4—3·8	IV	Br. R. B.
Steatite (talc, soapstone)	$3MgO, 4SiO^2, H^2O$	1—1·5	2·6	O	Ge. Gr. W. Br. Y.
Stephanite .	$5Ag^2S+Sb^2S^3$.	2—2·5	6·2—6·3	IV	B.
Stibnite (antimonite)	Sb^2S^3 . .	2	4·5	IV	Gr. B.
Stilbite . .	$CaO, Al^2O^3, 6SiO^2, 5H^2O$	3·5—4	2·1	V	C. Y. B. R. W.
Stilpnomelane	$(Fe, Ca, Mg, K^2)O, Al^2O^3, SiO^2, H^2O$	3—4	3—3·4	?	B. Y.
Stolzite .	PbO, WO^3 .	3	7·9—8·1	IIπ	Br. Gr. R. Y. Ge.
Stromeyerite	Ag^2S, Cu^2S . .	2·5—3	6·2—6·3	IV	Gr. B.
Strontianite .	SrO, CO^2 . .	3·5—4	3·6	IV	C. Ge. W. Y. Br.
Succinite . .	Fossil resin .	2—2.5	1·0	O	W. Y. Br. R.
Sulphur native	S	1·5—2.5	2·072	IV	Y.
Sylvanite .	$(Au, Ag)Te^3$.	1·5—2	7·9—8·3	V	Gr. W. Y.
Sylvite . .	KCl . . .	2	1·9—2	I	C.
Syngenite (kaluszite)	K^2O,SO^3+CaO, SO^3+H^2O	2·5	2·6	V	C.
Tachhydrite	$CaCl^2, 2MgCl^2, 12H^2O$	2	1·9—2	III×	C. Y.
Talc (steatite, soapstone)	$3MgO, 4SiO^2, H^2O$	1—1.5	2·5—2·8	IV	Ge. Gr. W.

LIST OF MINERALS (*continued*).

Name.	Composition.	Hardness.	Specific Gravity.	Crystalline System.	Colour.
Tantalite . .	FeO, Ta^2O^5 .	6—6·5	7—8	IV	B.
Tennantite .	$4Cu^2S, As^2S^3$.	3·5—4	4·3—4·5	I	Gr. B.
Tenorite (melaconite)	CuO . . .	3	6·25	IV	Gr. B.
Tetradymite.	$2Bi^2Te^3+Bi^2S^3$.	1·5—2	7·2—7·9	III×	Gr. W
Thenardite .	Na^2O, SO^3 .	2·5	2·73	IV	C.
Thomsonite (comptonite)	$(CaNa^2)O, Al^2O^3, 2SiO^2, 5H^2O$	5—5·5	2·3—2·4	IV	C. Br.
Thorite. .	$ThSiO^4, 2H^2O$.	4·5—5	5—5·4	II	Y. Br. B.
Tile ore . .	Limonite + Cuprite	...	...	O	R. Br.
Tinkal (borax)	$Na^2B^4O^7+10aq$	2—2·5	1·7	V	C. W. Gr. Bl. Ge.
Titanite (sphene)	CaO, SiO^2, TiO^2	5—5·5	3·4—3·56	V	Y. Ge. Br. Gr. B.
Topaz . .	$5(Al^2)SiO^5+Al^2SiF^{10}$	8	3·4—3·6	IV	Y. Br. R.
Torbernite (uranite)	$CuO, 2U^2O^3, P^2O^5, 8H^2O$	2—2·5	3·4—3·6	II	Ge.
Touchstone .	SiO_2 impure with Fe, &c.	7	2·8	O	B.
Tourmaline .	(Al, Fe, Mn, Mg)SiO^2, B^2O^3	7—7·5	2·9—3·3	III×	B. Br. R. Bl. Ge.
Tremolite (amphibole)	$(CaMg)OSiO^2$.	5—6·5	2·9—3·1	V	W. Gr.
Tridymite .	SiO^2. . . .	7	2·28—2·3	III	C. W.
Triphylite .	(Mn, Fe)$LiPO^4$	5	3·5—3·6	IV	Ge. Gr. Br.
Triplite . .	(Mn, Fe)$^3P^2O^8$, (Mn, Fe)Fl^2	5—5·5	3·4—3·8	IV	Br. B.
Tripolite (infusorial earth)	SiO^2. . . .	5·5—6·5	1·9—2	O	W.
Trona . .	$(Na^2O)^2(CO^2)^3$, 3—$4H^2O$	2·5—3	2·11	V	C. Gr. Y.
Tungstite .	WO^3. . . .	Soft	...	IV	Y. Ge.
Turgite. .	$H^2Fe^2O^7$ . .	5—6	4·1—4·6	O	R. B. RB.
Turquois . .	$2Al^2O^3, P^2O^5, 5H^2O$	6	2·6—2·8	O	Bl. Ge.
Ulexite. .	$Na^2O, 2CaO, 5Bo^2O^3, 14H^2O$	Soft	1·6—1·8	?	W.
Ullmannite .	$NiSbS$ . . .	5—5·5	6·2—6·5	I×	Gr. B.
Uraninite (pitchblende)	U^3O^4(Pb, Fe, Ag, Ca, Mg, Bi, SiO^2, &c.)	3—6	4·8—8	I	B.
Uranite (torbernite)	$CuO2U^2O^2P^2O^5, 8H^2O$	2—2·5	3·4—3·6	II	Ge.
Uranochalcite	U^3O^4(Fe, Cu, Ca)O, SO^3, H^2O	2—2·5	3·19	IV	Ge.
Valentinite .	Sb^2O^3 . .	2·5—3	5·6	IV	W. Y. Gr. R. Br.

LIST OF MINERALS (*continued*).

Name.	Composition.	Hardness.	Specific Gravity.	Crystalline System.	Colour.
Vanadinite .	$3Pb^3V^2O^8+PbCl^2$	2·7—3	6·6—7·2	IIIπ	Y. Br. R.
Vauquelinite.	$3(PbCu)O,Cr^2O^3$	2·5—3	5·5—5·8	V	Ge. Br. B.
Vesuvianite (idocrase)	$2(Al^2Ca^3)O^3, 3SiO^2$	6·5	3·3—3·45	II	Ge. Br. Bl. Y.
Vivianite . .	$3FeO, 2P^2O^5, 8H^2O$	1·5—2	2·58—2·68	V	Bl. Ge. W.
Volborthite .	$(Cu, Ca)V^2O^5, H^2O$	3—3·5	3·5	?	Ge
Wad . . .	$2MnO^2+aq$? .	0·5—6	3—4·2	O	Br. B.
Wagnerite .	$2MgPO^4,MgFl^2$	5—5·5	3	V	Y. Gr.
Wavellite .	$2Al^2P^2O^8+H^2Al^2O^6+9aq$	3·25—4	2·33	IV	C. Gr. Y. Ge. Br. B.
Witherite .	BaO,CO^2 . .	3—3·75	4·3—4·35	IV	C. W. Y. Ge.
Wöhlerite .	$(Ca, Na^2, Fe, Mn)O, SiO^2 Nb^2O^5, ZrO^2$	5·5	3·4	V	Y. Br.
Wolfram . .	$(Fe, Mn)O, WO^3$	5—5·5	7·1—7·5	V	Gr. B.
Wollastonite	CaO, SiO^2 .	4·5—5	2·8	V	C. Ge. Y. Gr.
Wulfenite .	PbO, MoO^3 . .	3	6·0—7·1	IIπ	C. Gr. Ge. R. Y. Br.
Wurtzite . .	ZnS . . .	3·5—4	3·9—4	III	Br. B.
Xanthophyllite	$2(Mg, Ca)^3SiO^8+3Al^2O^3, SiO^2$	4·5—5·5	3	V	Y. Ge.
Xanthosiderite	$Fe^2O^3, 2H^2O$.	2·5	...	?	Y. Br. R.
Xenotime .	$(Y, Ce,) PO^4$.	4·5	4·5	II	Br. R. Y. Gr.
Yttrocerite .	$2(9CaF^2+2YF^2+CeF^2)+3aq.$	4—5	3·45	?	W. Gr. V. R.
Yttrotantalite	$(Y, Ca, Fe,)^2 Ta^2O^7$	5—5·5	5·4—5·9	IV	B. Br.
Yttrotitanite	$SiO^2 + TiO^2 + Al^2O^3 + Fe^2O^3 + CaO + YO + CeO$	6—7	3·5—3·7	V	Br. B.
Zaratite .	$NiO, CO^2, 2Ni(OH)^2, 4H^2O$	3	2·6—2·69	?	Ge.
Zincite . .	ZnO . . .	4—4·5	5·4—5·7	III	R. Y.
Zircon . .	ZrO^2, SiO^2 . .	7·5	4—4·75	II	R. Br. Y. C. Gr.
Zoisite . .	$Ca^4(Al^2)^3H^2Si^6O^{26}$	6—6·5	3·1—3·4	IV	C. Gr. Ge. Y. Br. R.
Zwieselite (triplite)	$(Mn, Fe)PO^4, (Mn, Fe)Fl^2$	5—5·5	3·4—3·8	IV	Br. B.

Table of the Distinguishing Characteristics of Gems. (H. Emanuel.)

Name and Colour.	Lustre.	Specific Gravity.	Hardness.	No. in Scale of Hardness.	Composition.	System of Crystallization.	Form of Crystal.	Refraction.	Refractive Index.	Dispersive Power.	Electric Properties.	Fusibility.	Diaphaneity.
Diamond, white, pink, yellow, red, blue, green, black, orange, brown, opalescent. **Boart.** **Carbonate** (compact massive variety).	Adamantine; reflects prismatic colours. None.	3·4 to 3·6	Scratches all other precious stones.	10	Pure carbon	Cubical	Cube, octahedron, rhombic dodecahedron, tetrahedron, hexa-octahedron	Single.	White, 2·455 Brown, 2·487	0·38	Acquires positive electricity by friction; non-conductor of electricity.	Infusible; volatilized by long continued heat.	Transparent and translucent. Carbonate opaque.
Sapphire, white, blue, violet. **Ruby**, pink, red, violet-red. **Topaz, Oriental**, yellow. **Amethyst, Oriental**, purple, violet. **Emerald, Oriental**, green, generally pale.	Vitreous very lively.	3·9 to 4·2	Scratched by a diamond; scratches all others.	9	Alumina 98·5 Oxide of iron 1·0 Lime . . 0·5	Hexagonal	Hexagonal prism; often pointed at each end.	Double in a small degree.	1·765	0·026	Acquires electricity by friction, and retains it several hours.	..	Transparent.
Chrysoberyl, or Oriental Chrysolite, bright pale-green, greenish-yellow, reddish-brown. **Alexandrite**, when exhibiting a reddish transmitted light. **Cymophane or Chrysoberyl Cat's Eye**, when showing an opalescence like a cat's eye.	Vitreous sometimes pearly.	3·0 to 3·8	Scratched by sapphire, &c.; scratches quartz readily.	8·5	Alumina 80·2 Glucina . 19·8 (Trace of peroxide of iron; of oxide of lead and copper, depending on colour and locality.)	Rhombic.	In flat hexagonal crystals; generally in rolled pebbles.	Double.	1·760	0·033	Acquires electricity by friction and retains it several hours.	Infusible alone.	Transparent and semi-transparent.

TABLE OF THE DISTINGUISHING CHARACTERISTICS OF GEMS (*continued*).

Name and Colour.	Lustre.	Specific Gravity.	Hardness.	No. in Scale of Hardness.	Composition.	System of Crystallization.	Form of Crystal.	Refraction.	Refractive Index.	Dispersive Power.	Electric Properties.	Fusibility.	Diaphaneity.
SPINEL, dark red, white, blue, green. PLEONASTE or CEYLANITE, black. RUBICELLE, orange. BALAS RUBY, rose-red.	Vitreous.	3·8	Scratched by sapphire; scratches quartz readily.	8	Alumina 69·01 Magnesia 26·21 Protoxide of iron . 0·71 Silica . 2·02 Oxide of chromium 1·10	Cubical	Octahedron, rhombic dodecahedral octahedron, tri-octahedron.	Single.	1·755 to 1·810	0·040	..	Infusible alone.	Transparent translucent.
TOPAZ, white, greenish, yellow, orange, cinnamon, bluish, pink.	Vitreous.	3·5 to 3·6	Scratched by sapphire; scratches quartz easily.	8	Silica . 34·01 Alumina 58·38 Fluorine 15·06 Traces of metallic oxides.	Rhombic.	Right rhombic prism, octahedral rhombic prism.	Double in a slight degree.	1·635	0·025	Acquires electricity by friction and heat.	Infusible	Transparent translucent.
EMERALD, fine green. BERYL or AQUAMARINE, pale sea-green, blue, white, yellow, rarely pink.	Vitreous.	2·67 to 2·75	Scratched by spinel, scratching quartz (specimens vary).	7·5 to 8	Silica . 68·50 Alumina 15·75 Glucina . 12·50 Oxide of iron . 1·00 Lime . 0·25	Hexagonal	Hexagonal prism.	Double (very feeble).	1·585	0·026	Acquires positive electricity by friction.	Slightly fusible before the blow-pipe.	Transparent.

TABLE OF THE DISTINGUISHING CHARACTERISTICS OF GEMS (*continued*).

Name and Colour.	Lustre.	Specific Gravity.	Hardness.	No. in Scale of Hardness.	Composition.	System of Crystallization.	Form of Crystal.	Refraction.	Refractive Index.	Dispersive Power.	Electric Properties.	Fusibility.	Diaphaneity.
HYACINTH or **ZIRCON**, brownish-yellow, brownish-red, cinnamon. **JARGON**, various shades of green, yellow, white, brown.	Vitreous (almost adamantine).	4·07 to 4·70	Scratches quartz slightly.	7·5	Silica . . 33·0 Zircoma . 66·8 Peroxide of iron . 0·10	Tetragonal	Long and short square prisms. Long square octahedron. The prisms often doubly terminated with square pyramids.	Double in a very high degree, especially in the Jargoon of Ceylon.	1·990	0·044	Acquires positive electricity by friction.	Infusible before the blow-pipe.	Transparent to opaque.
GARNET. **ALMANDINE**, violet-red **CARBUNCLE**, red, brownish. **CINNAMON STONE**, white, yellow-orange. **PYROPE**, vermilion or Bohemian garnet.	Vitreous inclining to resinous. Rarely asteroid.	3·5 to 4·3	Scratches quartz slightly.	6·5 to 7·5	Silica . 38·25 Alumina 19·35 Red oxide of iron . 7·33 Lime . 31·75 Magnesia 2·40 Protoxide of manganese 0·50	Cubical	Rhombic dodecahedron, rhombic dodecahedral cube, trapezohedron, hexa-octahedron.	Simple.	1·759	0·033	Acquires positive electricity by friction.	Fusible before the blow-pipe.	Transparent, opaque.

TABLE OF THE DSTINGUISHING CHARACTERISTICS OF GEMS (*continued*).

Name and Colour.	Lustre.	Specific Gravity.	Hardness.	No. in Scale of Hardness.	Composition.	System of Crystallization.	Form of Crystal.	Refraction.	Refractive Index.	Dispersive Power.	Electric Properties.	Fusibility.	Diaphaneity.
TOURMALINE, reen, red, brown, yellow, blue, black, sometimes white.	Vitreous.	2·99 to 3·3	Scratches quartz slightly.	7 to 7·5	Fluorine 2·28 Silica . 38·85 Boracic acid . 8·25 Alumina 31·32 Red oxide of iron . 1·27 Magnesia 13·89 Lime . 1·60 Soda . . 1·28 Potash . 0·26	Hexagonal	Obtuse rhombohedron, hexagonal prisms.	Double.	1·625	0·028	Acquires positive and negative electricity by friction and heat.	Fusible.	From transparent to opaque.
QUARTZ or ROCK CRYSTAL, white. AMETHYST, violet. CAIRNGORM, yellow, brown. CHRYSOPRASE, fine apple green. CAT'S EYE, having *chatoyant* reflection. PLASMA, deep olive green. JASPER, yellow, red, green, black, brown. BLOODSTONE, dark green with red spots. CARNELIAN, red, white, yellow. AGATE, various colours. ONYX, having brown, black, and white layers.	Vitreous.	2·65	Scratches glass.	7	Silica . 99·37 Alumina trace Amethyst Silica . 97·50 Alumina 0·25 Red oxide of iron . 0·50 Oxide of manganese . 0·25	Hexagonal	Hexagonal prism and pyramid.	Double	1·549	0·026	Acquires positive electricity by friction.	Infusible	Transparent and translucent (many varieties nearly opaque).

TABLE OF THE DISTINGUISHING CHARACTERISTICS OF GEMS (*continued*).

Name and Colour.	Lustre.	Specific Gravity.	Hardness.	No. in Scale of Hardness.	Composition.	System of Crystallization.	Form of Crystal.	Refraction.	Refractive Index.	Dispersive Power.	Electric Properties.	Fusibility.	Diaphaneity.
SARDONYX, having red or brownish and white layers.													
MOCHA-STONE, having infiltrated oxides of iron or manganese producing dendritic appearances.													
CHRYSOLITE. PERIDOT, olive green. OLIVINE.	Vitreous.	3·3 to 3·44	Scratched by quartz.	6 to 7	Silica . 39·73 Magnesia 50·13 Protoxide of iron . 9·19 Oxide of nickel . 0·32 Oxide of manganese . 0·09 Alumina. 0·22	Rhombic	Generally in rolled grains and pebbles.	Double.	1·660	0·033	Acquires electricity by friction.	Infusible	Transparent and translucent.
TURQUOISE, blue green, white.	Vitreous.	2·62 to 3	Scratches glass feebly.	6	Phosphoric acid . 27·34 Alumina 47·45 Oxide of copper . 2·05 Oxide of iron . 1·10 Oxide of manganese . 0·50 Phosphate of lime. 3·41 Water . 18·18	None	None.	..	..	..	None.	Infusible	Opaque, translucent at edges.
OPAL, colourless, red, white, green, grey, black, yellow (iridescent).	Vitreous inclining to resinous.	2·0 to 2·3	Scratches glass slightly.	5·5 to 6·5	Silica . 91·32 Water . 8·68 Traces of mineral colouring matter.	None	None.	..	..	..	..	Infusible	Semi-transparent.

SPECIFIC GRAVITY OF SOLIDS.

Let (a) be the weight of dry substance in air.

(b) the increased weight of a given quantity of water to which the substance has been added, free from air bubbles; in other words the weight of the displaced water.

Then the specific gravity $= a \div b$.

Or weigh one or more small pieces of the substance in the air, partly fill a burette with water and take its reading; place the weighed material in the burette and shake to get rid of air-bubbles; read the burette again.

The difference is the volume of the material, and if the burette is divided into cubic centimetres, the weight in grams divided by the increased volume gives the specific gravity. If taking the specific gravity of tailings or other finely crushed material, weigh about 10 gram., add slowly to the water in the burette until its reading has been increased exactly 1 c.c., then weigh the portion remaining, and the difference in weight is the specific gravity.

Specific Gravity Solutions.

These are used for determining the specific gravity of gems and other stones; they can be easily carried about and are of great practical utility.

Sonstedt's Solution.—Double iodide of mercury and potassium. The density can be reduced by the addition of water. The solution is very poisonous.

Klein's Solution.—Boro-tungstate of cadmium. This can also be diluted with water. It has the disadvantage of rapidly darkening on exposure to light, but the transparency can be restored.

Methylene Iodide.—This is non-poisonous; it is also light-coloured so that the mineral fragment can be readily seen. It can be clarified by shaking with a few drops of mercury, and can be diluted with benzine.

Of the above methylene iodide is the most convenient; by means of it any density between 0·9 and 3·3 can be readily obtained, and it is also possible to reach 3·6 by saturating it with iodoform.

Use standard solutions in stoppered tubes, and obtain a series of minerals of known density for comparison.

SPECIFIC GRAVITY

(after Miers).

1·89	Melanterite
1·98	Sylvite
2·00	Goslarite
2·07	Sulphur
2·12	Chrysocolla
2·12	Chabazite
2·13	Nitre
2·14	Salt
2·15	Opal
2·16	Graphite
2·16	Stilbite
2·21	Chalcanthite
2·26	Analcite
2·30	Sodalite
2·32	Gypsum
2·33	Wavellite
2·35	Apophyllite
2·47	Leucite
2·55	Bauxite
2·56	Serpentine
2·56	Orthoclase
2·60	Nepheline
2·62	Chalcedony
2·63	Vivianite
2·64	Albite
2·65	Quartz
2·66	Oligoclase
2·66	Alunite
2·69	Beryl
2·70	Talc
2·71	Labradorite
2·72	Turquoise
2·72	Calcite
2·85	Dolomite
2·85	Lepidolite
2·85	Wollastonite
2·87	Prehnite
2·90	Biotite
2·93	Muscovite
2·94	Aragonite
3·06	Magnesite
3·10	Actinolite
3·14	Tourmaline
3·32	Dioptase
3·33	Olivine
3·34	Jaderite
3·40	Epidote
3·45	Orpiment
3·45	Hypersthene
3·50	Sphene
3·52	Diamond
3·52	Rhodocrosite
3·53	Topaz
3·54	Rhodonite
3·56	Realgar
3·62	Cyanite
3·65	Staurolite
3·67	Chrysoberyl
3·69	Strontianite
3·72	Pyrope
3·76	Atacamite
3·80	Limonite
3·80	Azurite
3·86	Chalybite
3·96	Celestite
4·03	Ilvaite
4·03	Corundum
4·06	Blende
4·10	Spinel (from 3·55)
4·15	Almandine
4·20	Gothite
4·20	Psilomelane
4·20	Copper Pyrites
4·22	Rutile (up to 5·2)
4·30	Witherite
4·30	Garnet (from 3·15)
4·37	Calamine
4·41	Stannite
4·44	Enargite
4·45	Chromite
4·48	Barytes
4·55	Kermesite
4·57	Antimonite
4·61	Pyrrhotite
4·69	Zircon
4·75	Molybdenite
4·79	Pyrolusite
4·79	Fahlore
4·84	Ilmenite
4·88	Marcasite
4·90	Thorite
4·90	Cerite
5·03	Pyrite
5·10	Monazite
5·15	Franklinite
5·17	Magnetite
5·20	Erubescite
5·20	Rutile (from 4·22)
5·23	Hematite (from 5·0)
5·25	Senarmontite
5·35	Embolite
5·48	Millerite
5·55	Cerargyrite
5·55	Zincite
5·57	Proustite
5·57	Valentinite
5·65	Iodyrite
5·68	Arsenic
5·68	Columbite
5·70	Samarskite
5·75	Copper Glance
5·75	Jamesonite
5·80	Bournonite
5·80	Fergusonite
5·85	Pyrargyrite
6·00	Cuprite
6·00	Crocoite
6·00	Scheelite
6·05	Mispickel
6·10	Polybasite
6·15	Cobaltite
6·22	Smaltite
6·25	Stephanite
6·25	Anglesite
6·45	Bismuthinite
6·51	Cerussite
6·69	Antimony
6·80	Pyromorphite
6·83	Vanadinite
6·85	Wulfenite
6·88	Bismutite
6·95	Cassiterite
7·12	Mimetite
7·15	Tantalite
7·28	Argentite
7·35	Wolfram
7·40	Tetradymite
7·50	Galena
7·55	Iron
8·00	Stolzite
8·00	Clausthalite
8·10	Cinnabar
8·10	Sylvanite
8·84	Copper
8·86	Petzite
9·00	Calaverite
9·35	Pitchblende
9·60	Dyscrasite
9·76	Bismuth
10·60	Silver
13·60	Mercury
13·90	Amalgam
17·00	Platinum
19·00	Gold
20·00	Iridosmine
23·00	Iridium

GEOLOGICAL FORMATIONS.

Cainozoic	Quaternary (Post Tertiary)	Recent or Human Period Pleistocene or Glacial
	Tertiary	Pliocene Miocene Oligocene Eocene
Mesozoic (Secondary)	Upper Cretaceous Lower Cretaceous Jurassic Triassic	
Palæozoic (Primary)	Permian (Permo-Carboniferous) Carboniferous Devonian Silurian Ordovician (Lower Silurian) Cambrian	
Proterozoic	Pre-Cambrian	
Archæozoic	Archæan	

PETROLOGY.

The rocks of the earth's crust are best classified in three main groups, according to their mode of origin as follows:—

1. Igneous. 2. Aqueous. 3. Metamorphic.

1. Classification of Igneous Rocks.

The classification and nomenclature of igneous rocks is a matter of exceptional difficulty. They are complex in chemical constitution and mineralogical composition, and are often found grading into one another imperceptibly. There is no generally accepted principle, and great confusion exists. Moreover, igneous rocks in the vicinity of ore deposits are usually much altered; their character may, indeed, be completely obliterated.

The methods of classification in most general use necessitate the exact determination of the minerals present $\frac{\text{and}}{\text{or}}$ a chemical analysis. The precise determination of the minerals involves the use of special microscopes and the preparation of slides; it can only be satisfactorily employed by the specialist. Similarly, the making of a chemical analysis is usually impracticable.

A. OUTLINE CLASSIFICATION BY SILICA AND ALKALI PERCENTAGES, COMBINED WITH TEXTURE.

	ACID (Silica greater than 60 %).	INTERMEDIATE (Silica greater than 52 %). Orthoclase felspar.	Plagioclase felspar.	BASIC (Silica less than 52 %).	ULTRABASIC.
Holocrystalline .	Granite Monzonite Quartz-diorite Grano-diorite	Syenite	Diorite	Gabbro	Peridotite, etc.
	Quartz-porphyry			Dolerite	
Hemicrystalline .	Rhyolite	Trachyte	Andesite	Basalt	Limburgite
Glassy	Pitchstones			Tachylite	—

B. Outline of Classification based primarily upon Mode of Occurrence, and secondarily upon Texture and Mineral Constitution.

1. Plutonic (holocrystalline rock masses consolidated at a depth).	Granite.	Quartz and alkali-felspar, with other minerals.
	Syenite.	Alkali-felspar the chief constituent.
	Diorite.	Lime - felspar and hornblende.
	Gabbro.	Lime-felspar and pyroxene.
	Peridotite.	Olivine the most prominent constituent.
2. Hypabyssal (most dyke rocks, mainly holocrystalline)	Acid porphyry.	Usually contains free quartz.
	Porphyry and porphyrite.	Porphyritic rocks of intermediate chemical composition.
	Dolerite.	Practically fine - grained gabbro.
	Lamprophyre.	High potash (often rich in biotite).
3. Volcanic (mainly lavas).	Rhyolite.	All truly acid lavas.
	Trachyte and phonolite.	Alkaline lavas without quartz.
	Andesite.	Alkali - felspar with ferro-magnesium minerals.
	Basalt.	All basic lavas not high in alkali.
	Alkali-basalt.	Alkaline basic lavas.

C. Classification of Igneous Rocks without the aid of the Microscope.

A system of Field Names based mainly upon texture and colour. Minerals constituent (when determinable) are used for subdivisions.

		Phanerites.		Aphanites.		Glass.
		The principal mineral constituents are readily visible.		The texture is too fine for the determination of the constituent minerals.		Mainly glassy.
		Essential Minerals.	Non-essential Minerals.	Non-porphyritic.	Porphyritic.	
Granitoid.	Granite . .	Quartz, felspar.	Mica, hornblende, pyroxene, etc.	Light coloured: Felsite.	Light coloured: Leucophyre.	Obsidian: Very glassy in appearance.
	Syenite . .	Felspar.	Mica, hornblende, pyroxene, quartz (a little only).			
	Diorite . .	Hornblende, felspar.	Mica, pyroxene.	Dark coloured: Basalt.	Dark coloured: Melaphyre.	Pitchstone: Resinous in appearance.
Gabbroid.	Gabbro . .	Pyroxene felspar.	Various minerals.		Quartz-porphyry (quartz-leucophyre, quartz-melaphyre).	Perlite: Pearly in appearance.
	Dolerite . .	Pyroxene or hornblende (undeterminable which).	Various minerals.		Felspar-porphyry (felspar-leucophyre, felspar-melaphyre).	Pumice: Highly vesicular.
	Peridotite .	Olivine and ferro-magnesian minerals.	Felspar.		Hornblende-porphyry. Augite-porphyry. Olivine-porphyry, etc.	
	Pyroxenite .	Pyroxene.				
	Hornblendite	Hornblende.				

Table for discrimination of the principal minerals of which Igneous Rocks are composed.

Quartz.	Vitreous lustre. No cleavage. Not touched by steel.
Felspar.	Vitreous lustre. Good cleavage. Just scratched by good steel. May be striated.
Mica.	Glistening appearance. Very easily split into flexible laminæ. Readily scratched. May be of any colour, but frequently black.
Amphibole (usually hornblende).	May show cleavage. Scratched with some difficulty, producing a streak much lighter than the mineral. Green to black.
Pyroxene (usually augite).	These minerals are difficult to distinguish from one another.
Olivine.	Vitreous lustre. No cleavage. Not touched with a knife. Often granular and green. (Only found in dark basic rocks, never in granitic varieties.)
Calcite.	Readily scratched, effervesces with cold dilute acid.

2. Classification of Sedimentary Rocks.

Conglomerate.	Pebbles cemented by iron oxide or other substances.
Sandstone.	Sand cemented by iron oxide or other substances. A sandstone is approximately uniform in grain-size. Different sandstones vary greatly in colour and grain-size. The constituent grains can generally be distinguished with a lens.
Breccia.	The constituent fragments are angular, and may vary in size.
Shale.	Laminated, indurated mudstone. Dark in colour, but may become reddened or even bleached by atmospheric agencies. Earthy odour when scratched and breathed upon.
Clayslate.	A shale splitting along planes of cleavage induced by pressure.
Slate.	Clayslate with perfect and regular fissility.
Phyllite.	Clayslate showing a not very conspicuous development of mica along the cleavage planes.

Limestone.	May exhibit every grade of colour and texture. Readily scratched. Effervesces freely under a drop of dilute cold acid.
Magnesian Limestone.	Differs from normal limestone in effervescing less freely or not at all unless warm acid is used.

3. Classification of Metamorphic Rocks.

Gneiss.	Comparable to a banded granite, the constituent minerals being respectively grouped in parallel bands.
Schist.	Highly foliated, consisting of layers of *mica*, *chlorite*, and other minerals, with or without more or less quartz between them.
Mica-schist, Chlorite-schist, Hornblende-schist, Talc-schist, etc.	
Serpentine.	Dark green, homogeneous, usually mottled. Easily scratched with a knife.
Crystalline Limestone.	
Quartzite.	Sandstone in which the grains are toughly cemented by silica. May even appear homogeneous to the eye, in extreme cases.

SAMPLING.

Truscott states that "Sampling includes all operations which result in obtaining from any bulk of ore a smaller quantity which fairly represents the bulk in all respects, except amount; and which in amount is convenient for testing, so as to enable the value or composition of the whole bulk to be ascertained."

One should sample what the miners will work, and classify it into (*a*) ore suitable for treatment, (*b*) ore to be dressed, (*c*) waste; if it occurs in such a manner. With a vein too narrow to stope in, some of the wall rock must be broken to make room for working; if it is cheaper to treat this than to pick it out, allowance must be made for the adulterant. In many veins the wall rocks are rotten and fall in, or the miners may put in a heavy charge and fetch down some of the rock, which increases the tonnage, but decreases the value per ton of ore. This is a frequent cause of discrediting systematic sampling by those who do not know any better. When once a fair amount of work has been done, a factor may be ascertained for any particular instance, with which a correction can be made. To standardise values to a fixed stoping width, suppose the average width of the true vein to be 17·5 inches and the average value 14·7 dwt., then to standardise this to 36 in., as 36 : 17·5 : : 14·7 : 7·1 dwt. When treating the ore, we must allow for tailings carrying away more of the values if increased in bulk by waste.

Every mine is not suitable for sampling. The more uniform the grade the more correct the sampling will be, while the greater the number of samples taken, the better any irregularities are averaged. Every precaution should be taken against salting, either by others or unintentionally by oneself. Where a sampler has to work alone amongst strangers it is almost impossible for him to take his samples and protect them too. The only thing is to use his judgment, take several duplicates in important places, mix barren samples among his other bags, be careful to clean down the faces to be sampled, keep strangers at a distance, and take any other precautions that local circumstances may suggest, but they should be done tactfully and without ostentation, otherwise men may be tempted to salt out of devilment. A salter generally gives himself away by overdoing it. He may prepare the place to be sampled, e.g. by firing gold into a face, or by packing alluvial deposits, or he may drop rich ore into the sample, or pick pieces of mullock out of a sample so as to enrich it. It is not always the wish of the man who shows one round that a so-called "good report" should be made; he may wish the mine to appear bad so that he can take it up himself later on, but more generally the desire is to make the mine appear better than it is. If a mine is "dressed" for sale, the faces are generally left off in rich ore, while poor or worked-out places are boarded over or filled up, and attention is specially drawn to the richer ore. Look carefully at timber that seems unnecessary. Some people are in favour of so-called bulk samples in preference to chip samples, i.e. several tons are taken and treated. If the salting danger can be eliminated, this is the better method for ores of irregular values, provided the tonnage is systematically distributed, and not taken from two or three places as is generally the case. Of course, the ore must be carefully weighed and the products and residues properly sampled. A man may salt his own samples by being careless, or adopting wrong means: he may take too much of one class of ore; he may take drillings where brittle or heavy minerals have separated out from the others. If he relies on grab samples, he may unconsciously give preference to fine or lump ore ; if he does not clean down a face in the old workings of a copper-mine, he may get effloresced sulphate of copper that has migrated there ; if he is not careful to clean the box or cloth in which he catches his samples, he may impoverish a rich sample and enrich a poor one.

