TECHNICAL CHEMISTS' HANDBOOK

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TABLES AND METHODS OF ANALYSIS FOR MANUFACTURERS OF INORGANIC CHEMICAL PRODUCTS

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THIRD EDITION REVISED

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PREFACE

THE aim of *The Technical Chemists' Handbook* is to effect, as far as possible, the task of establishing uniformity among practical chemists, buyers and sellers, and analysts, in regard to both the numerical data employed in their work and the analytical methods used for the control of processes, and for the testing of the resulting products.

In the preparation of this new edition, all the analytical factors have been recalculated on the basis of the atomic weights published by the International Committee for 1916. This has involved in exceedingly numerous cases changes of the data contained in the last edition, some of them of importance even for merely practical purposes. The tables of specific gravities and other tables have been selected from among the most recent and reliable determinations.

In regard to the analytical methods, they are again chosen as before, on the principle that, as a rule, only *one* method should be given for each analytical operation, as well as for the preparation of standard solutions and for sampling the materials, in order to avoid discrepancies such as might arise should two or more methods be described. The method chosen should always, of course, be that which permits the greatest degree of accuracy possible that can be attained in a well-appointed works laboratory by a properly trained chemist. In cases where there is a choice between equally accurate methods, that occupying least time or least apparatus, or which is already widely known and employed, has been preferred. Many new methods have accordingly had to be omitted, but in all cases such omissions have been justified by means of a careful examination of the relative merits of the processes under consideration, and only such methods as were found thoroughly reliable have been included. Also, a considerable number of tables of specific gravities of solutions not previously worked out, or which were unsatisfactory, have been very carefully checked and extended.

When necessary, reference is made to the more complete treatment of the subject-matter in my larger treatise, published with the co-operation of Dr Charles A. Keane, under the title *Technical Methods of Chemical Analysis*, in three volumes of two parts each, in 1908-1914. This treatise is referred to in the text as *Tech. Meth.*

THE AUTHOR.

ZÜRICH, *Jan.* 1916.

PREFACE TO THE THIRD EDITION

In preparing a new edition of this book, I have kept to the general lines explained by Dr Lunge in his preface to the last edition. Revision has necessarily involved many minor alterations, but there is no change in the general scheme of the book.

In a book of this kind, accuracy in figures is obviously of the greatest importance, and so many errors were discovered that so far as possible all figures in the book have been recalculated.

I desire to thank many friends for information and assistance. One of them, Mr Allin Cottrell, kindly rewrote the section on Nitric Acid and Nitrates shortly before his untimely death.

Mr J. W. Parkes has my thanks for not only revising the section on Sulphuric Acid, but also for sending me a list of errors in the previous edition which was very helpful to me.

I desire also to thank specially Dr J. Knox for reading the proofs and Miss Deakin for proof-reading and a great deal of laborious checking of figures.

ALEX. C. CUMMING.

LIVERPOOL, *October* 1929.

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GENERAL TABLES

NOTE

All *temperatures* are given in degrees Centigrade, unless otherwise stated.

The *atomic weights* are those adopted by the International Committee on Atomic Weights as given in Table No. 1 referred to Oxygen = 16.

TABLE 1.—INTERNATIONAL ATOMIC WEIGHTS

According to the Table issued by the International Committee on Atomic Weights. (Revised to 1929.)

Aluminium	Al	27·1	Molybdenum	Mo	96·0
Antimony	Sb	120·2	Neodymium	Nd	144·3
Argon	A	39·9	Neon	Ne	20·2
Arsenic	As	74·96	Nickel	Ni	58·68
Barium	Ba	137·37	Niton	Nt	222·4
Bismuth	Bi	208·0	Nitrogen	N	14·008
Boron	B	10·9	Osmium	Os	190·9
Bromine	Br	79·92	Oxygen	O	16·000
Cadmium	Cd	112·40	Palladium	Pd	106·7
Cæsium	Cs	132·81	Phosphorus	P	31·04
Calcium	Ca	40·07	Platinum	Pt	195·2
Carbon	C	12·005	Potassium	K	39·10
Cerium	Ce	140·25	Praseodymium	Pr	140·9
Chlorine	Cl	35·46	Radium	Ra	226·0
Chromium	Cr	52·0	Rhodium	Rh	102·9
Cobalt	Co	58·97	Rubidium	Rb	85·45
Columbi	Cb	93·1	Ruthenium	Ru	101·7
Copper	Cu	63·57	Samarium	Sm	150·4
Dysprosium	Dy	162·5	Scandium	Sc	45·1
Erbium	Er	167·7	Selenium	Se	79·2
Europium	Eu	152·0	Silicon	Si	28·3
Fluorine	F	19·0	Silver	Ag	107·88
Gadolinium	Gd	157·3	Sodium	Na	23·00
Gallium	Ga	70·1	Strontium	Sr	87·63
Germanium	Ge	72·5	Sulphur	S	32·06
Glucinum	Gl	9·1	Tantalum	Ta	181·5
Gold	Au	197·2	Tellurium	Te	127·5
Helium	He	4·00	Terbium	Tb	159·2
Holmium	Ho	163·5	Thallium	Tl	204·0
Hydrogen	H	1·008	Thorium	Th	232·15
Indium	In	114·8	Thulium	Tu	168·5
Iodine	I	126·92	Tin	Sn	118·7
Iridium	Ir	193·1	Titanium	Ti	48·1
Iron	Fe	55·84	Tungsten	W	184·0
Krypton	Kr	82·92	Uranium	U	238·2
Lanthanum	La	139·0	Vanadium	V	51·0
Lead	Pb	207·20	Xenon	X	130·2
Lithium	Li	6·94	Ytterbium	Yb	173·5
Lutecium	Lu	175·00	Yttrium	Y	88·33
Magnesium	Mg	24·32	Zinc	Zn	65·37
Manganese	Mn	54·93	Zirconium	Zr	90·6
Mercury	Hg	200·6			

TABLE 2.—WEIGHTS AND MEASURES OF DIFFERENT COUNTRIES.

1. **Metric System** (compulsory in France, Germany, Austria, the Netherlands, Belgium, Luxemburg, Switzerland, Italy, Greece, Turkey, Roumania, Spain, Portugal, and most of the South American Republics; optional in Great Britain, the United States, and Russia).

1 metre (m.) = 443·296 Paris lignes = 3·280899 English feet = 3·18620 Prussian feet = 1·00000301 mètres des archives.
1 kilometre (km.) = 10 hectometres (hm.) = 0·6214 English mile = 0·1328 Prussian mile = 0·9375 Russian verst = 0·5390 nautical mile = 0·1347 geographical mile (15 to 1 degree of longitude).
1 lieue (France) = 1 myriametre = 10 km.
1 German mile = 7½ km. = 0·996 Prussian mile = 4·66 English miles.
1 hectare (ha.) = 100 ares (a.) = 10,000 sq.m. = 0·01 sq.km. = 2·471 English acres.
1 litre (l.) = 0·001 cb.m. = 1000 c.cm. = 0·2201 gallon.
1 hectolitre (hl.) = 0·1 cb.m. = 100 l. = 22·01 gallons.
1 kilogram (kg.) = 1000 g. = weight of 1 litre of water at +4° C. = 2 German and Swiss pounds (zollpfund) = 0·999999842 kilogram prototype = 2·2046 pounds avoirdupois = 1·7857 Austrian pounds = 2·3511 Swedish pounds = 2·4419 Russian pounds.
1 gram (g.) = 15·432 grains (English).
1 quintal = 100 kg. = 196·84 lbs. avoirdupois = 1 cwt. 3 qrs. 0·84 lb.
1 metrical ton = 1000 kg. = 0·9842 English ton = 1·1023 American short tons (at 2000 lbs.).

2. **Great Britain and Ireland.**

1 foot = 0·3047943 m.
1 inch = 25·3995 mm.
1 yard = 3 feet = 0·9143835 m.
1 fathom = 2 yards = 1·829 m.
1 rod (pole, perch) = 5½ yards = 5·029109 m.
1 chain = 22 yards. 80 chains = 1 mile.
1 statute mile = 8 furlongs = 320 poles = 1760 yards = 5280 feet = 1·6093 kilometre (km.).
1 nautical mile = $\frac{1}{60}$th degree (at the equator).
6082·66 feet = 1854·96 m.
1 acre = 4 roods = 160 poles = 0·40467 ha. = 43560 square feet = 4047 square metres.
1 square mile = 640 acres = 258·989 ha.
1 gallon = 4 quarts = 8 pints = 277·274 cubic inches = 4·536 litres.
1 cubic foot = 1728 cubic inches = 28·3153 l.
1 cubic inch = 16·3862 c.cm.
1 quarter = 8 bushels = 32 pecks = 64 gallons = 2·903 hl.
1 bushel = 8 gallons = 0·3628 hl.

TABLE 2—*Continued.*

1 fluid ounce = $\frac{1}{20}$th pint = 28·35 c.cm.
1 pound avoirdupois (lb.) = 16 ounces (oz.) = 7000 grains = 0·4535926 kg.
1 ounce avoirdupois = 437½ grains = 28·35 g.
1 gallon = 10 lbs. water = 70,000 grains = 4·535926 kg. water.
1 hundredweight (cwt.) = 4 quarters (qr.) = 8 stones = 112 lbs. = 50·8024 kg.
1 ton = 20 cwt. = 2240 lbs. = 1016·648 kg.

Apothecaries' Weight.

1 pound troy = 12 ounces troy = 96 drams = 288 scruples = 5760 grains = 373·24195 g.
1 ounce troy = 8 drams = 24 scruples = 480 grains = 31·1035 g.
1 ounce troy (for gold and precious stones) = 20 pennyweight (dwt.) = 480 grains = 31·1035 g.
1 pennyweight (dwt.) = 1·552 g.
1 grain (common to avoirdupois and troy weight) = 0·06479895 g.

3. **Austria** (old measures and weights, now abolished for the metric system).

1 foot = 0·316102 m., at 12 inches of 12 lines each.
3 ruthen = 5 klafter = 30 feet = 360 zoll.
1 meile = 4000 klafter = 7586·455 m.
1 maass = 1·415 l.
1 eimer = 40 maass = 160 seidel.
1 metze = 61·4995 l.
1 Wiener pfund = 560·012 g.
1 centner = 5 stein = 100 pfund = 3200 loth.

4. **Denmark and Norway** employ, as unit of measure, the Prussian foot, as unit of weight the units of the metrical system, viz., kilos, etc.

5. **Prussia** (old system, now abolished for the metric system).

1 foot (Rhenish foot) = 12 zoll (inches) = 144 linien = 0·313853 m.
1 ruthe = 12 fuss = 3·76624 m.
1 lachter (fathom) = 80 zoll = 2·09326 m.
1 meile = 24,000 fuss = 7532·5 m.
1 morgen = 180 square ruthen = 0·2553 ha.
1 quart = 64 cubic inches = $\frac{1}{27}$ cubic foot = 1·14503 l.
1 scheffel = 16 Metzen = 48 quarts = 0·54961 hl.
1 tonne = 4 scheffel = 2·19846 hl.
1 klafter = 108 cubic fuss = 3·3389 cb.m.
1 schachtruthe = 144 cubic fuss = 4·4519 cb.m.
1 pfund = 30 loth = 300 quentchen = 500 g.
1 centner = 100 pfund = 50 kg. (Formerly 1 pfund = 32 loth = 467·711 g.; 1 centner = 110 pfund.)

TABLE 2—*Continued.*

6. Russia.

1 foot = 1 English foot.
1 sashehn = 7 feet = 3 arshin = 12 tchetvert = 48 vershok = 2·13357 m.
1 verst = 500 sashehn = 1066·78 m.
1 dessatine = 2400 square sashehns = 10925 m.
1 vedro = 10 krushky (stoof) = 12·299 l.
1 tchetvert = 1 osmini = 4 payok = 8 tchetverik = 209·9 l.
1 pound = 32 loth = 96 solotnik = 9216 doli = 0·9028 Eng. lb. = 409·531 g.
1 berkovets = 10 pud = 400 pounds = 163·81 kg.
1 pud = 40 pounds = 36·112 Eng. lb. = 16·3805 kg.

7. Sweden.

1 foot = 10 zoll (inches) = 100 lines = 0·97408 Eng. foot = 0·296901 m.
1 famn (fathom) = 3 alnar (ells) = 6 feet = 5·58445 Eng. feet = 1·7814 m.
1 mile = 6000 fathoms = 6·6417 Eng. statute miles = 10·6884 km.
1 kanne = 100 cubic inches = 0·57694 Eng. gallon = 2·617 l.
1 skålpund = 100 korn (at 100 art) = 0·9378 Eng. lb. = 425·3395 g.
1 centner = 100 skålpund.
1 skipspund = 20 liespund = 400 skålpund.

8. Switzerland. Metrical measure and weight. The following are sometimes still employed :—

1 fuss = 0·3000 m. = 0·9843 Eng. foot.
1 juchart = 36 are = 0·88956 Eng. acre.
1 maass = 1·51 l.
1 saum = 100 maass = 151 l.

9. United States. Weights and measures as in Great Britain, but instead of the "long ton" (gross ton) of 2240 lbs., more frequently the "short ton" (net ton) of 2000 lbs. = 907·1852 kg. = 0·89285 long ton, is employed.

The U.S. gallon differs from the British gallon; it is = 3·7854 litres. For timber, the measure is the "cord" = 4 × 4 × 8 feet = 128 cubic feet = about 2½ cubic metres.

10. South America (Bolivia, Chile, Colombia, Ecuador, Guatemala, Honduras, Nicaragua, Peru, San Salvador, Venezuela)—1 quintal = 46·0093 kg.

Argentina . . .	1 quintal = 45·9367 kg.
Brazil	1 ,, = 58·752 ,,
Paraguay . . .	1 ,, = 46·008 ,,
Uruguay . . .	1 ,, = 45·94 ,,

TABLE 2—*Continued.*

Square Feet, Square Metre.