First size up the nature of the deposit if possible ; then arrange a scheme of sampling. Most mineral properties are unprofitable and likely to remain so. Some can be condemned at sight, others are worth a little sampling, while the minority are worth going to some expense to sample thoroughly. The ore is the main asset of a mine, and if ore of sufficient quantity and quality has been judiciously opened up, money can always be raised on it. If a mine is being sampled as developed, this sampling can be done systematically by a properly qualified official, but if the sampling has to be done some time after, it is not always possible to take regular samples, for the ore overhead may have been worked out so that one has to take samples underfoot, or rotten country may require timbering which it is not safe to remove. Take samples from roof, floor, or face at whichever the most complete section can be obtained. The tools used depend on the nature of the ore. For soft material a pick may be used, for harder a hammer and moil, or a pneumatic hand-hammer drill. Very hard ore may have to be shaken by explosives. The broken material may be caught on a sheet of canvas, protected if necessary by boards, but this is not very good as the pieces are apt to fly off the sheet, the sample is apt to be contaminated with dirt from the men's boots, and if there is fine ore it may hang back on the cloth. Another way is to catch it in a suitable wooden box held by an assistant, or if the sample has to be taken in an awkward place a canvas bag may be used, tied at the bottom, mounted on a rim which can be attached to a long handle if necessary like a landing net. Where possible, samples should be taken in the face or overhead. If it is necessary to take samples underfoot, any drainage water should be kept back by a dam of clay and carried away by a launder, and crevices carefully cleaned out both before and while sampling. In any case the place to be sampled should be carefully cleaned by chipping, and any loose pieces removed before taking the proper sample. Samples should be taken across the deposit at right angles to its strike. If arched it may be necessary to break off the wings before sampling, otherwise take off-sets. One sample should not be too large. If the deposit is wide and uniform, one sample should represent, say, 4–5 feet in length, but judgment should be used in this, for if there should be a change in the nature of the ore, the sample should be taken accordingly. The depth of the cut may be, say, 2 inch and the width 3 inch, representing from 2 to 5 lbs. per foot. The proportion taken should be uniform. At first, samples may be taken, say, 20 feet apart, then, if satisfactory, the distance may be reduced till the samples are taken every 5 feet across or less for narrow lodes which are liable to fluctuate, and 10 feet for wide lodes. If too large to remove to the surface, as in places where the sampler has to carry his own samples, the sample may be reduced in some convenient place underground, using a hammer-head as an anvil. Each sample should be properly labelled and a corresponding note made in the sampler's notebook. It is advisable not to stencil the sample bags as strangers may note the mark; it is better to have stamped metal tags, or pieces of wood with Roman figures cut on them, which can be thrown in with the sample, to be picked out by the man who prepares the sample later on. Occasional dummy samples containing no values should be placed with the others as a check on the assay office, in case the numbers get mixed. If the assays are done at the mine, a certain number of duplicates are taken as a check on the sampling by another man, say 5–10 per cent. Each cut is given a special number, so when the assays are completed the engineer can go round, book in hand, comparing the look of the cuts with the assay results. If, as is often the case, the samples have to be taken elsewhere for assay, then a large proportion of check samples have to be taken in case of accident, say 20 per cent., as it might not be convenient to re-sample. If a lode is wide, then drive samples are incomplete, only the cross-cuts giving a fair indication. Stope samples are taken to ensure the face carrying payable ore. An extra poor sample is less likely to affect results than an extra rich one. If an abnormally high assay is obtained, it is usual to average it with others on either side and take the mean. Do not assume the number of cubic feet of ore that go to a ton, but take the specific gravity of different classes of ore and work it out. When sampling coal: clean a face, cut a channel at right angles to the bedding planes, and take out a sample of about 5 lbs. per foot of thickness of coal. Include everything in the sample except partings of more than ¼ in. thick, and concretions of "sulphur" greater than 2 in. diameter and ½ in. thick. A seam of coal of 1·3 specific gravity will contain about 130 tons per acre for every inch in thickness; allowing for waste, pillars, etc., 100 tons per acre per inch will be the probable yield.

It is not necessary to hand a sample of more than 3 lb. weight to the assayer. The ore is gradually reduced in size and bulk, being generally mixed, coned, and quartered on an iron plate or canvas sheet and finished up on American cloth. The samples should not be out of sight of a reliable man till reduced and under lock and key.

The results of the sampling and assaying are plotted on an assay plan. The workings as shown on an assay plan differ from the ordinary longitudinal section in so much as all bends in the drive, crosscuts, winzes, etc., are straightened out. With a narrow vein the width of the sample is put on one side of the workings, while the assay is placed on the other; the units taken may be inches, or feet for width, and dwt., ozs., or per cent. for values, according to convenience. If more than one metal of value is present, the figures belonging to it are generally noted in ink of a different colour. If a deposit consists of, say, a hanging-wall vein, a band of mullock and a foot-wall vein, or ore that can be mined direct for the smelters, concentrating ore, and waste; then these may be designated A, B, and C, a line drawn at the point sampled, and the width and value written opposite each. In order to catch the eye quicker, small circles may be drawn and filled in with washes of blue, red, etc., according to the value of the ore within certain limits, or the limits of different classes of ore may be plotted out and coloured. A sampler should make full notes of any geological features, change in country, faults, horses, etc. A graph drawn out to show the variation of values with depth is of interest; this may show that in certain cases payable ore does not go below the zone of secondary enrichment. On the other hand, if payable primary ore is going strongly underfoot, and geological conditions are favourable, e.g. an ore lens still widening, there is every chance of a fair quantity of ore ahead. A graph may show the ore to be nearly as rich as before, but a cross section may show the ore body to be narrowing. Both physical and chemical features must be studied. Ore may be classified as "ore blocked" and "ore which may reasonably be assumed to exist, though not actually blocked out." The less a mine is developed the more one must allow for horses, intrusions, and pinches.

When examining old workings it must be borne in mind that ground stoped was not necessarily profitable, and that what appears as wide stopes may be due to the presence of a horse, or winded wall rock having fallen in. A word of caution should also be given about old crushing returns, putting aside the probability of the upper part of a lode being naturally richer than that lower down, and that a larger volume of partly leached ore goes to a ton. In the early days of a mine ore sent away for treatment was generally picked, so as to save freight, and the tonnage was generally taken by measurement, the miners trying to get as many cubic feet into a ton as possible, a dray load often being taken as equivalent to a ton. When ore has to be sold to custom works, calculate an example for each tariff submitted. One tariff may be submitted in what appears to be a favourable form; but when worked out, on the short ton, an inferior assay, and various deductions, the terms are often found to be worse than that of a buyer who makes a straight out higher returning charge.

MINE EXAMINATION.

When called upon to make a report, an engineer should state the facts clearly and concisely. His opinion is asked for, and there should be no ambiguity or indecision about it. If there is not sufficient work done in a mine to enable him to give a definite opinion as to its value, then he should recommend a working option, should the property in his opinion warrant the expense.

Before proceeding to a mine, the engineer should provide himself with the necessary authority to inspect, take samples, abstract information from the books, etc. He should ascertain the route which has to be taken by machinery or ore, and follow that, noting the dimensions of any railway tunnels and such other information affecting transport. If in a foreign country it is better to obtain the necessary outfit in that country, experience dictating to the inhabitants what is most suitable for the climate and local conditions.

Any information about the mine or district, official or otherwise, should be secured, that obtained from interested parties being accepted with reserve. Insist on seeing everything, and if there is a chance of any doubt being thrown on your work, get a signed statement from the man in charge to the effect that you have been shown everything. There are many points that should be noted when reporting on mining properties, but those mentioned below are not likely to all occur at one mine, neither is it necessary to embody all one notes in a report.

Name.—The name or names and numbers by which the property is known. Note if the name has been changed.

Locality.—Parish, county, country. Nearest town.

Area.—Plan showing area, and relative position to other properties if near. Show position of deposit on area.

Lease.—Give conditions, royalty, taxes, labour condition, clear title.

How Reached.—Distance from nearest railway station or port. Nature of harbour, shelter, depth of water at low tide. Condition of road. Rivers to cross. Transport. Freight.

Topography.—Mountainous or flat; altitude; character of surface vegetation, timber supply.

Water.—Annual rainfall, rainy seasons, droughts, creeks and rivers, frequency and height of floods. Water available for power. Conservation of water.

Climate.—Tropical, temperate, or frigid. Can one work all the year round? is the climate injurious to health?

Labour.—Efficient or inefficient; plentiful or scarce; if liable to strikes and labour troubles, or labour likely to be interfered with by unstable government, or raids from unfriendly tribes.

History.—Dates of opening, abandoning, reopening. Reasons for closing down. Past and present owners. Reported yields. What contracts are in existence.

Geology.—Country rocks; their relation to the deposit, their strikes and dips, hardness and toughness. Faults: their relative ages, strike, hade, throw, and heave. Nature of deposit, vein, bed, stock, stockwork, pocket, shallow alluvial, deep lead, etc.; strike, underlie, dimensions, nature of walls, dig, ores, veinstones; how the ores occur, massive, bands, disseminated; associated minerals; leached, secondary enrichment, and primary zones; irregularities, e.g. horses, pinches, folds; shoots, pipes. If coal, its nature, gas, steam, household, coking or non-coking; liability to spontaneous combustion; presence of clay bands or "sulphur"; size of lumps into which it breaks; nature of roof and floor. Examine similar deposits in neighbourhood.

Extent of Workings.—Shafts, levels, winzes, crosscuts, their dimensions and state of preservation.

Drainage. — Water-level, quantity of water making per hour; whether corrosive or can be utilized; if mine subject to flood.

Ventilation.—Natural, furnace, fan (force or exhaust), sufficient or insufficient; gases.

Method of Working.—Variety of stoping, caving, sluicing, dredging, longwall, bord, and pillar. Condition of workings.

Method of Supporting Ground.—Timbering, filling; if subject to creeps.

Power.—Steam, water, air, gas, electricity.

Buildings and Machinery. — Nature, conditions, and suitability.

Maps and Plans.—District, surface and underground, assay and geological plans.

Market.—Disposal of products; tariffs.

Costs.—Present; what may be expected with improvements.

Conclusion.—Quantity of ore blocked out and ore partly blocked, average value of ore, probable life of the mine with a certain annual output, the proper metallurgical treatment and probable cost of same. Value of mine and plant. Profit that may be expected. Capital it will stand. Working capital required. Improvements suggested. The interest required on capital put into a mine increases with the risk incurred.

Mines must be operated according to their nature. Some are only suitable for co-operative working parties, e.g. small high-grade deposits from which wages men might steal ore; others are suitable for companies with a small capital on which to pay interest; while a third class, e.g. large low-grade propositions, or those that require expensive deep shafts, require a large capital to open them up and supply the necessary plant. It is unnecessary to lock up capital by fully developing a promising deposit before equipment, but it is well to have, say, two years ore blocked out, so that one can work a mine regularly and continuously. The cost of mining generally diminishes as a mining field gets older, owing to improved transport facilities, conservation of water, improved methods, etc., so that a low-grade ore, originally valueless, may be worked at a profit, thus lengthening the life of the mine. The object of mining is to get the greatest profit from a given body of ore. One might get cleaner residues, but it might cost more to extract the last fraction than it is worth. The sooner one can get a return on his capital the better, as it saves the loss of interest through locked up profits. By working on a large scale men can be placed to better advantage, and one can make better terms for freight, purchase of stores, etc., go in for schemes (e.g. water-supply) that smaller concerns could not afford. In addition to a suitable interest on the capital invested in a mine, the shareholders require the return of their capital and that within a fairly short period, since a mine is a wasting property. This money may be put aside by the Directors for the purchase of another property, or it may be handed over to the shareholders with the dividends to apportion as they think fit. The redemption of the capital is known as amortization. Plants should be built in convenient units, which may be multiplied from time to time if circumstances warrant. This may be determined in the following manner:—Working expenses may be divided into those which vary with tonnage, e.g. development, haulage, and treatment, which may be called fixed; and those which vary partly with tonnage and partly with time, e.g. management, and pumping which have to go on no matter how many tons are dealt with. All the additional profit due to the expanded output (of course not including the ordinary profit on the ore) is termed the "increment of profit." According to Hoover, "If by vigorous development the visible life of a mine, as shown by the ore reserves, is lengthened, so as to exceed the time required for a unit of treatment capacity to earn an amount, through the increment of profits, equal to amortization of the capital invested in that unit, then the instalment of another unit becomes not only justifiable but an obligation of good management." Also, "The economic and advisable ore reserves should be equal in volume to the annual output multiplied by a number of years just under that needed by the increment of profits to equalize the amortization required to construct increased treatment units." In practice this principle cannot always be carried out as shareholders may refuse to subscribe or borrow the necessary money to put their mine on a better footing. Some locally owned mines are allowed to linger on, as the storekeeper and hotel-keeper shareholders look for their profits to goods sold to the men rather than out of the mine itself. There are many other factors to be considered in successful mining besides the mine itself and its surroundings, not the least of which are the management and directorate. Because a mine has and is paying good dividends, it is no proof that it is in a condition to continue doing so. On the other hand, a property may have been developing for some years and never paid a dividend, but on account of the policy followed may be in a position to provide adequate interest for many years. Mines have been classified for speculation and investment purposes into (1) Excellent, (2) Fair, (3) Moderate, (4) Indifferent, (5) Remote, according to their prospects. J. H. Curle writes, "My formula is that a share is worth buying if the net profit in the mine—assuming developments in the bottom are normal as to worth and value—is equal to two-thirds of the market price of that mine. That means that I expect enough additional ore will be exposed in depth to at least return the one-third of the capital which is unguarded, and also pay a good interest on the whole of the capital at stake." This, of course, would only hold good where the market price of shares was not inflated. In mining expediency often predominates over system. The intrinsic value of a mine cannot be altered by market operations, but it can be very materially altered by mismanagement. Some people who are not acquainted with the technicalities of mining think they can judge which is the better worked of two mines by comparing the working costs. In most cases the mines are not comparable, as the conditions are different, but even where the conditions are similar one wants to know if in both cases the depleted stopes have been properly secured, whether the ore obtained in development was added to the stoped ore without being debited with its proportional cost or not, whether only the easily get-at-able ore was broken, whether the various incidental expenses were charged in each case, or whether in one they simply give the cost of breaking, etc. It is well to have the technical work of a mine examined by an independent man periodically, for a similar reason that it is advisable for an auditor to go through the books of a company.

Zimmermann's Rule for Determining the Direction in which to Drive to Find a Dislocated Reef.

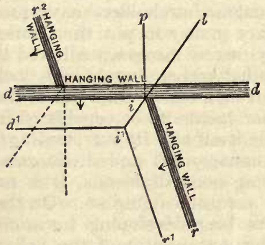


FIG. 1.

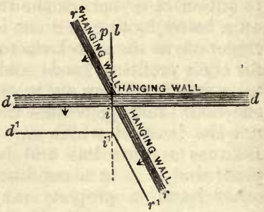


FIG. 2.

Determine the strike and underlie both of the reef and dislocator. Project this on paper to scale, at two different levels. Connect the points of intersection at the two levels as shown on the projection, by a straight line, and produce it through the dislocator. Draw another line from the upper point of intersection, on the far side of the dislocator, and at right angles to it. On whichever side of the line of intersection the line at right angles to the dislocator is found, is the direction to search for the lost reef.

Figs. 1, 2, and 3 show three examples in which *d d'* is the dislocator at two different levels; *r*, *r'*, *r''*, the reef; *i*, *i'*, the points of intersection; *i' l*, the line of intersection; and *i p* the line drawn at right angles to the dislocator. The small arrows show the direction of the dip or underlie. Then in

Fig. 1 on passing the dislocator we would have to drive on the left hand. In Fig. 2 the reef is not displaced at all, as the lines *i′ l*, *i p*, coincide; therefore, on passing the crosscourse the reef will be immediately cut. In Fig. 3 we would have to drive to the right hand. The dotted lines in the figures show how the case would be if we approached the dislocator on its footwall, instead of its hanging wall, as shown by the

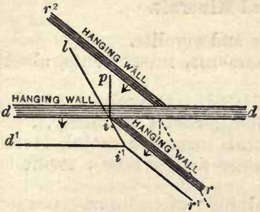


FIG. 3.

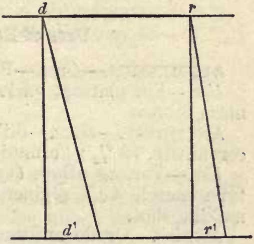


FIG. 4.

full lines of the diagram. Fig. 4 illustrates how you can easily set out the proportional distances of the underlie of the dislocator and reef at different levels for the purpose of projection.

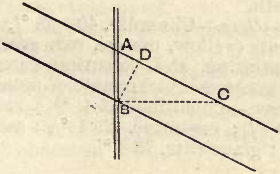
The *distance* to drive before finding a lost reef can only be determined in certain cases, which requires some geological knowledge.

To Calculate the True Thickness of an Inclined Bed when passed through in a Bore-hole.

Let A B be the thickness bored.

Then the angle A C B = the angle A B D = the dip of the bed.

D B (the true thickness sought) = A B cos. A C B.



To Calculate the Expense of Sinking,

Let a = the amount to be paid for the first unit of depth.
b = the rate of increase for each additional unit.
n = the number of units to be sunk.
Then the total cost will be:—

$$[2a + (n-1)b]\frac{n}{2}.$$

Uses of Rocks and Minerals.

ALUMINIUM.—*Ores.*—Beauxite and cryolite.

Use.—For plating, various ornaments, instruments, aluminium bronze.

ANTIMONY.—*Ores.*—Stibnite, 71·76 °/₀; valentinite, 83·56 °/₀; cervantite, 79 °/₀; kermesite, 75·3 °/₀; native antimony.

Use.—Various alloys (type metal, britannia metal, stereotype metal, &c.), pigments (orange and yellow), medicine, making shot.

Market.—Crude antimony (sulphide of antimony sweated out from its gangue), star metal. Impurities, iron, lead, tin, sulphur, arsenic.

ARSENIC.—*Ores.*—Native arsenic; orpiment 60·90 °/₀; realgar, 70 °/₀; arsenolite, 75·76 °/₀; mispickel, 46 °/₀; leucopyrite, 72·8 °/₀.

Use.—Manufacture of opal glass, pigments (Scheeles green, yellow, red), various alloys, fireworks, medicine, poison for animals.

Market.—White arsenic, red arsenic. Impurities, sulphur.

BISMUTH.—*Ores.*—Native bismuth; bismuth ochre, 89·5 °/₀; bismuthite, 75 °/₀; bismuthglance, 81·4 °/₀.

Use.—Alloys (soft solder, fusible metal, &c.), medicine, porcelain, and glass painting.

Market.—Impurities in commercial bismuth are copper, antimony, sulphur, arsenic.

CADMIUM.—*Ores.*—Greenockite, 77·7, also in some ores of zinc.

Use.—The iodide and bromide used in photography, the sulphide as a yellow pigment, also in pyrotechny, Wood's alloy for stopping teeth.

CHROMIUM.—*Ores.*—Chromite, 40—68 °/₀ Cr^2O^3.

Use.—Pigments (yellow, orange, red, green, blue) used in dying, calico printing, and colouring glass and porcelain. Chemicals (chromate and bichromate of potash, &c.).

COBALT.—*Ores.*—Cobaltine, 35·4 °/₀; smaltine, 28·1 °/₀; danaite, 5—10 °/₀; erythrine, 29·4 °/₀; asbolite, 2—15 °/₀; linnæite, 22 °/₀; glaucodite, 23·8 °/₀.

Use.—Pigments (smalt, cobalt or Thárard's blue, printers' blue, cobalt bronze, Rinmann's green) for colouring glass, porcelain, and stoneware.

COPPER.—*Ores.*—*Atacamite*, 59·45 %; *azurite*, 55·26 %; *bornite*, 55·58 %; bournonite, 13 %; chalcanthite, 24·45 %; *chalcocite*, 79·8 %; *chalcopyrite*, 34·6 %; chrysocolla, 37 %; *covellite*, 66·5 %; *cuprite*, 88·8 %; dioptase, 40 %; domeykite, 71·7 %; enargite, 48·4; libethanite, 53 %; *malachite*, 57·5 %; native copper, olivenite, stromeyerite, 31·2 %; tennantite, 51 %; *tenorite*, 79·85; tetrahedrite, 35—48 %; stannite.

Use.—Pipes, wire, various utensils, plates for ships, roofing, gold-saving mills, coins, alloys (brass, Prince's metal, gun metal, bell metal, German silver, yellow metal, mosaic gold, Bath metal, pinchbeck, statuary bronze), pigments (blue and green), electrical purposes, sheep-wash.

Market.—Matte, precipitate (cement copper), Chili bars (purple or blister copper in bars weighing about one and three quarter hundredweight, and containing about 95 % copper). The chief brands are: common marks, good named brands, best marks, Australian P C C (Burra) cake, Wallaroo cake English longcake (9″ × 12½″ × 1¾″, weigh 1 cwt. 1 qr.), tough ingot (11″ × 3½″ × 1½″, weigh 14—16 lbs.), best selected ingot, sheets and rod, sheets (4′ × 4′) for India, yellow metal sheets (4′ × 4′) for India, sheathing.

Impurities.—Best selected is nearly pure; tough cake and tile copper contain traces of As, Ni, Sn, Fe, Bi, Pb, Sb, S. Commercial copper is also contaminated with Pb, Fe, and Sb. The best copper is that refined by the electrical process.

GOLD.—*Ores.*—Native gold, electrum, sylvanite, 25—41 %, nagyagite, 6—9 %; also in native bismuth, iron pyrites, copper pyrites, zincblende, galena, mispickel, stibnite, magnetic pyrites, cinnabar, hematite, &c.

Use.—Coinage, ornaments, gold plating, gold leaf, wire, alloys, stopping teeth, pigments.

Market.—Gold may be produced as amalgam, retorted gold, or bar gold. The standard of purity is 24 carat; but this being too soft for most purposes is alloyed with silver or copper in various proportions; standard gold contains 22 pts. pure gold and 2 pts. of some other metal.

IRIDIUM.—*Ores.*—Osmium-iridium, also in connection with platinum and palladium.

Use.—Sesquioxide of iridium is used in porcelain painting to produce black and grey colours; for the nibs of gold pens; knife edges of fine balances; tips of rubber cutting tools; in the construction of electric apparatus; alloys with copper, gold, mercury, and platinum.

IRON.—*Ores.*—*Chalybite*, 48·3 °/。; goethite, 62·9 °/。; *hematite*, 70 °/。; *limonite*, 59·9; magnetite, 72·4 °/。; menaccanite, chromite, franklinite.

Use.—Rails, various machines, tools, instruments and utensils; in architecture, shipbuilding, nails, bridges, pigments, medicine, pipes, wire.

Market.—Iron is sold in pigs, bars, rods, hoops, sheets, plates, &c., and as copperas. Impurities in iron are silica, phosphorus, carbon, manganese, and sulphur. Besides cast iron, we get wrought iron, spiegeleisen, steel, chrome-steel, &c., blue billy (a ferruginous residue).

LEAD.—*Ores.*—Anglesite, 68·32 °/。; bournonite, 42·58 °/。; *Cerussite*, 77·53 °/。; crococite, 64 °/。; *galena*, 86·55 °/。; mimetite, 69·57 °/。; minium, 90 °/。; pyromorphite, 76·35 °/。.

Use.—Pipes, sheets for lining tanks, sulphuric acid chambers, roofing, flooring, shot, alloys (type metal, solders, &c.), white lead for paint, litharge, glass and pottery, medicine.

Market.—Sold in pigs as English favourite shipping brands, ordinary brands, Spanish pig with silver, rich with silver, or without silver. Litharge powdered and English flake. Red lead. Impurities: hard lead contains antimony, zinc, copper, iron, bismuth, nickel, cadmium, sulphur.

MANGANESE.—*Ores.*—Alabandite, 63·3 °/。; braunite, 69·6 °/。; dialogite, 47·7 °/。; hauerite, 46·3 °/。; Hausmannite, 76·9 °/。; *manganite*, 62·5 °/。; psilomelane, 52 °/。; *pyrolusite*, 63·2 °/。; rhodonite, 42 °/。; wad.

Use.—Glass staining and pottery painting; in the production of oxygen and chlorine (for bleaching powder), added to iron to improve steel. Chemicals (permanganate of potash).

Impurities.—Silica, phosphoric acid, sulphur, &c.

MERCURY.—*Ores.*—Native quicksilver, native amalgam, 64·93—73·53 °/。; calomel, 84·93 °/。; *cinnabar*, 86·21 °/。; some fahlerz contain from 3—16 °/。 mercury.

Use.—For amalgamating gold, for scientific purposes, manufacture of instruments (barometers, thermometers, &c.), silvering mirrors and reflectors. Chemicals (corrosive sublimate, calomel) for preserving skins, dyeing, printing, etching, pigments (vermilion), fulminate for percussion-caps, medicine.

Market.—Sold in iron bottles containing 75 lbs. each.

MOLYBDENUM.—*Ores.*—Molybdenite, 60 °/。; molybdite, wulfenite. *Use.*—Blue pigment for pottery ware.

NICKEL.—*Ores.*—Annabergite, 29·6 °/。; chloanthite, 28 °/。; *garnierite*, 10—30 °/。; gersdorffite, 35·1 °/。; *nickeline*, 43·6 °/。; *noumeite*, 5—20 °/。; millerite, 64·4 °/。; pentlandite to 20 °/。; linnæite, 33 °/。; zaratite; breithauptite, 32·2 °/。.

Use.—Alloys (German silver for coins and trinkets, nickel-steel, &c.), plating wares.

Osmium.—Used in the examination, staining, and preservation of microscopical anatomical specimens.

Palladium.—*Ores.*—Native.

Use.—Sometimes used for finely divided scales of mathematical and astronomical instruments, for smaller chemical weights, 1 °/o added to steel produces a smoother cutting edge; palladium amalgam used by dentists for stopping teeth. Alloys, 60—75 pts. Pd, 15—25 pts. Cu, and 1—5 pts. Fe, used for non-magnetic watches.

Impurities.—Rhodium.

Platinum.—*Ores.*—Native.

Use.—Chemical apparatus (evaporating dishes, crucibles, retorts, funnel points, spatulas, combustion boats, blowpipe tips, forceps, weights, foil, wire, &c.), pins in artificial teeth, tops of lightning-rods, electric lights, galvanic apparatus, trinkets, medals, mirrors, porcelain painting.

Impurities.—Iridium, gold, palladium, osmium, iron, copper, sulphur, phosphorus, arsenic.

Potassium.—Used as a chemical (cyanide, yellow and red prussiate, bromide, iodide, chloride, chlorate, carbonate, caustic, chromate, bichromate, nitrate, sulphate).

Silver.—*Ores.*—Amalgam, 26·5—65 °/o; argentite, 87·1 °/o; bromargyrite, 57·45 °/o; discrasite, 64 °/o; embolite, 66 °/o; hessite, 62 °/o; iodargyrite, 46 °/o; cerargyrite, 73·3 °/o; miargyrite, 37 °/o; native silver; polybasite, 64·2—72·4 °/o; stephanite, 68·35 °/o; sternbergite, 33 °/o; stromeyerite, 53·1 °/o; proustite, 65·45 °/o; pyrargyrite, 59·78 °/o; besides occurring in the following: galena, zincblende, up to 0·88 °/o, iron and magnetic pyrites up to 0·09 °/o, fahlerz, copper pyrites, mispickel, bournonite, &c.

Use.—Coinage, various ornaments and utensils, plating, photography, marking ink, alloys.

Market.—Sold as bar and fine silver. Standard silver is 11 oz. 2 dwts. fine, and 18 dwts. alloy; it is always alloyed with copper, as it is too soft to use by itself.

Sodium.—*Ores.*—Soda, trona, common salt.

Use.—Employed in the manufacture of aluminium and magnesium, and amalgamation of gold and silver. Common salt is used for food, in roasting certain ores, &c. Salts of sodium are used as chemicals.

Market.—Sold as metallic sodium, washing soda, bicarbonate of soda, caustic soda, salt (rock and table).

Strontium.—*Ore.*—Strontianite, celestine.

Use.—Manufacture of coloured lights, as nitrate; sugar refining.

Tellurium.—*Ores.*—Native, nagyagite, hessite, petzite, sylvanite, calaverite.

Use.—To alloy with copper.

TIN.—*Ore.*—Cassiterite, 78·67 %.

Use.—For coating thin sheets of iron, commonly known as tin-plates, manufactured into various utensils. Alloys (solder, pewter, gun-metal, britannia metal, bell-metal, type-metal, bronze, &c.), tinfoil for protecting certain edibles, amalgamated with quicksilver employed in the construction of mirrors, dyeing and calico-printing.

Market.—Brands, English common blocks and ingots, English common bars, Australian and Straits, Banca Billiton. Tin-plates, charcoal I. C., coke I. C.

Impurities.—Chiefly antimony and iron.

TITANIUM.—Used in the manufacture of false teeth.

TUNGSTEN (WOLFRAM). — *Ore.* — Wolfram, scheelite, tungstite.

Use.—Tungstate of soda and tungstic acid are employed in dyeing and in the production of bronze powder. Used to give a greater hardness to some metals, *e.g.*, tin and steel. Used as a substitute for tin in the manufacture of purple of cassius.

URANIUM.—*Ores.*—Pitchblende, 84·91 %.

Use.—Urinate of soda gives a yellow colour for painting porcelain and colouring glass.

VANADIUM.—*Ores.*—Vanadinite, dechanite, descloizite, purchesite, psittacinite, volborthite, roscœlite, mottramite.

Use.—Chemicals, photography, pigment (yellow), ink (blue black), indestructible by acids. For producing aniline black.

Market.—Ammonium vanadate, vanadium chloride, meta-vanadic acid.

ZINC.—*Ores.*—Calamine, 54·17 %; Smithsonite, 52 %; Willemite, 58·56 %; zincblende, 67 %; zincbloom, 56 %; zincite, 80·26 %; zinc vitriol.

Use.—For coating sheet iron (galvanised iron) when it is used for building purposes and manufacturing into various articles, coating wire for fences, &c., in electrical batteries, castings, dentistry, alloys, pigments (oxide and chromate), sulphate of zinc, as a mordant in dyeing, medicine.

Market.—Known as spelter, silesian (ordinary brand), and special brand, sheets.

Impurities chiefly cadmium.

BUILDING AND DECORATIVE STONES.—Granites, porphyries, basalts, sandstones, slates, limestones, marbles, serpentine, breccias, puddingstone, alabaster, malachite, fluorspar, gypsum, rock crystal, agates, jasper, jade.

ORNAMENTAL AND PRECIOUS STONES.—Diamond, sapphire (oriental ruby, oriental topaz, oriental amethyst, oriental emerald), chrysoberyl (oriental chrysolite, alexandrite), spinel (pleonast, blas ruby), topaz, beryl (aquamarine, emerald), zircon (hyacinth, jargon), garnet (alamandine, carbuncle, cinnamon, pyrope), tourmaline (Brazilian emerald, rubellite, indicolite, achroite), quartz (rock crystal, amethyst, cairngorm, chrysoprase, cat's eye, plasma, jasper, bloodstone, carnelian, agate, onyx, sardonyx, mocha-stone), opal, turquoise, malachite, amber.

GRINDING, WHETTING, AND POLISHING MATERIALS.—For sharpening tools and instruments; crushing and grinding various substances, food-stuff, chemicals, paper-pulp, clays, mortars, and cements; polishing and burnishing mineral and metals.

Millstones.—Grits, hard tough silicious sandstone, burrstone, quartzites, lavas.

Grindstones.—Sandstones and grits.

Polishing and Cutting.—Quartz sand, tripoli, rotten-stone, crocus, bath-brick, pumice, emery, diamond.

Whetstones and Hones.—Baths or sandstones, ragstones, hones or oilstones (metamorphic schists and slates).

Burnishers.—Agate, bloodstone, carnelian, jasper.

REFRACTORY OR FIRE-RESISTING SUBSTANCES.—Fire-clay, silicious sand, infusorial earth (tripolite), graphite, magnesite, limestone, potstone (steatite), sandstone, trap, asbestos, alum.

CLAYS WE FABRICATE.—Kaolin, pipe-clay, pottery-clay, brick- and tile-clay, fireclay, terra-cotta.

GLAZES, ENAMELS, COLOURS.—Glazings for hard porcelain which are transparent are formed by admixtures of quartz, kaolin, lime, or gypsum and broken porcelain. Lead glazes are also transparent. Enamel, or opaque glazes, may be white or coloured; contain oxide of tin as well as oxide of lead. Colôurs made from oxide of iron (red, brown, violet, yellow, and sepia), oxide of manganese (violet, brown, and black), oxide of copper (green, red), oxide of chromium (green), oxide of cobalt (blue-black), oxide of iridium (black), oxide of uranium (orange and black), oxide of titanium (yellow), oxide of antimony (yellow), chromate of iron (brown), chromate of lead (yellow), chromate of barium (yellow), chloride of silver (red), chloride of gold (purple and rose-red), sulphide of mercury (vermilion), carbonate of lead (white), sulphate of barium (for adulterating white lead).

MINERAL MANURES.—Carbonaceous (peat, coal slack, ashes, coke, soot); calcareous (marl, shell-sand, chalk, limestone, gypsum, apatite, coprolites, guano); saline (sulphate of ammonia, carbonates of potash and soda, nitrate of potash and soda, sulphates of potash, soda, lime, and magnesia, chloride of soda, silicates of soda and potash, soda-alum, magnesia-alum, borax, chloride of calcium, bromide of sodium, borate of lime).

FOOD AND MEDICINE.—Sodic chloride, lithia, lime, sulphate of magnesia.

FOSSIL FUELS.—Peat, lignite, brown coal, bituminous coals, anthracite, coke, petroleum, coal gas.

LIGHT PRODUCERS.—Gas and naphtha springs, petroleum, pitch, asphalt, albertite, pyroschists, magnesium. Incandescent light use oxides of calcium, thorium, lanthanum, cerium, zirconium, yttrium, neodymium, erbium, præsodymium, tantalum. Monazite (thorium, lanthanum, cerium and didymium), orthite (cerium and didymium), zircon (zirconium), gadolinite (yttrium).

MISCELLANEOUS.—*Sand.*—Used in glass making, for the preparations of mortars, concretes, and cements; as moulds for metals; for cutting and polishing; to mix with clayey soil; ballast.

Sulphur.—In manufacture of sulphuric acid and other chemicals, medicine, plugging holes.

Graphite.—Manufacture of refractory articles (crucibles retorts, dippers, stirrers, bricks, stoppers, nozzles, &c.), lubricating compounds, electrical supplies, stone polish, pencils, pigments.

Talc.—For dressing skins, leather, gloves; as an adulterant, on account of its lightness; as a filler, chiefly in the manufacture of soap, paper, and rubber; as a lubricant when mixed with other substances.

Soapstone.—Used for making ovens, lining lime-kilns, and hearths; for sizing rolls in cotton factories, on account of it not being attacked by acids; slate-pencils; ornaments.

Mica.—Large white sheets for panelling stove doors, lamps, placed over gas globes, electrical insulating material. Smaller bits used for decorative purposes on wall-papers, steam and valve seats, lubricant, fertilizer.

Infusorial Earth.—In the manufacture of dynamite as an absorbent; polishing powder; as a protection to steam boilers and pipes; moulds for casting medallions, &c.; manufacture of porcelain.

Barytes.—For adulterating white lead; for the surface finish of paper collars; in fireworks; sugar refining; clarifying water for use in boilers.

Fuller's Earth.—For cleaning cloths.

Magnesite.—Fireproof furnace linings; medicine.

Salt (sodic chloride).—Food; pickling; manure.

Saltpetre.—Preparing meat; chemical; manure; fireworks.

Diamonds.—Ornaments; cutting and grinding; drilling.

Asphaltum.—For paving, flooring, roofing, varnish, water and acid proof paint; cement; foundations of buildings when mixed with sand or carbonate of lime; bed for machinery; pipes when covering cylinders of paper.

Gypsum.—Fertilizer; stucco (plaster of Paris) casts, moulds, decorative purposes, surgery, dentistry, for adulterating flour, tamping blasts, cement when mixed with other substances, *e.g.*, alum, borax, potash; used in converting carbonate of ammonia into sulphate of ammonia; mixed with colouring matter under the name of "terra alba."

Ore Deposits.

Antimony.—In lodes with quartz and sometimes associated with heavy spar; in Australia it is frequently auriferous.

Arsenic.—Found in metalliferous veins, especially those of silver, gold, and lead.

Bismuth.—Generally found accompanying cobalt, nickel, silver, lead or gold ores associated with quartz, molybdenum, mispickel, and cassiterite in lodes, pipe veins, &c., in altered slates and granite.

Cadmium.—Found in zinc deposits.

Chromium.—Occurs as magmatic segregation in serpentine.

Cobalt.—Generally occurs in veins with nickel ores, also in wad which is found in veins, stockwork, and nodules.

Copper.—Copper lodes occur in rocks of all ages, including eruptive rocks (porphyry, melaphyre, diorite, gabbro, serpentine), crystalline schists and sedimentary strata up to Tertiary times. Copper ores are frequently associated with galena, zincblende, iron pyrites, quartz, fluorspar, calcspar, &c. Copper pyrites and erubescite, being sulphides of copper and iron, have an iron cap or gossan where the lode crops out at the surface caused by the oxidation of the iron; the copper generally being weathered out gives the gossan a honeycombed appearance. Copper ores may also occur in beds, *e.g.*, copper slates, or native copper may be won from alluvial workings.

Gold.—Gold reefs occur in shales, and sandstones of the Silurian and Devonian ages, also in various granites, porphyries, diorites, gneisses, and other metamorphic schists, serpentine, &c.; associated with quartz, calcspar, barytes, oxides of iron, iron pyrites, mispickel, scorodite, magnetic pyrites, copper pyrites, zincblende, galena, stibnite, cinnabar, &c. Gold may also occur disseminated throughout a rock, also in stockworks. Loam gold is found in the soil from the decomposition of auriferous rocks and minerals. Alluvial gold is found in the beds of creeks and rivers, and on the sea-beach of the present day, also in alluvial deposits of the Miocene and Pliocene age (so-called deep leads) associated with shingle, sand, and clay, sometimes containing titaniferous iron, cassiterite, platinum, garnets, zircons, rutile, sapphires, diamonds, &c.

Iridium.—In alluvial deposits associated with gold and platinum.

Iron.—Occurs in lodes, beds, segregations, and impregnations of various ages, also in sheets from the decomposition of some basic igneous rock, *e.g.*, basalt. Clay and black band are beds of iron ore found in carboniferous formation.

Lead.—These ores are found in lodes and irregular deposits in crystalline schists, shales, sandstones, and limestones, also in serpentine associated with copper and zinc ores, iron pyrites, barytes, quartz, fluorspar, calcite, &c., and are almost always more or less argentiferous.

Manganese.—In veins in the earliest formations, also in irregular deposits in sedimentary rocks, limestone, porphyry, and granite. Frequently associated with iron ores in beds.

Mercury.—Cinnabar is found impregnating rocks, in stockworks and lodes, also in nests, in porphyry, melaphyre, bituminous shales, dolomitic sandstones, and limestones, from the upper silurian to the triassic age, also in schists and serpentine.

Molybdenum.—In quartz reefs with lead, tin, and bismuth ores.

Nickel.—Found in veins and impregnations in the older rocks, *e.g.*, granite, gneiss, serpentine, diorite, gabbro, talcose, hornblendic and other schists, associated with lead, copper, and cobalt ores, and magnetic pyrites.

Palladium.—In alluvial with gold, platinum, and iridium.

Platinum.—Only occurs in payable quantities in alluvial deposits generally associated with gold and iridium.

Silver.—In lodes and irregular deposits. Occurs in andesite, gneiss, and other crystalline schists, shales, sandstones, and limestones generally associated with lead, copper, zinc or antimony ores.

Sodium minerals occur in beds, also in the sea and lakes.

Strontium.—In veins generally associated with baryta and galena; also in the craters of extinct valcanoes.

Tellurium.—In reefs with gold and silver.

Tin.—Cassiterite is associated with granitic rocks, porphyries, gneiss, slate, or sandstone, where it is found to occur in lodes, stocks and stockworks, together with quartz, lithium mica, tourmaline, fluorspar, apatite, topaz, beryl, wolfram, molyb, denite, mispickel, garnet, &c. Tin-stone is also found in ancient and modern streams associated with gems, gold, &c., when it is termed stream-tin.

Tungsten (Wolfram).—Wolfram occurs in lodes and in alluvial associated with tin-stone. Scheelite is found as irregular masses in quartz reefs.

Uranium.—This is found in veins with lead ores.

Zinc.—Zincblende, the chief ore of zinc, occurs in lodes of all ages associated with lead, copper, iron, tin, silver, and gold ores in slate, sandstone, limestone, granite and gneisses.

Occurrence of other Valuable Minerals.

Alum.—Occurs in alum slates, also in small veins, and in some springs.

Amber.—In tertiary brown coal and diluvial deposits.

Apatite.—In archæan rocks.

Asbestos.—In serpentine rocks in veins.

Anthracite and Coals.—In seams or beds.

Asphaltum.—Lakes.

Alabaster.—In veins and beds.

Bitumen.—In layers.

Barytes.—In veins.

Basalt.—Sheets, dykes.

Borax.—In lakes.

Bituminous Shales.—In beds.

Burrstone.—A porous silicious rock from tertiary formation.

Brick-clays.—Decomposed rock near the surface.

Cerium.—In veins.

Dydmium.—In veins.

Emery.—Beds in mica-schist, and granular limestone.

Fuller's Earth.—In beds of jurassic and cretaceous formations, also the result of decomposition of diabase and gabbro.

Fire-clay.—From coal measures, also decomposed dykestone.

Guano.—On islands on the coast of rainless regions; caves.

Graphite (Plumbago).—Beds in crystalline schists and granular limestone.

Gypsum.—In beds and lodes.

Iodine.—Associated with Chili saltpetre in beds.

Infusorial Earth (Tripolite).—In beds.

Kaolin.—In veins and beds.

Lignite.—Beds.

Mica.—In pegmatite veins.

Meerschaum.—Loose or distributed in limestone and serpentine.

Nitre.—Beds in rainless tracts.

Petroleum.—Permeating shales, sandstones, and limestones of nearly all geological ages from the lower silurian.

Precious Stones.—Diamonds (detritus of crystalline metamorphic rock), sapphires (dykes of serpentine and chrysolite), spinel (granular limestone and serpentine, also in lodes), topaz (rhyolite, quartz porphyry), beryl (limestone, clay-slate), zircon (decomposition of felspathic rocks), garnet (rhyolite, peridot trap-dykes, chlorite, granite, crystalline schists, limestone, sandstone), tourmaline (granite, limestone), turquoise (small veins in clay-slate), opal (small veins in igneous rocks).

Talc.—In veins in schists, serpentine, and granite.

ORE DRESSING.

General.

Ore dressing is carried out by mechanical means; smelting by chemical means. Must calculate which is the cheaper for any particular ore, taking local conditions into consideration. When calculating the cost of ore dressing, must take into consideration the cost of wages, stores, water, fuel, wear and tear, depreciation of plant, and the loss of ore in the waste. On the other side of the ledger place the saving by not having to handle flux and smelt, worthless material, depreciation of extra smelting plant, extra value of products, and if the tailings are used for filling underground credit must be given for this value. The increased value of the ore must at least fully cover the cost of dressing. The object of dressing is to separate the useful minerals from those that are worthless, and the former from one another for subsequent treatment. Associated minerals may be useful as fluxes, useless, or harmful. Ores may be too poor to smelt without previous concentration. Much dressing may be avoided by careful mining. The different sorts of minerals must first be set free from each other by reducing the ore in size, they can then be sorted, sized, classified, and concentrated. Results of ore dressing are generally given in percentages, but it would be better were the losses given in weight; for though a 75 per cent. saving might be good in a 3 per cent. copper ore, it would be bad work in a 10 per cent. ore.

The method of dressing employed depends on the nature of the valuable minerals to be saved, and that of the worthless material from which they must be separated. Ores that are easily converted into powder or are soluble in water are either difficult to treat or are not suitable for concentration, e.g. carbonates of copper or lead, and sulphate of copper. The latter would be lost in wet concentration, but may be precipitated out of solution as cement copper on scrap-iron.

Minerals that are hurtful often vary with the method employed for extracting the metal. If silver is to be amalgamated, then lead and antimony ores, clay and talc, are injurious. For gold, when it is to be chlorinated, talc and lime are objectionable. In antimony ores, lead is not desired. Cobalt when used for a blue paint should be free from calcite, manganese spar, hornstone, ferruginous quartz and galena, also nickel when predominating; arsenic intensifies the blue colour. Lead and bismuth should be separated from copper ores. Over 10 per cent. zinc is objected to in lead smelting. Sulphur and phosphorus are hurtful in iron ores. The degree of concentration may depend on the process necessary to extract the metal; for instance, tin smelters require 68–75 per cent. tin for treatment; wolfram buyers demand at least 60 per cent. WO_3; the minimum for molybdenite is 90 per cent. MoS_2. The percentage of metal required may depend on what is available. While users of chrome iron could handle lower-grade ore, they will not do so when there is plenty of 54 per cent. Cr_2O_3 available. Freight also affects the degree of concentration; in one place it may be necessary to dress an ore up to 30 per cent. Cu or higher, whereas under other conditions they might smelt 3 per cent. ore at a profit.

Some machines are made a standard size found by experience to be most suitable for general work, others have to be specially made. The capacity of a machine varies not only according to its size, but also according to the way in which it is run, and the nature of the material treated. The speed and quantity of water required must also be determined in each instance. Beware of freak machines, especially in out-of-the-way places where alterations and repairs are not easily obtained. A machine should be simple, strong, as far as possible fireproof, and the same type of machine should be of the same make so that only one kind of spares will be necessary.

Avoid as much manipulation as possible. As a rule dressing floors are better located at the mine than at the smelters, so as to avoid the expense of handling worthless stuff that might be used at the mine for filling depleted stopes. It is generally cheaper to pump water to the mine than convey ore to the water. By erecting works on the side of a hill one gets the advantage of gravity in handling the stone. A good inclination for a dressing site is 1 to 3, or 19 degrees. Must have a good tip for the tailings, and a suitable water-supply. Build the plant in units; leave ample space for handling machinery and adding possible improvements. Every machine has its economic limits. Proportion the capacity of the machines employed in successive stages.

The following properties of minerals affect ore dressing:—

Hardness.—This affects the wear of machinery.

Tenacity and Brittleness.—A hard brittle mineral like proustite will slime more readily than one that is soft and tough like hornsilver. Tough minerals are difficult to break, e.g. native copper, mica, talc, rhodonite, and some forms of hornblende. Mica may choke up the screens of a battery and cause them to burst.

Form.—The shape of particles, governed by their structure and fracture. May be cubical like galena; elongated like antimonite; scaly like mica, etc. It affects their power of settling in water, and adhesion to surfaces with which they come in contact.

Mineral Aggregation.—Valuable minerals may occur in a massive form in large pieces mixed with waste rock from which it may be hand-picked; or it may occur in fine particles intimately associated with waste so that the whole must be crushed small. It may occur as laminations through waste; or as loose grains like gold, platinum, and tin stone in alluvial, which requires no reduction in size.

Colour and Lustre.—These are useful to enable one to readily recognize certain minerals when hand-picking.

Specific Gravity.—This is one of the most useful properties of minerals in connection with their concentration. See specific gravity in table of minerals. The economic effect of specific gravity is greatly reduced when a mineral is in a fine powder. Of two particles the same shape and size the heavier will settle first. Of two particles of different specific gravity but of same settling velocity, that of higher specific gravity will be the smaller. Of two particles of same shape and size, the heavier will have the longer trajectory, and of two particles of different specific gravity but same trajectory, that of the higher specific gravity will be of smaller diameter than the other.

Adhesion.—Such as the attraction gold has for quicksilver, and diamonds have for a greasy surface.

Greasiness.—The tendency that certain minerals have to float on water as if they were greasy, owing to the difficulty of wetting the particles, e.g. zinc blende, copper pyrites, graphite, etc.

Magnetism.—The attraction of certain minerals to a magnet, e.g. magnetite, wolfram, and pyrrhotite. Useful for keeping bolts, nuts, and other pieces of iron or steel accidentally mixed with ore from getting into crushers.

Change of Magnetism by Heat.—Certain minerals, especially some of those containing iron, when heated lose O, CO_2, or S, and become magnetic.

Change of Porosity by Heat.—Iron pyrites when calcined loses its S, becomes porous, and lighter in specific gravity, so that it can be easily separated from other heavy minerals, e.g. cassiterite, not so affected.

Decrepitation.—Some minerals when heated fly to pieces on account of unequal expansion, e.g. calcite, fluorspar, and barite, which may then be separated by sizing.

DESICCATION.

It is necessary that some ores be dried before they are treated, or else they might clog crushing machinery or otherwise interfere with the subsequent process to be adopted. It is not always desirable to dry fine concentrates for transport too thoroughly, as it becomes too dusty; besides, a little moisture causes the material of the bags to swell, thus saving loss. With some material, e.g. pyrites, moisture may set up chemical decomposition that will rot the bags. Must consider the cost of drying, the degree of dryness desired, whether the mineral will be injured by passing through fire, and whether the ore is sandy or clayey. It is more difficult to dry down to ½ per cent. than to 2 per cent., which is generally sufficient. If ore has to be transported, the saving in freight by getting rid of the bulk of the moisture is often an important item.

Weathering.—In dry climates a large amount of moisture may be got rid of by exposure to the weather.

Stalls or Kilns.—The ore is heated in enclosed places, often built in the side of a bank or hill, the ore being placed on layers of wood. Used for run-of-mine ore.

Rotary Drier.—A slowly revolving iron cylinder, placed at a slight angle, at one end of which is a fire-box. The ore, which must be fairly fine, is lifted up inside the cylinder by blades, and allowed to shower down through the heated air. The cylinder is about 24 ft. long, 6 ft. in diameter, given a pitch of 1 in 3, and has 7 revolutions per minute.

Pans.—Iron plates or pans are placed over flues; mostly used for drying concentrates; or a special fire may be made under the pan, and an iron chimney pass up through it, against which the concentrates are directed by inverted cones.

Filters.—Filter presses and vacuum filters may be used to get rid of the excess of water.

Draining Belts. — Rubber belts revolving at an angle; generally serving as a conveyor at the same time.

REDUCTION.

The object of reducing in size is either to make the ore more convenient to handle, or else to separate particles for subsequent treatment. The finer the ore is reduced the greater the loss, and, as a rule, the more difficult it is to treat. Reduce in stages, never crush finer than that from which a payable quantity of ore can be concentrated. Use that method of reduction for which the ore in size and nature is most suitable, having regard to the product required.

A rough rule for power is 1 h.p., will reduce per twenty-four hours 24 tons to 2½ in. ring; 3·48 tons to $\frac{1}{16}$ in. mesh; 1 ton to 60 mesh.

WEATHERING OR HEATING.—Ore may be allowed to weather naturally, or a similar effect may be obtained more rapidly by heating in kilns if no objectionable chemical changes take place that will spoil subsequent treatment, e.g. the formation of sulphates when desired to amalgamate gold ores. Such treatment makes the ore break up easier. Can break up about 15 per cent. more stone after it has been burnt in kilns. Weathering does not require special apparatus, but causes loss of interest on the mined ore.

1. CRUSHING: (A) *Jaw-breakers.*—These have a knapping motion, which causes the ore to break along the lines of least resistance. They are used for reducing coarse ore, and do not make an undue proportion of very fine stuff. Jaw-breakers are measured by the length and breadth of the upper opening between the jaws. They have 150 to 200 strokes per minute. The ends of the toggle should be oiled every half-hour while the machine is in motion; all other working joints are lubricated every hour when the breaker is stopped. The ore is broken dry. Though jaw-breakers may break ore down to ⅝ in. it is better to reduce ore to below 2 in. by some other means. Ore is not reduced in one operation from very coarse to fine, as the efficacy of an ore-breaker rapidly falls off when the reduction exceeds 1 to 4. The horse-power required varies according to the size of the machine and the work it does. A breaker that will crush 11–12 tons per h.p. per twenty-four hours to 1½ in., will crush 15½–19 tons to 2 in., and 18–22 tons to 2½ in. The jaws of breakers as well as the shells of rolls are made of chilled white iron, manganese steel, or chrome steel. To avoid the breakage of some important part of the machine should a lump of iron find its way between the jaws, one of the toggles may be made of two pieces which overlap and are riveted together; the copper rivets being the weakest portion are sheared if too great a strain is brought to bear on them. There are two great types of jaw-breakers, (*a*) the Blake type, which has the movable jaw pivoted from above; this puts through a large quantity of ore, but the product is not regular in size; (*b*) the Dodge type, which has its movable

jaw pivoted from below; this puts through less material but the grade of the product is more uniform.

(B) *Gyratory Crushers.*—With these crushing may take place the whole time, instead of intermittently as with a jaw-breaker, if the hopper is kept full. Power required about 1 h.p., crushes 1 ton per hour to $2\frac{1}{2}$ in.

(C) *Rolls.* — These crush ore by squeezing it between revolving cylinders placed horizontally and parallel, which revolve toward each other, so that they draw in and gradually crush up the material fed between them. In some places rolls are now employed to reduce ore formerly crushed by gravity stamps. If required to crush fine must do so in stages. Ore should be reduced to 2 inches before being fed into rolls. Rolls reach their limit at $\frac{1}{50}$ in., but in practice seldom reduce finer than $\frac{1}{20}$ in., as beyond this ball and tube mills are more efficient. May crush wet or dry, the former being used for fine crushing so as to lay the dust and keep the rolls cool. Since cylinders placed parallel and close together can only touch along a line, the grade to which the ore is crushed depends on the distance the rolls are apart at that line, and when once past that mark the ore is not further acted upon by the machine, therefore any coarse ore that finds its way through must be re-crushed. To avoid breakages to machinery when hard pieces get between the rolls, some device, e.g. rubber or steel springs, weighted levers, or breaking-cups, are employed. The faces of rolls vary between 12 and 24 inches; if too long, a large quantity of coarse material passes through should the rolls be forced apart by a hard piece. The diameter of the rolls is between 14 and 36 inches, the most useful size being 26 inches. If too small, the angle formed by the rolls is so obtuse that they cannot well grip the ore which slips, thus wearing down the shells by friction; if too large the rolls become unwieldy to handle. Fine crushing rolls have a greater peripheral speed than coarse rolls. The minimum peripheral speed for rolls is considered to be 200 feet per minute, and the maximum 1,500 feet per minute. If rolls are worked too fast power is lost; if too slow they are apt to stop should a hard piece get between them. Three sets of rolls 36 × 16 inches will treat 200–250 tons per twenty-four hours, according to the material, and size of finished product. Rolls receiving $1\frac{1}{4}$ in. cube should be run with a peripheral speed of 300–400 feet per minute; receiving $\frac{1}{4}$ in. feed, 550–600 feet per minute; 14 mesh, 700–750 feet per minute; 20 mesh, for reduction to 40 mesh, 1,000 feet per minute. Over 1,000 feet per minute is not to be recommended. The surface of rolls is generally smooth but has been made corrugated; also one roll has been given a concave face and the other a corresponding convex face. Ordinary rolls are apt to hollow out in the middle because most ore is fed to that part. Small rolls wear away quicker than large rolls, because the same point comes into action more frequently than with large rolls. The distance between rolls can be regulated by screws. The wearing part of rolls is borne by the shells which are slipped over cores. The shells can be re-turned when worn till reduced to ¼ in. thick. When both fine and coarse rolls are employed, generally use the same size for both, so that the shells when worn on the fine rolls can be transferred to the coarse rolls. It is well to have a spare core and shell ready to replace an old one, so as to save time in changing. The journal boxes of rolls should be long and self-oiling. With Cornish rolls the bearings of one are fixed, while the bearings of the other can slide horizontally for adjustment. The driving-roll may be geared to the follower with long-toothed spur wheels, so as to allow sufficient play when hard particles push the rolls apart; or the follower may be worked by friction only or assisted by a separate belt. Coarse Cornish rolls, 36×16 inches, set to crush to ½ in., have a duty of 5½ tons per hour, and require 11 h.p. Krom rolls will crush from 12 to 50 tons a day.

2. Percussion.—This breaks up ore with a pounding action irrespective of its nature.

(A) *By Hand*. (*a*) *Hammers*.—Ragging, spalling, and cobbing are only different degrees of the same thing. Ragging hammers weigh from 10 to 16 lbs. and should have a handle in length from the palm of the operator's hand to his shoulder; it must be of springy wood to prevent jarring of the hands. It must have two faces, or one face and a sharp pean; the edges may be bevelled or sharp. Spalling hammers weigh from 2 to 3 lbs. and also have long handles; both faces are rounded. Cobbing hammers weigh from 1½ to 4 lbs. and have a handle the length of the forearm; they vary in shape according to the nature of the ore; generally they have one flat square face and a chisel-shaped pean, which latter may be either parallel with or at right angles to the handle, and is used for splitting purposes. Must use judgment in breaking stone, take advantage of joints, avoid striking the ore itself more than necessary as it is easily pulverized. Cobbing is done on a cast-iron die, 9 to 12 in. square and 4 to 6 in. thick, unless iron is objectionable, as with quicksilver ores, or in the subsequent treatment of tin or cobalt, when hard stone dies may be used. If ore is apt to fly, place a ring round it. Only rich ore is broken by hand; the poorer by machinery. The place where larger pieces of ore are broken up should be well stamped or cemented to prevent the loss of fines, or their contamination with mud or dirt. When working with a long-handled hammer, it is better to employ two men, one to hammer, the other to sort the ore.

(*b*) *Dollying*.—With a pestle and mortar; the pestle is often attached to a spring pole. Used for breaking up samples, also for reducing rich hand-picked specimens of gold, tin, or wolframfor subsequent concentration.

(B) *Tilt Hammer*.—This is practically a large hammer with a horizontal stem worked by machinery.

(C) *Gravity Stamp*.—These are hammers, with vertical stems, which work in a mortar-box. The standard number in one box is five. To find the mechanical effective power of the stampers in a battery per second, multiply the weight of one stamp by the number of stamps in the battery, by the lift in feet, by the number of lifts per minute, and divide by 60 seconds. Allow one-third of the effective power for friction. Then the effective power plus one-third the effective power, equals foot-pounds per second, including the coefficient of friction. Foot-pounds per second divided by 550 give the horse-power required for the battery. The capacity of a stamp per twenty-four hours varies with its weight, class of ore, size of feed, and size of discharge. Formerly pieces as large as would pass the feed hole were put through; the larger pieces reduced the drop of the stamp and prevented the effective crushing of the smaller pieces, which in turn cushioned the blow on the larger pieces. Now, the feed is generally reduced to 1½–2 inches by ore-breakers. A stamp that will crush 3 tons a day to 40 mesh, will crush 10–12 tons a day to pass ¼ in. mesh, which shows that most of the time is occupied in crushing from ¼ in. to 40 mesh. To increase the capacity of gravity stamps, the tendency is to increase the size of the discharged material, which is then reduced by some more suitable machine, e.g. a tube mill or grinding pan; also to separate by screening material too fine for the stamps. Formerly the foundations for mortar-boxes were made of timber, now they are generally of concrete. When timber is employed there are generally two vertical mortar-blocks for each five-head mortar-box, let 6 to 10 feet deep into the ground. Where possible a solid rock bottom is levelled off, a squared log 18 by 12 inches laid horizontally, on which are placed the mortar-blocks, connected together by 1¼ inch rods and cross timbers, having 12 inch section. The space all round the mortar-blocks for 2 feet is well packed with concrete or clay and stone. Auger holes are made in the mortar-blocks for 1¼ inch bolts by which the mortar-box is fastened to the mortar-blocks, all other holes and cracks are filled with sulphur, the top is placed level and coated with tar, a triple layer of well-tarred blanket is placed on the top, and the mortar-box bolted in position. If solid rock is at the surface, a horizontal mortar-block is anchored to it by 1½ inch blocks 3 feet long. Sometimes good sound timber cannot be obtained; in such a case vertical mortar-blocks can be built up of 2 inch planks fastened together and placed on end.

Where the battery site is on marshy ground, one must use a horizontal foundation spread over a wide area; the ground is dug out for 1 to 3 feet deep, carefully levelled, and timbers laid.

Concrete foundations are wider at the base than on the top. The top is carefully levelled off with a stiff mixture of sand and cement 2 : 1. On this is placed a sheet ⅜ in. rubber, then a piece of 6 inch thick wood, and finally the mortar-box. Holes are left in the concrete for the tie down bolts, and when they are in position they are held there by the space around the bolts being filled with sand, a little cement being placed on top to keep the sand in place; this enables a bolt to be readily withdrawn and replaced if necessary.

The framework may be of wood, steel, cast-iron, or wrought-iron, or a combination of them. Wood combines firmness with elasticity. Iron lasts longer, but the constant vibrations loosen the bolts. Frameworks are fastened to different timbers to those of the mortar-box, so as to make them less subject to vibrations.

There are two sets of guides for the stamp stems, one 3 feet above the top of the mortar-box, the other near the top of the stem; they may be of wood or iron, preferably the former; when the latter, they are lined with hardwood or brass. The mortar-box is generally one heavy iron casting, unless it has to be transported over difficult country. When used for inside amalgamation, the boxes are made wide, otherwise narrow boxes give a better discharge. If hand-fed, the feed platform should be level with the feed hole, so that a man can shovel instead of having to lift the ore into the mortar. The width of the feed hole is about 3 inches so as to prevent a piece of ore entering that is too large to be economically crushed. The slit does not extend right across the box, as it is desired to feed the centre stamps. To avoid having to renew mortar-boxes, 1 in. chilled cast-iron linings are used. Mortar-boxes generally have a front-discharge, but may have a back-discharge as well. The screens may be placed vertically or at an angle, the top leaning outwards. The height of the bottom of the screen from the top of the dies may be regulated, so as to get the most economic discharge as the dies wear down, either by placing a false bottom under the worn dies so as to raise them, or, better still, by placing chuck blocks of different heights below the screen frame.

Screens may have clean or burred punched holes, which may be circular or slotted in shape, or they may be of wire cloth. The smallest practicable clean punched hole is 0·3 mm.; can punch thicker sheets for burred holes than for clean holes; if burred holes are too large they can be closed by hammering. Screens may be distinguished by the number of holes per linear inch or square inch, but one also wants to know the proportion of hole area to the rest of the sheet. Wire cloth has a larger discharge area than punched iron, but only lasts about half as long. If chips of wood, mica, and such-like substances are likely to get into the mortar-box and choke the screen holes, thereby endangering the screen, it is well to have a slit in the mortar-box near the top of the screen so that this material can splash or be scraped out. Two holes are left in the cover of the mortar-box for the entrance of water; the quantity of water used varies from 100 to 500 gallons per stamp head per hour. Sand requires about six times its weight of water to wash it over the plates.

Modern heavy stamps have bearings for the cam shaft between each stem, and a separate motor is used for every ten stamps, being placed between each set of five, so as to reduce the torsional strain of the cam shaft, which generally serves two batteries of five stamps each.

If a number of batteries are driven by one engine placed at the end of a long line of shafting, those sections of shafting nearest the engine must be made proportionally stronger. The belt-wheel on the cam-shaft is best built up of iron and wood, as this is subject to less vibration than one of iron, and is therefore less likely to work loose. The cams usually have two wings, the face of which is a modified involute of a circle, the radius of which is equal to the horizontal distance between the axis of the cam-shaft and the centre of the stamp-stem. May have key-ways cast in the same place in each cam, in which case the same cam can be used for any stamp, key-ways being cut in different positions on the cam-shafting; or key-ways may be cut in different positions in each cam according to the stamp it has to serve, and one key-way only is cut right along the cam-shaft. The Blanton cam can be readily adjusted in any position.

The stamp proper includes the stem, disc, head, and shoe, the combined weights of which vary from 600 to 1,000 lbs. in light stamps, up to 2,000 lbs. in heavy stamps, which appears to be the economic maximum for cam-lifted stamps. The very light stamps are given a high drop, 16–20 inches, in a roomy mortar with a high discharge, and have twenty-eight to thirty-two drops per minute. The heavy stamps are given a low drop of about 8 inches and fall about ninety-five times per minute. The best order of drop, facing the battery from the front, counting from left to right, is 1, 4, 2, 5, 3.

The stem is solid wrought iron; both ends are generally tapered so that either can fit into the head. The stem may have a simple key-way cut on it, or be threaded where the disc is attached for about 2 feet long. If threaded, the threads should be rounded, not sharp, as they are stronger and easier to use.

The disc or tappet enables the lifting motion to be transmitted from the cam to the stem. It is made reversible so that when one face is worn, the other can be used; an annular groove is cut out near the stem, as that part is not worn by friction with the cam, so would leave a projection, which if everything was not in perfect order might cause the breakage of a cam. Discs may be keyed to the stem or fastened with a gib or wedge. When provided with a screw this is for nice adjustment. When out of commission, stamps are held up by fingers or stamp hangers placed under the discs. Oil is not suitable for lubricating tappets and cams, as it prevents the revolving of the stamp; it is better to use some tough grease, or a mixture of oil tar, resin, and tallow which turns thick on cooling.

The head is a cylindrical casting having the same diameter as the shoe; it is the connecting link between the stem and the shoe, and has a socket at either end for each, and channels for inserting an instrument to loosen the stem and shoe when desired to change either of them. The head also adds considerable weight to the stamp.

The shoe is cylindrical in shape, with a tapered shank that fits into the head; it is mostly made of cast steel or the hardest and toughest white iron. Strips of soft wood are tied round the shank, and the head carefully lowered on to it; the stem is then dropped two or three times, and the connection is complete. The crushing is done between the shoes and dies; the former wear faster than the latter. The dies may be cylindrical with a square base, or may be octagonal. One has to see that there are no blow-holes in the castings, which are sometimes hidden by filling with lead.

(D) *Steam Stamps.*—These may be large single stamps, e.g. Ball, Leavitt, Allis, etc. They are lifted and forced down by steam, with a striking weight of 2,500–5,570 lbs., having a capacity per h.p. per twenty-four hours of 1·745–1·852 tons;

height of drop 4–6 inches, and 100 drops per minute; water required, 5½ tons per ton of ore crushed.

Tremain stamps consist of two steam stamps in a box; individually they are light weights, being only 300 lbs. each; they are given a drop of 5–8 inches and 140–200 drops each per minute.

3. GRINDING MACHINERY.—With this class of machinery the ore receives a rubbing motion which tears the particles asunder. Used for reducing fine ore to sand and slime. Grinding machinery may be subdivided into:—

(A) *Edge-Runners.*—A cylinder will roll on a plane surface in a straight line without sliding friction; a cone also rolls on a plane surface without sliding friction, but in a circular path. Edge-running mill generally only have two runners, but may have three or four.

Chilian Mill.—This is a shallow cast-iron pan or annular ring in which short cylinders of comparatively large diameter work. The mills are measured by the diameter of pan, diameter of cylindrical runners, and the width of their faces. The tires on the runners are of hard white iron 2 inches thick; the die or false bottom is 1 inch thick made in two sections of the best chilled iron. The pan has three holes at different levels for discharging the pulp. The feed is ½ to ¼ in. in size. The runners revolve six to ten times per minute. The driving gear of the runners may be above or below the pan; or the bottom of the pan may be made to revolve which causes the runners to revolve by friction on their axle which is fixed. Chilian mills have not a positive discharge. They slime more than a ball mill. Modern fast running, 33 r.p.m., 6 feet mills, reduce about 4 tons per hour with a feed of ⅜ in., and of the discharge 60 per cent. will pass 150 mesh.

Schranz Mill.—This consists of a pan which revolves 12½ times per minute; its bottom is cone-shaped, having an angle of 1 in 10. This causes three conical runners, 18 inches at their smaller end and 28 inches in diameter at their larger end, to revolve by friction. Each runner is raised a different distance from the die so as to reduce the ore gradually. Rubber springs are so arranged against one end of each runner-axle that the runner can rise when passing over a hard bit of iron, etc. The machine requires 3–3½ h.p., and will break up 675 lbs. ore per hour, requiring 28 gallons of water per minute.

Bryan Roller Mill.—Consists of three steel-tired rollers 30 inches diameter, 6 in. face, each weighing 1,200 lbs.; tires 2½ inches thick, which last about 240 days. The die weighs 1,661 lbs. and lasts 120 days. The five screens weigh

19 lbs. and last four days. Total weight of mill 5½ tons. The belt-pulley is an iron tank so arranged above the rollers as to add weight to them. The mill revolves about forty times per minute, and requires 18 h.p.

(B) *Centrifugal Roller Mill.*—In which rollers are made to fly against the side of the pan by means of centrifugal force and crush the ore between them and the ring die.

Huntington Mill.—This consists of a cast-iron pan, in the centre of which is a spindle with a yoke, from which four arms are suspended, with a roller 13 inches diameter and 1½ inches thick at the bottom of each, so arranged that they are 1 inch above the bottom of the pan. The rollers are free to revolve on their axis, and are caused to do so by friction against the hardened ring-die inside the pan. The discharge screen is just above this die. The central spindle revolves 45–75 times per minute. Ore is fed in the size of walnuts or a little smaller. The rollers are apt to wear irregularly, assuming polygonal shapes. Made in sizes 3½ feet, 5 feet, and 6 feet diameter. The usual size is 5 feet, which weighs 5½ tons, and requires a space of 6 ft. 7 ins. by 4 ft. 8¾ ins. It will crush 10–20 tons per twenty-four hours through a 30-mesh screen and requires 10–12 h.p.