1 square metre (sq.m.) = 10·764 square feet (English and Russian) = 10·008 square feet (Austrian) = 10·152 square feet (Prussian and Danish) = 11·344 square feet (Swedish).
1 square foot (English and Russian) = 0·09290 square metre.

Cubic Feet, Cubic Metre.

1 cubic metre (cb.m.) = 35·316 cubic feet (English and Russian).
1 ,, ,, = 31·66 ,, (Austrian).
1 ,, ,, = 32·346 ,, (Prussian and Danish).
1 ,, ,, = 38·209 ,, (Swedish).
1 cubic foot (English and Russian) = 0·028315 cubic metre.

1 Kilogram per Running Metre

= 0·6719 English pound per running foot.
= 0·6277 zollpfund per Prussian foot.
1 English pound per 1 English foot = 1·4882 kg. per running metre.

1 Kilogram per Square Centimetre (for steam pressure)

= 14·223 English pounds per square inch.
= 13·681 zollpfund per Prussian square inch.
= 13·878 zollpfund per Austrian square inch.

HORSE-POWER (per second).

Kg.-m.	Austria. Foot-pounds.	Prussia. Foot-pounds.	England. Foot-pounds.	Sweden. Foot-pounds.	Russia. Foot-pounds.
75	474·53	477·93	542·47	593·90	600·85
76·041	481·11	484·56	550	602·14	609·19

75 kilogram-metres taken as unit,
550 English foot-pounds taken as unit,
= 1 Admiralty horse-power per second;
or, 33,000 foot-pounds per minute.

TABLE 3.—TABLES FOR CONVERTING ENGLISH TO METRICAL WEIGHTS AND MEASURES, AND VICE VERSA.

Reduction of Metrical Measure to English Measure.

Metre. Sq.m. Cub.m.	Feet.	Inches.	Square feet.	Square inches.	Cubic feet.	Cubic inches.
1	3·2809	39·3706	10·7642	1550·05	35·3161	61026·2
2	6·5618	78·7412	21·5284	3100·09	70·6322	122052·4
3	9·8427	118·1118	32·2926	4650·13	105·9483	183078·6
4	13·1235	157·4824	43·0568	6200·18	141·2644	244104·9
5	16·4044	196·8530	53·8210	7750·23	176·5805	305131·1
6	19·6853	236·2237	64·5852	9300·27	211·8966	366157·3
7	22·9662	275·5943	75·3494	10850·31	247·2126	427183·5
8	26·2471	314·9649	86·1136	12400·36	282·5287	488209·7
9	29·5280	354·3355	96·8778	13950·40	317·8448	549235·9

English Feet = Metres.

Ft.	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
0	0·0000	0 3048	0·6096	0·9144	1·2192	1·5240	1·8288	2·1336	2·4384	2·7432
10	3·0479	3·3527	3·6575	3·9623	4·2671	4·5719	4·8767	5·1815	5·4863	5·7911
20	6·0959	6·4007	6·7055	7·0103	7·3151	7·6199	7·9247	8·2295	8·5342	8·8390
30	9·1438	9·4486	9·7534	10·058	10·363	10·668	10·973	11·277	11·582	11·887
40	12·192	12·497	12·801	13·106	13·411	13·716	14·021	14·325	14·630	14·935
50	15·240	15·545	15·849	16·154	16·459	16·764	17·068	17·373	17 678	17·983
60	18·288	18·592	18·897	19·202	19·507	19·812	20·116	20·421	20·726	21·031
70	21·336	21·640	21·945	22·250	22·555	22·860	23·164	23·469	23·774	24·079
80	24·384	24·688	24·993	25·298	25·603	25·908	26·211	26·517	26·832	27·127
90	27·432	27·736	28·041	28·346	28·651	28·955	29·260	29·565	29·870	30·175
100	30·479	30·784	31·089	31·394	31·699	32·003	32·308	32·613	32·918	33 223
110	33·527	33·832	34·137	34·442	34·747	35·051	35·356	35·661	35·966	36·271
120	36·575	36·880	37·185	37·490	37·795	38·099	38·404	38·709	39·014	39·318
130	39·623	39·928	40·233	40·538	40·842	41·147	41·452	41·757	42·062	42·366
140	42·671	42·976	43·281	43·586	43·890	44·195	44·500	44·805	45·110	45·414
150	45·719	46·024	46·329	46·634	46·938	47·243	47·548	47·853	48·158	48·462
160	48·767	49·072	49·377	49·642	49·986	50·291	50·596	50·901	51·205	51·510
170	51·815	52·120	52·425	52·729	53·034	53·339	53·664	53·948	54·253	54·558
180	54·863	55·168	55·473	55·777	56·082	56·387	56·692	56·997	57·301	57·606
190	57·911	58·216	58·521	58·825	59·130	59·435	59·740	60·045	60·349	60·654

English Inches = Millimetres.

Inch.	Millimetres.	Inches.	Millimetres.	Inches.	Millimetres.
$\frac{1}{64}$	0·39	1	25·4	7	177·8
$\frac{1}{32}$	0·79	2	50·8	8	203·2
$\frac{1}{16}$	1·59	3	76·2	9	228·6
$\frac{1}{8}$	3·17	4	101·6	10	254·0
$\frac{1}{4}$	6·35	5	127·0	11	279·4
$\frac{1}{2}$	12·70	6	152·4	12	304·8

English Square Feet = Square Metres.

Sq. ft.	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
0	0·0000	0·0929	0·1858	0·2787	0·3716	0·4645	0·5574	0·6503	0·7432	0·8361
10	0·9290	1·0219	1·1148	1·2077	1·3006	1·3935	1·4864	1·5793	1·6722	1·7651
20	1·8580	1·9509	2·0438	2·1367	2·2296	2·3225	2·4154	2·5083	2·6012	2·6941
30	2·7870	2·8799	2·9728	3·0657	3·1586	3·2515	3·3444	3·4373	3·5302	3·6231
40	3·7160	3·8089	3·9018	3·9947	4·0876	4·1805	4·2734	4·3663	4·4592	4·5521
50	4·6450	4·7379	4·8308	4·9237	5·0166	5·1095	5·2024	5·2953	5·3882	5·4811
60	5·5740	5·6669	5·7598	5·8527	5·9456	6·0385	6·1314	6·2243	6·3172	6·4101
70	6·5030	6·5959	6·6888	6·7817	6·8746	6·9675	7·0604	7·1533	7·2462	7·3391
80	7·4320	7·5249	7·6178	7·7107	7·8036	7·8965	7·9894	8·0823	8·1752	8·2681
90	8·3610	8·4539	8·5468	8·6397	8·7326	8·8255	8·9184	9·0113	9·1042	9·1971

English Square Inches = Square Centimetres.

Sq. ins	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
0	0·0000	6·4514	12·903	19·354	25·805	32·257	38·708	45·160	51·611	58·062
10	64·514	70·965	77·416	83·868	90·319	96·771	103·22	109·67	116·12	122·58
20	129·03	135·48	141·93	148·38	154·83	161·28	167·74	174·19	180·64	187·09
30	193·54	199·99	206·44	212·90	219·35	225·80	232·25	238·70	245·15	251·60
40	258·05	264·51	270·96	277·41	283·86	290·31	296·76	303·21	309·67	316·12
50	322·57	329·02	335·47	341·92	348·37	354·83	361·28	367·73	374·18	380·63
60	387·08	393·53	399·98	406·44	412·89	419·34	425·79	432·24	438·69	445·14
70	451·60	458·05	464·50	470·95	477·40	483·85	490·30	496·76	503·21	509·69
80	516·11	522·56	525·01	535·46	541·91	548·37	554·82	561·27	567·72	574·17
90	580·62	587·07	593·53	599·98	606·43	612·88	619·33	625·78	632·23	638·66

English Cubic Feet = Cubic Metres.

Cub. ft.	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
0	0·0000	0·0283	0·0566	0·0849	0·1133	0·1416	0·1699	0·1982	0·2265	0·2548
10	0·2832	0·3115	0·3398	0·3681	0·3964	0·4247	0·4530	0·4814	0·5097	0·5380
20	0·5668	6·5946	0·6229	0·6513	0·6796	0·7079	0·7362	0·7645	0·7928	0·8211
30	0·8494	0·8778	0·9061	0·9344	0·9627	0·9910	1·0194	1·0477	1·0760	1·1043
40	1·1326	1·1609	1·1892	1·2176	1·2459	1·2742	1·3025	1·3308	1·3591	1·3875
50	1·4158	1·4441	1·4724	1·5007	1·5290	1·5573	1·5857	1·6140	1·6423	1·6706
60	1·6989	1·7272	1·7555	1·7839	1·8122	1·8405	1·8688	1·8971	1·9254	1·9538
70	1·9821	2·0104	2·0387	2·0670	2·0953	2·1236	2·1520	2·1803	2·2086	2·2369
80	2·2652	2·2935	2·3219	2·3502	2·3785	2·4068	2·4351	2·4634	2·4917	2·5201
90	2·5484	2·5767	2·6050	2·6333	2·6616	2·6900	2·7183	2·7466	2·7749	2·8032

English Cubic Inches = Cubic Centimetres.

Cub. in.	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
0	0·0000	16·386	32·772	49·159	65·545	81·931	98·317	114·70	131·09	147·48
10	163·86	180·25	196·63	213·02	229·41	245·79	262·18	278·56	294·95	311·34
20	327·72	344·11	360·50	376·88	393·27	409·65	426·04	442·43	458·81	475·20
30	491·59	507·97	524·36	540·74	557·13	573·52	589·90	606·29	622·67	639·06
40	655·45	671·83	688·22	704·61	720·99	737·38	753·76	770·15	786·54	802·92
50	819·31	835·69	852·08	868·47	884·85	901·24	917·63	934·01	950·40	966·78
60	983·17	999·56	1015·9	1032·3	1048·7	1065·1	1081·5	1097·9	1114·3	1130·6
70	1147·0	1163·4	1179·8	1196·2	1212·6	1229·0	1245·3	1261·7	1278·1	1294·5
80	1310·9	1327·3	1343·7	1360·1	1376·4	1392·8	1409·2	1452·6	1440·0	1458·4
90	1474·8	1491·1	1507·5	1523·9	1540·3	1556·7	1573·1	1589·5	1605·8	1622·2

English Pounds = Kilograms.

Lbs.	0.	1.	2.	3.	4.	5	6.	7.	8.	9.
0	0·0000	0·4536	0·9072	1·3608	1·8144	2·2680	2·7216	3·1751	3·6287	4·0823
10	4·5359	4·9895	5·4431	5·8967	6·3503	6·8039	7·2575	7·7111	8·1647	8·6183
20	9·0719	9·5254	9·9790	10·433	10·886	11·340	11·793	12·247	12·701	13·154
30	13·608	14·061	14·515	14·969	15·422	15·876	16·329	16·783	17·237	17·690
40	18·144	18·597	19·051	19·504	19·958	20·412	29·865	21·319	21·772	22·226
50	22·680	23·133	23·587	24·040	24·494	24·948	25·401	25·855	26 308	26·762
60	27·216	27·669	28·123	28·576	29·030	29·484	29·937	30·391	30·844	31·296
70	31·751	32·205	32·659	33·112	33·566	34·019	34·473	34·927	35·380	35·834
80	36·287	36·741	37·195	37·648	38·102	38·555	39·009	39·463	39·916	40·370
90	40·823	41·277	41·731	42·184	42·638	43·091	43·545	43·998	44·452	44·906

English Tons = Kilograms.

Tons.	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
0	0·0000	1016	2032	3048	4064	5080	6096	7112	8129	9145
10	10161	11177	12193	13209	14225	15241	16257	17273	18289	19305
20	20321	21337	22353	23369	24386	25402	26418	27434	28450	29466
30	30482	31498	32514	33530	34546	35562	36578	37594	38610	39627
40	40643	41659	42675	43691	44707	45723	46739	47755	48771	49787
50	50803	51819	52835	53851	54868	55884	56900	57916	58932	59948
60	60964	61980	62996	64012	65028	66044	67060	68076	69092	70108
70	71125	72141	73157	74173	75189	76205	77221	78237	79253	80269
80	81285	82302	83317	84333	85346	86366	87382	88398	89414	90430
90	91446	92246	93478	94494	95510	96526	97542	98558	99574	100590

English Grains = Grams.

Grains.	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
—	0	·065	·1296	·194	·259	·324	·389	·454	·518	·583
10	·648	·713	·778	·842	·907	972	1·037	1·102	1·166	1·231
20	1·296	1·361	1·426	1·490	1·555	1·620	1·685	1·749	1·814	1·879
30	1·944	2·009	2·074	2·138	2·203	2·268	2·333	2·397	2·462	2·527
40	2·592	2·657	2·721	2·786	2·851	2·916	2·981	3·045	3·110	3·175
50	3·240	3·305	3·369	3·434	3·499	3·564	3·629	3·693	3·758	3·823
60	3·888	3·953	4·018	4·082	4·147	4·212	4·277	4·341	4·406	4·471
70	4·536	4·601	4·666	4·730	4·795	4·860	4·925	4·989	5·054	5·119
80	5·184	5 249	5·314	5·378	5·443	5·508	5·573	5·637	5·702	5·767
90	5·832	5·897	5·962	6·026	6·091	6·156	6·221	6·286	6·350	6·415

Grams = English Grains.