The Griffin Roller Mill consists of a single roller suspended on a single vertical axis, which flies out by means of centrifugal force against an annular die. The size of a mill is measured by the inside diameter of the die ring. A 30 in. mill weighs 10,500 lbs., requires 15–25 h.p., and is fed with 1½ in. diameter ore. It may work wet with screens, or dry with fans. The roller revolves 190–200 times per minute on its own axis. The shell of a 30 in. mill is 18–20 inches diameter, 6 inches deep, and weighs about 100 lbs. Under the roller are ploughs which are arranged to stir up the ore on the bottom.

(C) *Mills with Drags.*—Instead of revolving runners, drags are used which conform to the surface of the die.

Arastras.—Like a Chilean Mill, only the runners are replaced by two shoes or drags, which are pulled round the pan twenty-four times per minute.

Berdan Pan.—A cast-iron basin, with a curved bottom, 3 feet in diameter, arranged on a spindle placed at an angle of 25 degrees from the vertical. The basin revolves twenty-eight times per minute. A drag is hung up by a hook so as to be a little off the lowest point of the basin. Cap. 10 cwt. per twenty-four hours. The pan is 2¼ inches thick and 15 inches deep. Iron balls are sometimes used instead of drags.

(D) *Grinding Pans* consist of a circular iron vessel, generally 5 to 8 feet diameter and 2½ to 3½ feet deep. On the bottom are segmental dies, above which revolve shoes, also in segments, fastened to a muller or circular plate attached to a yoke. The muller and yoke can be raised or lowered by working a set screw that presses on top of the vertical shafting. Shoes and dies are 2 to 3 inches thick, they may have a plain or corrugated surface, be placed horizontally or at an angle, and the segments may be placed close together so as to form the so-called positive pan, where the material is forced to pass between the shoes and dies before it can escape at the periphery, or there may be a space between the segments. In the positive pans the ends of the shoes nearest the centre of the pan are made trumpet-shaped so as to allow the feed to enter between the shoes and dies. Iron wings are keyed to the inside of the pans so as to direct the pulp towards the centre. Pans may work on a charge intermittently or continuously; the latter may have a classifier in connection with it. A pan may also be used as a stirrer or agitator. Pans revolve about sixty times per minute, and are suitable for grinding from one-twentieth to one-sixtieth of an inch. Some people prefer pans to tube mills for the same class of work, but the wear is very great.

(E) *Ball Mills.* Loose balls are mixed up with ore in a cylinder.

Common Ball Mill.—A pan having an annular ring, round which large cast-iron balls are pushed by guiding-rods attached to a revolving cross-arm.

Krupp Ball Mill.—This is a revolving drum, made of hard steel segmental plates arranged in steps; outside these is a perforated sheet steel cylinder, and outside that a cylindrical sieve; the whole being housed in so as to be dust-tight. A number of chrome-steel balls of various sizes are fed inside with the ore. The machine is used chiefly for dry crushing. It requires very careful feeding, and is apt to be overfed and choked. Used for reducing a feed of 2½ inches to 25 or 27 mesh.

Tube Mills.—These will grind to any fineness required, depending on their length. The standard size for gold ores is $22 \times 5\frac{1}{2}$ feet; use one to every ten head of stamps; allow 100 h.p. to drive it. Pulp of 50 per cent. and even 60 per cent. thickness has been found to give satisfactory results. When not required to slime make tubes shorter. Drive from discharge-end so as to have feed-end free. May line tubes with flints or steel or both. Steel linings ¾ to 1¼ inches thick, last from five to ten months, depending on material crushed, and are worn down to ¼ in. thickness; one set will grind 6,000 to 12,000 tons of quartz sand. Manganese steel linings are nearly double the cost of ordinary steel linings, but will serve for about 18,000 tons. Use hard flints from 3 to 4 inches diameter for balls; 1 cwt. flints will slime about 100 tons quartz sand, or will grind about 150 tons to, say, 40 mesh. Rate of revolution about thirty-eight per minute.

(F) *Cone Mills* used mostly for reducing samples or coal. They consist of a cylindrical or funnel-shaped ring, which serves as a die, inside of which revolves a cone attached to a vertical spindle.

(G) *Disc Mills.*—Two or more discs rub up ore between them.

Dingey's Disc Mill.—This consists of a large horizontal disc, with 1 to 4 other discs rotating on it, those on the top working faster than those on the bottom.

Heberle's Disc Mill.—In this case the discs are placed vertically, and arranged eccentrically to one another; they revolve in opposite directions, and the space between them gradually diminishes towards the periphery. One disc rotates 250 times per minute, the other only 0·3 time. The machine is 9 ft. 9 in. long, 3 ft. wide, 3 ft. 3 in. high; it uses 5 gallons water per minute. Total weight 882 lbs.

4. *Disintegrator.*—Carr's disintegrator consists of two rings arranged vertically and parallel, each having two circles of steel-rod beaters, the circles on the same rings being 6 inches apart. The beaters attached to one ring work between those of the other in opposite directions and at different rates, which breaks up any soft material, e.g. coal that gets between the beaters. The diameters of the four circles of beaters are 48, 42, 36, and 30 inches. One ring rotates at the rate of 300–400 per minute, and the other at the rate of 450–600 r.p.m. Coal should not be fed in larger than $\frac{3}{4}$ in. Requires 8–16 h.p.

SEPARATION.

1. WASHING OR CLEANING ORE.—Some ores are associated with clay or earth which makes subsequent ore-dressing operations more difficult by clogging machinery, thickening the water, etc. In some cases it may be allowed to weather off, or it may be played upon by water from a hose; at other times certain washing apparatus are employed.

(A) *Stationary:* (*a*) *Sluices* or troughs made in 12 ft. sections known as a box, $1\frac{1}{2}$ to 2 feet wide and 1 foot deep; the material may be stirred about with hand tools, and the coarser pieces thrown out by a sluice fork.

(*b*) *Step Sluices.*—Every 4 feet or so a section is dropped a short distance from the one above, so as to give the ore a better chance of being cleaned by falling from step to step; the bottom of each division slants upwards from the back.

(B) *Movable:* (*a*) *Log Washer.*—This is a trough about 17 feet long placed at an angle of ¾ in. per foot, in which revolves an axle at the rate of 13 r.p.m., provided with blades set at an angle to the axis. The ore is fed at the lower end, and the water at the upper; the blades slowly convey the ore uphill, and discharge it at the top, the clay floating out at the lower end.

(*b*) *The Mud Wheel* is a paddle wheel 5–6 feet diameter, which revolves in a curved box; the paddles lift the ore to be washed, and allow it to fall again.

(*c*) *Puddler.*—This is a vat in which vertical stirrers attached to revolving arms work up the stone and water together. A horse puddler is an annular ring, 6 feet wide and 20 inches deep, the outer diameter being 16 feet. A horse pulls round two sweeps to which are attached harrows which are circular or triangular iron frameworks from which vertical rods project and scrape on the bottom. There are gates through which the clayey water and the washed gravel can be discharged. Can treat 16–28 loads of gravel a day. A mechanical puddler is somewhat similar to a horse puddler, but uses mechanical means for motive-power. Can treat 120 cubic yards per twenty-four hours. Stir for 15–20 minutes, and then sluice.

(*d*) *Wash Trommels.*—A wash trommel may be cylindrical, in which case its axis is inclined about 1 in 12; or it may be conical when the axis is horizontal. They are 3–5 feet in diameter, 8–15 feet long, and require ½–¾ h.p. to work them. They may revolve on shafting or friction rollers. They may be made of steel plate, sometimes with 4 in. spikes to break up clayey matter, or with ribs for lifting the ore, or may consist of bars of iron. Water may play on the dirty ore, or the drums may partly revolve in a trough of water. Lifting blades may be attached to an axle which rotates independently of the drum, which revolves on friction rollers. Work up 3–10 cubic yards per hour. Use 12–25 gallons of water per minute. Speed at periphery 1 to 2½ feet per second.

2. Sorting.—Dressing by hand is more completely carried out with valuable ores than with those that are poorer, which are better treated in bulk by machinery. Ore may be sorted to a certain extent underground, where the mullock is used to support worked-out places, and the transport of worthless material to the surface is avoided. If the ore is very rich or very fine it may be bagged underground to avoid loss. At the surface the ore is sorted into "firsts" ready to be sent to have the metal extracted from it; "seconds" to be sent to the dressing floors for further treatment; "waste," including bits of iron and wood, to be thrown away. These three

divisions, which may be further subdivided, according to the nature and conditions of the minerals present, are carried through each department of the dressing floor. If the ore is associated with two or more sorts of gangues which greatly differ in specific gravity, e.g. baryta and slate, keep each class by itself as far as possible and treat separately. When hand-picking, may use water to lay the dust and clean the ore, so that it can be more easily recognized by its colour as well as its structure, for sorting mostly depends on the eye; or by breaking a doubtful stone and exposing a fresh fracture the quality of the ore may be seen.

(*a*) *Picking Belts* may be of rubber or consist of linked sheet-iron trays (steel rusts too easily), 2–3 feet wide, with sides turned up for 2 inches, which travel about 35 feet per minute. Boys on either side may pick out the waste to enrich the balance if going direct to a furnace; or they may pick out the richer ore to save it from being crushed if desired to dress the balance; or each boy may pick out some particular class of ore as it passes by him, and the larger quality is allowed to fall over the end. The capacity depends on the size of the ore and the speed at which the belt moves.

(*b*) *Revolving Table.*—This is a circular table round which the pickers stand. The ore falls on to one part of the table, each boy selects his particular class, after which the residue is swept off.

(*c*) *Fixed Sorting Tables* are generally used when it is necessary to break up stones, mostly rich ore. Each sorter works at his own bench, in front of which is a bin from which he draws fresh ore when he requires it. The floor about a sorting table should be of cement or other hard substance that can be easily cleaned up.

(*d*) *Heat.* Asphalt may be separated from sand by heating them to 180° F.

SIZING.

Ore should be sized or classified before concentrating in order to get the best work from the concentrators. Sizing may be done wet or dry. The larger stones in run-of-mine may be roughly separated from the finer by tipping the lot over a wall, when the coarser lumps fall to the bottom where they can be collected. Ore is conveniently separated into the following sizes:—1st group, $2\frac{2}{3}$ in., 2 in., $1\frac{1}{3}$ in., 1 in., which require No. 11–18 B.W.G. sheet iron; 2nd group, $\frac{2}{3}$ in., $\frac{1}{2}$ in., $\frac{1}{3}$ in., $\frac{1}{4}$ in., requiring No. 12–14 B.W.G. sheet iron; 3rd group, $\frac{1}{6}$ in., $\frac{1}{8}$ in., $\frac{1}{12}$ in., $\frac{1}{16}$ in., $\frac{1}{24}$ in., requiring No. 15–19 B.W.G. sheet; 4th group, that under $\frac{1}{24}$ in., requiring No. 25 B.W.G.

sheet. Sheet iron is used for the coarser grains, but finer holes are apt to rust up, so may use punched copper instead, but this is more expensive. For the finest grain, iron or brass wire gauze is employed. Material which passes through a hole 0·01 in. diameter is too small to separate economically by means of sieves.

1. STATIONARY: (*a*) *Grizzlies* are made of bars of iron or wood; the section of the bars or rods may be circular, square, oblong, or trapezoidal with the broader end up, say, ¾ in. wide on top, ½ in. wide on bottom, and 2½ inches deep. In the latter case the larger surface is exposed to wear, and the space between the bars being wider below large pieces of ore are less likely to become jambed. They are 8–12 feet long and generally bolted together to make a grating 4 feet wide with bars 1¼–2 inches apart. Different ores slide at different angles, but for general purposes iron grizzlies are placed at an angle of 45 degrees, while wooden grizzlies are placed at an angle of 55 degrees. The grizzlies must have high sides to prevent the ore from jumping over. The bars are sometimes kept apart by small rollers, thus forming a large mesh, and preventing large, flat pieces from falling through. Grizzlies are used to relieve ore-breakers and stamps from having to deal with fine material.

(*b*) *Screens.*—These may be made of wooden or iron rods fixed in a frame which can be placed at any convenient angle, against which the material to be screened is thrown. Screens are sometimes made of punched sheet iron, the space between the holes generally being half the diameter of the hole.

2. MOVABLE: (*a*) *Hand Sieves* are limited in their usefulness. If used for sizing tests or sampling purposes the sieve should have a cap, also an airtight tray below, in which the fine material collects without loss by dusting. Hand sieves for other purposes are generally run backwards and forwards on two strips of wood which support the weight.

(*b*) *Mechanical Sieves.*—These may receive a horizontal, vertical, or gyrating motion; the first is less likely to choke up the holes than the second; a series of sieves should be independent of each other, so that their inclination and speed can be regulated to suit the material treated on each. The sieves are rectangular boxes bound round with iron, having wood or sheet iron at one end for the ore to fall on so as not to damage the perforated portion. They vary in length between 3 and 7 feet and their inclination between 1 and 5 inches per foot; the number of strokes they receive varies between 30 and 68, and the quantity of water required is 20 to 100 gallons per minute. The sieves receiving a horizontal motion may be classified according to the kind of motion imparted, as percussion-riddles and swinging-riddles; likewise those with a vertical motion may be divided into jarring-riddles, spring-riddles, and rocking-riddles ; these may be single or compound. The constant shaking causes much wear and tear.

(*c*) *Grizzlies.*—These are sometimes made so that alternate bars are moved slightly by means of an eccentric ; this not only helps the ore forward, but prevents the spaces between the bars from becoming clogged. If grizzlies are fixed at such an angle that the ore runs down before the fine material has time to be separated, it may be retarded in its progress by a series of knives or short rods that project up between the bars in a line across the middle ; these are counterbalanced, so that when the pressure of ore against the knives is too great they are depressed, and the ore passes onwards, but when relieved of the pressure the counterweight draws the knives up to their original position again.

(*d*) *Trommels* are cylindrical, prismatic, or conical in shape, and are made to revolve on an axle 8–30 times per minute, mostly 16–20; the shell may be of perforated iron or copper sheet, or wire gauze. A series of drums may be placed side by side or end to end ; in either case each drum is on a different level. They are usually 2–4 feet in diameter, and must be long enough to give each particle a reasonable number of chances to get through, say, 9 feet long. The mantle may be perforated with holes of one size, or may be made up in sections of different sizes. The holes may be prevented from choking by jets of water playing on the mantle from the outside, or by blows from a hammer. The ore may be sized by first passing over the finest holes, or by commencing with the coarsest ; the wear is greatest in the former case. Drums may be made double by having a smaller one inside a larger. The angle of the cone or axle of the horizontal trommel varies from ½ to 2 inches to the foot. Some trommels with a prismatic frame have the feed presented to the outside of the mantle instead of to the inside ; the holes when fine may be kept free by jets of exhaust steam.

(*e*) *Spiral Sieves* are made up of sheets of iron, each section being punched with holes of a different size ; these are coiled up into a spiral, and from four to twenty-seven different sizes of material may be obtained, according to the number of sections employed ; the whole revolves seven to nine times per minute.

CLASSIFYING.

Classifiers are used for settling particles that are too fine for economical sizing. The horizontal current conveying the pulp slows down as it opens out into boxes of successively larger areas. This allows the free settling of particles of similar weight but different sizes. Sometimes an upward current of fresh water is used to make a better classification. The sizes of grain fed into hydraulic classifiers vary from 5 mm. to 30 mesh. Some form of classifier or settling tank may also be used for dewatering purposes so as to thicken pulp or clarify water.

1. Settling Tank.—May consist either of a large box or an excavation in the ground lined with wood or cement. Owing to surface currents, and the fact that the coarsest particles fall as soon as the pulp reaches the settling tank, the deposit is not regular. The water may be pumped, syphoned, or more generally run off; in the latter case there is usually a built-up wooden pipe at the far end. There may be a false bottom with a filter to allow the water to drain off. The tanks are of various sizes and may be emptied by hand or mechanical means, e.g. with an archimedian screw; in the former case, if the tanks are very large, rails are laid and trucks run in. In forming triangular slime basins a large rhomb-shaped excavation is dug out and divided into two triangles by a diagonal division or weir, a little lower than the top of the excavation; the pulp passes over a distributor at one corner of the first triangle, and spreads out fan-shaped, allowing the particles in suspension to gradually settle out. The water and finer slimes from the first triangle pass over the weir into a launder which convey them to the corner of a second triangle where the former process is repeated. Tailings may be settled from water so as to form a heap, the sides being built up with brushwood and tailings as the hollow gets silted up; when the heap rises too high for the pulp to flow on to it by gravity, the pulp has to be elevated by some form of pump.

2. Trough Classifiers: (*a*) *Labyrinths.*—These are launders which increase in width and decrease in depth with their length, and which wind about, constantly changing the direction of the current. The first lengths may be 9 inches in width, the following 12 inches, 15 inches, 18 inches, etc.

(*b*) *Shallow Pocket Trough Classifiers* are used for the coarser sands, e.g. those treated on fine jigs. They consist of troughs, in the bottom of which are occasional pockets where the horizontal current is momentarily retarded, giving the sand a chance to settle. A stream of fresh water is generally caused to rise from the bottom of each pocket.

3. Pointed Boxes.—Each box is a large wooden or sheet-iron inverted pyramid. A baffle board is placed across the end where the pulp enters, so as to prevent surface currents.

The pulp is strained through a 20 mesh sieve before passing into the pointed box so as to strain off chips of wood, etc. The launder conveying pulp to the box should have 5 square inches cross-section for each cubic foot of pulp per minute, and its inclination should be for every 6 feet in length 1 to 1½ inches for coarse sand, ½–¾ in. for middle sand, ¼–½ in. for fine sand, and ⅛–¼ in. for slime. The inclination of the longer sides of the box is 50°. At the bottom of the box is a hole to which a T tube is attached; one opening is plugged when not required for cleaning-out purposes, the other has a tube connected with it which rises within 2–3 feet of the top of the box. It is through this latter tube that the pulp is forced by hydrostatic pressure. A rising column of fresh water enters the box near the bottom. In a series of boxes, that one made to catch the coarsest sand must have $\frac{1}{10}$ of a foot of material flowing through it per minute; each of the succeeding boxes is given twice the width of the preceding. A pointed box lasts six to eight years. Such a box without the upward current of fresh water may be used to thicken the pulp without any attempt at classification.

4. TUBULAR HYDRAULIC CLASSIFIER.—*The Spitz-lutten* consists of a box with a V-shaped cross-section the sides of which slope at an angle of 60°. Inside is a wedge-shaped displacer which can be moved up and down in order to vary the space between it and the box. The length of the tube between the box and the displacer along which the pulp flows, from the highest to lowest part, should be about 914 mm. for coarse material, the width may be 620 mm., and the thickness will depend on the size grain it is desired to lift. The pulp flows down one side and up the other, the coarser particles settle at the lowest point where it comes in contact with a sorting column of fresh water. Classifiers of this type are now made of sheet metal of a conical shape, this offering less disturbance from eddies.

5. PNEUMATIC CLASSIFIERS.—These depend on currents of air. Either the material is blown through chambers of increasing cubic contents, in which the dust settles, or else the material travelling on a belt is subjected to blasts of different velocities.

CONCENTRATING.

Determine the most advantageous degree of concentration for commercial purposes; close concentration is difficult, and generally there is a larger proportional loss in the tailings, but if transportation costs are great it may be cheaper to lessen the bulk of concentrates and leave a higher percentage of values than would otherwise be considered good work in the tailings. Concentration may be carried out by hydraulic, pneumatic, flotation, or magnetic means. The apparatus may be stationary, steady moving, vibrating, percussive, or oscillating. The chief principle used in concentration is the resistance due to friction of a grain sliding down an incline plane to the impulse of water on the surface of the grain; the larger the surface of a grain exposed the greater the hindrance. A 1 in. cube has an area of 6 square inches; if this is broken up into cubes $\frac{1}{10}$ in. in size, they would in the aggregate have an area of 600 square inches. When treating slime, the adhesion between the particles and the water impedes the action resulting from specific gravity. Important factors are the angle of the incline plane, the quantity of water and its rate of flow, also the size and specific gravity of grains.

1. CONCENTRATION BY FLOW OF WATER: (A) *Apparatus on which the concentrates are allowed to collect and are cleaned off immediately.*

(*a*) *The Dish* and *Batea* are used mostly for testing ore and cleaning up small quantities of rich material. The former is a flat-bottomed dish with bevelled sides, made of sheet iron, black for gold, tinned for tinstone; while the batea is a shallow, cone-shaped dish made of wood. The *Vanning Shovel* has a shallow, basin-like blade, and is good for separating several varieties of fine material of different specific gravity.

(*b*) *Round Buddles* are used for fine sand and slime, which should be previously classified. They consist of a fixed basin lined with wood, cement, or asphalt, 10 to 30 feet in diameter; they may have either a convex or concave bottom; the latter works quicker than the former, but occasions more loss, so should only be used for poor material or to get the bulk of the concentrates out of pulp. The inclination of the bottom is 5–10 degrees. A central shaft, from which four adjustable arms radiate, revolves ten to twelve times per minute. The arms have brushes or canvas sweeps attached, to level off any irregularities on the surface of the deposit. When concave bottoms are used, the launder conveying the pulp to the periphery also revolves with the arms. The machine requires $\frac{1}{20}$ to $\frac{1}{2}$ h.p. The length of the diameter of the table does not effect the cleanliness of the ore so much as guards against loss. As the material builds up, plugs are inserted in holes in the tailboard till 9–12 inches of material have collected on the table. The revolving of the arms is then stopped, and the concentrates classified into three lots by drawing concentric rings, and the different qualities of material dug out separately. If the sand builds up too fast at the upper end, it shows that the pulp is too thick, or is fed in insufficient quantity. If it settles too thick below, it shows the pulp is too thin or that it is fed in too great a quantity.

(c) *Sluices* are long, wooden or iron launders with false bottoms or riffles of various design. They may consist of boards with holes about 1½ in. diameter, or blocks of wood with or without similar holes, venetian riffles of cast iron, or strips of wrought iron let into wooden sides made in convenient sections for handling, angle iron or old rails placed either length or crossways, expanded metal riffles, curly riffles, etc.

(d) *Tye*.—This is a wooden box 12–14 feet long, 22 inches deep, and 22 inches broad. The angles at which it is placed are 8, 6, 3½, and 2½ degrees, according to the size of the material to be treated. At the foot of the box is a tailboard with holes in it, which are plugged up as the settled material rises. The settled material is divided into three qualities, the lines between these being determined by panning off samples.

(e) *End Percussion Table*.—This is an oblong table 9–12 feet long, 4–5 feet wide, with low sides and ends. The frame is suspended by four rods or chains. The whole table is pushed forward by a cam, and then falls back against a prell-block, thus causing the heavier particles to collect towards the back of the machine. As the concentrates collect upon the table, the tail-board is raised until the material nearly reaches the top of the sides, when it is classified into three portions and dug out. The richer portion must never be allowed to advance more than one-half to two-thirds the length of the table. A table 5 feet wide will take 0·5–0·7 cubic feet pulp, containing 20–40 lbs. sand. The length of stroke is 4 to ½ inches, the number of blows 12–80 per minute, the inclination per 6 feet when treating sand is 5–8 inches, when treating slime 2–3 inches. Two men can attend to three machines. The surface of the concentrated material on the table should be free from furrows, and the pulp should flow over it in regular waves. The first third of the material on the table must show a distinct difference in colour to the other two-thirds, easily seen by stopping the pulp and allowing fresh water to flow over.

(f) *Blanket Table*.—This is a fixed inclined table of various lengths 20–30 inches wide, given a fall of 1 in 10 to 1 in 6; the angle can be adjusted by wedges between the table and its support; the table is covered with blankets so arranged that the bottom of the upper blanket overlaps the top of the next below it. When the blankets have accumulated sufficient concentrates, they are folded up and washed in tubs close to the tables every two to four hours. The tables are often made double, so that one can be working while the other is being cleaned.

(*g*) *Sweeping Table.*—This is a table 12 feet long and 4 feet wide, given an angle of 10 to 12 degrees for coarse sand, and 5 to 6 degrees for fine sand. The former treats 0·3 to 0·5 cubic feet pulp per minute, the latter 0·08 to 0·12 cubic feet, and requires 0·6 and 0·15 cubic feet wash-water per minute respectively. The pulp is allowed to flow over the table for four minutes, and the wash-water for two minutes, after which the concentrates are swept down slits placed across the table when required to classify different materials, which were covered by flaps during concentration and washing. Capacity 4 to 30 cwt. material per twenty-four hours.

(*h*) *Canvas Table.*—Generally used as a save-all. They consist of a large area of wooden tables placed at an angle of 5 to 7 degrees, each about 20 inches wide and covered with 6 to 20 oz. cotton duck or cloth, which is shifted up periodically to prevent it getting worn at the joints of the planks. There are always one or two extra tables, so that the pulp can be turned on to them while others are being swept or hosed down.

(*i*) *Keeve or Tossing Tub* is used to enrich concentrates saved on buddles, mostly in the case of tin. The tub is 30 inches deep and 48 inches diameter on top, and 42 inches diameter on bottom, made of wooden staves 2 inches thick bound together with three iron hoops 2 inches wide and ¼ in. thick. Passing through the tub is a 3 in. spindle, on the top of which is a yoke carrying eight flat iron stirrers 2 inches wide. During the process of filling the tub, the stirrers rotate forty-eight times per minute; they are then withdrawn and two hammers commence to work against the side of the tub, delivering from 80 to 150 blows per minute. At the end of forty to fifty minutes the water is syphoned off, and the contents of the tub classified into tops, middles, and bottoms.

(*j*) *Cradle or Rocker.* — This is a box 40 inches long by 16 inches wide, being 12 inches high at the back, but tapering down to nothing at the front end. On the top of the back end is a sieve 20 inches long, 16 inches wide, and 4 inches high, perforated with ½ in. holes. The material that passes through this is guided by a canvas apron to the back end of the bottom of the box. On the bottom of the cradle are two riffles about ¾ in. high, one placed across near the middle, the other near the lower end. The whole apparatus is fixed on two transverse rockers, so that it can be worked from side to side by means of a handle. A pin in the centre of each rocker serves as a pivot to prevent the cradle from walking. The cradle is set at an angle. Gravel is shovelled into the hopper on the top, and the cradle rocked with one hand, while the operator pours water into the charge from a dipper with the other hand.

(B) *Apparatus which are continuously cleaned up.*—This class of concentrator being automatic and labour-saving is more generally in use than intermittent concentrators.

(*a*) *Revolving Buddles.*—As in the case of stationary round buddles, these may be either concave or convex; frequently one is placed above the other on the same vertical shaft, so as to save floor-space. The table is made of wood, and is from 10 to 16 feet diameter, the slope being 6–9 degrees. The surface of the table may be in one plane, or may be stepped; the pulp may flow over the surface of the wood, or the wood may be coated with enamel paint or other substance. The table revolves once in 1–5 minutes. Round the centre of the convex table is a fixed launder; 120–150 degrees of this is used to distribute the pulp on the revolving table; the remaining section of 240–210 degrees is used for the wash-water. Tailings flow down one-half of the table, middlings flow over the next third of the buddle area assisted by fresh water, and the headings are cleaned off by fixed brushes or jets of water, just before a revolution of the table is completed. Each product passes into its own division of an outside circular launder. There are 10 lbs. of sand or 5 lbs. solid slime in a cubic foot of pulp. A table requires 15 cubic feet water per minute when treating sand, and 8 cubic feet water when treating slime. When sand is treated, can put through 6–8 tons in twenty-four hours, when treating slime 2·8–3·6 tons. Concave buddles have the pulp fed over $\frac{1}{8}$–$\frac{1}{4}$ of its circumference.

(*b*) *Side Percussion Table.*—The bump is given at right angles to the flow of the water. The surface of the table may be plane or riffled, the latter being grooves or strips of wood. The Rittinger table is 8 feet long and 4 feet wide, suspended by four $\frac{1}{4}$ in. iron rods. The inclination of the table varies from 6 degrees for sand to 3 degrees for the finest slime. The pulp passes on to the table at one corner for a length of 8–12 inches; over the rest of the upper part of the table wash-water flows down. Can treat 0·2 cubic feet sand pulp per minute or 0·1 cubic feet slime; the sand requires 0·20 cubic feet wash-water, and the slime 0·12 cubic feet for every foot in width. The table is pushed to one side by a cam, and forced back by a spring against a bumping post. From 70 to 80 thrusts of $2\frac{1}{2}$ inches per minute is given when treating sand, and 90–100 thrusts of $\frac{3}{4}$–1 in. when treating slime. The bumping action causes the heavier particles to move across the table in jerks, while the wash-water causes them to move down the table at the same time. Dividing fingers can guide the various products into their different boxes. The Luhrig table has a swinging frame the length of which is horizontal, while the width is given a slope depending on the material treated. This frame receives a shaking motion at right angles to the flow of the pulp from 150 to 210 strokes per minute of $\frac{1}{8}$–$1\frac{1}{2}$ in. A travelling belt 19 feet long and 4 feet wide passes over the frame, being supported on corrugated iron to give it a level surface with little friction; it travels at the rate of 18–20 feet per minute. The feed passes on to the belt near one end, and wash-water over the rest of the upper side. The Wilfley table, which is 16 by 7 feet, is arranged somewhat similarly to the Luhrig, only the moving frame is covered with linoleum, it does not have any travelling belt passing over it, and the head and lower end have tapering riffles nailed to its surface to assist in concentrating and guiding the ore. Many shaking tables, instead of being suspended by rods or chains, are mounted on wooden toggle rods. As a rule it is well not to make the main adjustments of such machines too easy, otherwise the men in charge are apt to be constantly altering them for every little abnormal irregularity in feed, water, or power. By directing the feed uphill instead of down, the flow of pulp is momentarily retarded, which gives the heavier particles a better chance of clinging to the surface of the table. The stroke of the Wilfley should not be less than $\frac{5}{8}$ in. or more than 1 in. The speed should be 240 strokes per minute. Most of the ore treated on these machines is between 16 and 30 mesh. The capacity depends on the size of the material, generally about one ton an hour. The Card table has grooves instead of raised riffles, and is good for rough concentration of sands. The Buss table is something like the Luhrig vanner, consisting of an endless canvas belt which revolves round a swinging table inclined sideways, which receives four to six oscillations per second. The frame is mounted on vertical wooden springs which give the table an oscillating motion in an arc approximately cylindrical; this prevents any packing of the material on the belt.

(c) *End Shaking Tables.*—These have a bump or shaking motion in the opposite direction to the flow of the water. The Gilpin County concentrator is a continuous-working bumping-table with cam, spring, and bumping-post. The bump sends the mineral back uphill, but the flow of wash-water carries the lighter material down grade quicker than the jerk can send it up; the heavier material remains on the table till discharged over the top end. The table receives 120–180 shocks per minute, the movement being $1\frac{1}{2}$ to 3 inches. The maximum size grain fed is generally between 40 and 80 mesh. Unlike most concentrators, the pulp for these tables should not be classified, as fine material does not discharge well without coarser grains to drag it over. This table is generally mounted in pairs, each being about 7 feet long by 18 inches wide; the lower $5\frac{1}{2}$ feet is a flat surface with a slope of about $\frac{3}{8}$ in. per foot, while the upper portion has a concave cylindrical surface to a height of about 2 inches above the flat surface.

(*d*) *Vanners.*—By a quick shaking motion the heavier minerals settle down on to a moving belt which then conveys it away to one end, while wash-water carries the lighter material away at the other end. These may have a side shake, e.g. the Frue Vanner, or end shake, e.g. the Triumph or Embrey Vanners. The Frue Vanner consists of an endless rubber belt, either plain or corrugated, with raised sides, which revolves over suitably arranged rollers; it is 4 feet wide and has a total length of $27\frac{1}{2}$ feet. The upper portion of this belt is horizontal for its width, but has a grade of $\frac{1}{4}$ to $\frac{1}{2}$ in. per foot for its length, and travels at the rate of 2 to 7 feet per minute uphill and against the flow of water that carries the tailings over the foot of the machine. The heavier particles cling to the belt and are carried past the wash-water over the head roller into a tank of water, where they fall off. The vanner receives from 180 to 200 lateral thrusts per minute of 1 in. in length. Each machine requires about $\frac{1}{4}$ h.p. and has a capacity of 6–10 tons per twenty-four hours. Use 1–3 gallons wash-water per minute. One man can look after sixteen machines. This class of table can only form two products, headings and tailings.

2. Pulsating Machinery.—*Jigs.* The German method is to size the ore before jigging; the English method is to jig coarse and fine together. The former is the better. When pieces of mineral of the same size but of different specific gravity are allowed to settle through some medium, the heaviest sink fastest; if forced upwards, the lightest pieces will go highest. In jigging, the drop is not long enough for the ore to separate with one blow, so several short perpendicular blows or pulsations are given. The limits of size for jigging are $1\frac{5}{8}$ to $\frac{1}{32}$ in. If coarse, too much power is required; if fine, the action due to its specific gravity is too much hindered by friction, and the material lies too close together. Jigs are divided into coarse and fine, according to the size of particles they deal with. Much material formerly used on fine jigs is now worked on tables as the latter use less water than jigs, and it is easier to see how work is proceeding. The shape of

the particles has a great influence on their treatment; they may be roundish, oblong, or tabular. These fall in water at the following proportional rates, 112, 97, and 79. Jigs may be worked intermittently or continuously; by hand or machinery. The sieve may move up and down in water, or water may be caused to pulsate through a stationary sieve. Hand jigs are of the movable sieve type, the sieve with the charge or ore being worked up and down in box of water by means of a lever. When the heavier and lighter materials have separated into layers, the latter is skimmed off by hand. A jig is the best form of coarse concentrator. It may be used to separate two or more kinds of products, generally "heads," "middlings," and "tailings," the first and last often being final products; hutch product is that which passes through the sieve into the hutch. The ordinary Hartz jig is a box 3 ft. 6 in. deep, the length depending on the number of compartments required; this is divided lengthways by a board 18 inches deep to separate the plungers from the sieves. The sieve compartment is about 2 ft. 4 in. by 1 ft. 6 in.; the first sieve is 8 inches below the top of the box; the difference in height between each succeeding sieve is 2 to 3 inches. Coarse jigs work material down to 4 mm., while fine jigs work that between 4 mm. and 2 mm. The length of stroke must be sufficient to lift the grains the height of their diameter, and the time between each stroke must be sufficient to allow the grains to settle. The stroke for coarse jigs is $\frac{1}{2}$ to 3 inches, and for fine jigs $\frac{3}{4}$ to $\frac{1}{2}$ in. The number of strokes for coarse jigs is about 100 per minute, and for fine jigs 120–150. The stroke may be communicated by an eccentric, or a pulsating mechanism may be arranged so as to give a quick down stroke and a slow up stroke. The total depth of the ore being worked is $3\frac{1}{2}$ to 4 inches, the depth of the coarse concentrate is about 2 inches. Coarse jigs make their own bedding. For fine jigs the bedding should be of about the same specific gravity as the ore; if too heavy it requires too much power to lift it, and causes boiling of the top layer; if too light it lets tailings through to the hutch. A grating divided into coarse cells is placed above the sieve so as to keep the ragging from working down lengthways. For coal jigs use felspar as bedding. Must not have the ragging too large; it is preferable to use coarse pieces of the ore being treated. Ore with a large percentage of concentrates requires a thin bottom bed, for the reverse a thick bed; the thicker the bed the cleaner the hutch work. May use iron punchings or shot as bedding. Fine jigs have 12–14 mesh sieves. Coarse jigs have special outlets for the concentrates, either a slit in the side of the sieve compartment, protected by a slide which regulates the discharge, or else a tube passing through the sieve, protected by a cylinder which does not quite reach the bottom of the sieve; this serves to keep back the upper layer, while the lower layer of concentrates can pass up from below. The capacity of jigs varies very considerably, but is largely governed by the sieve area, more especially by the width, the limit being from about 0·15 ton per square foot of sieve per twenty-four hours to 9·6 tons, but averaging 0·5 to 2·0 tons. Hard banks form from the suction, and boils are due to vents from the upward current. The horse-power varies according to the number of sieves; it is well to provide 1½ h.p. for one sieve; 2 h.p. for a two sieve; 2½ h.p. for a three sieve; and 3 h.p. for a four sieve jig. Coarse jigs require more water than fine jigs, but average about 34,000 gallons per twenty-four hours for a three sieve jig. The Handcock jig is an example of a mechanically worked jig with movable sieve. The Willoughby is a kind of finishing jig used in New South Wales for cleaning tin from heavy sands, and fetching it up to 75 per cent. metallic tin. It consists of a pressure box 5 feet high, and the width of the sieve box 2 feet square by 18 inches deep, with which it is connected near the bottom, below the sieve, by a short wooden pipe. The sieve consists of a copper plate with $\frac{1}{32}$ in. perforations. About 4 cwt. of ore is put into this box, making a layer about 6 inches deep. The valve between it and the pressure box is suddenly opened, causing the lighter impurities to ascend to the top where they are scraped off. The operation is repeated about five times, the water being let out of the concentrating box through a valve at the bottom.

3. Pneumatic Concentration.—Air as a medium for concentration is chiefly used (*a*) as a continuous blast which grades the particles subjected to it; (*b*) as intermittent pulsations. In both cases the ore should be dry. The former principle may be used to separate coal dust from slate with which it is mixed; if the mixture is blown up an inclined plane, the floor of which is composed of overlapping boards like a venetian blind, the coal will be kept in suspension by the air current, while the slate in its passage will sooner or later present its edge to the blast, fall down, and escape between the boards. The latter consists of some form of pneumatic jig, or dry blower, used in districts where water is scarce. They are used for concentrating alluvial gold, tin, precious stones, dollied wolfram, horn silver, and other substances that will not stand the expense. Dry blowers on alluvial fields are generally mounted on wheelbarrows so that they can be readily moved from one place to another. They consist of an inclined coarse screen resting on thin legs, into

which the ore is fed so as to separate the large pebbles; this is caused to shake by means of a rod or cam connected to the handle that works the bellows. The fine material that passes through the coarse screen falls into a steeply inclined perforated plate, forming the top of the wind chest of the bellows. Riffles are placed horizontally across this to catch the heavier particles; the blast of air blows the lighter particles away. The capacity of these machines is about four to five loads a day under normal conditions.

4. FLOTATION.—The first attempt at flotation by Everson was to make use of the selective action of oily substances in bulk to float up certain minerals by means of the inferior specific gravity of the oil. This has given way to the use of much smaller quantities of oil with which the powdered mineral is agitated, with or without the addition of acid. The acid may have the effect of cleaning sulphides so that they can be more readily oiled, or it may set free CO_2, which, clinging to the particles, helps to buoy them up. Various patents have been taken out claiming certain actions, dependent on the employment of different mediums and reagents in varying quantities. It is doubtful if any of the flotation processes work to advantage on their original claims. The cause of the flotation may be due to (*a*) the buoyancy of a large quantity of thick oily substances, (*b*) bubbles of air or gas caused by agitation or chemical means which carry up certain particles, (*c*) emulsification entangling certain particles. Most of the flotation processes are not suitable for slimes, but the float of the Mineral Separation process matts together better with a certain percentage of slime, and will even work on slime alone. For this process, the ore is reduced to pass through a 40 mesh screen, it is then agitated with 24 in. diameter propeller-like stirrers, which revolve 250–300 times per minute, with three to five times its weight of water, to which is added, for Broken Hill zinc-lead ore, about 15–20 lbs. sulphuric acid per ton ore, and the liquid is passed on to another agitator where 1 lb. oleic acid per ton of ore is added. From this the mixture passes into a separating wedge-shaped box, where the liquid being comparatively quiet, allows the float to rise to the surface and pass away down a launder. The liquid is sucked through from the bottom into another agitator, and the agitation and separation repeated about five times altogether. For copper ores there is no occasion to use sulphuric acid, and about ½ lb. eucalyptus oil is used per ton of ore instead of oleic acid.

5. MAGNETIC CONCENTRATION. — When substances are attracted by magnets, they are said to be paramagnetic; they

are few in number, and vary considerably in their power of attraction. Those substances which are not attracted by a magnet are said to be diamagnetic. The minerals mostly attracted by magnets are those containing iron, e.g. magnetite, pyrrhotite, wolfram, zinc blende (black jack), etc. If, say, wolfram and bismuth have been concentrated together, and it is desired to separate them by an electro-magnet, the wolfram product will not be clean, as being in a concentrated form it entangles some bismuth mechanically when attracted by the magnet. The practical use of magnetic concentration is at present confined to the concentration of iron ores. Magnetic separators may be classed into those (*a*) where a cylinder revolves round a series of fixed electro-magnets wound in such a manner that opposite poles are adjacent to one another: these are so placed as to attract those minerals affected by magnets when touching a certain portion of the cylinder. As the ore is fed on to the top of the cylinder, the magnetic particles cling to the cylinder, while the non-magnetic particles fall into a receptacle prepared for them; as soon as the magnetic particles pass beyond the field of the magnets, they are flung off by centrifugal force. The capacity of a Monarch Magnetic Separator with two drums, 2 feet diameter and 2 feet face, varies from 15 to 20 tons crude ore per hour which has passed through a 16–20 mesh sieve. For the best work the feed should not be over 1 mm. in size and perfectly dry. The power required is 1–1½ h.p. for the magnets of each drum, and ½–¾ h.p. for revolving the drums. The first drum makes forty revolutions per minute and uses a current of 10½ amp., uses a current of 13 amp. The Wenstrom Magnetic Separator while the second drum makes fifty revolutions per minute and consists of a revolving drum made up of alternate magnetic and non-magnetic bars parallel to the axis; within this cylinder, and placed eccentrically to it, is a fixed electro-magnet. This machine is specially suitable for treating coarse stuff which need not be dry. A 5 ton per hour machine requires 1½ h.p. to furnish the current and ½ h.p. to revolve the drum. (*b*) Magnetic separators with conveying belts. The idea is to have a conveyor belt to bring the ore under the influence of powerful magnets; another belt travels between the magnets and the ore on the conveyor belt, the magnetic ore clings to this as it passes under the magnets, and is thus carried to its proper receptacle. The Wetherill Magnetic Separator is one of this type; it has a very strong magnetic field and can be used for weakly magnetic material. (*c*) A single electro-magnet is sometimes suspended above the belt conveying ore to a breaker, in order to extract nails, hammer-heads, and other pieces of foreign iron and steel that may have accidentally fallen among the ore.

SUNDRY APPLIANCES.

A. TIPPLERS: (*a*) *End Tipplers*, or kick ups, used when the empty truck is withdrawn the same way as the full truck is introduced.

(*b*) *Side Tipplers*, may be used for box trucks; the empty truck is pushed out at the far end by the incoming full truck; the side tippler is balanced so that it revolves automatically, the motion being regulated by a brake. Tipplers may be fixed over the place where the ore is tipped, or may be made to travel on rails. If the material to be tipped is soft and must not be broken up, e.g. coal, it may be discharged against a hinged iron sheet down which it slides. Sometimes a three-truck side tippler is used which revolves slowly the whole time so that trucks can be run in, out, and emptied at the same time.

B. ELEVATORS AND CONVEYORS: (*a*) *Cage or Platform Elevators*.—Worked by compressed air, steam, water, electricity, or friction. Mostly used for raising ore in trucks.

(*b*) *Inclined Plane*.—Trucks of ore are often drawn up an inclined plane to the necessary height by a rope, a movable trigger being placed between the rails to open the gate of the truck where desired to discharge it.

(*c*) *Creeper Chain*.—This is a strong long-link endless chain, in which at regular intervals a link has a vertical projection or horn sufficiently long to engage the axle of a truck. Trucks are pushed to the foot of an incline where the creeper chain takes them in charge and delivers them to a flat or oppositely inclined place higher up.

(*d*) *Raff Wheel*.—Somewhat like a water-wheel with the buckets inside instead of out. Its diameter depends on the height it is required to raise the material, which is tipped out at $\frac{8}{10}$ths, the inner diameter of the wheel. The breadth is seldom more than 1 foot; the angle of the buckets is 40–50 degrees for dry material, and 30 degrees for pulp. The speed at the periphery is 1 to 4 feet per minute.

(*e*) *Bucket Elevators*.—These consist of buckets attached to chains or belts which revolve, taking the buckets with them, the latter being filled in the boot or pit and emptying themselves at a higher level, depending on the length of chains or belt. Should provide drain holes in the boot. If the elevator is housed-in to prevent splashing or dust, have panels that can be removed so that one can get to any part of the elevator.

(*f*) *Endless Belt Conveyor.*—A rubber three-ply belt resting on bottom and side friction rollers which give it the shape of a trough. May be used to convey ore or products of dressing from one part of a shed to another, or to stack tailings, when the belt may be placed, if required, at an angle of 22 degrees from the horizontal; when required to discharge material from different parts of a belt, may employ a travelling unloader. Speed 300 to 900 feet per minute. While conveying ore on a belt the opportunity is often taken to hand-pick the ore; or if conveying a wet product, the belt may be used for draining purposes.

(*g*) *Flight Conveyor.*—This is an endless belt made up of a series of iron plates, the ends of which are turned up and form the sides of the conveyor.

(*h*) *Scraper Conveyors.*—Scrapers attached to an endless belt pass along a trough into which the material is tipped and dragged along.

(*i*) *Push Conveyor.*—Generally used for hot material. It consists of a rod to which rectangular pieces of plate iron are attached which remain vertical when moving forward, but can work on a hinge when moving backwards.

(*j*) *Screw Conveyor.*—This is a large screw cased round, which screws up fine material from settling-pits. The angle of its axis is 30 degrees; the width of the thread 6 inches, the peripheral speed 3 feet.

(*k*) *Hydraulic Elevator.*—This is a large iron pipe on a stand placed in a pit where the material to be elevated collects; a jet connected with a smaller pipe containing water under sufficient pressure is placed in the bottom of the larger pipe; the force of water issuing from the jet draws up the material in the pit and delivers it higher up.

(*l*) *Sand Pump.*—This is similar to a Cornish plunger pump, only provision is made to force in a small quantity of clean water so as to prevent the sand from entering the gland.

(*m*) *Centrifugal Pumps.*—These in one form or another are sometimes used to elevate tailings; they wear out very rapidly and require frequent renewals.

(*n*) *Chinamen.*—These are covered in wooden chutes built at various angles, used to guide ore in its descent.

(*o*) *Sluices.*—Wooden or iron launders in which material is conveyed by water. The former may be lined with cement to make them last longer. Launders are best made of rectangular cross-section, twice as wide as deep.

C. AGITATORS.—The object of agitation is generally to keep fine particles in suspension; this is generally done by stirrers arranged vertically or horizontally that are made to rotate in a vessel; or air, steam, or water under pressure is caused to pass into the pulp from below, thus keeping it in motion.

D. FEEDERS.—Apparatus for automatically supplying material to various machines for treatment. When properly set they ensure a regular feed and reduce labour.

(*a*) *Shaking Feeder.*—This has a reciprocating motion similar to shovelling by hand, e.g. Stanford's; suitable for fairly coarse stone.

(*b*) *Roller Feeder.*—A cylinder arranged at the bottom of a hopper revolves slowly, drawing out the stone above it, e.g. Tullock's.

(*c*) *Disc Feeder.*—A rotating disc arranged below the hopper containing the ore placed at an angle, e.g. Hendy's challenge ore feeder.

(*d*) *Water Feeder.* — Used for fine material. Water cuts a channel through sand contained in a box, fresh sand falls into the space to replace that washed out.

E. DISTRIBUTORS.—Used for dividing pulp into proper proportions for different machines, or for spreading it evenly at the head of a machine.

(*a*) *Nicking Board.*—A fan-shaped shallow trough over the surface of which diamond-shaped buttons are fastened in regular order by a screw through the centre; these buttons may be turned in different directions so as to make the flow at the lower and broader side even. Sometimes the diamonds are replaced by longer strips or fingers.

(*b*) *Pipe Distributor.*—When required to distribute pulp to various machines from one centre or to spread it evenly over a circular vat, may feed it into an annular trough from which pipes radiate. Butter's distributor used for filling vats has pipes of different lengths arranged so as to balance each other; the outflow ends are bent in such a manner that as the pulp escapes the distributor is caused to revolve.

F. FILTERS, either pressure or vacuum, may be used to clarify solutions or for leaching purposes.

(*a*) The ordinary filter press of the Dehne's type consists of a series of frames into which the pulp is forced from montejus by compressed air. The filling takes about eighteen minutes, the washing twenty minutes, while discharging, cleaning, and closing require thirty-seven minutes. The thickness of cake formed depends on the build of the press, from 1½ to 3 inches. The pressure used in filling is 60 lbs. per square inch, and in washing 80 lbs. The pulp consists of one part by weight of water to one part of solid. On account of the time and labour required to discharge these presses they have largely given place to Merrill's or some form of vacuum filter.

(*b*) Merrill's filter press is also of the flush-plate and distance-frame pattern, but is larger than the ordinary type, containing ninety-two frames. The pulp is charged under pressure of about 30 lbs., and consists of three parts of water to one of solid. The cyanide treatment is carried out in the press itself. The cake formed in the frame is 2 to 4 inches thick. When leached and washed, it is sluiced out without opening the press. In addition to the ordinary channels for introducing pulp and solutions, at the bottom of the frame is a continuous chamber, within which lies a sluicing pipe with a nozzle projecting into each compartment. This nozzle can be revolved through an arc of any magnitude so as to wash the cake down to the channel. It takes four tons of water to sluice one ton of slime. Requires one-tenth horse-power per ton of slime treated.

(*c*) Moore's vacuum filter consists of vertical frames forming a "basket" suspended in a tank containing the pulp, which has been previously agitated with cyanide solution. Each frame is connected with the vacuum pump which sucks through the solution, at the same time building up a cake of slime about 0·75 to 1·75 inches thick. The basket is then hoisted up by an overhead crane, and lowered into a wash tank, where the cakes are washed by the vacuum pump sucking through water; the basket is again raised and traversed to the tip, where compressed air is forced into each frame, which causes the cake to fall off. The whole operation occupies seventy-five minutes. Butter's filter remains stationary in the same tank all the time, the contents of the tank being changed for each stage in the process. The pulp has a specific gravity of 1·3 to 1·4, and the thickness of the cake is the same as in Moore's. The amount of wash-water left in the cake varies from 20 to 30 per cent.

(*d*) The Ridgway continuous type of vacuum filter consists of a series of cast-iron filtering frames, the form of a sector of a circle 12 feet in diameter. The under surface is corrugated and has a screen attached; to this a filter-cloth is fixed. The frame is suspended horizontally and makes one revolution a minute. The underside of the filter frame dips into an annular trough divided into three compartments, one for the pulp, the next for wash-water, and the last is the discharge chamber. Each sector has three pipes provided with valves which work automatically; one carries away the solution, the second wash-water, while the third has compressed air blown through it to discharge the cake of slime, which is 0·125 to 0·375 in. thick. The cake takes thirteen seconds to build up, thirty seconds to wash, and seventeen seconds passing between the divisions and being discharged. The machine requires 5 h.p. Each frame has 4 square feet filtering area, and each machine treats 50 tons per twenty-four hours of clean quartz slime with 20 in. vacuum.

MECHANICAL DRAWING.

HINTS.—When choosing *instruments* look well to workmanship. With bad instruments no good work can be done.

Bowpens should be broad, thick, and strong, and not much bowed—the points should be rounded off.

Needle-pointed instruments are much to be preferred.

Never draw more pencil lines than necessary.

Accuracy is all important, small errors are multiplied in long construction.

Always ink-in circles and curves before straight lines.

When many concentric circles are required, use a horn centre, to avoid making a big hole in the paper and consequent false lines.

Never leave a pen with ink between the nibs to dry.

Use bread in preference to indiarubber, especially when cleaning the whole surface of a drawing.

Shade lines are drawn *outside* the outline of the object, and *dimensions* are measured from *inside* the shade line.

When shading or shade lines are employed, the light is supposed to come over the left shoulder.

Shade lines should never be drawn to indicate the outline or contour of a curved surface.

COLOURS.—*Illuminated* plane surfaces *parallel* to the plane of projection receive flat tints. The nearer the surface is to the eye the lighter such tints should be.

Illuminated plane surfaces *inclined* to the plane of projection receive graduated tints, becoming *darker* as such surfaces recede from the eye.

Unilluminated plane surfaces *parallel* to the plane of projection receive flat tints. The nearer the surface is to the eye the darker such tints should be.

Unilluminated plane surfaces *inclined* to the plane of projection receive graduated tints becoming *lighter* as the surface recedes from the eye.

Shading in colour is done in strips, softening the edges each time, *beginning* always with the *darkest* portions of the object, and washing over and beyond the previously coloured portion each time.

The following colours are in general use to represent the more common materials :—

1. *Cast Iron.*—Payne's Grey or mixture of indigo, sepia, and lake.

2. *Wrought Iron.*—Prussian blue.

3. *Steel.*—Prussian blue and crimson lake.
4. *Brass.*—{ Elevation . . Gamboge. / Section . . Dark Indian yellow.
5. *Copper.*—Gamboge and crimson lake.
6. *Ordinary building.*—Sepia and yellow ochre.
7. *Brick (common).*—{ Elevation . . Light red. / Section . . Crimson lake.
8. *Brick (fire).*—{ Elevation . Light red and yellow ochre. / Section . . Ditto with crimson lake.
9. *Wood.*—{ Elevation . . Yellow ochre. / Section . . Burnt sienna.
10. *Earth.*—Burnt umber.

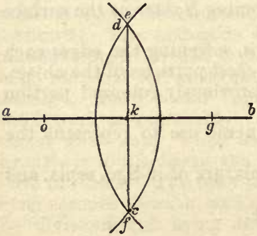
Lines.—{ Red . . Carmine. / Blue . French ultramarine.

Cast shadows are seldom used, but if desired they should be washed in neutral tint or Indian ink before colouring.

In *Mine plans* the spaces left by the removed ore masses are coloured purple for tin ; green for copper ; blue for lead. The adit level is coloured blue and the levels below it red, green, yellow, violet, and brown in succession.

SURVEY SCALES.—The scales usually employed for the plans of metalliferous mines are 4 or 8 fathoms to the inch, sometimes 5 or 10 fathoms. For colliery plans scales of 2 or 3 chains to the inch, or of 25·34 inches to the mile, are the most usual. In the construction of maps of the Ordnance Survey of Great Britain, the following scales are used :—

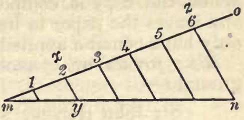
Towns	1 : 500	or 126·72 inches to the mile.
Parishes	1 : 2500	25·34 " "
Counties	1 : 10560	6 " "
The Kingdom	1 : 63360	1 " "



To divide a given line a b into two equal parts.—From its ends *a* and *b* as centres, and with any radius greater than half *a b*, describe the arcs *c* and *d*, cutting each other at *e* and *f*; join *e* and *f*; *a b* is bisected at *k*.

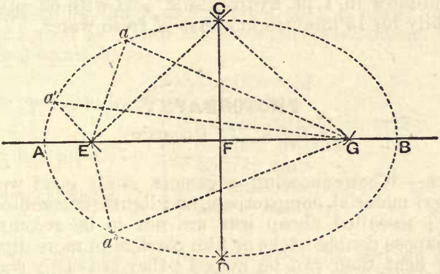
If *a b* is very long first lay off equal distances *a o*, *b g* from *a* and *b*, and then proceed as if *o g* were the line to be divided.

To divide a given line into any number of equal parts.—Let *m n* be the given line, from *m* draw *m o* of indefinite length, and from *m* along *m o* step off the required number of equal parts, say 6, join *n* 6 and draw lines parallel to *n* 6 through 5, 4, 3, 2, 1, and cutting *m n*, when *m n* will be divided into six equal parts.



To divide a given line into two parts which shall have a given proportion to one another.—This is done on the same principle as the last: thus let the proportion be as 1 to 2. First draw any line *m o* (last fig.) and with any convenient opening of the dividers make *m x* equal to one step; and *x z* equal to two steps. Join *z n* and draw *x y* parallel to *z n*. Then *m y* is to *y n* as 1 is to 2.

To draw an ellipse.—An ellipse may be quickly and fairly accurately drawn thus:—Given the major and minor axes A B, C D. With C and D as centres and radius equal to A F (semimajor axis) drawing arcs cutting A B in E and G. Stick in two ordinary pins, through the paper and into the drawing



board, at E and G and tie to them a piece of silk or thread of such a length that it equals E C + C G. If the point of a pencil be carried round in this loop so the thread will take up such positions as E *a* G, E *a′* G, E *a″* G. &c., and the pencil point will trace an ellipse having the major and minor axes A B and C D.

Copying drawings.—To trace on to ordinary drawing paper, stretch the paper over the drawing and saturate it with benzine by means of a cotton pad; this makes it transparent so that the drawing below may be traced. Pencil, Indian ink, and water colours, take equally well on the benzinized surface.

When the copy is completed the benzine rapidly evaporates and leaves the paper in its original condition. Large drawings only have benzine applied to a portion at a time.

Blue prints or cyanotypes: giving white lines on blue ground :—

Sir John Herschel's.	Marion's.
140 grs. ferric ammonic citrate.	$9\frac{3}{8}$ oz. ferric ammonic citrate.
120 grs. potassic ferri-cyanide.	$6\frac{1}{4}$ oz. potassic ferric oxide.
2 oz. distilled water.	Dissolve separately in pure water, and make up to 1 quart.

Willis's platinotype process, giving white lines on black ground :—

Sensitising solution. 60 grs. potassic-platinous chloride.
60 grs. ferric oxalate.
1 oz. water.

Expose until the paper acquires a dull orange tint.

Developing solution. 130 grs. potassic oxalate.
1 oz. water.

Develop for 4 seconds at temp. of 150°—200° F., then wash for 10 minutes in 1 pt. hydrochloric acid with 60 pts. water, and finally for 15 minutes in relays of fresh water.

PHOTOGRAPHY.

By S. J. Becher.

Hints.—When choosing a camera study good workmanship, good material, compactness, and lightness combined with rigidity; so-called cheap sets are not to be recommended. Never expose double backs or film carriers to more direct sunlight or heat than can be helped; they are easily warped or cracked, and the plates or films within them consequently fogged.

For landscape and general outdoor-work, a single meniscus lens gives brilliant pictures. For architectural or structural work, a doublet or triplet is necessary, to avoid distortion of marginal lines.

For a complete outfit for outdoor-work it is well to have :—

(1.) An ordinary wide angle single landscape lens.
(2.) A narrow angle single landscape lens (for distant views).
(3.) A rapid rectilinear doublet lens.

If only one can be provided, No. (3) should be given the preference.

Always clean a lens carefully with *silk*, and not coarse material, before making an exposure. Avoid dust inside camera. The smaller the stop used the longer the exposure may be, and the better the marginal definition will be. For interiors use very small stop, and give very long exposure.

Do not use a lens which will more than cover the plate, lest rays be reflected from the sides of the bellows on to the plate.

It is better to over expose than under expose. Over exposure can be compensated by slow and careful development; an under exposed plate can never produce good prints. A good rule for exposure, "Expose for the shadows, and the lights will take care of themselves."

Never have harsh contrasts of bright light and deep shade.

Having found a brand of plates or films that give satisfaction, always work with them, so that knowing their capabilities and peculiarities, you can by comparison with notes of former exposures, light, stop, &c., be more certain of your results. Always note details of exposure, plate, stop, light, time, subject, and when complete, results. These references are invaluable. It is generally advisable to use the Developer recommended by the manufacturers of the brand of plate used, but a good all round set for Pyro development are the following 3 solutions :—

A. "Pyro solution."	Pyrogallic acid	1 oz.
	Citric acid	$\frac{1}{4}$ oz.
	Water (distilled), to make	9 oz.
B. "Restrainer."	Potassium Bromide	1 oz.
	Water, to make	9 oz.
C. "Accelerator."	Liq. Ammonia (0·80)	1 oz.
	Water to make	10 oz.

These are practically 10 per cent. solutions, and are used in the usual way. A correctly exposed plate will require about 20 minims of each solution to each ounce respectively of water. B. & C. being added according to requirement.

Alum Bath	Alum	1 oz.
	Water	$\frac{1}{2}$ pint.
Fixing Bath	Hyposulphite of soda	5 oz.
	Water	1 pint.
Clearing Bath	Alum	1 oz.
	Citric Acid	1 oz.
	Sulphate of Iron	3 oz.
	Water	20 oz

Always wash well between each operation, and after fixing wash for 12 hours.

"*Frilling*" is when the gelatine leaves the glass plate during development or subsequent operations, and occurs more especially in hot climates. It is sometimes due to bad manufacture. The best preventive is the unfailing use of the alum bath both before and after fixing.

"*Fogging*."—Chiefly caused by unintentional admission of light to the plate, either through cracks or holes in the double-backs, film-holders, camera, or dark room. Also by sudden addition of excess of ammonia during development.

"*Flatness of Image*," usually due to over exposure and development with alkaline developer.

Yellow stain or veil may be removed by the clearing bath.

Too great density is also reduced by clearing bath.

Want of density may be caused by excessive over exposure, or poorness of quality of the plate.

Thin transparent negatives are due to excessive under exposure.

"*Pinholes*," are due to dust on the surface of the plate. Always dust the plate with a soft flat brush before changing, and again before development.

Brown stains on the fingers after pyro-development may be removed with dilute Hydrochloric Acid.

Dishes used for negatives should never be used for prints, and special dishes should be used for each operation and for no other purpose. Cleanliness is all important.

Printing.—The fresher the paper the better. Preserve it from all access of light and damp. Do not finger it more than is necessary. If possible, trim prints before washing and toning, as they lie flatter, and much toning bath and space therein is saved.

When using ready sensitized paper (silver) always print considerably darker than the resulting shade desired. A good negative will require to be printed from till the whites just commence to color and the shadows to bronze.

The sooner toned, &c., the better, but a few days' keeping will not ruin the prints. Variety of shade from brown to purple is regulated in the toning bath. Tone slightly darker than the resulting tone desired, as both colour and shade are reduced in the fixing bath. Wash well between all operations.

Take great care that the fixing bath is not acid, the addition of a few drops of ammonia is a good preventive.

Wash for 12 hours at least after fixing.

Formulæ for good Toning Baths.

No. (1.)	Sodium Acetate	30 grs.
	Gold trichloride	1 gr.
	Water	10 oz.
No. (2.)	Borax	100 grs.
	Gold trichloride	1 gr.
	Water	20 oz.

No. (1) must be mixed the day before it is used, but will keep indefinitely, and may be used repeatedly, more stock gold solution and soda being added occasionally.

No. (2) must be used the same day it is made, and will not keep.

Fixing Bath.

Sodium Hyposulphite	4 oz.
Water	1 pint.

This can be used several times, as long as it is not acid.

A test for presence of hypo in last washing water in order to ascertain whether extraction is complete.

Potassium permanganate	2 grs.
Potassium carbonate	20 grs.
Water	1 quart.

Add a few drops of this rose-coloured solution to sample of water. If any trace of hypo is present, the colour will be of a greenish hue.

Dishes for toning and fixing should be labelled and used for no other purpose. Porcelain dishes are the best.

A good mounting solution.

Gelatine	2 oz.
Glycerine	½ oz.
Methylated spirits	2½ oz.
Water	8 oz.

When this mountant is used the prints need not be damped as when using starch, paste, &c. Thus the mounts, or leaves of books, are not cockled up or bent.

A simple method of burnishing unmounted silver prints is to lay them when wet, after the final washing, face downwards on a sheet of highly polished vulcanite; smooth out any bubbles and the surplus water. As they dry they peel off of their own accord, and retain the burnished surface which the albumen in contact with the vulcanite has taken. This shows up detail in the shadows. With other papers such as platinotype, bromide, &c., follow the instructions given by the makers. Matt surface papers are more artistic than shiny ones.

Platinotype, &c., have the immense advantage of being permanent, and are especially valuable in hot, damp, climates.

When rolling silver prints for storage put them face outwards.

If prints look chalky and cold, they may be dyed in a very weak solution of a pink or rose dye with advantage.

Measliness or yellow dirty prints are due to bad paper, acidity of fixing bath, or want of cleanliness in manipulation.

If prints soon fade and turn yellow, it shows that the extraction of hypo has not been complete, *i.e.*, insufficient washing.

TOXICOLOGY.

Poison.	Antidote and Remedies.
Acid, acetic	Chalk, whiting, magnesia, soap or oil. Alkaline bicarbonates, white of egg, or almost any demulcent.
Acid, hydrocyanic or prussic acid ; bitter almonds (oil of laurel water).	Drink at once one teaspoonful of ammonic hydrate (spirits of hartshorn) in one pint of water. Inhale odour of ammonia. Chlorine either taken in vapour or internally. Cold infusions, artificial respiration, stimulating injections. Sulphate of iron.
Acid hydrochloric (muriatic or marine acid).	Neutralise the acid by chalk or calcined magnesia, or a dilute solution of an alkaline carbonate, milk, white of egg, strong soapsuds and lime. Large draughts of tepid water or mucilage should follow antidote.
Acid, sulphuric (oil of vitriol).	Same as hydrochloric acid.
Acid, oxalic.	Powdered chalk ; magnesia, or its carbonate, suspended in water or milk. An emetic, if free vomiting is not induced by the above means.
Acid, phosphoric.	Magnesia, emetics, and emollient drink.
Acid, nitric, or aquafortis.	Same as hydrochloric acid.

Poison.	Antidote and Remedies.
Alcohol.	The stomach pump. Cold affusions, ammonic hydrate (spirits of hartshorn).
Chloroform and ether.	Cold affusions on the head and neck, ammonia to the nostrils, artificial respiration, electricity, opening the trachea.
Ammonic hydrate (Ammonia or spirits of hartshorn), potash or soda.	Weak acids as vinegar and water, followed by acidulated demulcent drinks: lemon juice, olive oil in large quantities, large draughts of cream or milk. Use no emetic. In poisoning by the vapour of ammonia the inhalation of the vapour of acetic acid or of dilute HCl.
Iodine and iodide of potassium (potassic iodide).	Take a mustard emetic. Drink a mixture of starch, gruel, or arrowroot beaten up in water.
Toadstools (non-edible mushrooms).	Prof. Maurice Schiff of Florence has demonstrated, that the non-edible mushrooms contain a common poison, muscarin, and that its effects are counteracted by atropin or daturine.
Arsenic, cobalt (fly powder), king's yellow, ratsbane, Scheele's green.	An emetic, stomach-pump, zincic sulphate, cupric sulphate; or mustard may be used as an emetic, or salt and water; or vomiting may be produced by tickling the throat with a feather. The vomiting should be assisted by demulcent drinks. After free vomiting give large quantities of calcined magnesia. The antidote for arsenic is hydrated sesquioxide of iron freshly precipitated. If the poison has passed into the bowels, castor oil.
Antimony (wine of), tartar emetic.	Vomiting should be produced by tepid water; any astringent infusion, such as tea, oak, bark, tannin (ground nutgall); afterward opiates (paregoric), warm bath and mustard poultices.

Poison.	Antidote and Remedies.
Baryta salts, copper, verdigris, blue vitriol.	Stomach-pump, or emetics, magnesia sulphate of soda. Demulcent fluids to induce vomiting, stomach-pump, albumen in large excesses, milk, cooking soda, iron filings, manna, preparations of sulphur.
Iron.	Sodic carbonate ; mucilaginous drinks.
Lead, acetate of lead (sugar of lead), white lead, litharge.	Emetic—mustard. Follow with zincic sulphate (Epsom or Glauber salts). Antidote is weak sulphuric acid. Take large draughts of milk, containing white of eggs.
Iodine.	Starch or wheat flour beaten up in water, taken in large quantities. Take a mustard emetic ; tepid baths.
Mercury, corrosive sublimate (bug-powder), white precipitate, red precipitate (vermilion).	Beat the white of six eggs (albumen) in one quart of cold water ; give a cupful every two minutes. Induce vomiting. A substitute for eggs is soapsuds slightly thickened with wheat flour. The white of one egg neutralises four grains of the poison. Emetics should not be given.
Nitrate of potash (saltpetre), nitrate of soda (Chili saltpetre).	Take at once a mustard emetic ; drink copious draughts of warm water, followed with oil or cream.
Pearl-ash ley (from woodashes), salts of tartar.	Drink freely of vinegar and water ; followed with a mucilage, as flax-seed tea.
Phosphorus matches, rat exterminator.	Give two tablespoonfuls of calcined magnesia, followed by mucilaginous drinks.
Carbonic acid gas (charcoal fumes), chlorine gas, nitrous oxide gas, or ordinary gas, burning fluid.	Fresh air, and artificial respiration ; may inhale ammonia, ether, or the vapour of warm water.