Grams.	0.	·1.	·2.	·3.	·4.	·5.	·6.	·7.	·8.	·9.
0	0	1·543	3·086	4·629	6·172	7·716	9·259	10·802	12·345	13·888
1	15·482	16·975	18·518	20·061	21·604	23·148	24·691	26·234	27·777	29·320
2	30·864	32·407	33·950	35·493	37·036	38·580	40·123	41·666	43·209	44·752
3	46·296	47·839	49·382	50·925	52·468	54·012	55·555	57·098	58·641	60·184
4	61·728	63·271	64·814	66·875	67·900	69·444	70·987	72·530	74·073	75·616
5	77·160	78·703	80·246	81·789	83·332	84·876	86·419	87·962	89·505	91·048

Conversion of English to Metric Measures.

1 English pound (lb.) per sq. foot = 4·883 kg. per sq. metre (sq. m.).
1 ,, ,, ,, sq. inch = 0·07031 kg. per sq. m.
1 ,, ton per sq. inch = 158 kg. per sq. cm.
1 ,, pound per cub. foot = 16·02 gm. per litre.
1 kilogram per sq. metre = 0·2048 lb. per sq. foot.
1 English grain per gallon = 0·014286 gm. per litre.
1 ,, ,, ,, English cub. foot = 2·287 gm. per cub. metre.
1 grm. per litre = 70 grains per gallon = 0·06243 lb. per cub. foot.
1 metre-kilogram (mkg.) = 7·235 foot pounds.
1 foot-pound = 0·1382 mkg.
1 foot-pound per cub. foot = 4·8807 mkg. per cub. met.

(See also page 109 for other figures used in converting English to metric measures and *vice versa*.)

TABLE 4.—COMPARISON OF THERMOMETRIC SCALES.

$t°C = \frac{4}{5}t°R = \frac{9}{5}t + 32°F\ ;\ t°R = \frac{5}{4}t°C = \frac{9}{4}t + 32°F\ ;\ t°F = \frac{5}{9}(t - 32°)C = \frac{4}{9}(t - 32°)R.$

Celsius' (Centigrade) degrees as units.

Cels.	Réau.	Fahr.	Cels	Réau.	Fahr	Cels.	Réau.	Fahr.	Cels.	Réau.	Fahr.	Cels.	Réau.	Fahr.	Cels.	Réau.	Fahr.
−40	−32	−40	−16	−12·8	+3·2	+8	+6·4	+46·4	+32	+25·6	+89·6	+55	+44	+131	+78	+62·4	+172·4
39	31·2	38·2	15	12	5	9	7·2	48·2	33	26·4	91·4	56	44·8	132·8	79	63·2	174·2
38	30·4	36·4	14	11·2	6·8	10	8	50	34	27·2	93·2	57	45·6	134·6	80	64	176
37	29·6	34·6	13	10·4	8·6	11	8·8	51·8	35	28	95	58	46·4	136·4	81	64·8	177·8
36	28·8	32·8	12	9·6	10·4	12	9·6	53·6	36	28·8	96·8	59	47·2	138·2	82	65·6	179·6
35	28	31	11	8·8	12·2	13	10·4	55·4	37	29·6	98·6	60	48	140	83	66·4	181·4
34	27·2	29·2	10	8	14	14	11·2	57·2	38	30·4	100·4	61	48·8	141·8	84	67·2	183·2
33	26·4	27·4	9	7·2	15·8	15	12	59	39	31·2	102·2	62	49·6	143·6	85	68	185
32	25·6	25·6	8	6·4	17·6	16	12·8	60·8	40	32	104	63	50·4	145·4	86	68·8	186·8
31	24·8	23·8	7	5·6	19·4	17	13·6	62·6	41	32·8	105·8	64	51·2	147·2	87	69·6	188·6
30	24	22	6	4·8	21·2	18	14·4	64·4	42	33·6	107·6	65	52	149	88	70·4	190·4
29	23·2	20·2	5	4	23	19	15·2	66·2	43	34·4	109·4	66	52·8	150·8	89	71·2	192·2
28	22·4	18·4	4	3·2	24·8	20	16	68	44	35·2	111·2	67	53·6	152·6	90	72	194
27	21·6	16·6	3	2·4	26·6	21	16·8	69·8	45	36	113	68	54·4	154·4	91	72·8	195·8
26	20·8	14·8	2	1·6	28·4	22	17·6	71·6	46	36·8	114·8	69	55·2	156·2	92	73·6	197·6
25	20	13	1	0·8	30·2	23	18·4	73·4	47	37·6	116·6	70	56	158	93	74·4	199·4
24	19·2	11·2	0	0	32	24	19·2	75·2	48	38·4	118·4	71	56·8	159·8	94	75·2	201·2
23	18·4	9·4	+1	+0·8	33·8	25	20	77	49	39·2	120·2	72	57·6	161·6	95	76	203
22	17·6	7·6	2	1·6	35·6	26	20·8	78·8	50	40	122	73	58·4	163·4	96	76·8	204·8
21	16·8	5·8	3	2·4	37·4	27	21·6	80·6	51	40·8	123·8	74	59·2	165·2	97	77·6	206·6
20	16	4	4	3·2	39·2	28	22·4	82·4	52	41·6	125·6	75	60	167	98	78·4	208·4
19	15·2	2·2	5	4	41	29	23·2	84·2	53	42·4	127·4	76	60·8	168·8	99	79·2	210·2
18	14·4	0·4	6	4·8	42·8	30	24	86	54	43·2	129·2	77	61·6	170·6	100	80	212
17	13·6	+1·4	7	5·6	44·6	31	24·8	87·8	...	...	...	...	...	...	...	...	...

TABLE 5.—COMPARISON OF THERMOMETRIC SCALES WITH FAHRENHEIT DEGREES AS UNITS.

Fah.	Cel.	Réau.	Fah.	Cel.	Réau.	Fah.	Cel.	Réau.	Fah.	Cel.	Réau.	Fah.	Cel.	Réau.	Fah.	Cel.	Réau.	Fah.	Cel.	Réau.
−40	−40·0	−32·0	−3	−19·4	−15·6	+33	+0·6	+0·4	+69	+20·6	+16·4	+105	+40·6	+32·4	+141	+60·6	+48·4	+177	+80·6	+64·4
39	39·4	31·6	2	18·9	15·1	34	1·1	0·9	70	21·1	16·9	106	41·1	32·9	142	61·1	48·9	178	81·1	64·9
38	38·9	31·1	1	18·3	14·7	35	1·7	1·3	71	21·7	17·3	107	41·7	33·3	143	61·7	49·3	179	81·7	65·3
37	38·3	30·7	0	17·8	14·2	36	2·2	1·8	72	22·2	17·8	108	42·2	33·8	144	62·2	49·8	180	82·2	65·8
36	37·8	30·2	+1	17·2	13·8	37	2·8	2·2	73	22·8	18·2	109	42·8	34·2	145	62·8	50·2	181	82·8	66·2
35	37·2	29·8	2	16·7	13·3	38	3·3	2·7	74	23·3	18·7	110	43·3	34·7	146	63·3	50·7	182	83·3	66·7
34	36·7	29·3	3	16·1	12·9	39	3·9	3·1	75	23·9	19·1	111	43·9	35·1	147	63·9	51·1	183	83·9	67·1
33	36·1	28·9	4	15·6	12·4	40	4·4	3·6	76	24·4	19·6	112	44·4	35·6	148	64·4	51·6	184	84·4	67·6
32	35·6	28·4	5	15·0	12·0	41	5·0	4·0	77	25·0	20·0	113	45·0	36·0	149	65·0	52·0	185	85·0	68·0
31	35·0	28·0	6	14·4	11·6	42	5·6	4·4	78	25·6	20·4	114	45·6	36·4	150	65·6	52·4	186	85·6	68·4
30	34·4	27·6	7	13·9	11·1	43	6·1	4·9	79	26·1	20·9	115	46·1	36·9	151	66·1	52·9	187	86·1	68·9
29	33·9	27·1	8	13·3	10·7	44	6·7	5·3	80	26·7	21·3	116	46·7	37·3	152	66·7	53·3	188	86·7	69·3
28	33·3	26·7	9	12·8	10·2	45	7·2	5·8	81	27·2	21·8	117	47·2	37·8	153	67·2	53·8	189	87·2	69·8
27	32·8	26·2	10	12·2	9·8	46	7·8	6·2	82	27·8	22·2	118	47·8	38·2	154	67·8	54·2	190	87·8	70·2
26	32·2	25·8	11	11·7	9·3	47	8·3	6·7	83	28·3	22·7	119	48·3	38·7	155	68·3	54·7	191	88·3	70·7
25	31·7	25·3	12	11·1	8·9	48	8·9	7·1	84	28·9	23·1	120	48·9	39·1	156	68·9	55·1	192	88·9	71·1
24	31·1	24·9	13	10·6	8·4	49	9·4	7·6	85	29·4	23·6	121	49·4	39·6	157	69·4	55·6	193	89·4	71·6
23	30·6	24·4	14	10·0	8·0	50	10·0	8·0	86	30·0	24·0	122	50·0	40·0	158	70·0	56·0	194	90·0	72·0
22	30·0	24·0	15	9·4	7·6	51	10·6	8·4	87	30·6	24·4	123	50·6	40·4	159	70·6	56·4	195	90·6	72·4
21	29·4	23·6	16	8·9	7·1	52	11·1	8·9	88	31·1	24·9	124	51·1	40·9	160	71·1	56·9	196	91·1	72·9
20	28·9	23·1	17	8·3	6·7	53	11·7	9·3	89	31·7	25·3	125	51·7	41·3	161	71·7	57·3	197	91·7	73·3
19	28·3	22·7	18	7·8	6·2	54	12·2	9·8	90	32·2	25·8	126	52·2	41·8	162	72·2	57·8	198	92·2	73·8
18	27·8	22·2	19	7·2	5·8	55	12·8	10·2	91	32·8	26·2	127	52·8	42·2	163	72·8	58·2	199	92·8	74·2
17	27·2	21·8	20	6·7	5·3	56	13·3	10·7	92	33·3	26·7	128	53·3	42·7	164	73·3	58·7	200	93·3	74·7
16	26·7	21·3	21	6·1	4·9	57	13·9	11·1	93	33·9	27·1	129	53·9	43·1	165	73·9	59·1	201	93·9	75·1
15	26·1	20·9	22	5·6	4·4	58	14·4	11·6	94	34·4	27·6	130	54·4	43·6	166	74·4	59·6	202	94·4	75·6
14	25·6	20·4	23	5·0	4·0	59	15·0	12·0	95	35·0	28·0	131	55·0	44·0	167	75·0	60·0	203	95·0	76·0
13	25·0	20·0	24	4·4	3·6	60	15·6	12·4	96	35·6	28·4	132	55·6	44·4	168	75·6	60·4	204	95·6	76·4
12	24·4	19·6	25	3·9	3·1	61	16·1	12·9	97	36·1	28·9	133	56·1	44·9	169	76·1	60·9	205	96·1	76·9
11	23·9	19·1	26	3·3	2·7	62	16·7	13·3	98	36·7	29·3	134	56·7	45·3	170	76·7	61·3	206	96·7	77·3
10	23·3	18·7	27	2·8	2·2	63	17·2	13·8	99	37·2	29·8	135	57·2	45·8	171	77·2	61·8	207	97·2	77·8
9	22·8	18·2	28	2·2	1·8	64	17·8	14·2	100	37·8	30·2	136	57·8	46·2	172	77·8	62·2	208	97·8	78·2
8	22·2	17·8	29	1·7	1·3	65	18·3	14·7	101	38·3	30·7	137	58·3	46·7	173	78·3	62·7	209	98·3	78·7
7	21·7	17·3	30	1·1	0·9	66	18·9	15·1	102	38·9	31·1	138	58·9	47·1	174	78·9	63·1	210	98·9	79·1
6	21·1	16·9	31	0·6	0·4	67	19·4	15·6	103	39·4	31·6	139	59·4	47·6	175	79·4	63·6	211	99·4	79·6
5	20·6	16·4	32	+0·0	+0·0	68	20·0	16·0	104	40·0	32·0	140	60·0	48·0	176	80·0	64·0	212	100·0	80·0
4	20·0	16·0																		

TABLE 6.—CONVERSION OF CENTIGRADE INTO FAHRENHEIT DEGREES ABOVE 100, AND VICE VERSA.

Divide the degrees above 100 into hundreds and a remainder. The figure corresponding to the hundreds is taken from the following tables and added to that corresponding to the remainder as taken from Table 4. If, on converting Fahrenheit into Centigrade, the "remainder" amounts to 32°, or less, the degrees Centigrade corresponding to it are negative (below freezing point), and hence must be *deducted* from the figures of the following table. Also note, for example, that 300° F. is not = 166·7° C., but = 166·7 − 17·8, = 148·9° C.

A.

C.	Fahr.	C.	Fahr.	C.	Fahr.	C.	Fahr.
100	180	600	1080	1100	1980	1600	2880
200	360	700	1260	1200	2160	1700	3060
300	540	800	1440	1300	2340	1800	3240
400	720	900	1620	1400	2520	1900	3420
500	900	1000	1800	1500	2700	2000	3600

B.

Fahr.	C.	Fahr.	C.	Fahr.	C.	Fahr.	C.
100	55·6	1000	556·6	1900	1055·6	2800	1555·6
200	111·1	1100	611·1	2000	1111·1	2900	1611·1
300	166·7	1200	666·7	2100	1166·7	3000	1666·7
400	222·2	1300	722·2	2200	1222·2	3100	1722·2
500	277·8	1400	777·8	2300	1277·8	3200	1777·8
600	333·3	1500	833·3	2400	1333·3	3300	1833·3
700	388·9	1600	888·9	2500	1388·9	3400	1888·9
800	444·4	1700	944·4	2600	1444·4	3500	1944·4
900	500	1800	1000	2700	1500	...	...

TABLE 7.—THE UNITS OF ENERGY AND WORK.

The "absolute" unit of mechanical energy, the **erg**, is the product of the unit of length into the "absolute" unit of force, or **dyne**, *i.e.*, the force necessary to impart to a mass of 1 gram in a second a velocity of 1 cm. per second.