Poison.	Antidote and Remedies.
Aconite or aconitin (Monkshood).	Thorough evacuation of the stomach, either by an emetic (mustard) or the stomach-pump ; ammonia and brandy, and the use of stimulating injections ; free use of finely powdered animal charcoal ; vegetable infusion containing tartaric acid, tincture of nux vomica, iodine and potassic iodide. Keep patient active. Emetics—mustard, zinc sulphate, or ipecacuanha wine, vegetable acids, (vinegar, acid fruits).
Atropin, belladonna (deadly nightshade).	An emetic and use of stomach pump, as with aconite. Morphine administered by the mouth or subcutaneous injection. Drink black coffee.
Daturine.	Same as above.
Hellebore (Hellebore niger).	Emesis and subsequent stimulation. Opium has been used.
Nicotin.	Same as above.
Opium.	Any portion of the unabsorbed poison should be removed quickly from the stomach. Use the stomach pump or an emetic of gr. xx or gr. xxx zincic sulphate, or about gr. x cupric sulphate, or powdered mustard or salt. Keep patient in motion. Apply cold water to head and chest. Belladonna is recommended as an antidote.
Strychnine, nux vomica.	An emetic, or use of the stomach pump ; internal use of chloroform by inhalation, tannic acid, 25 parts of tannin to 1 of strychnine ; solution of potassic iodide, iodine, chlorine, camphor, animal charcoal, lard or fat, nicotin.

As a rule for vegetable poisons give an emetic of mustard, drink freely of warm water, irritate the throat to induce vomiting. Keep the patient awake until a physician arrives.

Receipts for Solders.

Metal.	Tin.	Copper.	Zinc.	Antimony.	Lead.	Silver.	Gold.	Brass.
For lead . . .	1	...	...	...	1½	...	...	...
,, tin . . .	1	...	...	...	2	...	...	...
,, pewter . .	2	...	...	...	1	...	...	...
,, brazing (hardest)	...	3	1	...	...	...	...	...
,, ,, (hard) .	...	1	1	...	...	...	...	...
,, ,, (soft) .	1	4	3	...	...	...	...	...
,, ,, ,, *or*	2	...	...	1	...	...	...	...
,, iron . . .	...	2	1	...	...	...	...	...
,, steel . . .	...	3	1	...	...	19	...	...
,, silver (hard) .	...	1	...	...	...	4	...	...
,, ,, (soft) . .	...	...	...	...	...	2	...	1
,, gold . . .	...	1	...	...	...	2	24	...

Fluxes for Soldering or Welding.

Metal.	Flux.
Iron or steel . .	Borax and sal-ammoniac.
Tinned iron . .	Resin or chloride of zinc.
Copper and brass .	Sal-ammoniac or chloride of zinc.
Zinc . . .	Chloride of zinc.
Lead . . .	Tallow or resin.
Lead and tin pipes	Resin and sweet oil.

GLOSSARY OF TERMS

USED IN PROSPECTING, MINING, METALLURGY, ETC.

ABBREVIATIONS.—(Chem.) = Chemistry. (Mec.) = Mechanics. (Met.) = Metallurgy. (Eng.) = Engineering. (Min.) = Mining. (Geo.) = Geology. (As.) = Assaying. (Phy.) = Physics. (Sur.) = Surveying.

Acid (Chem.). A compound containing one or more *atoms* of *hydrogen*, which become displaced by a *metal* when the latter is presented in the form of a *hydrate*.

Adit (Adit level). (Min.) An underground *level* which comes to the surface, generally used for drainage purposes.

Afterdamp (Min.). The deadly gases resulting from an explosion of *fire-damp*, composed chiefly of *carbonic anhydride*.

Air compartment (Min.). An air-tight portion of any *shaft*, *winze*, *rise*, or *level*, used for improving ventilation.

Air course (Min.). Any underground roadway for the special purpose of ventilation.

Air crossing (Min.). A bridge that conveys one *air course* over another.

Air cushion (Phy.). A spring caused by confined air.

Air door (Min.). A door for the regulation of currents of air through the workings of a mine.

Air hole (Min.). A hole drilled in advance, to improve ventilation by communication with other workings on the surface.

Air oven (As.). A heated chamber for drying samples of *ore*, &c.

Air shaft (Min.). A *shaft* sunk for ventilation purposes, *e.g.*, at the end of a long tunnel.

Air sollar (Min.). An air-tight wooden flooring in a *level* at a sufficient height above the rock bottom to allow the drainage water to flow out, and cool air to pass in.

Air stack (Min.). A *stack* or chimney built over a *shaft* for ventilation.

Alkalies (Chem.). Soluble *hydroxides* which turn red litmus paper blue, and neutralize acids, *e.g.*, potash, soda.

Alloy (Met.). A homogeneous mixture of two or more *metals* by fusion.

Alluvial (Geo.). Clay, sand, and gravel deposited by water.

Alluvial gold (Min.). Gold found associated with water-worn material.

Amalgam (Met.). An *alloy* of *quicksilver* with some other metal. *Amalgam* is said to be *wet*, *dry*, *crisp*, &c.

Amalgamator (Met.). One who *amalgamates* gold and silver *ores.*

Amygdaloidal (Geo.). Almond-shaped.

Analysis (Chem.). *Qualitative*—separates matter into its various elements.
Quantitative—states their relative proportions.

Anemometer (Phy.). An instrument for measuring the velocity of ventilating currents in mines.

Angle beam (Min.). A two-limbed beam used for turning angles in shafts, &c.

Anhydride (Chem.). The residue obtained by the extraction (in combination with *oxygen* as water) of all the displaceable *hydrogen* from one or more *molecules* of an *oxygen acid.*

Anhydrous (Chem.). Without water in its composition.

Anneal (Met.). To toughen certain metals, glass, &c., by heating and then allowing to cool slowly.

Anticlinal (Geo.). When rocks are bent over in the form of an arch.

Antimony crude (Met.). The mineral *antimonite* sweated out from its *gangue.*

Antimony star (Met.). The metal antimony when crystallized, showing fernlike markings on the surface.

Apron (Eng.). A covering of timber, stone, or metal, to protect a surface against the action of water flowing over it.

Aqua fortis (Chem.). Another name for *nitric acid.*

Aqua regia (Chem.). A mixture of *hydrochloric acid* and *nitric acid.*

Aqueduct (Eng.). An artificial elevated way for carrying water.

Archean (Geo.). Crystalline schists supposed to be of metamorphic origin.

Arenaceous (Geo.). Sandy.

Argentiferous. Silver bearing.

Argillaceous (Geo.). Clayey.

Argol (As.). *Crude tartar* deposited from wine.

Arrastra (Met.). A circular trough in which *drags* are pulled round by being connected with a central revolving *shaft* by an arm and chain. Used for grinding and *amalgamating* gold *ores.*

Artesian well (Eng.). An artificial channel of escape, made by a bore hole, for a subterranean stream, subject to hydrostatic pressure.

Assay (As.). The determination of the amount of *metal* or other substances in the material treated chemically. The assay may be of a picked *specimen*, or an *average* sample. If treated on a large scale it is called a *bulk assay*.

Assayer (As.). One who performs *assays*.

Attle (Addle) (Min.). The waste of a mine.

Attrition (Geo.). The act of wearing away by friction.

Auriferous. Gold bearing.

Axle (Axle tree) (Mec.). The central bar on which the *axle box* revolves.

Axle box (Mec.). The *thimble* or *shell* that turns upon the *axle*.

Azimuth (Sur.). The *azimuth* of a body is that *arc* of the horizon that is included between the *meridian* circle at the given place, and another great circle passing through the body.

Azoic (Geo.). The age of rocks that were formed before animal life existed.

Backing (Eng.). The rough masonry of a wall faced with finer work; earth deposited behind a *retaining wall*, &c.

Backlash (Min.). Backward suction of air currents, produced after an explosion of *fire damp*.

Backs (Min.). The overlying portion of a *lode* that has not been worked.

Back shift (Min.). Afternoon *shift* of miners.

Back stay (Min.). A wrought iron forked bar attached to the back of trucks when ascending an inclined plane, so as to throw them off the track in case the hauling rope, or *coupling*, gives way.

Baffends (Min.). Long wooden wedges for adjusting *tubbing plates* or *cribs* in sinking *pits* during the operation of fixing the *tubbing*.

Balance box (Min.). A large box placed on one end of a *balance bob*, and filled with old iron, rock, &c., to counterbalance the weight of *pump rods*.

Balance brow (Min.). A self-inclined plane in steep *seams* on which a platform on wheels travels and carries the tubs of coal.

Balance pit. The *pit* in which the *balance* moves.

Balk. A large beam of timber (Min.). (1) Timber for supporting the roof of a mine, or for carrying any heavy load.
(2) A more or less thinning out of a *seam* of coal.

Ballast (Eng.). Broken stone, gravel, sand, &c., used for keeping railroad *sleepers* steady; also used to keep ships down in the water when out of cargo.

Bank (Min.). The top of a *pit;* the surface around the *mouth* of a *shaft.*

Bank-claim (Min.). A claim which includes the bank of a river or creek.

Banket (Min.). Auriferous conglomerate of South Africa.

Bar (Min.). (1) A ridge deposited in a river's bed.
(2) A "*hard bar of ground*" is a harder belt of rock than usually met with in a district.

Baring (Min.). See *Stripping.*

Bar mining (Min.). Working *bars* above river level.

Barrel amalgamation (Met.). *Amalgamating ores* in revolving barrels.

Barrow. A box with two handles at one end, and a wheel at the other.
(Min.) Heap of waste stuff raised from a mine.

Base metal (Met.). One that is not classed with the precious metals, gold, silver, platinum, &c., that are not easily oxydized.

Basin (Geo.). A natural surface hollow.

Basset (Min.). *Outcrop* of a *lode* or *stratum.*

Batch (Min.). An assorted parcel of *ore*, sometimes called *doles*, when divided into equal quantities.

Batea (Min.). A wooden bowl for washing off gold, &c.

Batt (Min.) A highly bituminous *shale* found in the coal measures.

Batten. A piece of thick board of less than 12 inches in width.

Batter (Eng.). The slope backwards of a *face* of masonry.

Battery. A set, *e.g.*, a set of *stamps* for crushing purposes.

Bay of Biscay country (Geo.). See *Crabholes* 2.

Beach-combing (Min.). Working the sands on a beach for gold, tin, or platinum.

Beans (Min.). All coal which will pass through about ½ in. screen.

Bear (Met.). A deposit of iron at the bottom of a furnace.

Bearers (Min.). Pieces of timber 3 ft. or 4 ft. longer than the breadth of a *shaft*, which are fixed into the solid rock at the sides, at certain intervals apart; used as foundations for *sets* of timber.

Bearing (Sur.) The course of a compass.
(Mec.) The points of support of a *beam*, *shaft axle pivot*, &c.

Bearing-up-pulley (Eng.). A *pulley* wheel fixed in a frame, and arranged to tighten or take up the *slack* of an endless belt or rope.

Beataway (Min.). Working hard ground by means of *wedges* and *sledge-hammers.*

Bed (Geo.). A layer of one sort of rock.

Bed claim (Min.). A claim which includes the *bed* of a river or creek.

Bed-plate (Eng.). A large plate of iron laid as a foundation for something to rest on.

Bed rock (Min.). The rock on or in which alluvial deposits collect.

Belland. A kind of lead poisoning lead miners are subject to.

Belly (Min.). A swelling mass of *ore* in a *lode.*

Ben, Benhayl (Min.). The productive portion of a tin stream.

Bench (Min.). A terrace on the side of a river having at one time formed its bank.

Bench mark (Sur.). A mark, cut in a tree or rock by surveyors for future reference.

Bessemer steel (Met.) Formed by forcing air into a mass of melted *cast iron,* by which means the excess of carbon present is separated from it until only enough remains to constitute *cast steel.*

Beton (Eng.). *Concrete* of hydraulic cement with broken stone, bricks, gravel, &c.

Bevel. The slope formed by trimming away an edge.

Bevel gear (Eng.). *Cogwheels,* with *teeth* so formed that they can work into each other at an angle.

Bin. A box with cover, used for tools, stones, *ore,* &c.

Bind (Min.) Indurated *argillaceous shales* or clay, very commonly forming the *roof* of a *coal seam* and frequently containing *clay ironstone.*

Bing ore (Min.). The largest and best kind of lead *ore.*

Bit (Min.). Steeled point of a *borer,* or *drill.*

Black band (Min.). Carbonaceous ironstone in beds, mingled with coaly matter, sufficient for its own calcination.

Black batt, or Black stone (Min.). Black carbonaceous *shale.*

Black-jack (Min.). Properly speaking dark varieties of *zinc blende,* but many miners apply it to any black mineral.

Black ore (Min.). Partly decomposed *pyrites* containing copper.

Black sand (Min.). Black minerals (*magnetite, titaniferous iron, chromic iron, wolfram pleonaste, tourmaline, cassiterite,* &c.) accompanying gold in alluvial.

Black tin (Min.). Dressed *cassiterite,* oxide of tin.

Blanch (Min.). A piece of *ore* found isolated in the hard rock.

Blanket tables (Min.). Inclined planes covered with blankets, to catch the heavier minerals passing over them.

Blast (Min.). To bring down minerals, rock, &c., by an explosion.

(Met.) Air forced into a furnace.

Blast pipe (Met.). A pipe for supplying air to furnaces.
Blende (Geo.). *Sulphide* of zinc.
Blind coal (Min.). Coal altered by the heat of a *trap dyke.*
Blind creek (Geo.). A creek in which water only flows in very wet weather.
Blind lode (Min.). Having no visible *outcrop.*
Blind shaft (Min.). A *shaft* not coming to the surface.
Block coal (Min.). Coal in large lumps.
Blocking out (Min.). Working *deep leads* in *blocks;* somewhat like horizontal *stoping.*
Block reefs (Min.). *Reefs* showing frequent contractions longitudinally.
Blossom rock (Min.). Coloured *vein stone* detached from an *outcrop.*
Blow (Min.). A large increase in the size of a *lode.*
Blower (Min.). A sudden emission or outburst of *firedamp* in a *mine.*
Blow in (Met.) To commence a smelting process.
Blow off (Eng.). To let off excess of steam from a *boiler.*
Blow out (Met.). To finish a smelting *campaign.*
(Min.) *Blown out shot,* a blast that has gone off but not done its work.
Blow-pipe (As.). An instrument for creating a *blast* whereby the flame of a candle or lamp can be better utilised.
Blue-cap (Min.). A blue or brownish coloured halo of ignited *firedamp* and air on the top of a *safety lamp* in a dangerous atmosphere.
Blue-john (Min.). Fluorspar.
Blue-stone (Min.). (1) Sulphate of copper.
(2) Lapislazuli.
(3) Basalt.
Board or Bord (Min.). A wide *heading* or *road.*
Bob (Min.). A large *crank* for transmitting power from the *motor* to *pump rods* in a *shaft*; may have L *bobs,* ⊥ *bobs,* V *bobs.*
Body. The thickness of a lubricating oil or other liquid; also the measure of that thickness expressed in the number of seconds in which a given quantity of the oil at a given temperature flows through a given aperture.
Bonanza (Min.). An aggregation of rich *ore* in a *mine.*
Bond (Eng.). The arrangement of blocks of stone or brickwork to form a firm structure, by a judicious overlapping of each other so as to break joint.
Bone ash (As.). Burnt bones, pulverised and sifted.
Bonnet (Eng.). A *cap* over the end of a pipe or aperture.
Booming (Min.). Ground *sluicing* on a large scale, by empty-

ing the contents of a *reservoir* at once on material collected below, thus removing boulders.

Bosh (Met.). The plane in a *blast furnace* where the greatest diameter is reached.

Boss (Eng.). An increase of the diameter at any part of a *shaft* (2).

Botryoidal (Geo.). In grape-like bunches.

Bottle-jack (Eng.). An appliance for lifting heavy weights.

Bottom (Min.). In *alluvial*, the *bed rock* or *reef*.

Bottomer (Min.). The person who loads the *cages* at the *pit's* bottom and gives the signal *to bank*.

Bottom lift (Min.). The deepest *column* of a pump.

Bottom pillars (Min.) See *Shaft pillars*.

Boulders (Geo.). Loose rounded masses of stone detached from the parent rock.

Bow (Min.). The handle of a *kibble*.

Bowl metal (Met.). The impure antimony obtained from *doubling*.

Box (Min.). A 12ft.—14ft. section of a *sluice*.

Boxing (Min.). A method of securing *shafts* solely by slabs and wooden pegs.

Brace (Eng.). An inclined beam, bar, or strut, for sustaining compression.

(Min.). A platform at the top of a *shaft* on which miners stand to work the *tackle*.

Brace-heads (Min.). Wooden handles or bars for raising and rotating the rods when boring a deep hole.

Brasque (Met.). A mixture of clay and coke or charcoal, used for furnace bottoms.

Brass (Min.). Iron pyrites.

Brasses (Eng.). Fitting of brass in *plummer blocks*, &c., for diminishing the friction of revolving *journals* which rest upon them.

Brattice (Min.). A partition in a *drive* or *shaft* for ventilation purposes.

Breakstaff (Min.). The lever for blowing a blacksmith's bellows, or for working *bore rods* up and down.

Breast (Met.). The front part of a *cupola furnace*.

(Min.). (1) The standing end of rock, *lode*, &c., immediately before one.

(2) Timber placed across a *drive* behind the main *set* of timber, used in soft ground.

Breastwall (Eng.). One built to prevent the falling of a vertical *face* cut into the natural soil.

Breccia (Geo.). A rock composed of angular fragments cemented together.

Breese (Min.). Fine *slack*.

Bridle-chains (Min.). Short chains by which a *cage* is attached to a winding rope.

Brow (Min.). An underground roadway leading to a working place driven either to the *rise* or to the *dip.*

Brown spar (Min.). *Dolomite* containing carbonate of iron.

Brown stone (Min.). Decomposed iron pyrites.

Brush (Min.). To mix gas with air in a mine by buffeting it with a jacket, &c.

Bucket (Min.). A vessel used for holding rock, water, &c., to be hauled to the surface.
(Eng.). (1) Each division on a *water-wheel* for holding water.
(2) The top valve or *clack* of a *lifting set* of pumps.

Bucketsword (Min.). A wrought-iron rod to which the pump *bucket* is attached.

Bucket tree (Min.). The pipe between the *working barrel* and the *wind bore.*

Bucking hammer (Min.). An iron disk provided with a handle, used for breaking up minerals by hand.

Buck quartz (Min.). Hard non-auriferous quartz.

Buck-staff (Met.). Uprights for bracing *reverberatory* furnaces together.

Buddle (Min.). An inclined table, circular or oblong, on which ore is concentrated.

Buller shot (Min.). A second shot put in close to, and to do the work not done by, a *blown out shot*, loose powder being used.

Bullion (Met.). The metallic product from *ore.*

Bull-wheel (Min.). A wheel upon which the rope carrying the *boring rod* is coiled, when boring by steam machinery.

Bunch (Min.). A small rich deposit of *ore.*

Burrow (Min.). See *Dump.*

Bush (Eng.). To line a circular hole with a ring of metal, to prevent the hole from wearing out.

Butterfly-valve (Eng.). A circular *valve* which revolves on an axis passing through its centre.

Butty (Min.). A contractor for getting coal.

By level (Min.). A side *level* driven for some unusual but necessary purpose.

Cab (Min.). The side parts of a *lode*, nearest the *walls*, which are generally hard and deficient in *ore.*

Cage (Min.). (1) An iron vehicle used to convey men, &c., up and down *shafts.*
(2) The hollow *drum* of a *horse whim* round which the rope is wound.

Cage-seat (Min.). Scaffolding, sometimes fitted with strong springs, to take off the shock, and upon which the *cage* drops when reaching the *pit bottom.*

Cage sheets (Min.). Short props or catches on which *cages* stand during *caging* or changing *tubs.*

Cainozoic (Geo.). Tertiary.

Cake (Met.). An agglomeration, as when *ore* sinters together in roasting, or coal *cakes* together in *coking.* A *cake* of gold is *retorted gold* before melting.

Calcareous (Geo.). Containing lime.

Calcine (Met.). To heat a substance ; not sufficiently to melt it, but enough to drive off the volatile contents.

Californian pump (Min.). A rude pump made of a wooden box through which an endless belt with *floats* circulates ; used for pumping water from shallow ground.

Cam (Eng.). A curved *arm* or *wiper* attached to a revolving *shaft* for raising *stamps.*

(Min.). Carbonate of lime and fluorspar, found upon the joints of *lodes.*

Campaign (Met.). The length of time a furnace remains in *blast.*

Canker. The ochreous sediment in mine waters; being bicarbonate of iron, precipitated by the action of air upon that mineral.

Cannel-coal. A coal that burns like a candle. Highly bituminous.

Cants (Eng.). The pieces forming the ends of *buckets* of a *water-wheel.*

Cap (Min.). (1) The upper portion of a *lode.*

(2) A piece of wood placed on *props* or *legs* in a *drive.*

Cap-rock (Min.). The uncertain upper rock that covers the older bed rock.

Capstan (Eng.). A vertical axle used for heavy hoisting, and worked by horizontal arms or bars.

Captain (Min.). Cornish name for manager or boss of a mine.

Car. A waggon or truck.

Carat. A weight nearly equal to four grains.

Carbona (Min.). A rich bunch of *ore* in the *country rock* connected with the *lode* by a mere thread of mineral.

Carbonaceous. Containing carbon.

Carbonate (Chem.). Carbonic acid combined with a *base.*

Cartridge (Min.). A cylindrical shell for containing blasting material, made just the size of the hole to be fired.

Case-harden. To convert the outer surface of wrought iron into steel by heating it while in contact with charcoal.

Casing (Min.). (1) The material found between a *reef* and its *walls*.
(2) A partition of planks dividing a *shaft* into compartments.
(3) The lining of *shafts*.

Cast-iron (Met.). *Pig iron* resulting from the reduction of iron ores which contain carbon (up to 5 per cent.), silicon, sulphur, phosphorus, &c.

Catch-pit (Min.). A reservoir for saving tailings from reduction works.

Caulk. To fill seams or joints with something to prevent leaking.

Caunter lode (Min.). A *vein* running obliquely across the regular *veins* of the district.

Caved in (Min.). Undermined ground that has fallen in.

Cement (Min.). Auriferous gravel consolidated together.

Cementation (Met.). The process of converting *wrought iron* into *steel* by heating it in contact with charcoal : this produces blisters on the steel bars; hence *blister steel*. When the blisters are removed and the steel made more compact by reheating and subjecting it to a *tilt-hammer*, it is called *tilted* or *shear steel*. If the blister steel is broken up, remelted, and run into *ingots*, it is called *ingot steel*, which is harder and closer grained than *tilted steel*.

Center (Eng.). The supports of an arch while being built.

Centrifugal force (Phy.). Flying off from the centre.

Centripetal force (Phy.). Drawing towards the centre.

Chain (Sur.). A measure 66 feet long, divided into 100 links.

Chamber (Min.). See *Plat*.

Chamois leather. Soft untanned buckskin.

Charge (Met.). The material *fed* into a furnace at one time.

Chili-bars (Met.). Bars of impure copper, weighing about 200 lbs.; imported from Chili, corresponding to the Welsh *blister copper*, containing 98 per cent. of copper.

Chill hardening. Giving a greater hardness to the outside of *cast iron* by pouring it into iron moulds which causes the skin of the casting to cool rapidly.

Chinese pump (Min.). Like a *Californian pump*, but made entirely of wood.

Chloride (Chem.). Chlorine chemically united with some *base*.

Chock. Any piece of material used for filling up a chance hole or vacancy.

Choke-damp (Min.). Carbonic acid gas left after an explosion of *fire-damp*.

Chromate (Chem.). Chromic acid with a *base*.

Churn-drill (Min.). A long iron bar with a cutting end of steel, used in quarrying, and worked by raising and letting it fall. When worked by blows of a hammer or *sledge* it is called a *jumper*.

Chute (shoot) (Min.). (1) A wooden or metal pipe or hole in the ground for passing down minerals to a lower *level*.
(2) The mineralized portion of a *vein*.

Clack (Eng.). A common pump *valve*.

Clack-door (Eng.). A *cap* near the *valve* that can be easily taken off, to allow an examination of the *clack*.

Clack-seat (Eng.). The receptacle for the *valve* to rest on.

Claim (Min.). A portion of ground *pegged out* and held by virtue of a *miner's right*.

Clasp (Eng.). A snugly fitting *ferrule* for connecting *pump-rods* together. *Cast and step* when the rods clutch in cross steps. *Clasp and tongue* when the *tongue* of one rod lies in a corresponding recess of the other.

Clay course (Min.). A clay seam or *gouge* found at the sides of some *veins*.

Claying-bar (Min.). For moulding clay in a wet *bore-hole*.

Clean-up (Met.). To collect all the quicksilver and *amalgam* about a *battery*, after crushing.

Cleavage (Geo.). The planes at which cleavable stones break into plates or laminæ.

Clinometer (Sur.). An instrument for measuring vertical angles.

Clutch (Eng.). An arrangement at the end of separate *shafts* by means of which they catch into each other, so that both can revolve together.

Coarse (coose) (Min.). When *lode stuff* is not rich, the *ore* being only thinly disseminated throughout it.

Coarse metal (Met.). In copper smelting, the compound containing the copper concentrated in it after the first smelting to get rid of the bulk of the *gangue* in the *ore*.

Cobbing hammer (Min.). A short double-ended hammer for breaking minerals to sizes.

Cock (Eng.). A kind of *valve* for the discharge of water, gas, steam, &c.

Coffer (Min.). *Mortar box* of a *battery*.

Coffer dam (Eng.). An inclosure built in the water, and then pumped dry, so as to permit masonry or other work to be carried on inside of it.

Cog (Eng.). A *tooth* of a *cogwheel*.

Coke (Met.). The fixed carbon and ash of coal sintered together.

Collar. A flat ring surrounding anything closely.
(Min.). *Collar of a shaft* is the first wood frame of a *shaft*.

Colour (Min.). Minute traces or individual specs of gold.

Concentric. Circles having the same centre.

Conchoidal. Shell-like, such as the curved fracture of flint.

Concrete (Eng.). Artificial stone, formed by mixing broken stone, gravel, &c., with common lime. When *hydraulic cement* is used instead of lime the mixture is called *beton.*

Concretion (Geo.). A cemented aggregation of one or more kinds of minerals around a nucleus.

Conduit (Eng.). A covered waterway.

Conduit hole (Min.). A flat hole drilled for blasting up a thin piece in the bottom of a *level.*

Conformable (Geo.). Strata are conformable when they lie one over the other with the same *dip.*

Conglomerate (Geo.). Rounded stones cemented together to form a *massive rock.*

Connecting rod (Eng.). A piece which connects a *crank* with something that moves it, or to which it gives motion.

Contact lode (Geo.). A *vein* lying between two differently constituted *rocks.*

Contour (Sur.). The line which bounds the figure of an object.

Copper plate (Met.). A sheet of copper which, when coated with mercury, is used in *amalgamation.*

Copper regulus or matt (Met.). $Cu_2 S$ with Fe S, Zn S, Pb S &c., as impurities.

Cord of wood. A pile of wood 8 ft. × 4 ft. × 4 ft. = 128 c. ft.

Costeaning (Min.). Trenching for a *lode.*

Cotter bolt (Eng.). A *key bolt ;* or a bolt, which instead of a screw and *nut* at one end, has a *slot* cut through it at that end for the insertion of a wedge-shaped *key* or *cotter,* which is sometimes split.

Counter (Eng.). An apparatus for recording the number of strokes made by the Cornish pumping engine.

Counter shaft (Eng.). A secondary *shaft* or *axle* which receives motion from the principal one.

Country rock (Min.). The *rock* in which a mineral *vein* occurs.

Couplings (Eng.). Arrangements for connecting two *shafts* so that they shall revolve together.

Course (Min.). The direction of a *lode.*

Crab (Eng.). A variety of *windlass* or *capstan* being a short *shaft* or *axle,* either horizontal or vertical, which serves as a rope *drum* for raising weights, it may be worked by a *winch* or *handspikes.*

Crab holes (Min.). Holes often met with in the *bed rock* of alluvial. Also depression on the surface, owing to unequal decomposition of the underlying *rock.*

Cradle (Min.). A box with a *sieve* mounted on *rockers* for washing auriferous alluvial.

Cramp (Eng.). A short bar of metal having its two ends bent downwards at right angles, for insertion into two adjoining pieces of stone, wood, &c., to hold them together.

Crane (Eng.). A hoisting machine consisting of a revolving vertical post or *stalk*, a projecting *jib* and a *stay* for sustaining the outer end of the *jib;* these do not change their relative positions as they do in a *derrick.* There is also a rope *drum*, with winding rope, &c.

Crank (Eng.). A double bend at right angles in a *shaft* or *axle* to enable it to revolve.

Creaze (Min.). The *middle* of a *buddle.*

Creep (Min.). The gradual movement of the mineral matter of a mine, caused by improper support.
(Eng.). Also, a very slow movement of the winding engine when the *brake* is not sufficiently applied.

Crevicing. Picking out the gold caught in cracks and crevices in the rocks, over which it has been washed.

Crib (Min.). A *cast iron* or wooden ring upon which *tubbing* or the brick lining of a *shaft* is built.

Crop (Min.). *Ore* of the first quality after it is dressed for smelting.

Croppings (Min.). Portions of a *vein* as seen exposed above ground.

Cross course (Min.). A *vein* lying more or less at right angles to the regular *vein* of the district.

Cross cut (Min.). A *level* driven across the regular *veins* or workings of a district.

Cross spur (Min.). A *vein* of quartz which crosses the *reef.*

Crow bar. A strong iron bar with a slightly curved and flattened end.

Crown-wheel (Eng.). A *cogwheel* in which the *teeth* stand not upon its outer circumference as usual, but upon the plane of its circle.

Crucible (Met.). The bottom of a *cupola* furnace in which the molten materials collect.
(As.). Pots for smelting *assays* in.

Crushing (Min.). Reduction of mineral in size by machinery
(Met.). Ditto, together with *amalgamation.*

Crystal (Geo.). A solid of definite geometrical form, which mineral (or sometimes organic) matter has assumed.

Culm (Min.). Inferior *anthracite*, and the smaller or *slack* of smokeless coal.

Cupel (As.). A cup made of bone ash for absorbing *litharge.*

Cut (Min.). (1) To strike or reach a *vein*.
(2) To excavate in the side of a hill.

Cutting down (Min.). To cut down a *shaft* is to increase its size.

Dam (Eng.). An embankment for stopping backwater.

Damp (Min.). *Fire damp*, *choke damp*, *ground damp*, &c., light carburetted hydrogen, carbon dioxide, and other gases injurious to life.

Damper (Eng.). A sliding door or *valve* to regulate the admission of air to a furnace.

Datum water level (Min.). The level at which water was first struck in a *shaft* sunk on a *reef* or *gutter*.

Day (Min.). Light seen at the top of a *shaft*.

Deadmen's graves (Geo.). Applied to country, generally *basaltic*, when owing to the unequal decomposition of the underlying rocks, heaps like graves occur.

Dead points (Eng.). Those two positions in the revolution of a *crank* where the *crank-arm* is parallel with the rod which connects it with the moving power, when the said rod exerts no tendency to turn the *crank*.

Dead roast (Met.). To completely drive off all volatile substances.

Deads (Min.). Waste or rubbish from a mine.

Dead work (Min.). The *opening up* or preparatory work for mining which produces no *ore*.

Débris (Geo.). Fragments from any kind of disintegration.

Decrepitate (Met.). To fly to pieces with a crackling sound when heated.

Delta (Geo.). A triangular-shaped piece of *alluvial* land at the mouth of a river.

Denudation (Geo.). Rock laid bare by water or other agency.

Derrick (Eng.). A kind of *crane* in which the rope or chain forming the *stay* can be let out or hauled in at pleasure, thus altering the inclination of the *jib*.

Detritus (Geo.). Finely powdered deposits worn from hard substances.

Devil's dice (Min.). Cubes of *limonite*, pseudomorphs after *pyrites*.

Dial, miners' (Sur.). An instrument for measuring angles when surveying underground.

Diaphragm. A thin plate or partition placed across a tube or other hollow body.

Die (Min.). The bottom iron block of a *battery*, or *grinding pan* on which the *shoe* acts.

Diggings (Min.). Where gold and other minerals are dug out from shallow *alluvials*.

Diluvium (Geo.). *Alluvial* deposits of the *Pleistocene* period.

Dip (Geo.). The angle which the slope of a *stratum* forms with the horizontal.

Dirt (Min.). See *Wash Dirt*.

Disintegration (Geo.). Separated by mechanical means; not by decomposition.

Ditch (Min.). A narrow excavated channel for carrying water.

Divining or Dowsing rod (Min.). A small forked hazel twig, which when held loosely in the hands is supposed to dip downwards when passing over water or metallic minerals.

Dog-iron. A short bar of iron with both ends pointed and bent down, so as to hold together two pieces of wood, into which the points are driven. Or one end may be bent down and pointed, while the other is formed into an *eye*, so that if the point be driven into a log, the other end may be used to haul on.

Doles (Min.). Small piles of assorted or concentrated *ore*.

Dolly (Min.). A machine for breaking up minerals, being a rough *pestle* and *mortar*, the former being attached to a *spring pole* by a rope.

Donkey engine (Eng.). A small *steam engine* attached to a large one, and fed from the same *boil er;* used for pump ing water into the *boiler*.

Doorpiece (Eng.). The portion of a *lift* of pumps in which the *clack* or *valve* is situated.

Dradge (Min.). Pulverized refuse.

Draftage. A deduction made from the gross weight of *ore* when transported, to allow for loss.

Draw a charge, To (Met.). To take a *charge* from a *furnace.*

Drawlift (Eng.). A *pump* that receives its water by suction, and which will not force it above its *head.*

Dressing (Min.). Preparing poor or mixed *ores* mechanically, for *metallurgical* operations.

Dressing floors (Min.). The floors or places where *ores* are *dressed.*

Drift (Min.). (1) Very loose *alluvial* deposits requiring close *timbering* to enable one to work them.
(2) See *Drive.*

Drifting (Min.). *Winning paydirt* from the ground by means of *drives.*

Drill (Min.). An instrument used in *boring* holes.

Drive (drift) (Min.). A horizontal passage in a *lode.*

Dropper (Min.). A *spur* dropping into the *lode*. A *feeder.*

Dropshaft (Min.). A *monkey shaft* down which earth and other matter is lowered by means of a *drop* (*i.e.*, a kind of *pulley* with break attached; the empty bucket is brought up as the full one is lowered).

Drum (Min.). A revolving cylinder around which ropes are wound.