For most purposes, it is more convenient to use a gravitation unit, in the definition of which the value of the earth's gravitation attraction for bodies on its surface is involved. The unit of force, thus defined, is the weight of 1 gram and is equal to 981 dynes. The corresponding unit of mechanical energy is the product of this unit into the unit of length, *i.e.*, the **gram-centimetre.**

The relations between the mechanical unit of energy and the units of heat and electricity are given in Tables 8 and 10.

TABLE 8.—THE UNIT OF HEAT.

The usual unit of heat for chemical purposes is the "small calorie" or **gram-calorie** (cal.). It is roughly defined as the quantity of heat required to raise 1 gram of water 1° C., but as this quantity is not exactly the same for all temperatures, it is necessary to specify the temperature. The normal calorie is that which raises 1 gram of water from 14·5° to 15·5°.

The great or **kilogram-calorie** (Cal.) is 1000 times the small calorie. The **centuple-calorie** (K) is the quantity of heat required to raise 1 gram of water from 0° to 100°, and is very nearly equal to 100 small calories. We have then

$$1 \text{ Cal.} = 10 \text{ K} = 1000 \text{ cal.}$$

Another unit of heat used for thermochemical work is the **joule**, which is equivalent to 10,000,000 ergs. It is denoted by the letter j, while a larger unit, the kilojoule, equal to 1000 j is denoted by the symbol Kj. The relations between these and the calorie are as follows:—

1 cal = 4·189 j.	1 j = 0·2387 cal.
1 Cal = 4·189 Kj.	1 Kj = 0·2387 Cal.

The **British heat-unit**, is the quantity of heat required to raise 1 pound of water from 32° to 33° Fahr. and is = 252 gram-calories. The British thermal unit is denoted by the symbol B.Th.U.

TABLE 8—*Continued.*

(*a*) Calorific Value of Fuels.

(The data given are the *upper* heating values, *i.e.*, they are referred to the combustion of hydrogen to liquid water as found in the calorimeter.)

	gram-cal.		gram-cal.
Ether	9,000	Petroleum residue	10,500
Alcohol	7,100	Petroleum	11,000
Lignite-tar oil	9,950	Fatty oils	9,300
Wood	4,100	Tallow	8,370
Methyl alcohol	5,300	Beeswax	9,000
Charcoal (C to CO_2)	8,000	Cellulose	4,200
,, (C to CO)	2,300		

(*b*) Calorific Value of Gases.

	Molec. Weight.	Calories when one gram-mol. is burnt to		Calories per cub. met. when burnt to	
		Liquid Water.	Steam.	Liquid Water.	Steam.
Hydrogen, H_2	2	69·0	58·1	3064	2585
Methane, CH_4	16	213·5	192·1	9565	8606
Ethylene, C_2H_4	28	334·8	313·4	14,999	14,060
Benzene vapour, C_6H_6	78	788·0	755·9	35,302	33,864
Naphthalene vapour, $C_{10}H_8$	128	1258 4	1230·6	50,376	55,131
Carbon monoxide, CO	28	68·4	68·4	3064	3064

TABLE 9.—THE EVAPORATION UNIT.

(G. A. Rossetti.)

After the fundamental unit, the British thermal unit (B.Th.U.), the most important unit of heat measurement in use among engineers is the evaporation unit (ev.u.). The B.Th.U. means the amount of heat needed to raise 1 lb. of water 1° F. at the mean specific heat of water between 32° F. and 212° F.; the ev.u. means the amount of heat needed to convert 1 lb. of water at 212° F. into saturated steam at the same temperature and consequently at the atmospheric pressure of 14·7 lb. per sq. in.

TABLE 9—*Continued.*

In the case of boilers generating steam for power production and for various industrial uses, the conditions of this steam generation vary widely, and, in order readily to compare results from different sources, it is customary to reduce the boiler output to evaporation units (sometimes termed "lb. evaporated as from and at 212° F."). For this reduction it is necessary to know the equivalent of the evaporation unit in British thermal units. This equivalent is given in the steam tables, the best known of which are those of Professors Callendar, Marks and Davis, and Peabody. Of these, Professor Callendar's table is probably the most reliable, being founded on the soundest basis yet possible, both theoretical and experimental. The table of Professors Marks and Davis is recognised as standard in the United States, and is frequently specified as the basis for test calculations by British engineers. Professor Peabody's table, though perhaps somewhat superseded by the two later tables, was undoubtedly the best authority on the subject twelve years ago, when its eighth edition was published. Naturally, the principal differences between these tables occur in regard to the properties of steam at the higher temperatures and pressures, where experimental difficulties are most serious. But there is not absolute agreement as to the fundamental constant, the number of British thermal units equivalent to one evaporation unit. The following table gives the equivalent of the ev.u. in B.Th.U. according to each of the three authorities above mentioned, and also gives the conversion factor for each of the values of the ev.u. in terms of each of the others, and for the number of ev.u. equivalent to 1000 B.Th.U. The logarithm of each of the

Conversion Factors and Logarithms.

	Factor.		Logarithm.
1 Ev.u. (C.)	= 970·74	B.Th.U.	2·98710293
	= 1·00035037	Ev.u (M. & D.)	0·00015214
	= 1·00107250	Ev.u. (P.)	0·00046553
1 Ev.u. (M. & D.)	= 970·4	B.Th.U.	2·98695079
	= 0·99964976	Ev.u. (C.)	0·99984786-1
	= 1·00072187	Ev.u. (P.)	0 00031839
1 Ev.u (P)	= 969·7	B.Th.U.	2·98663740
	= 0·99892865	Ev.u. (C.)	0·99953447-1
	= 0·99927865	Ev.u. (M. & D.)	0·99968661-1
1,000 B.Th.U.	= 1·03014195	Ev.u. (C.)	0·01289707
	= 1·03050288	Ev.u. (M. & D.)	0·01304921
	= 1·03124679	Ev.u. (P.)	0·01336260

conversion factors is also given, thus providing assistance for calculations. The several values of the evaporation unit are referred to by the initials (C.), (M. and D.), (P.).

TABLE 10.—ELECTRICAL UNITS.

A **joule** or watt-second is the unit of electrical energy and is defined as the energy expended in one second by an unvarying electric current of one ampere flowing under an electrical pressure of one volt.

For technical use, the above units are inconveniently small and the following are the units commonly used in practice.

A **kilowatt** (K.W.) is 1000 watts. The kilowatt-hour, 1000 watt-hours, is commonly known in this country as the Board of Trade Unit (B.T.U.).

One **horse-power** (H.P.) is 746 watts. (The value taken for one H.P. in Germany is 736 watts.)

The **kilowatt-hour** (K.W.H.) and **horse-power hour** (H.P.H.) are the energy units which represent the energy consumption per hour of systems absorbing energy at the respective rates of one kilowatt and one horse-power. A horse-power year is not a recognised unit, but an H.P. year is generally taken as 8760 H.P.H. The quantitative relations between electrical energy and heat energy are as follows:—

1 joule = 0·23835 *cal.* (gram-calories).
1 kilo-joule (kilowatt-second) = 0·23865 *Cal.* (kilogram-calories).
1 cal. = 4·189 joules.
1 Cal. = 4·189 kilowatt-seconds.

TABLE 11.—ELECTRO-CHEMICAL EQUIVALENTS.

The separation of a gram equivalent requires 96,540 coulombs = 26·86 ampere hours. 1 ampere hour is capable of yielding:—

	Grams.		Grams.
Silver	4·0228	Platinum	3·6395
Copper (from solutions of cupric salts)	1·1852	Mercury	3·7290
Zinc	1·219	Tin	2·2188
Nickel	1·0941	Chlorine	1·3223
Hydrogen	0·0376	Bromine	2·982
Aluminium	0·3369	Iodine	4·7328
Lead	3·862	Oxygen	0·2983
Gold	2·4512	Potassium chlorate	0·7618
Potassium	1·4580	Potassium hydroxide	2·094
Magnesium	0·4584	Sodium hydroxide	1·494

TABLE 12.—REDUCTION OF THE VOLUME OF

General formula for Dry Gases, $V_0 = \dfrac{V \times 273 b}{(273+t)760}$

b = Barometric pressure, reduced to 0°; t = temperature; f = tension

I. Table for reducing the volumes of

0°.	1°.	2°.	3°.	4°.	5°.	6°.	7°.	8°.	9°.	10°.	0°.
1	0·996	0·993	0·989	0·986	0·982	0·978	0·975	0·972	0·968	0·965	1
2	1·993	1·985	1·978	1·971	1·964	1·957	1·950	1·943	1·936	1·929	2
3	2·989	2·978	2·967	2·957	2·946	2·935	2·925	2·915	2·904	2·894	3
4	3·985	3·971	3·956	3·942	3·928	3·914	3·900	3·886	3·872	3·859	4
5	4·982	4·964	4·946	4·928	4·910	4·893	4·876	4·858	4·841	4·824	5
6	5·978	5·956	5·935	5·913	5·892	5·871	5·850	5·830	5·809	5·788	6
7	6·974	6·949	6·924	6·899	6·874	6·850	6·825	6·801	6·777	6·753	7
8	7·970	7·942	7·913	7·885	7·856	7·828	7·800	7·773	7·745	7·718	8
9	8·967	8·934	8·902	8·870	8·838	8·807	8·775	8·744	8·713	8·682	9
10	9·963	9·927	9·891	9·856	9·820	9·785	9·750	9·716	9·681	9·647	10
11	10·96	10·92	10·88	10·84	10·80	10·76	10·73	10·69	10·65	10·61	11
12	11·96	11·91	11·87	11·83	11·78	11·74	11·70	11·66	11·62	11·57	12
13	12·95	12·91	12·86	12·81	12·76	12·72	12·68	12·63	12·59	12·54	13
14	13·95	13·90	13·85	13·80	13·75	13·70	13·65	13·60	13·55	13·50	14
15	14·95	14·89	14·84	14·78	14·73	14·68	14·63	14·57	14·52	14·47	15
16	15·94	15·88	15·83	15·77	15·71	15·66	15·60	15·55	15·49	15·43	16
17	16·94	16·87	16·82	16·75	16·69	16·64	16·58	16·52	16·46	16·40	17
18	17·93	17·87	17·81	17·74	17·67	17·61	17·55	17·49	17·43	17·36	18
19	18·93	18·86	18·79	18·72	18·65	18·59	18·53	18·46	18·39	18·33	19
20	19·93	19·85	19·78	19·71	19·64	19·57	19·50	19·43	19·36	19·29	20
21	20·93	20·84	20·77	20·69	20·62	20·55	20·48	20·40	20·33	20·26	21
22	21·92	21·84	21·76	21·68	21·60	21·53	21·45	21·37	21·30	21·22	22
23	22·92	22·83	22·75	22·66	22·58	22·51	22·43	22·35	22·26	22·18	23
24	23·92	23·82	23·74	23·65	23·56	23·48	23·40	23·32	23·23	23·15	24
25	24·91	24·81	24·73	24·64	24·55	24·46	24·38	24·29	24·20	24·11	25
26	25·91	25·81	25·72	25·62	25·53	25·44	25·35	25·26	25·17	25·08	26
27	26·90	26·80	26·71	26·61	26·52	26·42	26·33	26·23	26·13	26·04	27
28	27·90	27·79	27·69	27·59	27·50	27·40	27·30	27·20	27·10	27·01	28
29	28·90	28·78	28·68	28·58	28·48	28·38	28·28	28·17	28·07	27·97	29
30	29·89	29·78	29·67	29·57	29·46	29·36	29·25	29·15	29·04	28·94	30
31	30·89	30·77	30·66	30·55	30 44	30·34	30·23	30·12	30·01	29·91	31
32	31·88	31·76	31·65	31·54	31·42	31·32	31·20	31·09	30·98	30·87	32
33	32·88	32·76	32·64	32·52	32·40	32·30	32·18	32·06	31·94	31·84	33
34	33·88	33·75	33·63	33·51	33·39	33·27	33·15	33·03	32·91	32·80	34
35	34·87	34·74	34·62	34·50	34·37	34·25	34·13	34·01	33·88	33·77	35
36	35·87	35·74	35·61	35·48	35·35	35·23	35·10	34·98	34·85	34·73	36
37	36·87	36·73	36·60	36·47	36·33	36·21	36·08	35·95	35·82	35·70	37
38	37·86	37·72	37·59	37·45	37·32	37·19	37·05	36·92	36·79	36·66	38
39	38·86	38·71	38·58	38·44	38·30	38·16	38·03	37·89	37·75	37·62	39
40	39·85	39·71	39·56	39·42	39·28	39·14	39·00	38·86	38·72	38·59	40
41	40·85	40·70	40·55	40·41	40·26	40·12	39·98	39·83	39·69	39·55	41
42	41·85	41·69	41·54	41·39	41·24	41·10	40·95	40·80	40·66	40·52	42
43	42·84	42·68	42·53	42·38	42·22	42·08	41·93	41·78	41·62	41·48	43
44	43·84	43·68	43·52	43·37	43 20	43·05	42·90	42·75	42·59	42·45	44
45	44·84	44·67	44·51	44·35	44·19	44·03	43·88	43·72	43·56	43·41	45
46	45·83	45·66	45·50	45·34	45·17	45·01	44·85	44·69	44·53	44·38	46
47	46·83	46·65	46·48	46 32	46·15	45·99	45·83	45·66	45·50	45·34	47
48	47·83	47·65	47·48	47·31	47·13	46·97	46·80	46·63	46·47	46·31	48
49	48·82	48·64	48·47	48·29	48·12	47·95	47·78	47·60	47·44	47·27	49
50	49·82	49 64	49·46	49 28	49·10	48·93	48·75	48·58	48·41	48·24	50

GASES TO NORMAL TEMPERATURE & PRESSURE.

General formula for Moist Gases, $V_0 = \dfrac{V \times 273(b-f)}{(273+t)760}$

of aqueous vapour at t°. Compare Table 13.

gases to a temperature of 0° C.

0°.	1°.	2°.	3°.	4°.	5°.	6°.	7°.	8°.	9°.	10°.	0°.
51	50·82	50·63	50·45	50·26	50·08	49·91	49·73	49·55	49·38	49·21	51
52	51·81	51·62	51·44	51·25	51·06	50·89	50·70	50·52	50·35	50·17	52
53	52·81	52·62	52·43	52·24	52·05	51·87	51·68	51·49	51·31	51·13	53
54	53·81	53·61	53·42	53·22	53·03	52·84	52·65	52·46	52·28	52·10	54
55	54·80	54·60	54·41	54·21	54·01	53·82	53·63	53·44	53·25	53·06	55
56	55·80	55·60	55·40	55·19	54·99	54·80	54·60	54·41	54·22	54·03	56
57	56·80	56·59	56·39	56·18	55·97	55·78	55·58	55·38	55·19	54·99	57
58	57·79	57·58	57·37	57·16	56·95	56·76	56·55	56·35	56·15	55·96	58
59	58·79	58·57	58·37	58·15	57·93	57·74	57·53	57·32	57·12	56·92	59
60	59·78	59·56	59·35	59·13	58·92	58·71	58·50	58·30	58·09	57·88	60
61	60·78	60·56	60·34	60·12	59·90	59·69	59·48	59·27	59·06	58·85	61
62	61·78	61·55	61·33	61·10	60·88	60·67	60·45	60·24	60·03	59·81	62
63	62·77	62·54	62·32	62·09	61·86	61·65	61·43	61·21	60·99	60·77	63
64	63·77	63·53	63·31	63·07	62·84	62·63	62·40	62·18	61·96	61·74	64
65	64·76	64·53	64·30	64·06	63·83	63·61	63·38	63·15	62·93	62·70	65
66	65·76	65·52	65·29	65·04	64·81	64·58	64·35	64·13	63·89	63·67	66
67	66·75	66·51	66·27	66·03	65·79	65·56	65·33	65·10	64·86	64·63	67
68	67·75	67·50	67·26	67·02	66·77	66·54	66·30	66·07	65·83	65·60	68
69	68·75	68·50	68·25	68·01	67·75	67·52	67·28	67·04	66·80	66·56	69
70	69·74	69·49	69·24	68·99	68·74	68·50	68·25	68·01	67·77	67·53	70
71	70·74	70·48	70·23	69·98	69·72	69·48	69·23	68·98	68·74	68·49	71
72	71·74	71·48	71·22	70·96	70·70	70·46	70·20	69·95	69·71	69·46	72
73	72·73	72·47	72·21	71·95	71·69	71·44	71·18	70·93	70·67	70·42	73
74	73·73	73·46	73·20	72·93	72·66	72·41	72·15	71·90	71·64	71·39	74
75	74·72	74·45	74·19	73·92	73·65	73·39	73·13	72·87	72·61	72·35	75
76	75·72	75·45	75·18	74·90	74·63	74·37	74·10	73·84	73·58	73·32	76
77	76·72	76·44	76·17	75·89	75·61	75·35	75·08	74·81	74·55	74·28	77
78	77·71	77·43	77·15	76·87	76·59	76·33	76·05	75·78	75·51	75·25	78
79	78·71	78·42	78·14	77·86	77·58	77·31	77·03	76·75	76·48	76·21	79
80	79·70	79·42	79·13	78·85	78·56	78·28	78·00	77·73	77·45	77·18	80
81	80·70	80·41	80·12	79·83	79·54	79·26	78·98	78·70	78·42	78·14	81
82	81·69	81·40	81·11	80·82	80·52	80·24	79·95	79·67	79·39	79·11	82
83	82·69	82·39	82·10	81·81	81·51	81·22	80·93	80·64	80·36	80·07	83
84	83·69	83·39	83·09	82·79	82·49	82·20	81·90	81·61	81·32	81·04	84
85	84·68	84·38	84·08	83·78	83·47	83·17	82·88	82·58	82·29	82·00	85
86	85·68	85·37	85·07	84·76	84·45	84·15	83·85	83·55	83·26	82·97	86
87	86·68	86·37	86·06	85·75	85·43	85·13	84·83	84·53	84·23	83·93	87
88	87·67	87·36	87·05	86·73	86·42	86·11	85·80	85·50	85·20	84·90	88
89	88·67	88·35	88·04	87·72	87·40	87·09	86·78	86·47	86·16	85·86	89
90	89·67	89·34	89·02	88·70	88·38	88·07	87·75	87·44	87·13	86·82	90
91	90·66	90·34	90·01	89·69	89·36	89·05	88·73	88·41	88·10	87·79	91
92	91·66	91·33	91·00	90·67	90·34	90·03	80·70	89·38	89·07	88·75	92
93	92·66	92·32	91·99	91·66	91·33	91·01	90·68	90·36	90·03	89·72	93
94	93·65	93·31	92·98	92·64	92·31	91·98	91·65	91·33	91·00	90·68	94
95	94·65	94·31	93·97	93·63	93·29	92·96	92·63	92·30	91·97	91·65	95
96	95·65	95·30	94·96	94·61	94·27	93·94	93·60	93·27	92·94	92·61	96
97	96·64	96·29	95·95	95·60	95·25	94·92	94·58	94·24	93·91	93·57	97
98.	97·64	97·28	96·93	96·58	96·24	95·90	95·55	95·21	94·87	94·54	98
99	98·64	98·27	97·92	97·57	97·22	96·87	96·53	96·18	95·84	95·50	99
100	99·63	99·27	98·91	98·56	98·20	97·85	97·50	97·16	96·81	96·47	100

TABLE 12—

I. Table for reducing the volumes of

0°.	11°.	12°.	13°.	14°.	15°.	16°.	17°.	18°.	19°.	20°.	0°.
1	0·961	0·958	0·955	0·951	0·948	0·945	0·941	0·938	0·935	0·932	1
2	1·923	1·916	1·909	1·903	1·896	1·889	1·883	1·876	1·869	1·864	2
3	2·884	2·874	2·864	2·854	2·844	2·834	2·824	2·815	2·805	2·795	3
4	3·845	3·832	3·818	3·805	3·792	3·779	3·766	3·753	3·740	3·727	4
5	4·807	4·790	4·773	4·757	4·740	4·724	4·707	4·691	4·675	4·659	5
6	5·768	5·747	5·728	5·708	5·688	5·668	5·648	5·629	5·600	5·591	6
7	6·729	6·705	6·682	6·659	6·636	6·613	6·590	6·567	6·544	6·523	7
8	7·690	7·663	7·637	7·610	7·584	7·558	7·531	7·506	7·479	7·454	8
9	8·652	8·621	8·591	8·562	8·532	8·502	8·472	8·444	8·414	8·386	9
10	9·613	9·579	9·546	9·513	9·480	9·447	9·414	9·382	9·349	9·318	10
11	10·57	10·53	10·50	10·46	10·43	10·39	10·35	10·32	10·28	10·25	11
12	11·53	11·49	11·45	11·42	11·38	11·33	11·30	11·26	11·21	11·18	12
13	12·49	12·45	12·41	12·36	12·32	12·28	12·24	12·20	12·15	12·11	13
14	13·45	13·41	13·36	13·31	13·27	13·22	13·17	13·13	13·08	13·04	14
15	14·42	14·37	14·32	14·27	14·22	14·17	14·12	14·07	14·02	13·97	15
16	15·38	15·32	15·27	15·22	15·17	15·11	15·06	15·01	14·96	14·01	16
17	16·34	16·28	16·23	16·17	16·12	16·06	16·00	15·95	15·89	15·84	17
18	17·30	17·24	17·18	17·12	17·06	17·00	16·94	16·89	16·82	16·76	18
19	18·26	18·20	18·14	18·07	18·01	17·95	17·89	17·83	17·76	17·70	19
20	19·23	19·16	19·09	19·03	18·96	18·89	18·83	18·76	18·69	18·64	20
21	20·19	20·12	20·04	19·98	19·91	19·84	19·77	19·70	19·62	19·57	21
22	21·15	21·08	21·00	20·93	20·86	20·78	20·71	20·64	20·56	20·50	22
23	22·11	22·03	21·95	21·88	21·80	21·73	21·65	21·58	21·50	21·43	23
24	23·07	22·99	22·91	22·83	22·75	22·67	22·59	22·51	22·43	22·37	24
25	24·03	23·95	23·86	23·78	23·70	23·61	23·54	23·45	23·37	23·30	25
26	25·00	24·91	24·81	24·73	24·65	24·56	24·48	24·39	24·30	24·23	26
27	25·96	25·87	25·77	25·69	25·60	25·50	25·42	25·33	25·23	25·16	27
28	26·92	26·82	26·72	26·64	26·54	26·45	26·36	26·27	26·17	26·09	28
29	27·88	27·78	27·68	27·59	27·49	27·39	27·30	27·20	27·10	27·02	29
30	28·84	28·74	28·64	28·54	28·44	28·34	28·24	28·15	28·05	27·95	30
31	29·80	29·70	29·59	29·49	29·39	29·28	29·18	29·09	28·09	28·87	31
32	30·76	30·66	30·55	30·44	30·34	30·23	30·12	30·03	29·92	29·81	32
33	31·72	31·61	31·50	31·39	31·28	31·17	31·06	30·97	30·86	30·74	33
34	32·68	32·57	32·46	32·34	32·23	32·12	32·01	31·90	31·79	31·68	34
35	33·65	33·53	33·41	33·30	33·18	33·06	32·95	32·84	32·73	32·61	35
36	34·61	34·49	34·37	34·25	34·13	34·01	33·89	33·78	33·66	33·54	36
37	35·57	35·45	35·32	35·20	35·08	34·95	34·83	34·72	34·59	34·47	37
38	36·53	36·40	36·28	36·15	36·02	35·90	35·77	35·66	35·53	35·40	38
39	37·49	37·36	37·23	37·10	36·97	36·84	36·71	36·59	36·46	36·34	39
40	38·45	38·32	38·18	38·05	37·92	37·79	37·66	37·53	37·40	37 27	40
41	39·41	39·28	39·14	39·00	38·87	38·73	38·60	38·47	38·34	38·20	41
42	40·37	40·24	40·09	39·95	39·82	39·68	39·54	39·41	39·27	39·13	42
43	41·33	41·19	41·05	40·90	40·76	40·62	40·48	40·35	40·21	40·07	43
44	42·30	42·15	42·00	41·86	41·71	41·57	41·43	41·28	41·14	41·00	44
45	43·26	43·11	42·95	42·81	42·66	42·51	42·37	42·22	42·08	41·93	45
46	44·29	44·07	43·91	43·76	43·61	43·46	43·31	43·16	43·01	42·86	46
47	45·18	45·03	44·86	44·71	44·56	44·40	44·25	44·10	43·94	43·79	47
48	46·14	45·98	45·82	45·66	45·50	45·35	45·19	45·04	44·88	44·73	48
49	47·10	46·94	46·77	46·61	46·45	46·29	46·13	45·97	45·81	45·65	49
50	48·07	47·90	47·73	47·57	47·40	47·24	47·07	46·91	46·75	46·59	50

Continued.