Drum rings (Min.) Cast-iron wheels with projections to which are bolted the *staves* or *laggings* forming the surface for the ropes to *lap* upon. The outside rings are *shrouded* to prevent the ropes from slipping off the sides of the drum.

Drusy (Geo.). A hollow cavity lined with small *crystals*.

Dry ore (Met.). Argentiferous *ores* which do not contain enough lead for smelting process.

Duck-machine (Min.). An arrangement of two boxes, one working within the other, for forcing air into mines.

Dump (Min.). The pile of *mullock* as discharged from a mine.

Dust gold (Min.). Pieces under 2–3 dwt.

Dyke (Geo.). A *vein* of *intrusive rock*.

Eccentric (Eng.). A disc attached to a revolving *shaft* at some other point than its centre, which is surrounded by a loose ring, that receives an alternating motion.

Efflorescence (Geo.). An incrustation by a secondary mineral; due to loss of water of crystallization.

Elbow. A sharp bend as in a *lode*, or pipe.

Electric blast (Min.). Instantaneous blasting of rock by means of electricity.

Elevator pump (Eng.). An endless band with *buckets* attached, running over two *drums* for draining shallow ground.

Elvan (Min.). A Cornish name applied to most *dyke* rocks of that county, irrespective of the mineral constitution, but in the present day restricted to quartz porphyries.

Erosion (Geo.) The scooping out or wearing away of rocks, as by rains, &c.

Escarpment (Geo.) A nearly vertical natural face of rock or soil.

Eye (Eng.). A circular hole in a bar for receiving a *pin* and for other purposes.

(Min.). The *eye of a shaft* is the very beginning of a *pit*.

Face (Min.). The extreme end of a *tunnel* or other mining excavation.

Face wall (Eng.). A wall built to sustain a *face* cut into the natural earth, in distinction to a *retaining wall* which supports earth deposited behind it.

False bedding (Geo.). Irregular lamination, wherein the laminæ though for short distances parallel to each other, are oblique to the general stratification of the mass at varying angles and directions.

False bottom (Min.). (1) A movable bottom in some apparatus. (2) A *stratum* on which *pay dirt* lies, but which has other layers below it.

False set (Min.). A temporary *set of timber* placed in a *drive* until work is far enough advanced to put in a *permanent set*.

Fan (Min.). A machine for forcing air into, or sucking it out of a mine.

Fascines (Eng.). Bunches of twigs and small branches for forming foundations on soft ground.

Faucet (Eng.). (1) A short tube for emptying liquids from a cask and stopped by a *spigot*. (2) The wider end of a common cast-iron water or gas pipe.

Fault (Geo.). A dislocation in a rock, *lode*, or *seam*.

Feather (Eng.). A slightly projecting narrow rib lengthwise on a *shaft*, arranged to catch into a corresponding groove in anything that surrounds and slides along the *shaft*.

Feather edge (Min.). A passage from false to true bottom.

Feather ore (Min.). Sulphide of lead and antimony.

Feeder (Min.) A small *vein* running into a *main lode*.

Feed-pump (Eng.) A small pump for forcing water into a steam boiler.

Felloe (Eng.). The circular *rim* of a wheel into which the outer ends of the *spokes* fit, and which is often surrounded by a *tire*.

Fencing (Min.). *Fencing in a claim* is to make a *drive* round the boundaries of an *alluvial claim*, to prevent *wash-dirt* from being worked out by adjoining *claim*-holders.

Fend-off (Eng.). A sort of *bell crank* for turning a *pump-rod* past the angle of a crooked *shaft*.

Fire bars (Eng.). The iron bars of a *grate* on which the fuel rests.

Fire-damp (Min.). Carburetted hydrogen, an explosive gas.

Firsts (Min.). The best *ore* picked from a mine.

Fish (Eng.) To join two *beams*, *rails*, etc. together, by long pieces at their sides.

Fissure (Geo.). An extensive crack.

Flags (Geo.). Broad flat stones for paving.

Flange (Eng.). A projecting ledge or rim.

Flat rod (Eng.). A horizontal rod for conveying power to a distance.

Flats (Min.). Narrow decomposed parts of limestones which are mineralized.

Flat sheet (Min.). Sheet-iron flooring at the *brace* and in the *plats*, *chambers* and junctions of *drives*, to facilitate the turning and management of trucks.

Float-gold (Met.). Gold in thin scales which float on water.
Float-stones (Min.). Loose boulders from *lodes* lying on or near the surface.
Floodgate (Eng.). A *gate* to let off excess of water in flood or other times.
Floor (Min.) (1) A *lode* bent into a flat *bed*.
(2) A seam or joint in a rock.
(3) A *false bottom*.
Flour-gold (Min.). The finest alluvial gold.
Flouring (Met.). Reducing mercury to fine globules, that being coated do not readily unite.
Flucan (Min.). A soft greasy clayey substance found in the joints of *veins*.
Flume (Eng.). An artificial watercourse.
Fluming (Eng.). Lifting a river out of its *bed* with wooden *launders* or pipes, in order to get at the *bed* for working.
Flush (Eng.). (1) To clean out a *line* of pipes, gutters, etc., by letting in a sudden rush of water.
(2) The splitting of the edges of stone under pressure.
(3) Forming an even continuous line or surface.
Flux (Met.). Used for promoting fusion when reducing *ores*.
Fly-wheel (Eng.). A heavy revolving wheel for equalizing the motion of machinery.
Foaming (Eng.). An undue amount of boiling, caused by grease or dirt in a boiler.
Foliated (Geo.). Lamellar or leaf-like.
Follower (Eng.). Any *cog-wheel* that is driven by another which is called the *leader*.
Foot-hole (Min.) Holes cut in the sides of *shafts* or *winzes* to enable miners to ascend and descend them.
Foot-piece (Min). (1) A wedge of wood or part of a *slab* placed on the *footwall* against which a *stull piece* is jammed.
(2) A piece of wood placed on the floor of a *drive* to support a *leg* or *prop* of timber.
Footwall (Min.). The lower boundary of a *lode*.
Footway (Min.). Ladders in mines.
Force-pump (Min.). A pump that forces water above its valves.
Fore bay (Eng.). *Penstock*. The reservoir from which water passes directly to a *water-wheel*.
Fork (Eng.). A deep receptacle in the rock to enable a pump to extract the *bottom water*. A pump is said to be "*going in fork*" when the water is so low that air is sucked through the *wind-bore*.

Formation (Geo.). A series of *strata* comprising those that belong to a single geological *age.*

Fossicking (Min.) Overhauling old *workings* and refuse heaps for gold.

Fossil (Geo.). Organic remains found in mineral matter.

Frame (Min.). A table composed of boards, slightly inclined, over which water runs to wash off waste from *slime tin.*

Frame set (Min.). The *legs* and *cap* arranged so as to support a passage mined out of the rock or *lode.*

Friction rolls (Eng.). Hard cylinders placed under a body, so that it may be moved more readily than by sliding.

Friction wheels (Eng.). Wheels so placed that the *journals* of a *shaft* may rest upon their *rims* and thus be enabled to revolve with diminished friction.

Fulcrum (Eng.). The point about which a *lever* turns.

Furnace (Met.). A suitable heating apparatus for *roasting* and *smelting* ores.

Fuse (Min.). A hollow tube filled with an explosive mixture for igniting *cartridges.*

(Met.) To melt.

Gad (Min.). A small steel wedge used for loosening jointy ground.

Gangue (Min.). Waste material from *lodes.*

Gannister (Min.). A hard compact extremely siliceous *fire-clay.*

Gas. Any air like elastic vapour.

Gash vein (Min.). A wedge-shaped *vein.*

Gasket (Eng.). Rope, yarn or hemp, used for stuffing at the joints of water-pipes, etc.

Gearing (Eng.). A *train* of *cog-wheels.*

Geodes (Min.). Large *nodules* of stone with a hollow in the centre.

Gėyser (Geo.). Natural fountains of hot water and steam.

Gib (Min.). A short prop of timber by which coal is supported whilst being *holed* or *undercut.*

(Eng.) A piece of metal often used in the same hole with a wedge-shaped *key* for holding pieces together.

Gin (Eng.). A revolving vertical axis, usually furnished with a rope *drum*, and having one or more long arms or levers by means of which it is worked by horses walking in a circle round it.

Giraffe (Min.). A mechanical appliance for receiving and tipping a car full of *ore* or waste rock, when it arrives at the surface.

Girder (Eng.). A beam larger than a common *joist.*

Gland (Eng.). The lid of a stuffing box.

Gob or **Goaf** (Min.) That part of a mine from which the coal, etc. has been worked away, and the space more or less filled up.

Gold (Min.). See *Alluvial*, *Paint*, *Flour*, *Rust gold*, etc.

Gossan (Min.). A spongy ferruginous *oxide*, left after the soluble substances have been dissolved out of a *lode*.

Governor (Eng.). Two balls, so attached to an upright revolving *shaft*, as to fly outward by their centrifugal force, thus regulating a *valve*.

Grade (Eng.). The amount of fall or inclination in *ditches*, *flumes*, roads, etc.

Grass (Min.). The surface of the ground.

Grating (Min.). A perforated iron sheet or wire-gauze placed in front of reducing machinery.

Gravel (Geo.). Water-worn stones about the size of marbles.

Greenstone (Geo.). A general term employed to designate green-coloured *igneous* rocks as *diorite*, *dolorite*, *diabase*, *gabbro*, etc.

Greywacke (Geo.). A compact grey *sandstone* frequently found in *Palæozoic* formations.

Griddle (Min.). A coarse sieve used for sifting *ores*, clay, etc.

Groin (Eng.). An *arch* formed by two segmental *arches* or vaults intersecting each other at right angles.

Groundsill (Min.). A log laid on the *floor* of a *drive* on which the *legs* of a *set* rest.

Ground sluicing (Min.). Washing alluvial, loosened by pick and shovel, in trenches cut out of the *bed rock*, using *bars* of rock as natural *riffles*. Used in shallow *placers*, *hill claims*, *bank claims*, and *stream diggings*.

Grout (Eng.). Thin *mortar* poured into the interstices between stones and bricks.

Guano (Geo.). A brown, grey, or white, light powdery deposit, consisting mainly of the excrement of seafowl in rainless tracts, or of bats in caves.

Gudgeons (Eng.). The metal *journals* of a horizontal *shaft*.

Guides (Min.). Continuous lengths of ropes or squared timber which run down the drawing compartment of a *shaft* for keeping the *cage* in position, while ascending and descending.

Gussets (Eng.). Plain triangular pieces of plate iron riveted by their vertical and horizontal *legs* to the sides, tops, and bottoms of *box-girders*, *tubular bridges*, etc., inside, for strengthening their angles.

Gutter (Min.). (1) A small water-draining channel.
(2) The lowest part of a *lead* that contains the most highly auriferous *dirt*.

Guy (Eng.). A *stay* of iron, wood, rope or chain.

H-piece (Eng.). A strong pipe cast in the form of the letter H, containing the bottom *clack* of a *set* of pumps.

Hade (Min.). The *dip* or inclination of a *vein* or *fault*, taking the horizontal (America) or vertical (England) as zero.

Half set (Min.). One *leg piece* and a *cap*.

Halvans (Min.). *Gangue* containing a little *ore*.

Hand-barrow (Min.). A long box with handles at each end.

Hand-dog (Min.). A kind of *spanner* or *wrench* for screwing up and disconnecting the joints of *boring rods* at the surface.

Hand-spike (Eng.). A wooden *lever* for working a *capstan* or *windlass*.

Hand-whip (Min.). An apparatus used in shallow alluvial workings, consisting of an upright, at the top of which is balanced a long sapling ; at the thick end of the sapling a bag of earth is fastened, to counter-balance the bucket of dirt to be raised at the other end.

Hanger-on (Min.). The man who runs the full *trucks* on to the *cage*, and gives the signal to *bank*.

Hangers (Eng.). Fixtures projecting below a ceiling to support the *journals* of long lines of *shafting*.

Hanging-spear-rod (Min.). Wooden *pump-rods* adjustable by screws, etc., by which a *sinking set* of pumps is suspended in a *shaft*.

Hanging wall (Min.). The rock on the upper side of a *reef*.

Harrow (Min.). Somewhat like an agricultural harrow ; it is fixed to the *pole* of a *puddling machine* and dragged round to mix and break up the auriferous clays with water.

Hat-rollers (Eng.). Cast-iron or steel rollers shaped like a hat, revolving on a vertical *pin* for guiding inclined hauling ropes around curves.

Hatter (Min.). A miner working by himself on his own account.

Hauling (Min.). The drawing or conveying of the produce of the mine from the working places to the bottom of the *winding shaft*, also elevating it to the surface.

Haunches (Eng.). The parts of an arch from the *keystone* to the *skewback*.

Hawser. A strong and tightly-made hempen rope.

Head (Eng.). Pressure of water in lbs. per square inch.
(Min.). Any subterraneous passage driven in solid coal. Also, that part of a *face* nearest the *roof*.

Head-board (Min.). A wedge of wood placed against the *hanging wall*, and against which one end of the *stull piece* is jammed.

Header (Min.). (1) A rock that *heads off* or delays progress.
(2) A blast hole at or above the *head*.
(Eng.). A stone or brick laid lengthwise at right angles to the *face* of the masonry.

Heading (Min.). (1) A small *driftway* or passage excavated in advance of the main body of a tunnel, but forming part of it, for facilitating the work.
(2) Coarse gravel or *drift* overlying the *wash-dirt*.

Head-race (Min.). An *aqueduct* for bringing a supply of water on to the ground.

Heave (Min.). The shifting of rocks, *seams*, or *lodes* upon the face of a *crosscourse*, etc.

Helve (Min.). The handle of a *pick* or *mandrill*.

Hewer (Min.). A *collier* who *cuts* coal.

High-reef (Min.). The *bedrock* or *reef* is frequently found to rise more abruptly on one side of a *gutter* than on the other, and this abrupt *reef* is termed a *high-reef*.

Hitch (Min.). A *fault* or dislocation of less *throw* than the thickness of the *seam* in which it occurs.

Hitches (Min.). Steps cut in the rock or *lode* for holding *stay-beams*, *beams*, or timber, etc., for various purposes.

Hoarding. A temporary close fence of boards placed around a work in progress.

Hod. A V-shaped trough with a long handle, used for carrying bricks, mortar, etc., to masons.

Hole (Min.). To *undercut* a *seam* of coal, etc.

Horn (Min.). A piece of bullock's horn about 8″ in length, cut boat shape, for concentrating by water on a small scale.

Horse (Min.). A large enclosure of rock in a *lode*.
(Eng.). A mechanical support for anything.

Horse-power (Eng.). Work equal to raising 33,000 lbs. one foot high per minute.

Horse-whim (Min.). A vertical *drum* worked by a horse for hauling.

Hose (Min.). A strong flexible pipe, made of leather, canvas, rubber, etc., and used for the conveyance of water under pressure to any particular point.

Hub. The central part of a wheel through which the *axle-tree* passes, and from which the *spokes* radiate.

Hurdy-gurdy (Eng.). A *water-wheel* which receives motion from the force of travelling water.

Hydraulic cement (Eng.). A mixture of lime, magnesia, alumina and silica that solidifies beneath water.

Hydrometer (Chem.). An instrument for ascertaining the densities or specific gravities of liquids, by the depth of flotation as read on its graduated column.

Igneous rocks (Geo.). Those that have been in a more or less fused state.

Inbye (Min.). Going into the interior of a mine away from the entrance.

Indicator (Eng.). A mechanical contrivance to show the position of the *cage* in the *shaft*.

Indoor-catches (Eng.). Strong beams in Cornish pumping-engine houses to catch the *beam* in case of a smash, thus preventing damage to the engine itself.

In-fork (Min.). When a pump continues working after water has receded below the holes of the *windbore*.

Ingot (Met.). A lump of cast metal.

Inset (Min.). The entrance of a mine pathway down a *shaft*, or at the bottom, where the *cages* are loaded.

Iron hat or **cap** (Min.). The oxidised ferruginous material overlying *lodes*.

Jack (Eng.). An apparatus for raising heavy objects, consisting of an iron *rack*, supported on a short stout block of wood, and worked by *cog-wheels* and a *winch*. A *screw-jack* is a large screw working in a strong frame, the base of which serves for it to stand on.

Jacket (Eng.). An extra surface covering, as a *steam jacket*.

(Met.). A *water jacket* is a furnace having double iron walls, between which water circulates.

Jib (Eng.). The upper projecting arm of a *crane* supported by a *stay*.

Jig (Min.). An apparatus with a perforated bottom, on which *ore* is placed, which is frequently disturbed by vertical throws, giving the heavier particles an opportunity to collect on the bottom.

Jockey (Min.). A self-acting apparatus carried on the front truck of a *set* for releasing it from the hauling rope.

Joggle. A joint of trusses or *sets of timber* for receiving pressure at right angles or nearly so.

Joint (Geo.). Natural division, crack or parting in *strata*.

Journal boxes (Eng.). A fixture upon which a *journal* rests and revolves, instead of a *plummer block*.

Journals (Eng.). The cylindrical supporting ends of a revolving horizontal *shaft*.

Jump (Min.). (1) To take clandestine possession of another's *claim*.
(2) An *up-throw* or *down-throw fault*.

Jumper (Min.). A *drill* used for boring in stone by simply lifting and dropping. It frequently has an enlarged knob or weight in the middle, and may be sharpened at one or both ends.

Kaolin (Geo.). A white clay produced from decomposed orthoclase felspar.

Keelwedge (Eng.). A long iron wedge for driving over the top of a pick *hilt*.

Keeve (Min.). A large wooden tub used for the final concentration of tin oxide.

Key (Eng.). (1) An iron bar of suitable size and taper for filling the *keyways* of *shaft* and *pulley* so as to keep both together.
(2) A kind of *spanner* used in deep boring by hand.

Keybolt. See *Cotter-bolt*.

Keystone. The centre stone of an arch.

Keyways (Eng.). Suitable corresponding grooves in *shaft* and *pulley* for receiving the *key*.

Kibble (Min.). The bucket used for raising stones, etc., from *shafts*.

Kick-up (Min.). An apparatus for emptying trucks.

Kiln (Met.). A chamber built of stone or brick or sunk in the ground for burning minerals in.

Kind (Min.). (1) Tender, soft, easy.
(2) Likely looking stone.

King post (King rod). The centre post, vertical rod or piece, in a *truss;* similar posts or rods when not at the centre, are *Queen posts* or *rods*.

Kit. Any workman's really necessary travelling outfits, as tools, etc.

Knee-piece (Eng.). A bent piece of piping.

Knocker (Min.). A lever which strikes on a plate of iron at the *mouth of a shaft*, by means of which miners below can signal to those on the top.

Knocker-line (Min.). The signal line extending down a *shaft* from the *knocker*.

Knuckle-joint (Eng.). Two rods connected together by a *pin* in such a way, that one *laps* each side of the other, thus affording a free side motion.

Ladder way (Ladder road) (Min.). The particular *shaft* or compartment of a *shaft* used for ladders.

Lagging (Min.). Thick flat boards fastened over the outside of regular *frame timber* of *shafts* and *levels*, in order to more safely secure the ground.

Laminæ. Sheets not naturally separated but which may be forced apart.

Lander (Min.). The man who receives a load of *ore* at the *mouth of a shaft*.

Lander's crook (Min.). A hook or tongs for upsetting the bucket of hoisted rock.

Lap. (1) To place one piece upon another with the edge of one reaching beyond that of the other.
(2) One coil of rope upon a *drum* or *pulley*.

Laths. See *Slabs*.

Launder (Eng.). A *flume* or *aqueduct*.

Lava (Geo.). A common term for all rock matter that has flowed from a *volcano* or fissure.

Leaching (Met.). To dissolve out by some liquid.

Lead (pronounced leed) (Min.). (1) *Ledge* (America), *Reef* (Australia), *Lode* or *vein* (England). A more or less vertical deposit of *ore*, formed after the rock in which it occurs.
(2) A *bed* of alluvial *pay-dirt* or *auriferous gutter*.
(3) The distance to which earth is hauled or wheeled.
(Eng.). A certain amount of opening of the *port-valve* of a steam engine, before each stroke of the *piston* begins.

Leader (Min.). A small *vein* supposed to lead to a larger one.
(Eng.). A *cog-wheel* that gives motion to the next one or *follower*.

Leat. A small water ditch.

Leg-piece (Min.). An upright log placed against the side of a *drive* to support the *cap-piece*.

Level (Min.). An underground road *driven* in the rock or *lode*.

Lifting guard (Min.). Fencing placed around the mouth of a *pit* or *shaft* which is lifted out of the way for *decking* by the *cages* as they reach the surface.

Lift of pumps (Eng.). The *column* or *set* of pipes, with *valves*, etc., reaching from one *cistern* to another.

Lignite (Geo.). Altered vegetable matter showing ligneous structure.

Linch pin (Eng.). A *pin* near the end of an *axle* to hold the wheel on.

Lining (Min.). The planks arranged against *frame sets.*

Little giant (Min.). The name given to a special sort of *hydraulic nozzle* used for *sluicing* purposes.

Lixiviating (Met.). See *Leaching.*

Loam (Geo.). Any natural mixture of sand and clay which is neither distinctly sandy nor clayey.

Lock (Eng.). A short *basin* in a river or canal, with *gates* at each end, for raising and lowering barges, etc.

Lode (Geo.). A mineral *vein.*

Lode- or **Loadstone** (Min.). (1) Magnetic iron ore.
(2) Stone found in *veins* or *lodes.*

Logs (Min.). Portions of trunks of trees cut to lengths and built up so as to raise the *mouth* or *collar* of a *shaft* from the surface, in order to give the requisite space for the lodgment of *mullock* and *ore.*

Long tom (Min.). A wooden *sluice* about 24 feet long, 2 feet wide, and 1 foot high, for washing auriferous gravel.

Long wall (Min.). A system of working low *beds* and *seams* with long *faces*, by means of which all the valuable mineral is won.

Low grade (Min.). Not rich in mineral.

Lug (Eng.). Small projections on castings made for various purposes, *e.g.*, for support, for connections, for lifting the casting by, &c.

Lumber. Timber cut to the various sizes and shapes for carpenter's purposes.

Lute. An adhesive clay used either to protect any iron vessel from too strong a heat, or for securing air and gas-tight joints.

Lydian stone (Geo.). A hard black siliceous rock used as a *touchstone* for testing the quality of gold.

Macadamize (Eng.). A method of making roads with small stones which become settled and firm under pressure of the traffic.

Made ground (Geo.). Recent deposit.

Man-engine (Min.). An apparatus consisting of one or two reciprocating rods, to which suitable *stages* are attached, used for lowering and raising men in *shafts.*

Manhole (Eng.). An opening through which a man can pass to enter a *boiler*, *culvert*, or get the other side of a *ladder-stage*, &c.

Marl (Geo.). Clay containing *calcareous* matter.

Marlin-spike. A sharp-pointed and gradually tapered round iron, used in splicing ropes.

Marsh gas (Min.). *Fire-damp.* CH_4.

Massive rocks (Geo.). Igneous or eruptive rocks.

Match (Min.). *Gunpowder* put into a paper several inches long, and used for igniting *charges* of explosives.

Matrix (Geo.). The associated rocks and minerals in which an *ore* naturally occurs.

Matte (Met.). A product obtained when smelting certain kinds of *ores* whereby the valuable *metals* are concentrated in a *sulphide.*

Mattock (Min.). A kind of pick with broad ends for digging with.

Maul (Min.). A driver's hammer.

Maundril (Min.). A *pick* with two *shanks* and points, used for getting coal, &c.

Meridian (Sur.) A north and south line.

Mesozoic (Geo.). The second great division of *sedimentary* rocks.

Metal (Min.). In coal-mining, indurated clay or slate.
(Met.). Certain elements which are solid at ordinary temperature (with the exception of quicksilver), are opaque (except in the thinnest possible films), have a metallic lustre, and are better conductors of heat and electricity, and as a rule have higher specific gravity, than the non-metals.

Mill (Met.). Works for crushing and *amalgamating* gold and silver *ores.*

Miner (Min.). An underground workman skilled in extricating rock and minerals.

Mineral (Geo.). A natural homogeneous inorganic substance.

Miner's dial (Sur.). An instrument used in surveying underground workings.

Miner's inch (Min.). A measure of water varying in different districts, being the quantity of water that passes through a slit an inch high, of a certain width under a given *head.*

Miner's right (Min.). An annual permit from the Government to occupy and work mineral land.

Mining engineer (Min.). A man having knowledge and experience in the many departments of mining.

Monkey (Eng.). The hammer or *ram* of a *pile-driver.*

Monkey-shaft (Min.). A *shaft* rising from a lower to a higher *level.*

Monkey-wrench (Eng.). A *screw-wrench* or *spanner*, the gripping end of which can be adjusted by means of a screw to fit objects of different sizes.

Mop (Min.). Some material surrounding a *drill* in the form of a disc, to prevent water from splashing up.

Mortar (Min.). The vessel in which ore is put to be pulverised by a *pestle* or *shoe*.

Mortise. A hole cut in one piece of timber, &c., to receive the *tenon* which projects from another piece.

Mote (moat) (Min.). A straw filled with *gunpowder* for igniting a *shot*.

Mother lode (main lode) (Min.). The principal *vein* of any district.

Mouth (Min.). The top of a *shaft*.
(Met.). The hole at the top of a *blast furnace* that the *charges* are *fed* in at.

Moyle (Min.). An iron with a sharp steel point, for driving into clefts when levering off rock.

Mudstone (Geo.). A fine more or less sandy argillaceous rock, having no fissile structure, and somewhat harder than clay.

Muffle (As.) A thin clay oven heated from the outside.

Muller (Met.). The upper grinding iron or rubbing *shoe* of *amalgamating pans*, *&c.*

Mullock (Min.). *Country rock* and worthless minerals taken from a mine.

Mundic (Min.). Iron pyrites.

Naked light (Min.). A candle, or any form of lamp which is not a *safety-lamp*.

Native metal (Geo.). A metal found naturally in that state.

Natural ventilation (Min.). When the workings of a mine are so arranged that air currents are produced without having to resort to artificial means.

Nave. The *hub* of a wheel.

Neck (Geo.). A cylindrical body of rock, differing from the *country* around it.

Needle (Min.). A sharp-pointed copper or brass rod with which a small hole is made through the *stemming* to the *cartridge* in blasting operations.

Nichol's prism (Phy.). A crystal of Iceland spar specially cut and prepared for optical purposes, to enable rays of light to be polarised.

Nick (Min.). To cut or *shear* coal after *holing*.

Nip (Min.). When the *roof* and *floor* of a *coal seam* come close together, pinching the coal between.

Nitrate (Chem.). Nitric acid chemically combined with a *base*.

Nodules (Geo.). Concretions which are frequently found to enclose organic remains.

Nozzle. The front *nose piece* of bellows of a *blast-pipe* for a furnace, or of a water-pipe.

Nugget (Geo.). A natural lump of gold or other metal, applied to any size above 2—3 dwts.

Nutt (Eng.). A short piece with a central *female screw*, used on the end of a *screw-bolt*, &c., for keeping it in place.

Nutts (Min.). Small lumps of coal which will pass through a *screen*, the bars of which vary in the distance they are apart, from ½″ to 2½″.

Off-take (Min.). (1) The raised portion of an *upcast shaft* above the surface.
(2) The *length* of *boring rods* taken off at the top of the *bore-hole*.

Oil-smellers (Min.). In Pennsylvania men who profess to be able to indicate where petroleum oil is to be found.

Old man (Min.). Old workings in a mine.

Oolitic (Geo.). A structure peculiar to certain rocks, resembling the roe of a fish.

Open-cast (Min.). *Workings* having no *roof.*

Open-cut (Min.). To commence working after sinking the *shaft.*

Open-cutting (Min.). An excavation made on the surface for the purpose of getting a *face* wherein a *tunnel* can be driven.

Ores (Min.). Minerals or mineral masses from which *metals* or metallic combinations can be extracted on a large scale, in an economic manner.

Organic. Something animal or vegetable, that has life or has lived.

Out-bye (Min.). In the direction of the *pit* bottom.

Out-crop (Min.). The exposure of a mineral deposit at the surface.

Out-set (Min.). The *walling* of *shafts* built up above the original level of the ground.

Overburden (Min.). The covering of rock, earth, &c., overlying a mineral deposit which must be removed before effective work can be performed.

Overhand stoping (Min.). The ordinary method of *stoping* upwards.

Overlap fault (Geo.). A *fault* in which the shifted *strata* double back over themselves.

Oxide (Chem.). A chemical combination of oxygen and a *base*

Pack (Min.). A rough wall built up to support the *roof.*

Packing (Eng.). The material placed in a *stuffing-box* to prevent leaks.

Paddock (Min.). (1) An excavation made for procuring *wash-dirt* in shallow ground.
(2) A place built near the *mouth* of a *shaft* where *ore* is stored.

Paint, gold (Min.). The very finest films of gold coating other minerals.

Palæozoic (Geo.). The oldest series of rocks in which fossils of animals occur.

Palm. A piece of stout leather fitting the palm of the hand, and secured by a loop to the thumb; this has a flat indented plate for forcing the needle.

Palm-needle. A straight triangular sectioned needle, used for sewing canvas.

Pan (Min.). A thin sheet-iron dish 16 inches across the top, and 10 inches at the bottom, used for panning off.

Panel (Min.). A large rectangular block of coal *in situ.* In *panel workings* the mine is divided into several *panels*, each worked by its own *board* and *pillar*.

Panning-off (Min.). Separating gold or tin from its accompanying minerals, by washing off the latter in a *pan*.

Parrot-coal (Min.). A kind of coal that splits or cracks with a chattering noise when on the fire.

Pass (Min.). (1) A convenient hole for throwing down *ore* to a lower level.
(2) A passage left in old workings for men to travel in from one *level* to another.

Pass-by (Min.). A *siding* in which *tubs* pass one another underground.

Pass into (Min.). When one mineral gradually passes into another without any sudden change.

Patent fuel. Small coal mixed with 8 to 10 per cent. of *pitch* or *tar*, and compressed by machinery into bricks.

Pay-dirt (Min.). That portion of an *alluvial* deposit that contains gold in payable quantities.

Pay-out. To slacken or let out rope.

Peas (Min.). Small coal about ½ to ¾ inch cube.

Peat (Geo.). The decayed organic matter of bogs, swamps, &c.

Penstock (Eng.). See *Forebay.*

Pentice (Min.) A few pieces of timber laid as a roof over men's heads, to screen them when working in dangerous places, *e.g.*, at the bottom of *shafts.*

Pent-house (Min.). A wooden covering for the protection of *sinkers* working in a *pit* bottom.

Pestle. A hard rod for pounding minerals, etc.

Petrification (Geo.). Organic remains converted into stone.

Picker (Min.). A pointed instrument for picking out the *tamping* from a *blast-hole* that has missed fire.

Pier (Eng.). (1) The support of two adjacent arches.
(2) The wall space between windows.
(3) A structure built out into water.

Pig (Met.). A piece of lead or iron cast into a long iron mould.

Pigsty timbering (Min.). Hollow pillars built up of logs of wood laid crossways, for supporting heavy weights.

Piling (Min.). A method of sinking a *shaft* through *drift* by driving *piles* down into it behind *frames* of timber.

Pillar (Min.). A portion of natural or artificial ground, left to support the *roof*.

Pillar and stall (Min.). A method of working *seams* or *beds* by first leaving blocks of coal or *ore* to support the *roof*, and then *robbing* them.

Pillow-block (Eng.). See *Plummer block*.

Pinched out (Min.). When a *lode* runs out to nothing.

Pinion wheel (Eng.). The smaller of two *cogwheels*, which gives motion to the larger one.

Pipe-clay (Geo.). A soft white clay.

Piping (Min.). *Hydraulicing*.

Pit (Min.). The *shaft* and workings of a coal mine.

Pitch (Min.). *Dip* or *rise* in a *seam*.
(Eng.). (1) The slope of a roof.
(2) The distance apart of *rivets;* the *cogs* of a *cogwheel* or the *thread* of a *screw*.
(3) Boiled tar.

Pit's eye (Min.). *Pit-bottom* or entrance into a *shaft*.

Pitman (Min.). The man who attends to the *pumps* and timbers in the *engine shaft;* and the security of permanent *levels*.

Pivot (Eng.). The lower end of a vertical revolving *shaft*.

Placer mining (Min.). Surface mining for gold, where there is but little depth of *alluvial*.

Plane (Min.). A *main road* either level or inclined, along which coals, &c., are conveyed by gravity or engine power.

Plane table (Sur.). A simple surveying instrument by means of which one can *plot* on the field.

Plant (Eng.). All the appliances, machinery, sheds, &c., belonging to a mine or works.

Plat (Min.). A *chamber* or excavation made at the point of departure of a *level* from a *shaft*.

Plugging (Min.). When *drift* water forces its way through the puddle clay into the *shaft*; holes are bored through the *slabs* near the leakage point, and plugs of clay forced into them until the leakage is stopped.

Plumb. Vertical.

Plummer block (Eng.). A metal *chair* or support on which the *journals* of horizontal *shafts* generally rest and revolve

Plummet (Sur.). A *plumb-bob* or weight at the lower end of a string.

Plunger (Eng.). A cylinder used to force water up a *column* of pump pipes.

Pocket (Met.). A receptacle for fumes to collect in.
(Min.). A cavity in a rock.

Poling (Met.). Refining metal when in a molten condition by stirring it up with a green pole of wood.

Poll pick (Min.). A pick having the longer end pointed and the shorter end hammer shaped.

Poppet-heads (Min.). The *pulley frame* or *hoisting gear* over a *shaft.*

Porphyry (Geo.). A rock having a felsitic matrix, in which are developed crystals of quartz or other minerals.

Port (Eng.). The opening or passage controlled by a *valve.*

Post-tertiary (Geo.). *Strata* younger than the *Tertiary formation.*

Prian (Min.). A soft and soapy white clay found in the joints of *veins.*

Pricker (Min.). (1) A thin brass rod for making a hole in the *stemming* of *blast holes* for the insertion of a *fuse*, so that the flame can obtain access to the cartridge.
(2) A bent wire for regulating the size of a lamp wick.

Prill (Min.). An extra rich stone of *ore.*
(As.). A bead of metal.

Prime (Eng.). When water passes into a *steam cylinder* together with the steam.

Primitive rocks (Geo.). Those of the earliest formation.

Prong (Eng.). The forked end of the *bucket-pump rods* for attachment to the travelling *valve* and *seat.*

Prop (Min.). A piece of timber of varying dimensions, generally 1 inch diameter for every 1 foot in length, used in securing the ground of a *mine.*

Prospect (Min.). The yield of gold by *panning off.*

Prospecting (Min.). Searching for valuable minerals.