gases to a temperature of 0° C.—*Continued.*

0°.	11°.	12°.	13°.	14°.	15°.	16°.	17°.	18°.	19°.	20°.	0°.
51	49·03	48·86	48·69	48·52	48·35	48·18	48·01	47·85	47·68	47·52	51
52	49·99	49·82	49·64	49·47	49·30	49·13	48·95	48·79	48·62	48·45	52
53	50·95	50·77	50·59	50·42	50·24	50·07	49·89	49·72	49·55	49·38	53
54	51·91	51·73	51·55	51·37	51·19	51·02	50·54	50·66	50·49	50·32	54
55	52·87	52·69	52·50	52·33	52·14	51·96	51·78	51·60	51·43	51·25	55
56	53·84	53·65	53·46	53·28	53·09	52·91	52·72	52·54	52·36	52·18	56
57	54·80	54·61	54·41	54·23	54·04	53·86	53·66	53·48	53·29	53·71	57
58	55·76	55·56	55·37	55·18	54·98	54·80	54·60	54·42	54·23	54·04	58
59	56·72	56·52	56·32	56·13	55·93	55·74	55·54	55·35	55·16	54·97	59
60	57·68	57·47	57·28	57·08	56·88	56·68	56·48	56·29	56·09	55·91	60
61	58·64	58·43	58·23	58·03	57·83	57·63	57·42	57·23	57·02	56·84	61
62	59·60	59·39	59·19	58·98	58·78	58·57	58·36	58·17	57·96	57·77	62
63	60·56	60·35	60·14	59·93	59·72	59·52	59·30	59·11	58·90	58·71	63
64	61·53	61·31	61·10	60·88	60·67	60·46	60·25	60·04	59·83	59·64	64
65	62·49	62·26	62·05	61·84	61·62	61·40	61·19	60·98	60·77	60·57	65
66	63·45	63·22	63·01	62·79	62·57	62·35	62·13	61·92	61·70	61·50	66
67	64·41	64·18	63·96	63·74	63·52	63·29	63·07	62·86	62·63	62·43	67
68	65·37	65·13	64·92	64·69	64·46	64·23	64·01	63·80	63·57	63·36	68
69	66·33	66·09	65·87	65·64	65·41	65·18	64·95	64·73	64·50	64·30	69
70	67·29	67·05	66·82	66·59	66·36	66·13	65·90	65·67	65·44	65·23	70
71	68·25	68·01	67·77	67·54	67·31	67·07	66·84	66·61	66·38	66·16	71
72	69·21	68·97	68·73	68·49	68·26	68·02	67·78	67·55	67·31	67·09	72
73	70·17	69·92	69·68	69·44	69·20	68·96	68·72	68·49	68·26	68·03	73
74	71·14	70·88	70·64	70·40	70·15	69·91	69·66	69·42	69·18	68·96	74
75	72·10	71·84	71·59	71·35	71·10	70·85	70·61	70·37	70·12	69·89	75
76	73·06	72·80	72·55	72·30	72·05	71·80	71·55	71·30	71·05	70·82	76
77	74·02	73·76	73·51	73·25	73·00	72·74	72·49	72·24	71·98	71·75	77
78	74·98	74·71	74·46	74·20	73·94	73·69	73·43	73·18	72·92	72·68	78
79	75·94	75·67	75·41	75·15	74·89	74·63	74·37	74·11	73·85	73·61	79
80	76·90	76·63	76·37	76·10	75·84	75·58	75·31	75·06	74·79	74·54	80
81	77·86	77·59	77·32	77·05	76·79	76·52	76·25	76·00	75·73	75·47	81
82	78·82	78·55	78·28	78·00	77·74	77·47	77·19	76·94	76·66	76·40	82
83	79·78	79·50	79·23	78·95	78·68	78·41	78·13	77·87	77·60	77·34	83
84	80·75	80·46	80·19	79·91	79·63	79·35	79·08	78·81	78·53	78·27	84
85	81·71	81·42	81·14	80·86	80·58	80·30	80·02	79·75	79·47	79·20	85
86	82·67	82·38	82·10	81·81	81·53	81·24	80·96	80·69	80·40	80·13	86
87	83·63	83·33	83·05	82·76	82·48	82·19	81·90	81·63	81·33	81·06	87
88	84·59	84·29	84·01	83·71	83·42	83·13	82·84	82·57	82·27	81·99	88
89	85·56	85·25	84·96	84·66	84·37	84·08	83·78	83·50	83·22	82·93	89
90	86·52	86·21	85·92	85·62	85·32	85·02	84·72	84·44	84·14	83·86	90
91	87·48	87·17	86·87	86·57	86·27	85·96	85·66	85·38	85·07	84·79	91
92	88·44	88·13	87·83	87·52	87·22	86·91	86·60	86·32	86·01	85·72	92
93	89·40	89·08	88·78	88·47	88·16	87·85	87·54	87·25	86·95	86·66	93
94	90·36	90·04	89·73	89·42	89·11	88·80	88·49	88·19	87·88	87·59	94
95	91·33	91·00	90·68	90·38	90·06	89·74	89·43	89·13	88·82	88·52	95
96	92·29	91·96	91·64	91·33	91·01	90·69	90·37	90·07	89·75	89·45	96
97	93·25	92·92	92·59	92·28	91·96	91·63	91·31	91·00	90·68	90·38	97
98	94·21	93·87	93·55	93·23	92·90	92·58	92·25	91·94	91·62	91·31	98
99	95·17	94·83	94·50	94·18	93·85	93·52	93·19	92·88	92·55	92·24	99
100	96·13	95·79	95·46	95·13	94·80	94·47	94·14	93·82	93·49	93·18	100

TABLE 12—

I. Table for reducing the volumes of

0°.	21°.	22°.	23°.	24°.	25°.	26°.	27°.	28°.	29°.	0°.
1	0·929	0·926	0·922	0·919	0·916	0·913	0·910	0·907	0·904	1
2	1·857	1·851	1·845	1·839	1·832	1·826	1·820	1·814	1·808	2
3	2·786	2·777	2·767	2·758	2·749	2·739	2·730	2·721	2·712	3
4	3·714	3·702	3·690	3·677	3·665	3·652	3·640	3·628	3·616	4
5	4·643	4·628	4·612	4·597	4·581	4·566	4·551	4·535	4·520	5
6	5·572	5·553	5·534	5·516	5·497	5·479	5·461	5·442	5·424	6
7	6·500	6·479	6·457	6·435	6·413	6·392	6·371	6·349	6·328	7
8	7·429	7·404	7·379	7·354	7·330	7·305	7·281	7·256	7·232	8
9	8·357	8·330	8·302	8·274	8·246	8·218	8·191	8·163	8·136	9
10	9·286	9·255	9·224	9·193	9·162	9·131	9·101	9·070	9·040	10
11	10·21	10·18	10·15	10·11	10·07	10·04	10·01	9·98	9·94	11
12	11·14	11·11	11·07	11·03	10·99	10·96	10·92	10·88	10·85	12
13	12·07	12·03	11·99	11·95	11·91	11·87	11·83	11·79	11·75	13
14	13·00	12·96	12·91	12·87	12·83	12·78	12·74	12·70	12·66	14
15	13·93	13·88	13·84	13·79	13·74	13·70	13·65	13·61	13·56	15
16	14·86	14·81	14·76	14·71	14·66	14·61	14·56	14·51	14·46	16
17	15·79	15·73	15·68	15·63	15·58	15·52	15·47	15·42	15·37	17
18	16·71	16·66	16·60	16·55	16·49	16·44	16·38	16·33	16·27	18
19	17·64	17·58	17·53	17·47	17·41	17·35	17·29	17·23	17·18	19
20	18·57	18·51	18·45	18·39	18·32	18·26	18·20	18·14	18·08	20
21	19·50	19·43	19·37	19·31	19·24	19·17	19·11	19·05	18·98	21
22	20·43	20·36	20·29	20·23	20·15	20·09	20·02	19·95	19·89	22
23	21·36	21·29	21·21	21·15	21·07	21·00	20·93	20·86	20·79	23
24	22·28	22·21	22·14	22·07	21·99	21·91	21·84	21·77	21·70	24
25	23·21	23·14	23·06	22·99	22·90	22·83	22·75	22·68	22·60	25
26	24·14	24·06	23·98	23·91	23·82	23·74	23·66	23·58	23·50	26
27	25·07	24·99	24·90	24·83	24·73	24·65	24·57	24·49	24·41	27
28	26·00	25·91	25·82	25·74	25·65	25·57	25·48	25·40	25·31	28
29	26·93	26·84	26·75	26·67	26·57	26·48	26·39	26·30	26·22	29
30	27·86	27·77	27·67	27·58	27·49	27·39	27·30	27·21	27·12	30
31	28·79	28·70	28·59	28·50	28·41	28·30	28·21	28·12	28·02	31
32	29·72	29·62	29·51	29·42	29·32	29·22	29·12	29·02	28·93	32
33	30·65	30·55	30·44	30·34	30·24	30·13	30·03	29·93	29·83	33
34	31·57	31·47	31·36	31·26	31·16	31·04	30·94	30·84	30·74	34
35	32·50	32·40	32·28	32·18	32·07	31·96	31·85	31·75	31·64	35
36	33·43	33·32	33·20	33·10	32·99	32·87	32·76	32·65	32·54	36
37	34·36	34·25	34·12	34·02	33·90	33·78	33·67	33·56	33·45	37
38	35·29	35·17	35·05	34·93	34·82	34·70	34·58	34·47	34·35	38
39	36·22	36·10	35·97	35·85	35·74	35·61	35·49	35·47	35·26	39
40	37·14	37·02	36·90	36·77	36·65	36·52	36·40	36·28	36·16	40
41	38·07	37·95	37·82	37·69	37·57	37·43	37·31	37·19	37·06	41
42	39·00	38·87	38·74	38·61	38·48	38·35	38·22	38·09	37·97	42
43	39·93	39·80	39·66	39·53	39·40	39·26	39·13	39·00	38·87	43
44	40·85	40·72	40·59	40·45	40·32	40·17	40·04	39·91	39·78	44
45	41·78	41·65	41·51	41·37	41·23	41·09	40·95	40·82	40·68	45
46	42·71	42·57	42·43	42·29	42·15	42·00	41·86	41·72	41·58	46
47	43·64	43·50	43·35	43·21	43·06	42·91	42·77	42·63	42·49	47
48	44·57	44·42	44·27	44·12	43·98	43·83	43·68	43·54	43·39	48
49	45·50	45·35	45·19	45·04	44·89	44·74	44·59	44·44	44·30	49
50	46·43	46·28	46·12	45·97	45·81	45·66	45·51	45·35	45·20	50

Continued.

gases to a temperature of 0° C.—*Continued.*

0°.	21°.	22°.	23°.	24°.	25°.	26°.	27°.	28°.	29°.	0°.
51	47·86	47·20	47·04	46·89	46·73	46·57	46·42	46·26	46·10	51
52	48·29	48·13	47·96	47·81	47·64	47·49	47·33	47·16	47·01	52
53	49·22	49·06	48·89	48·73	48·56	48·40	48·24	48·07	47·91	53
54	50·14	49·98	49·81	49·65	49·48	49·31	49·15	48·98	48·82	54
55	51·07	50·91	50·73	50·57	50·39	50·23	50·06	49·89	49·72	55
56	52·00	51·83	51·65	51·49	51·31	51·14	50·97	50·79	50·62	56
57	52·93	52·76	52·58	52·41	52·22	52·05	51·88	51·70	51·53	57
58	53·86	53·68	53·50	53·32	53·14	52·97	52·79	52·61	52·43	58
59	54·79	54·61	54·42	54·24	54·06	53·88	53·70	53·51	53·34	59
60	55·72	55·53	55·34	55·16	54·97	54·79	54·61	54·42	54·24	60
61	56·65	56·46	56·26	56·08	55·89	55·70	55·52	55·33	55·14	61
62	57·58	57·38	57·19	57·00	56·80	56·62	56·43	56·23	56·05	62
63	58·51	58·31	58·11	57·92	57·72	57·53	57·34	57·14	56·95	63
64	59·42	59·23	59·03	58·84	58·64	58·44	58·25	58·05	57·86	64
65	60·36	60·16	59·95	59·76	59·55	59·36	59·16	58·96	58·76	65
66	61·29	61·08	60·87	60·68	60·47	60·27	60·07	59·86	59·66	66
67	62·22	62·01	61·79	61·60	61·38	61·18	60·98	60·77	60·57	67
68	63·15	62·93	62·72	62·51	62·30	62·10	61·89	61·68	61·47	68
69	64·08	63·86	63·64	63·43	63·22	63·01	62·80	62·58	62·38	69
70	65·00	64·79	64·57	64·35	64·13	63·92	63·71	63·49	63·28	70
71	65·93	65·71	65·49	65·27	65·05	64·83	64·62	64·40	64·18	71
72	66·86	66·64	66·42	66·19	65·96	65·75	65·53	65·30	65·09	72
73	67·79	67·57	67·34	67·11	66·88	66·66	66·44	66·21	65·99	73
74	68·61	68·49	68·26	68·03	67·80	67·57	67·35	67·12	66·90	74
75	69·64	69·42	69·18	68·95	68·71	68·49	68·26	68·03	67·80	75
76	70·57	70·34	70·10	69·87	69·63	69·40	69·17	68·93	68·70	76
77	71·50	71·27	71·03	70·79	70·54	70·31	70·08	69·84	69·61	77
78	72·43	72·19	71·95	71·70	71·46	71·22	70·99	70·75	70·51	78
79	73·36	73·12	72·87	72·62	72·38	72·14	71·90	71·65	71·42	79
80	74·29	74·04	73·79	73·54	73·30	73·05	72·81	72·56	72·32	80
81	75·22	74·97	74·71	74·46	74·22	73·96	73·72	73·47	73·22	81
82	76·15	75·89	75·63	75·38	75·13	74·88	74·63	74·37	74·13	82
83	77·08	76·82	76·56	76·30	76·05	75·79	75·54	75·28	75·03	83
84	78·00	77·74	77·48	77·22	76·96	76·70	76·45	76·19	75·94	84
85	78·93	78·67	78·40	78·14	77·88	77·62	77·36	77·10	76·84	85
86	79·86	79·59	79·32	79·06	78·80	78·53	78·27	78·00	77·74	86
87	80·79	80·52	80·25	79·98	79·71	79·44	79·18	78·91	78·65	87
88	81·72	81·44	81·17	80·90	80·63	80·36	80·09	79·82	79·55	88
89	82·65	82·37	82·09	81·82	81·55	81·27	81·00	80·72	80·46	89
90	83·57	83·30	83·02	82·74	82·46	82·18	81·91	81·63	81·36	90
91	84·50	84·22	83·94	83·66	83·38	83·09	82·82	82·54	82·26	91
92	85·43	85·15	84·86	84·58	84·29	84·01	83·73	83·44	83·17	92
93	86·36	86·08	85·79	85·50	85·21	84·92	84·64	84·35	84·07	93
94	87·28	87·00	86·71	86·42	86·13	85·83	85·55	85·26	84·98	94
95	88·21	87·93	87·63	87·34	87·04	86·75	86·46	86·17	85·88	95
96	89·14	88·85	88·55	88·26	87·96	87·66	87·37	87·07	86·78	96
97	90·07	89·78	89·48	89·18	88·87	88·57	88·28	87·98	87·69	97
98	91·00	90·70	90·40	90·09	89·79	89·48	89·19	88·89	88·59	98
99	91·93	91·63	91·32	91·01	90·71	90·40	90·10	89·79	89·50	99
100	92·86	92·55	92·24	91·93	91·62	91·31	91·01	90·70	90·40	100

TABLE 12—*Continued.* II. Table for reducing the

Deduct from the barometric pressure 1 mm. for temperature between 0° and 12° for the expansion

760	710	712	714	716	718	720	722	724	726	728	760
1	0·934	0·937	0·940	0·942	0·945	0·947	0·950	0·953	0·955	0·958	1
2	1·868	1·874	1·879	1·884	1·890	1·895	1·900	1·905	1·911	1·916	2
3	2·803	2·810	2·818	2·826	2·834	2·842	2·850	2·858	2·866	2·874	3
4	3·738	3·747	3·758	3·768	3·779	3·789	3·800	3·810	3·821	3·832	4
5	4·672	4·685	4·697	4·711	4·724	4·736	4·750	4·763	4·777	4·790	5
6	5·607	5·621	5·637	5·653	5·669	5·684	5·700	5·716	5·732	5·747	6
7	6·540	6·558	6·577	6·595	6·614	6·631	6·650	6·668	6·687	6·705	7
8	7·474	7·494	7·516	7·537	7·558	7·578	7·600	7·621	7·642	7·663	8
9	8·409	8·431	8·456	8·479	8·503	8·526	8·550	8·573	8·598	8·621	9
10	9·34	9·37	9·40	9·42	9·45	9·47	9·50	9·53	9·55	9·58	10
11	10·28	10·31	10·34	10·36	10·39	10·42	10·45	10·48	10·51	10·54	11
12	11·21	11·24	11·27	11·30	11·34	11·37	11·40	11·43	11·46	11·50	12
13	12·14	12·18	12·21	12·24	12·28	12·31	12·35	12·38	12·41	12·45	13
14	13·08	13·12	13·16	13·19	13·23	13·26	13·30	13·34	13·37	13·41	14
15	14·02	14·06	14·10	14·13	14·17	14·21	14·25	14·29	14·33	14·37	15
16	14·95	14·99	15·03	15·07	15·11	15·15	15·20	15·24	15·28	15·33	16
17	15·88	15·93	15·98	16·02	16·06	16·10	16·15	16·19	16·23	16·28	17
18	16·82	16·87	16·92	16·96	17·01	17·05	17·10	17·15	17·19	17·24	18
19	17·76	17·81	17·86	17·90	17·95	18·00	18·05	18·10	18·15	18·21	19
20	18·68	18·74	18·79	18·84	18·90	18·95	19·00	19·05	19·11	19·16	20
21	19·62	19·68	19·73	19·78	19·84	19·90	19·95	20·00	20·06	20·12	21
22	20·55	20·61	20·67	20·72	20·78	20·84	20·90	20·96	21·01	21·07	22
23	21·49	21·55	21·61	21·66	21·73	21·79	21·85	21·91	21·97	22·03	23
24	22·43	22·49	22·55	22·61	22·68	22·74	22·80	22·86	22·92	22·99	24
25	23·35	23·42	23·49	23·55	23·62	23·69	23·75	23·81	23·88	23·95	25
26	24·29	24·36	24·43	24·50	24·57	24·64	24·70	24·77	24·83	24·90	26
27	25·23	25·30	25·37	25·44	25·51	25·58	25·65	25·72	25·79	25·86	27
28	26·16	26·23	26·30	26·37	26·45	26·53	26·60	26·67	26·74	26·82	28
29	27·10	27·17	27·24	27·31	27·40	27·48	27·55	27·62	27·70	27·78	29
30	28·03	28·10	28·18	28·26	28·34	28·42	28·50	28·58	28·66	28·74	30
31	28·97	29·04	29·12	29·20	29·29	29·37	29·45	29·53	29·62	29·70	31
32	29·90	29·98	30·06	30·14	30·23	30·32	30·40	30·48	30·57	30·66	32
33	30·83	30·91	31·00	31·08	31·17	31·26	31·35	31·43	31·52	31·61	33
34	31·77	31·85	31·94	32·03	32·12	32·21	32·30	32·39	32·48	32·57	34
35	32·71	32·79	32·88	32·97	33·07	33·16	33·25	33·34	33·44	33·53	35
36	33·64	33·73	33·82	33·91	34·01	34·10	34·20	34·29	34·39	34·49	36
37	34·57	34·66	34·76	34·86	34·96	35·05	35·15	35·25	35·35	35·45	37
38	35·50	35·60	35·70	35·80	35·90	36·00	36·10	36·20	36·30	36·40	38
39	36·44	36·54	36·64	36·74	36·85	36·95	37·05	37·15	37·26	37·37	39
40	37·38	37·48	37·58	37·68	37·79	37·89	38·00	38·10	38·21	38·32	40
41	38·31	38·41	38·52	38·62	38·74	38·84	38·95	39·05	39·17	39·28	41
42	39·23	39·35	39·46	39·57	39·69	39·79	39·90	40·01	40·12	40·23	42
43	40·18	40·29	40·40	40·51	40·62	40·73	40·85	40·96	41·08	41·19	43
44	41·11	41·22	41·34	41·44	41·56	41·68	41·80	41·91	42·03	42·16	44
45	42·05	42·16	42·28	42·39	42·52	42·63	42·75	42·87	42·99	43·11	45
46	42·98	43·10	43·22	43·34	43·46	43·58	43·70	43·82	43·94	44·06	46
47	43·91	44·03	44·15	44·27	44·40	44·52	44·65	44·77	44·90	45·03	47
48	44·84	44·96	45·09	45·22	45·35	45·47	45·60	45·72	45·85	45·98	48
49	45·78	45·91	46·04	46·17	46·30	46·42	46·55	46·67	46·80	46·94	49
50	46·72	46·85	46·97	47·11	47·24	47·36	47·50	47·63	47·77	47·90	50

volumes of gases to a pressure of 760 mm.

C., and 2 mm. between 13° and 19° C., 3 mm. between 20° and 25° C., to compensate of mercury.

760	710	712	714	716	718	720	722	724	726	728	760
51	47·65	47·79	47·92	48·05	48·18	48·31	48·45	48·59	48·73	48·86	51
52	48·58	48·72	48·85	48·99	49·13	49·26	49·40	49·54	49·68	49·82	52
53	49·52	49·66	49·79	49·93	50·07	50·21	50·35	50·48	50·64	50·78	53
54	50·45	50·59	50·73	50·87	51·01	51·15	51·30	51·44	51·59	51·73	54
55	51·38	51·53	51·67	51·82	51·96	52·10	52·25	52·39	52·54	52·69	55
56	52·32	52·47	52·61	52·76	52·91	53·05	53·20	53·35	53·50	53·65	56
57	53·25	53·41	53·55	53·70	53·85	54·00	54·15	54·30	54·45	54·60	57
58	54·19	54·34	54·49	54·64	54·79	54·94	55·10	55·25	55·41	55·56	58
59	55·13	55·28	55·43	55·59	55·74	55·89	56·05	56·21	56·37	56·52	59
60	56·07	56·22	56·37	56·53	56·69	56·84	57·00	57·16	57·32	57·47	60
61	57·00	57·15	57·31	57·47	57·63	57·79	57·95	58·11	58·27	58·43	61
62	57·93	58·09	58·25	58·41	58·58	58·74	58·90	59·06	59·23	59·39	62
63	58·87	59·03	59·19	59·35	59·52	59·68	59·85	60·01	60·18	60·35	63
64	59·80	59·96	60·13	60·30	60·47	60·63	60·80	60·97	61·14	61·30	64
65	60·74	60·90	61·07	61·24	61·41	61·58	61·75	61·92	62·09	62·26	65
66	61·67	61·84	62·01	62·18	62·35	62·52	62·70	62·87	63·05	63·22	66
67	62·60	62·77	62·95	63·12	63·30	63·47	63·65	63·82	64·00	64·18	67
68	63·54	63·71	63·89	64·06	64·24	64·42	64·60	64·78	64·96	65·13	68
69	64·47	64·65	64·83	65·01	65·19	65·37	65·55	65·73	65·91	66·09	69
70	65·40	65·58	65·77	65·95	66·14	66·32	66·50	66·68	66·87	67·05	70
71	66·34	66·52	66·71	66·89	67·08	67·26	67·45	67·63	67·82	68·01	71
72	67·27	67·46	67·65	67·83	68·02	68·21	68·40	68·59	68·78	68·97	72
73	68·20	68·39	68·58	68·77	68·97	69·16	69·35	69·54	69·73	69·92	73
74	69·14	69·33	69·53	69·72	69·92	70·11	70·30	70·49	70·69	70·88	74
75	70·07	70·27	70·47	70·66	70·86	71·05	71·25	71·44	71·64	71·84	75
76	71·01	71·21	71·41	71·60	71·80	72·00	72·20	72·40	72·60	72·80	76
77	71·94	72·14	72·34	72·54	72·75	72·95	73·15	73·35	73·55	73·75	77
78	72·87	73·07	73·28	73·48	73·69	73·89	74·10	74·30	74·51	74·71	78
79	73·80	74·01	74·22	74·42	74·63	74·84	75·05	75·25	75·46	75·67	79
80	74·74	74·94	75·16	75·37	75·58	75·78	76·00	76·21	76·42	76·63	80
81	75·67	75·88	76·10	76·31	76·53	76·74	76·95	77·16	77·37	77·58	81
82	76·60	76·82	77·04	77·25	77·47	77·68	77·90	78·11	78·33	78·54	82
83	77·54	77·76	77·98	78·19	78·41	78·63	78·85	79·07	79·28	79·50	83
84	78·47	78·69	78·91	79·13	79·35	79·57	79·80	80·02	80·24	80·46	84
85	79·41	79·63	79·86	80·08	80·31	80·53	80·75	80·97	81·19	81·41	85
86	80·34	80·57	80·80	81·02	81·25	81·47	81·70	81·92	82·15	82·37	86
87	81·28	81·50	81·74	81·96	82·19	82·42	82·65	82·87	83·10	83·33	87
88	82·21	82·44	82·68	82·90	83·13	83·36	83·60	83·83	84·06	84·29	88
89	83·15	83·38	83·62	83·85	84·08	84·31	84·55	84·78	85·02	85·25	89
90	84·09	84·31	84·56	84·79	85·03	85·26	85·50	85·73	85·98	86·21	90
91	85·02	85·25	85·50	85·73	85·98	86·21	86·45	86·69	86·93	87·17	91
92	85·95	86·19	86·44	86·68	86·92	87·16	87·40	87·64	87·89	88·13	92
93	86·89	87·12	87·38	87·62	87·87	88·11	88·35	88·59	88·84	89·08	93
94	87·82	88·06	88·32	88·56	88·81	89·05	89·30	89·54	89·80	90·04	94
95	88·76	89·01	89·26	89·50	89·75	90·00	90·25	90·50	90·75	91·00	95
96	89·69	89·94	90·20	90·45	90·70	90·95	91·20	91·45	91·70	91·95	96
97	90·62	90·87	91·13	91·38	91·64	91·89	92·15	92·40	92·66	92·91	97
98	91·56	91·82	92·07	92·33	92·59	92·84	93·10	93·35	93·62	93·87	98
99	92·49	92·75	93·01	93·26	93·53	93·79	94·05	94·31	94·57	94·83	99
100	93·42	93·68	93·95	94·21	94·47	94·74	95·00	95·26	95·53	95·79	100

TABLE 12—*Continued.* II. Table for reducing the

760	730	732	734	736	738	740	742	744	746	748	760
1	0·961	0·963	0·966	0·968	0·971	0·974	0·976	0·979	0·982	0·984	1
2	1·921	1·926	1·932	1·937	1·942	1·947	1·953	1·958	1·963	1·968	2
3	2·882	2·889	2·898	2·905	2·913	2·921	2·929	2·937	2·945	2·953	3
4	3·842	3·852	3·864	3·874	3·884	3·895	3·905	3·916	3·926	3·937	4
5	4·803	4·816	4·830	4·842	4·855	4·868	4·882	4·895	4·908	4·921	5
6	5·763	5·779	5·796	5·810	5·826	5·842	5·858	5·874	5·890	5·905	6
7	6·724	6·742	6·762	6·779	6·797	6·816	6·834	6·853	6·871	6·889	7
8	7·684	7·705	7·728	7·747	7·768	7·790	7·810	7·832	7·853	7·874	8
9	8·645	8·668	8·693	8·716	8·739	8·763	8·787	8·811	8·834	8·858	9
10	9·61	9·63	9·66	9·68	9·71	9·74	9·76	9·79	9·82	9·84	10
11	10·57	10·59	10·62	10·65	10·68	10·71	10·74	10·77	10·80	10·82	11
12	11·53	11·56	11·59	11·62	11·65	11·68	11·71	11·75	11·78	11·81	12
13	12·49	12·52	12·55	12·59	12·62	12·66	12·69	12·73	12·76	12·79	13
14	13·45	13·48	13·52	13·56	13·59	13·63	13·66	13·70	13·74	13·78	14
15	14·41	14·44	14·48	14·52	14·56	14·60	14·64	14·69	14·73	14·77	15
16	15·37	15·41	15·45	15·49	15·53	15·58	15·62	15·67	15·71	15·75	16
17	16·33	16·37	16·41	16·46	16·50	16·55	16·60	16·65	16·69	16·73	17
18	17·29	17·33	17·38	17·43	17·47	17·52	17·57	17·62	17·67	17·72	18
19	18·25	18·29	18·35	18·40	18·45	18·50	18·55	18·60	18·65	18·70	19
20	19·21	19·26	19·32	19·37	19·42	19·47	19·53	19·58	19·63	19·68	20
21	20·17	20·22	20·28	20·34	20·39	20·44	20·50	20·56	20·61	20·66	21
22	21·13	21·19	21·25	21·31	21·36	21·42	21·48	21·54	21·59	21·65	22
23	22·09	22·15	22·21	22·27	22·33	22·39	22·45	22·51	22·57	22·64	23
24	23·05	23·11	23·18	23·24	23·30	23·36	23·43	23·50	23·56	23·63	24
25	24·01	24·07	24·14	24·21	24·27	24·34	24·41	24·48	24·54	24·61	25
26	24·97	25·04	25·11	25·18	25·24	25·31	25·38	25·45	25·52	25·59	26
27	25·93	26·00	26·07	26·14	26·21	26·28	26·36	26·43	26·50	26·58	27
28	26·89	26·96	27·04	27·12	27·18	27·26	27·33	27·41	27·48	27·56	28
29	27·85	27·92	28·00	28·08	28·15	28·23	28·31	28·39	28·47	28·55	29
30	28·82	28·89	28·97	29·05	29·13	29·21	29·29	29·37	29·45	29·53	30
31	29·78	29·86	29·94	30·02	30·10	30·18	30·26	30·35	30·43	30·51	31
32	30·74	30·82	30·91	30·99	31·07	31·15	31·24	31·33	31·41	31·50	32
33	31·70	31·78	31·87	31·96	32·04	32·13	32·21	32·30	32·39	32·48	33
34	32·66	32·75	32·84	32·93	33·01	33·10	33·19	33·28	33·37	33·46	34
35	33·62	33·71	33·80	33·89	33·98	34·07	34·17	34·27	34·36	34·45	35
36	34·58	34·67	34·77	34·86	34·95	35·05	35·15	35·25	35·34	35·43	36
37	35·54	35·63	35·73	35·83	35·92	36·02	36·12	36·22	36·32	36·42	37
38	36·50	36·60	36·70	36·80	36·90	37·00	37·10	37·20	37·30	37·40	38
39	37·47	37·57	37·67	37·77	37·87	37·97	38·07	38·18	38·28	38·39	39
40	38·42	38·52	38·64	38·74	38·84	38·95	39·05	39·16	39·26	39·37	40
41	39·38	39·48	39·60	39·71	39·81	39·92	40·02	40·14	40·24	40·36	41
42	40·34	40·44	40·56	40·68	40·78	40·89	41·00	41·12	41·22	41·34	42
43	41·30	41·41	41·53	41·64	41·75	41·86	41·97	42·10	42·20	42·32	43
44	42·27	42·38	42·50	42·62	42·73	42·84	42·95	43·07	43·18	43·30	44
45	43·22	43·34	43·46	43·58	43·69	43·81	43·93	44·06	44·17	44·29	45
46	44·18	44·30	44·42	44·54	44·66	44·78	44·90	45·03	45·15	45·27	46
47	45·15	45·26	45·39	45·52	45·64	45·76	45·88	46·01	46·13	46·26	47
48	46·10	46·23	46·36	46·49	46·61	46·73	46·85	46·99	47·12	47·24	48
49	47·06	47·19	47·32	47·44	47·57	47·70	47·83	47·97	48·10	48·23	49
50	48·03	48·16	48·30	48·42	48·55	48·68	48·82	48·95	49·08	49·21	50