Prospector (Min.). One engaged in searching for minerals.

Pseudomorph (Geo.). When a mineral occurs in a false form, or one belonging to another species.

Pudding stone (Geo.). A *conglomerate* or *breccia.*

Puddle (Eng.). Earth well rammed into a trench, &c., to prevent leaking.
(Met.). A process for converting *cast-iron* into *wrought.*

Puddling machine (Min.). A circular machine for washing *pay dirt.*

Pug-mill. A mill for tempering clay for bricks, pottery, &c.

Pulley (Eng.). A wheel which carries a *belt* for driving purposes, or over which a rope passes.

Pulleying (Min.). *Overwinding* or drawing up a *cage* into the *pulley frame.*

Pulp (Met.). The moist pulverised mineral from a *mill.*

Pump-ring (Eng.). A flat iron ring which when *lapped* with tarred baize or *engine shag* secures the joints of water *columns.*

Pump rod (Eng.). The rods which connect the motive power to the pump.

Pumptree (Eng.). Cast iron pipes generally 9 feet long of which the *column* or *sett* is formed.

Punch-prop (Min.). A short timber prop set on the top of a *crown tree*, or used in *holing* as a *sprag.*

Putty-stones (Min.). Soft pieces of decomposed rock found in placer deposits.

Pyrometers (Met.). Instruments for measuring high degrees of heat.

Quarry (Min.). (1) An open surface excavation for working valuable rocks or minerals.
(2) An underground excavation for obtaining stone for *stowage* or *packwalls.*

Quaternary (Geo.). *Post-tertiary* period.

Queen post. Vertical *ties* employed to support roofs when *kingbolts* are not sufficient.

Quick (Geo.). Soft watery *strata*, *e.g.*, running sand.
(Met.). Abbreviation for quick lime.

Rabbling (Met.). Stirring up a *charge* of *ore* in a *reverberatory furnace* with specially designed iron rods.

Race (Eng.). A channel for conducting water to or from the place where it performs work. The former is termed the *head race*, and the latter the *tail race.*

Rack-pinion (Eng.). The *rack* is a straight row of *cogs* on a bar called a *rack-bar* ; the *pinion* is a small *cogwheel* that works into it.

Raff (Min.). The coarse *ore* after crushing by *Cornish rolls.*

Raff-wheel (Min.). A revolving wheel with side *buckets* for elevating the *raff.*

Rag-wheel (Eng.). *Sprocket wheel.* A wheel with *teeth* or *pins* that catch into the links of chains.

Ram (Eng.). The *plunger* of a pump.

Raw ore (Met.). Not *roasted* or *calcined.*

Reaming (Min.). Enlarging a *bore hole.*

Receiving pit (Met.). A shallow pit for holding material run into it.

Reduced (Chem.). When a metal is freed from its chemical associate it is said to be reduced to the metallic state.

(Min.). To make smaller in size.

Reduction works (Met.). Works for reducing metals from their *ores*.

Reef (Min.). (1) A *vein* of *quartz*.

(2) *Bed rock* of *alluvial claims*.

Reef-drive (Min.). In *alluvial* mines, *drives* made in the *country rock* or *reef*.

Refining (Met.). The freeing of metals from impurities.

Refractory (Met.). *Rebellious ore*, not easily treated by ordinary processes.

Refuge-hole (Min.). A place formed in the side of an underground *plane* in which a man can take refuge during the passing of a train or when firing *shots*.

Regulus (Met.). See *Matte*.

Reserve (Min.). Mineral already opened up by *shafts, winzes, levels, &c.*, which may be *broken* at short notice for any emergency.

Reservoir (Eng.). An artificially built, dammed or excavated place for holding a reserve of water.

Retaining wall (Eng.). Built to retain earth behind it.

Retort (Met.). An iron vessel with a long neck used for distilling the quicksilver from *amalgam*.

Reverberatory (Met.). A class of *furnaces* in which the flame from the fire grate is made to beat down on the *charge* in the *body* of the *furnace*.

Reversed fault (Geo.). See *Overlap fault*.

Riddle (Min.). An oblong frame holding iron bars parallel to each other, used for sifting material that is thrown against it.

Rider (As.). The movable weight on a *beam* of a *balance*.

Riffle or Ripple (Min.). Cross pieces placed on the bottom of a *sluice* to save gold; or grooves cut across inclined tables.

Right shore. The *right shore* of a river is on the right hand when descending the river.

Rill (Min.). The coarse *ore* at the periphery of a pile.

Ring bolt. A bolt with an *eye* and a ring at one end.

Rise (Geo.). The inclination of *strata* when viewed in the opposite direction to their *dip*.

(Min.). A hole worked from below upwards.

River Mining (Min.). Working *beds* of existing rivers by deflecting their course, or by dredging.

Roasting (Met.). Heating *ores* at a temperature sufficient to cause a chemical change, but not enough to smelt them. *Oxidising*, *chloridizing*, and *reducing roasting*.

Rob (Min.). To cut away or reduce the size of *pillars* of coal.

Rock (Geo.). A mixture of different *minerals* in varying proportions.

Rock-breaker (Min.). A machine for reducing *ore* in size by crunching it between powerful jaws.

Rock-drill (Min.). A rock boring machine worked by hand, compressed air, or steam.

Rocker (Min.). See *Cradle*.

Rock-shaft (Eng.). A *shaft* which only rocks from side to side, instead of making a complete revolution.

Rodding (Min.). The operation of fixing or repairing wooden *eye guides* in *shafts*.

Rolling ground (Geo.). When the surface is much varied by many small hills and valleys.

Roof (Min.). The upper portion of any under-ground excavation.

Room and Rance (Min.). See *Pillar and stall*.

Round-coal (Min.). Coal in large lumps, either hand picked or after passing over *screens* to take out the *smalls*.

Rubble. Coarse pieces of rock.

Run (Min.). (1) A *chute* of *ore*.
(2) A *run* of ground, means that the ground has given way.

Rung, Rundle or Round. A step or cross bar of a ladder.

Runner (Min.). See *Guides*.

Running lift (Min.). A *sinking sett* of pumps constructed to lengthen or shorten at will, by means of a sliding or telescoping *windbore*.

Rush (Min.). An old-fashioned way of exploding *blasts* by filling a hollow stalk with slow powder and then igniting it.

Rush-together (Min.). See *Caved in*.

Rust-gold (Min.). Gold coated with oxide of iron or manganese.

Rusty (Min.). Stained by iron oxide.

Saddle reef (Geo.). A *reef* having the form of an inverted V.

Safety cage (Min.). A *cage* used for hoisting and lowering in *shafts* which is provided with a *safety catch*.

Safety catch (Min.). An apparatus attached to *cages* to prevent them from falling in case the rope or chain connecting them with the motive power should break.

Safety door (Min.). A strongly constructed *door* hinged to the *roof* of a coal mine, and always kept open and hung near to a *main door* for immediate use in case of damage to the *main door*.

Safety fuse (Min.). A cord with slow burning powder in the centre for exploding charged *blast holes*.
Safety lamp (Min.). A coal miner's lamp protected from explosive gases by glass and wire gauze.
Safety valve (Eng.). A *valve* loaded with a certain weight or a spring of given strength, so that when steam or air of great pressure is present, it can escape.
Sag. A depression, *e.g.*, in ropes, ranges of mountains, &c.
Salting (Min.). Fraudulently enriching mineral matter.
Sampler (Min.). An instrument or apparatus for taking samples.
Sand bag (Eng.). A bag filled with sand for stopping leaks.
Scaffolding (Met.). Incrustations on the inside of a *blast furnace*.
Scantling. The depth and breadth of pieces of timber.
Scorifier (As.). A small dish used in *assaying*.
Schist (Geo.). Crystalline or *metamorphic* rocks having a slaty structure.
Scoriæ (Geo.). Ashes.
Scraper (Min.). An instrument for cleaning a hole that has been bored or drilled.
Screen (Min.). (1) A mechanical apparatus for separating *smalls* from *large*.
(2) A cloth *brattice* or curtain hung across a *road* in a mine to direct the ventilation.
Scupper nails. Nails with broad heads for nailing down canvas, &c.
Seam (Geo.) A horizontal *bed* of coal.
Seating (Eng.). (1) The stone masonry in which a steam boiler is *set*.
(2) The ring upon which a *valve* shuts tightly.
Secondary rocks (Geo.). Those situated above the *primitive* and below the *tertiary* formations.
Seconds (Min.). The second class *ore* of a mine that requires *dressing*.
Section (Geo.). A vertical exposure of *strata*.
Sedimentary rocks (Geo.). Rocks formed from deposits by wind or water.
Segregated (Geo.). Separated from its surroundings and collected together.
Self-acting inclined plane (Eng.). An *inclined plane* on which the full set draws the *empties* up hill.
Self-feeders (Min.). Automatic appliances for feeding ore dressing machines.
Selvage (Min.). The clay seam on the *walls* of *veins*.
Serpentine (Geo.). A hydrated magnesian silicate formed by the alteration of certain *igneous* rocks.

Set-hammer. The flat-faced hammer held upon hot iron by a blacksmith when shaping or smoothing a surface by aid of his striker's *sledge*.

Set of timber (Min.). Those timbers used in a *level* consisting of a *ground sill*, *cap piece* and two *leg pieces*.

Set-off (Eng.). An iron projection from the main pump-rod on which the *bucket pumping rod* is fixed.

Set-screw (Eng.). A screw passing through a fixed piece so as to adjust or secure a movable piece.

Sett (Eng.). A column of *pumptrees* with *buckets* or *ram*, &c., complete.

Shackle. An U-shaped link in a chain, closed by a *pin;* when the latter is withdrawn the chain is severed at that point.

Shaft (Min.). A vertical or diagonal hole in the ground, used for the working way of a mine.
(Eng.). A large *axle*.

Shaft pillar (Min.). Solid coal left unworked beneath colliery buildings and around the *shafts*, to support them against *creeps*.

Shaking table (Min.). An inclined table for concentrating fine grains of *ore* which is rapidly shaken by a short motion.

Shale (Geo.). A fine grained rock with fissile structure.

Shank. The body of a *bolt* exclusive of its *head*.

Shear legs (Eng.). A high wooden frame placed over an engine or pumping *shaft* fitted with small *pulleys* and rope for lifting heavy weights.

Shears or **Sheers** (Eng.). Two tall poles with their feet some distance apart and their tops fastened together for supporting hoisting *tackle*.

Sheave (Eng.). A wheel or round block, with a groove around its circumference, for guiding a rope.

Shoad stones (Min.). Stray stones or *floaters* from the *croppings* of a deposit of minerals.

Shoes (Min.). (1) Steel or iron guides fixed to the ends or sides of *cages* to fit and run upon the *conductors*.
(2) The upper working face of a *stamp* or *grinding pan*.

Shoot (**Shute, Chute**) (Min.). (1) A run of minerals in a *vein*.
(2) A *pass* down which minerals are tipped.

Shore (Eng.). A *studdle* or *thrusting stay*.

Shot (Min.). The *firing* of a *blast*.

Shotty gold (Min.). Granular pieces like shot.

Sickening (Met.). A coating of impurities on Quicksilver that retards *amalgamation* or the coalescence of globules of quicksilver.

Sidelong reef (Min.). An overhanging wall of *bed rock* in *alluvial* formations running parallel with the course of the *gutter;* generally only on one side of it.

Siding (Eng.). A short piece of railroad track branching off from the main one to serve as a passing place.

Sill (Min.). A piece of wood placed across the bottom of a *drive* on which the *legs* of a *set* stand.

Silver (Met.). (1) A white ductile metal.
(2) Short for quicksilver.

Sink (Min.). To excavate *strata* in a downward direction.

Sizing (Min.). To sort minerals into sizes.

Skew-back (Eng.). The inclined stone from which an arch springs.

Skid (Min.). *Guides* on which *sledges*, *trucks*, *buckets*, *bags*, or *cages* are run.

Skip (Min.). A long waggon used for hoisting rock from mines.

Slab (Min.). Split pieces of timber from 2″ to 3″ thick, 4′ to 6′ long, and 7″ to 14″ wide, placed behind *sets* or *frames* of timber in *shafts* or *levels*.

Slack (Min.). Small coal that passes through a ¾″ *screen*.

Slag (Met.). The molten *gangue* from treating *ores* in furnaces.

Slate (Geo.) Compact clay which has assumed a hard regular laminated structure.

Sledge. A heavy double-handed hammer.

Sleeper (Eng.). The foundation pieces on which rails rest.

Sleeve (Eng.). A hollow cylinder fitting over two pieces to hold them together.

Sleigh. A vehicle with double *kiel-runners* instead of wheels.

Slicken side (Geo.). The smooth striated surface on opposite walls of *joints*, caused by motion of the rock.

Slide (Geo.). A *vein* of clay intersecting the rock when the latter has been faulted.

Sliding wind bore (Eng.). The bottom pipe or *suction piece* of a *sinking sett* of pumps, having a lining made to slide like a telescope within it; to give length without altering the adjustment of the whole *column* of pipes.

Slime, Sludge (Min.). The pulp or fine mud from a *mill*, or from a *drill-hole*.

Slings. Pieces of ropes or chains to be put around stones, &c., for raising them by.

Slip. The sliding down of the sides of earthworks or banks.

Sluice-box (Min.). A trough with *ripples* or *false bottom* for catching gold.

Sluice-head (Min.). A measure to gauge the quantity of water that flows in a channel.

Sluicing (Min.). *Ground sluicing* is working gravel by excavating with pick and shovel, and washing the débris in trenches with water not under pressure.

Snag (Eng.). A *lug* with a hole through it for a *bolt.*

Snift (Min.). A match for igniting a train of gunpowder, arranged to give miners time to retire.

Snore-piece (Eng.). The lowest end of a *pump sett* through which the water passes.

Sole (Eng.). That lining round a *water-wheel* which forms the bottoms of the *buckets.*

Sole-plate (Min.). See *Foot-piece.*

Sollar (Min.). A wooden platform fixed in a *shaft* for the ladders to rest on.

Sows (Met.). Iron deposits at the bottom of *furnaces.*

Spall (Min.). To break up rocks with a large hammer for hand-sorting.

Span-beam (Eng.). A long wooden beam supporting the head *pivot* of the *drum-axle* of a *gin,* and resting at its extremities upon inclined *legs.*

Spanner (Eng.). A *lever* with a square *eye* at one end, for tightening *nuts* on *screw-bolts,* &c.

Spar (Min.). A name given to certain white quartz-like minerals, *e.g.*, calcspar, felspar, fluorspar.

Spear-plate (Eng.). Wrought-iron plates bolted to the sides of *spears* when joined together.

Specific gravity (Phy.). A comparative degree of weight; that of water being taken as unity.

Specimen (Min.). A picked piece of mineral.

Speiss (Met.). Combinations of arsenic or antimony with iron, copper, nickel, &c.

Spelter (Met.). The commercial name for zinc.

Spent-shot (Min.). A *blast-hole* that has been *fired,* but has not done its work.

Spew (Min.). The extension of mineral matter on the surface past the ordinary limits of the *lode.*

Spider. See *drum-ring.*

Spiking-curbs (Min.). A light ring of wood to which planks are spiked when *plank-tubbing* is used.

Splay. To widen or *flare* like the *wing walls* of most *culverts.*

Splint (Min.). A laminated, coarse, inferior, dull-looking, hard coal, intermediate between *cannel* and *pit coal.*

Spoil (Min.). Débris from a coal mine.

Sprag (Min.). A short wooden prop set in a slanting position for keeping up the coal during the operation of *holing.*

Spring-beams (Min.). Two short parallel timber beams built with a Cornish pumping-engine house, nearly on a level with the engine beam, for catching the beam, &c., and preventing a smash in case of a breakdown.

Spring of an arch (Eng.). The rise or vertical height between the *skew-back* and the highest part of the arch.

Spring-pole (Min.). An elastic wooden pole from which *boring-rods* are suspended.

Sprocket-wheel (Eng.). *Rag-wheel.* A wheel with *teeth* or *pins* which catch in the *links* of a chain.

Spur (Min.). An off-setting pointed branch from a *lode* or mountain.

Spur-wheel (Eng.). A comparatively small driving *cog-wheel.*

Stack (Met.). A high chimney built on a separate foundation. (Min.). To heap *ore* or wood into piles.

Stage-pumping (Min.). Draining a mine by means of two or more pumps placed at different levels in the *shaft*, so that the lower passes on the water to the upper one.

Staging. The temporary flooring of a scaffold, platform, &c.

Stalactites (Geo.) Icicle-shaped appendages of mineral matter suspended from above.

Stalagmites (Geo.). Lumps of mineral matter which accumulate on the floor below *stalactites.*

Stall (Min.). A working place in a coal mine.

Stamps (Min.). Large pestles worked mechanically; used for pulverising stone.

Stanchion (Eng.). A vertical *prop* or *strut.*

Standing bolt. See *Stud-bolt.*

Standing sett (Eng.). A fixed *lift* of pumps in a *sinking set.*

Staple. An U-shaped band with screw ends, for tightening two or more pieces together. Also an U-shaped double pointed nail for driving into wood.

Starved (Eng.). When a pump is choked at the *brass holes.*

Station (Min.). A *plat* or convenient resting place in a *shaft* or *level.*

Stave. A ladder step.

Stay (Eng.). *Props*, *struts*, or *ties* for keeping anything in its place.

Stay-bolts (Eng.). Long bolts placed across the inside of a *boiler*, &c., to give it greater strength.

Steam coal (Min.). A hard, free-burning, non-caking white ash variety of coal.

Steel needle (Min.). An instrument used in preparing *blasting holes* before the *safety fuse* was invented.

Stemmer (Min.). A copper rod used for *stemming.*

Stemming (Min.). See *Tamping.*

Step (Eng.). The cavity in a piece for receiving the *pivot* of an upright *shaft*, or the end of an upright piece.

Stobb (Min.). A long steel wedge used in bringing down coal after it has been *holed*.

Stock (Eng.). The *eye* with handles attached to it, in which the *dies* for the cutting of screws are held.

(Geo.). A body of rock with *ore* disseminated through it

Stockwork (Geo.). A rock run through with a number of small *veins* close together, the whole of which has to be worked when mining such deposits.

Stomp (Min.). A short wooden plug fixed in the *roof* of a *level* to serve as a *bench-mark* for surveys.

Stone coal (Min.). *Anthracite;* also other hard varieties of coal.

Stone-tubbing (Min.). Water-tight stone-*walling* of a *shaft* cemented at the back.

Stoop and room (Min.). A system of working coal similar to *pillar* and *stall*.

Stoping (Min.). Working out *ore* between two *levels* or on the surface by *stopes* or steps.

Stove up or stoved. *Upset*. When a rod of iron heated at one end is hammered endwise, so that that part becomes stouter than the remainder.

Straight end and walls (Min.). A system of working coal, somewhat similar to *board* and *pillar*.

Straightwork (Min.). A system of getting coal by *headings* or narrow work.

Strake (Min.). A slightly inclined table for separating heavier minerals from lighter ones.

Strap (Eng.). A long thin narrow piece of metal bolted to two bodies to hold them together.

Strapping-plate (Eng.). Strong iron plates used in connecting wooden pump-rods with transverse *bolts* and *nuts*.

Stratum, strata (Geo.). A layer or *bed* of rocks.

Streak (Geo.). The colour of a mineral when scratched.

Strike (Geo.). (1) The line of *outcrop* of a *stratum* in the direction at right angles to the *dip*.

(2) To meet with.

Strike joints (Geo.). Joints in *strata* parallel to the *strike*.

Striking deal (Min.). Planks fixed in a sloping direction just within the *mouth* of a *shaft* to guide the *tub* to the surface.

Stringer (Eng.). Any longitudinal timber on beam, &c.

Stripping (Min.). Baring a *lode* by removing the rock, generally on its *footwall* preparatory to breaking it down.

Strut (Eng.). A *prop* to sustain compression whether vertical or inclined.

Stud (Eng.). A short stout projecting *pin*.

Stud-bolt (Eng.). A bolt with a *worm* cut at both ends ; one to be screwed into something permanently, the other to hold by means of a *nut* something that may have to be removed at times.

Studdle (Min.). A piece of squared timber placed vertically between two *sets of timber* in a *shaft.*

Stuffing box (Eng.). A small box round the *piston rod*, at the end of the *cylinder*, so arranged as to prevent the escape of steam, air, or water.

Stull (Min.). A piece of timber laid across a *drive* or workings, inclined upwards towards the *hanging wall*, when it is fixed against a *head board*, while the lower end rests in a hole in the *footwall. Slabs* are placed on these *stull-pieces* when required to store *mullock.*

Stumping (Min.). A kind of *pillar-and-stall* plan of getting coal.

Substratum (Geo.). The underlying rock *formation.*

Subsoil (Geo.) The broken upper part of a rock immediately under the soil.

Suction-pump (Eng.). A pump wherein by the movement of a *piston*, water is drawn up into the vacuum caused.

Sulphate (Chem.). Sulphuric acid combined with a *base.*

Sulphide (Chem.). A combination of sulphur and a base.

Sulphuret (Chem.). See *Sulphide.*

Sump (Min.). The lowest part of a *shaft* into which the water drains.

Surface deposits (Geo.). Those which are exposed and can be mined from the surface.

Swabstick (Min.). A short wooden rod bruised into a kind of brush at one end, used for cleaning out a *drilled hole.*

Swage or Swedge. A hammer-like instrument, on one face of which is an indenture, which being held upon a piece of hot iron and struck with a heavy hammer, leaves the impression of the indentation upon the iron.

Sweet roast (Met.). To roast *dead* or completely.

Swing (Phy.). The arc or curve described by the point of an instrument such as a pick or hammer when being used.

Swinging plate (Met.). Amalgamated copper plates hung in *sluices* to catch *float gold.*

Switch (Eng.) The moveable tongue or rail by which a train is diverted from one track to another.

Synclinal curve (Geo.). A trough-shaped curve.

Tackle (Eng.). Ropes, chain, *detaching hooks*, *cages*, and all other apparatus for raising coal or *ore* in *shafts.*

Tailings (Met.). The detritus from reduction works or gold-washing machinery.

Tail-race (Min.). The channel along which water flows after it has done its work.

Tail-rope (Min.). A rope working in conjunction with a main rope in a system of underground haulage on slightly *inclined planes*, also used as a balance in *shafts*.

Tamp (Min.). To fill up a *blast-hole* above the explosive charge with some substance before firing a *shot*.

Tamping (Min.) The material used to *tamp* with.

Tamping bar (Min.) A copper bar for ramming down the *tamping*.

Tap (Min.). To cut or bore into old workings for the purpose of liberating accumulations of water or gas.

Tape, Tap (Eng.). *Plug-tap*. A steel screw suitably grooved and sharpened for cutting out the *mother screws* in *nuts*.

Tappet (Eng.). A short arm or projection from a revolving *shaft* or alternating bar, intended to come in contact with, or tap something at each revolution or stroke.

Teeth (Eng.). See *Cog*.

Telluride (Chem.). Tellurium combined with a base.

Temper. (1) To change the hardness of metals by first heating and then plunging them into water, oil, &c.
(2) To mix mortar, or to prepare clay for bricks, &c.

Tenon. A projecting tongue fitting into a corresponding cavity called a *mortise*.

Terrace (Geo.). A raised level bank, such as *river terraces*, *lake terraces*, &c.

Tertiary (Geo.). The third great division of rocks in which the highest class of vertebrate animals first appear.

Test (Met.). An iron framework which is filled with bone-ash for *cupelling* on a large scale.

Test-tubes (Chem.). Very thin glass tubes closed at one end for testing substances in the wet way.

Theodolite (Sur.). An instrument used in *surveying*. For taking both vertical and horizontal angular measurements.

Thick seams (Geo.). *Coal seams* of greater thickness than (say) 8 feet.

Thimble (Eng.). (1) A short piece of tube slid over another piece to strengthen a joint, etc.
(2) An iron ring with a groove round it on the outside, used as an *eye* when a rope is doubled about it.

Thin seam (Geo.). *Coal seams* less than (say) 3 feet thick.

Thread (Eng.). The continuous spiral projection or *worm* of a screw.

Through and through (Min.). A system of getting bituminous coal without regard to the size of the lump.

Throw (Geo.). The throw of a *fault* is the vertical displacement of the rocks *faulted*.

Thrust (Geo.) A *creep* due to weight.

Ticketing (Min.). English periodical markets for the sale of *ores.*

Tie (Eng.). Any piece that sustains tension or pull.

Tie-back (Min.). A beam serving a similar purpose as a *fend-off beam*, but fixed at the opposite side of the *shaft* or inclined road.

Tip (Tipper, Tippler) (Min.). (1) A platform with rails attached, fixed upon an *axle* and connected with a *lever* on which a *car* is run and tilted over.
(2) Also a place where *ore* or *mullock* is tipped.

Token (Min.). A mutually understood mark placed upon a bucket of *ore* when it is hoisted or lowered into a shaft, to acquaint the *lander* or *filler* of some important matter.

Topit (Min.). A kind of *brace-head* screwed to the top of *boring rods* when withdrawing them from the hole.

Tramway (Eng.). A small roughly constructed iron track for running waggons or trucks on.

Transome (Eng.). A heavy wooden *bed* or supporting piece.

Trap (Geo.). Igneous rocks that form " trappen " or steps.

Trass (Geo.). A rock composed of earthy or compact pumiceous dust ; in which fragments of *pumice*, *trachyte*, *greywacke*, *basalt*, carbonised wood, etc., are imbedded.

Tree-nail. A long wooden pin for securing planks or beams together.

Trestle (Eng.). Any structure which is composed of a network of timbers securely stayed.

Tribute (Min.). A method of working mines by contract, whereby the miners receive a certain share of the products won.

Trig. A *sprag* used to block or stop a wheel or any machinery.

Trommel (Min.). A drum, consisting of a cylindrical or conical shaped sheet-iron *mantle*, generally punched with holes, which revolves ; used for *washing* or *sorting ores.*

Trompe (Min.). A *water-blast* for producing ventilation by the fall of water down a *shaft*.

Trough fault (Geo.). A mass of rock let down between two *faults.*

Truck system (Min.). Paying miners in food instead of money.

Trundle (Eng.). Two parallel circular pieces some distance apart, connected by a central *axis* and by cylindrical rods placed round near the periphery and parallel to the *axis*, which serve the purpose of *teeth* in a *cog-wheel.*

Trunnions (Eng.). Cylindrical projections, forming a sort of interrupted *shaft*, attached to some vessel, so that it can have a vertical movement.

Tubbing (Min.). The cast iron, timber, or *walling* of a *shaft* for keeping back springs of water.

Tubbing wedges (Min.). Small wooden wedges hammered between the joints of *tubbing plates.*

Tubing (Min.). The lining of *bore-holes* with wrought-iron tubes to keep the sides from giving way.

Tuff (Geo.). The finer kinds of volcanic detritus, generally more or less stratified.

Tunnel (Min.). A *level* put in from the surface.

Turbine (Eng.). A rapidly revolving *water-wheel* impelled by the pressure of water upon curved *blades.*

Turnbuckle (Eng.). A tightening *swivel.*

Turntable (Eng.). A horizontal table revolving on a vertical *axis* supported by small wheels; used to turn trucks round on.

Turn-out (Min.). A *siding* or *pass-by* upon an underground *level.*

Tut-work (Min.). Breaking ground at so much per foot or fathom.

Tuyeres (Met.). The *nozzles* through which the *blast* passes into a furnace.

Two-throw (Min.). When in sinking a depth of about 12 feet has been reached, and the débris has to be raised to the surface by two lifts or throws with the shovel, one man working above another.

Tye (Min.) An inclined table used for *dressing ores.*

Unconformability (Geo.). When one layer of rock, resting on another layer, does not correspond in its angle of *bedding.*

Undercast (Min.). An *air course* carried underneath a *waggon way.*

Undercut (Min.). To hole.

Underhand stoping (Min.). Working out ground downwards in *stopes* or steps.

Underlie or Underlay (Min.). The inclination of a *lode* at right angles to its *course.*

Underpin (Eng.). To introduce additional support of any kind beneath anything already completed.

Unit (Met.). The *unit* of metals is 1 per cent. of whatever ton is used. Generally the 20 cwt. ton, equal to 2240 lbs., is employed, but when dealing with copper *ores* the 21 cwt. ton of 2352 lbs. is taken; therefore, the *unit* equals 22·4 lbs. and 23·52 lbs. respectively.

Upcast (Min.). A *shaft* through which *return air* ascends.

Upheaved (Geo.). When a *seam* or *lode* has been broken and one part shifted upwards.

Valve (Eng.). Stops for steam, air, water, &c., generally used in pipes, e.g., *safety*, *slide*, *ball* or *spherical*, *conical* or *puppet*, *clap*, *clack*, *flap* or *door*, *butterfly*, *throttle*, *rotary*, *snifting*, *port*, *double seat* or *double beat*, *cup*, *check valve*, &c.

Vat (Met.). Large wooden tub used for *leaching* or *precipitation.*

V-bob (Min.). *Fend-off-bob*, or *Pull-back.* A two-limbed *bell-crank* secured with *bridles* for connecting with *pumping rods* over angles in a *shaft.*

Veins (Geo.). Sheets of mineral matter which have been formed since the rocks in which they occur.

Veinstone (Min.). The non-metallic portion of a *vein* associated with the *ore.*

Vernier-scale (Eng.). One scale moving upon another of different graduation, so as to enable one to read intermediate distances.

Vice (Eng.). *Bench-vice*, *Hand-vice.* Two strong iron *jaws* so hinged that they may be opened and closed by a powerful screw and *lever.*

Viewer (Min.). The general manager or mining engineer of one or more *collieries.*

Walking beam (Eng.). See *Working beam.*

Wall (Min.). The *face* of a *stall* called the *coal wall.*

Walling (Min.). The brick or stone lining of *shafts.*

Walling crib (Min.). Wooden *cribs* upon which *walling* is built.

Wallow (Eng.). A *water-wheel*, &c., is said to *wallow* when it does not revolve evenly in its *journals.*

Wall-plates (Min.). The two longest pieces of timber in a *set* used in a rectangular *shaft.*

Wash (Min.). *Drift*, *clay*, *gravel*, &c., from old river beds, &c.

Wash-dirt (Min.). That portion of *alluvial* working in which most of the gold is found.

Washer (Eng.). A flat disc with a round hole in the centre, used around *bolts* to receive the tightening strain from screw-*nuts.*

Wash-fault (Min.). A portion of a *seam* of coal replaced by *shale* or *sandstone.*

Waste (Min.). (1.) The more or less empty space between two *packs.*
(2.) *Mullock.*

Waste-gate (Eng.). A door for regulating discharge of surplus water.

Waste-weir (Eng.). An *overfall* provided along a *canal*, &c.,

over which the water may discharge itself in case of becoming too high. Sometimes called a *tumbling bay.*

Water cartridge (Min.). When the *cartridge* containing the explosive is surrounded by another containing water to destroy the flames produced by the *shot* when *fired.*

Watercourse. A channel or passage for water.

Watergate (Eng.). See *Waste-gate.*

Water gauge (Eng.). A *tap* or *float* for showing the height of water in *boilers*, &c.

Water hammer (Min.). The hammering noise caused by the intermittent escape of *gas* through water in *mines.*

Water level (Min.). That level in a mine at which water would remain constant if not drained. This varies slightly in winter and summer.

Water-right (Min.). The privilege of taking a certain quantity of water from a *water-course.*

Water-shed. The elevated land which divides drainage areas.

Water-wheel (Eng.). *Overshot*, *undershot*, *breast-wheels.* A wheel provided with *buckets*, which is set in motion by the weight or impact of a stream of water.

Weather (Geo.). To fall down or crumble when exposed to atmospheric agencies, &c.

Web (Min.). The *face* of a *long wall stall* in course of being *holed* and broken down for removal.

Wedging-crib (Min.). A crib of hollow cast iron upon which *tubbing* is built up, and to which it is tightly wedged, to stop back all water.

Weigh-bridge (Eng.). A platform large enough to carry a waggon, resting on a series of *levers*, by means of which heavy bodies are weighed.

Weir (Eng.). A *dam* over which water flows.

Weld (Eng.). To join two pieces of metal by first softening them by heat, and then hammering them together.

Well (Met.). The *well* of a *furnace* is the deepest lying portion or hollow in which the metal collects.

Whim (Min.). A large horizontal *drum*, supported by suitable framework, round which the rope attached to a bucket in the *shaft* is fixed. The whole is worked by a horse which walks round it.

Whip (Min.). A post fixed in the ground at an inclination of 45°, its upper end, to which a *pulley* is attached, overhanging a *shaft.* A rope with a bucket fixed to one end is passed over the *pulley*, and is drawn up by a horse moving along a *horse-walk.*

White damp (Min.). *Carbonic oxide.*

White tin (Met.). The commercial name for metallic tin.

Winch (Eng.). A strong power machine for hoisting heavy weights by winding a rope round a *barrel.*

Wind-bore (Eng.). The bottom or *suction pipe* of a *lift* of pumps which has suitable brass holes or perforations for suction of water or air.

Windlass (Min.). A long horizontal *barrel* with hook handles attached at one or both ends; used for winding ropes and weights.

Windmill (Eng.). A horizontal *axle* with vertical divergent *arms* and *sails* for obtaining power from the wind.

Windsail (Min.). The top part of canvas-piping which is used for conveying air down shallow *shafts.*

Wing-bore (Min.). A side or flank *bore-hole.*

Wing-dam (Eng.). A projection carried out part way across a shallow river for the temporary diversion of the water.

Winnowing gold (Min.). *Air-blowing.* Tossing up dry powdered auriferous material in the air, and catching the heavier particles not blown away.

Winze (Min.). A *shaft* extending from one *level* to another, but which does not come to the surface.

Wiper (Eng.). See *Cam.*

Work lead (Met.). *Base bullion,* silver lead.

Working barrel (Eng.). The *pump-tree* or cylinder in which the *bucket* moves up and down.

Working beam (Eng.). A beam having a vertical motion on a *rock shaft* at its centre, one end being connected with the *piston rod* and the other with a *crank* or *pump rod, &c.*

Worm (Eng.). The so-called *endless screw* which by revolving without advancing, gives motion to a *cog-wheel* (*worm-wheel*), the *teeth* of which catch in the *thread* of the screw.

Wrench (Eng.). A handle with an *eye* or *jaw* at one end, for gripping *nuts* when screwing them on or off.

Wrought iron (Met.). Iron in its minimum state of carburization.

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THE END.

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