volumes of gases to a pressure of 760 mm.—*Continued.*

760	730	732	734	736	738	740	742	744	746	748	760
51	48·99	49·12	49·26	49·39	49·52	49·65	49·79	49·93	50·06	50·19	51
52	49·96	50·08	50·22	50·36	50·49	50·63	50·77	50·91	51·04	51·18	52
53	50·91	51·05	51·19	51·33	51·46	51·60	51·75	51·89	52·02	52·16	53
54	51·87	52·01	52·16	52·30	52·44	52·58	52·72	52·87	53·01	53·15	54
55	52·83	52·98	53·13	53·27	53·41	53·55	53·70	53·85	53·99	54·14	55
56	53·79	53·94	54·09	54·23	54·37	54·52	54·68	54·83	54·97	55·11	56
57	54·75	54·90	55·05	55·20	55·35	55·50	55·65	55·80	55·95	56·10	57
58	55·71	55·86	56·02	56·17	56·32	56·47	56·63	56·78	56·93	57·08	58
59	56·67	56·83	56·99	57·14	57·29	57·44	57·60	57·76	57·92	58·07	59
60	57·63	57·79	57·95	58·10	58·26	58·42	58·58	58·74	58·90	59·05	60
61	58·59	58·75	58·91	59·07	59·23	59·39	59·56	59·72	59·88	60·04	61
62	59·55	59·72	59·88	60·04	60·20	60·36	60·53	60·70	60·86	61·02	62
63	60·51	60·68	60·85	61·01	61·17	61·34	61·51	61·68	61·84	62·00	63
64	61·47	61·64	61·81	61·98	62·15	62·32	62·49	62·66	62·82	62·99	64
65	62·43	62·60	62·77	62·94	63·11	63·28	63·46	63·64	63·81	63·98	65
66	63·39	63·57	63·74	63·91	64·08	64·26	64·44	64·62	64·79	64·96	66
67	64·35	64·53	64·71	64·88	65·05	65·23	65·41	65·59	65·77	65·94	67
68	65·31	65·50	65·68	65·85	66·02	66·20	66·38	66·56	66·74	66·92	68
69	66·27	66·45	66·64	66·82	67·00	67·18	67·37	67·55	67·73	67·91	69
70	67·24	67·42	67·61	67·79	67·97	68·16	68·34	68·53	68·71	68·89	70
71	68·20	68·39	68·58	68·76	68·94	69·13	69·32	69·51	69·69	69·88	71
72	69·16	69·35	69·54	69·73	69·92	70·11	70·30	70·49	70·68	70·86	72
73	70·12	70·31	70·51	70·69	70·88	71·08	71·27	71·47	71·66	71·85	73
74	71·08	71·28	71·48	71·66	71·85	72·05	72·25	72·45	72·64	72·83	74
75	72·04	72·24	72·44	72·63	72·82	73·02	73·22	73·42	73·62	73·82	75
76	73·00	73·20	73·40	73·60	73·80	74·00	74·20	74·40	74·60	74·80	76
77	73·96	74·17	74·37	74·57	74·77	74·97	75·18	75·39	75·59	75·79	77
78	74·93	75·12	75·33	75·53	75·74	75·95	76·16	76·37	76·57	76·77	78
79	75·88	76·09	76·30	76·50	76·71	76·92	77·13	77·34	77·55	77·75	79
80	76·84	77·05	77·27	77·47	77·68	77·90	78·10	78·32	78·53	78·74	80
81	77·80	78·02	78·23	78·44	78·65	78·87	79·08	79·30	79·51	79·72	81
82	78·76	78·98	79·20	79·41	79·62	79·84	80·06	80·28	80·50	80·71	82
83	79·72	79·94	80·16	80·38	80·60	80·82	81·04	81·26	81·48	81·69	83
84	80·68	80·90	81·12	81·34	81·56	81·79	82·01	82·24	82·46	82·68	84
85	81·64	81·87	82·10	82·31	82·53	82·76	82·99	83·22	83·44	83·66	85
86	82·60	82·83	83·06	83·28	83·50	83·73	83·97	84·20	84·42	84·64	86
87	83·56	83·79	84·02	84·25	84·48	84·71	84·94	85·17	85·40	85·62	87
88	84·52	84·76	85·00	85·22	85·45	85·68	85·92	86·15	86·38	86·61	88
89	85·48	85·72	85·98	86·19	86·42	86·66	86·89	87·13	87·36	87·59	89
90	86·45	86·68	86·93	87·16	87·39	87·63	87·87	88·11	88·34	88·58	90
91	87·41	87·65	87·89	88·12	88·36	88·61	88·85	89·09	89·33	89·56	91
92	88·37	88·61	88·86	89·09	89·33	89·58	89·82	90·07	90·31	90·55	92
93	89·33	89·57	89·82	90·06	90·30	90·55	90·80	91·05	91·29	91·53	93
94	90·29	90·54	90·79	91·03	91·27	91·53	91·78	92·03	92·27	92·51	94
95	91·25	91·50	91·75	92·00	92·25	92·50	92·75	93·00	93·25	93·50	95
96	92·21	92·46	92·72	92·97	93·22	93·47	93·73	93·98	94·23	94·48	96
97	93·17	93·43	93·68	93·93	94·19	94·45	94·71	94·96	95·22	95·47	97
98	94·13	94·39	94·65	94·90	95·16	95·42	95·68	95·94	96·20	96·45	98
99	95·09	95·35	95·61	95·87	96·13	96·39	96·66	96·92	97·18	97·43	99
100	96·05	96·32	96·58	96·84	97·11	97·37	97·63	97·89	98·16	98·42	100

TABLE 1[illegible]—*Continued.* II. Table for reducing the

760	750	752	754	756	758	762	764	766	768	770	760
1	0·987	0·989	0·992	0·995	0·997	1·003	1·005	1·008	1·011	1·013	1
2	1·974	1·979	1·984	1·989	1·995	2·005	2·011	2·016	2·021	2·026	2
3	2·960	2·968	2·976	2·984	2·992	3·007	3·016	3·024	3·032	3·039	3
4	3·947	3·958	3·968	3·979	3·990	4·010	4·021	4·032	4·042	4·052	4
5	4·934	4·947	4·960	4·974	4·987	5·013	5·026	5·040	5·053	5·066	5
6	5·921	5·937	5·952	5·968	5·984	6·016	6·032	6·047	6·063	6·079	6
7	6·908	6·926	6·944	6·963	6·982	7·018	7·037	7·055	7·074	7·092	7
8	7·894	7·916	7·936	7·958	7·979	8·021	8·042	8·063	8·084	8·106	8
9	8·881	8·905	8·929	8·952	8·977	9·023	9·048	9·071	9·095	9·119	9
10	9·87	9·89	9·92	9·95	9·97	10·03	10·05	10·08	10·11	10·13	10
11	10·85	10·88	10·91	10·94	10·97	11·03	11·06	11·09	11·12	11·14	11
12	11·84	11·87	11·90	11·94	11·97	12·04	12·07	12·10	12·13	12·16	12
13	12·83	12·86	12·89	12·93	12·96	13·04	13·07	13·10	13·14	13·17	13
14	13·82	13·85	13·88	13·92	13·96	14·04	14·07	14·11	14·15	14·17	14
15	14·81	14·84	14·87	14·92	14·96	15·04	15·08	15·12	15·16	15·19	15
16	15·79	15·83	15·87	15·91	15·95	16·05	16·09	16·13	16·17	16·21	16
17	16·78	16·82	16·86	16·91	16·95	17·05	17·09	17·14	17·18	17·22	17
18	17·77	17·81	17·85	17·90	17·95	18·05	18·10	18·15	18·19	18·23	18
19	18·75	18·80	18·85	18·90	18·95	19·05	19·10	19·15	19·20	19·25	19
20	19·74	19·79	19·84	19·89	19·95	20·05	20·11	20·16	20·21	20·26	20
21	20·72	20·77	20·83	20·89	20·94	21·05	21·11	21·17	21·22	21·27	21
22	21·71	21·76	21·82	21·88	21·94	22·06	22·12	22·18	22·23	22·28	22
23	22·70	22·75	22·81	22·88	22·94	23·06	23·12	23·18	23·24	23·30	23
24	23·69	23·74	23·80	23·87	23·93	24·06	24·13	24·19	24·25	24·31	24
25	24·67	24·73	24·80	24·87	24·93	25·06	25·13	25·20	25·26	25·32	25
26	25·66	25·72	25·79	25·86	25·93	26·06	26·14	26·21	26·27	26·34	26
27	26·65	26·71	26·78	26·86	26·93	27·07	27·15	27·22	27·28	27·35	27
28	27·63	27·70	27·77	27·85	27·92	28·07	28·15	28·23	28·29	28·36	28
29	28·62	28·69	28·76	28·84	28·92	29·07	29·16	29·24	29·30	29·37	29
30	29·60	29·68	29·76	29·84	29·92	30·07	30·16	30·24	30·32	30·39	30
31	30·59	30·67	30·75	30·84	30·92	31·08	31·17	31·25	31·33	31·41	31
32	31·58	31·66	31·74	31·83	31·92	32·08	32·17	32·26	32·34	32·42	32
33	32·56	32·65	32·73	32·82	32·91	33·08	33·18	33·27	33·35	33·43	33
34	33·55	33·64	33·73	33·82	33·91	34·09	34·18	34·28	34·36	34·45	34
35	34·54	34·63	34·72	34·82	34·91	35·09	35·19	35·28	35·37	35·46	35
36	35·52	35·62	35·71	35·81	35·91	36·09	36·19	36·29	36·38	36·47	36
37	36·51	36·61	36·71	36·81	36·90	37·09	37·20	37·30	37·39	37·49	37
38	37·50	37·60	37·70	37·80	37·90	38·10	38·20	38·30	38·40	38·50	38
39	38·49	38·59	38·69	38·80	38·90	39·10	39·21	39·31	39·41	39·51	39
40	39·47	39·58	39·68	39·79	39·90	40·10	40·21	40·32	40·42	40·52	40
41	40·46	40·56	40·67	40·79	40·89	41·11	41·22	41·33	41·43	41·54	41
42	41·44	41·55	41·66	41·78	41·89	42·11	42·22	42·34	42·44	42·55	42
43	42·43	42·54	42·66	42·78	42·89	43·11	43·23	43·35	43·45	43·56	43
44	43·42	43·53	43·65	43·77	43·89	44·12	44·23	44·35	44·46	44·58	44
45	44·40	44·52	44·64	44·76	44·88	45·12	45·24	45·36	45·47	45·59	45
46	45·39	45·51	45·63	45·76	45·88	46·12	46·24	46·36	46·48	46·60	46
47	46·38	46·50	46·63	46·76	46·88	47·12	47·25	47·38	47·49	47·61	47
48	47·36	47·49	47·62	47·75	47·87	48·13	48·25	48·39	48·51	48·63	48
49	48·35	48·48	48·61	48·74	48·87	49·13	49·26	49·40	49·52	49·64	49
50	49·34	49·47	49·60	49·74	49·87	50·13	50·26	50·40	50·53	50·66	50

volumes of gases to a pressure of 760 mm.—*Continued.*

760	750	752	754	756	758	762	764	766	768	770	760
51	50·33	50·46	50·60	50·74	50·87	51·14	51·27	51·41	51·54	51·67	51
52	51·32	51·45	51·59	51·73	51·87	52·14	52·28	52·42	52·55	52·68	52
53	52·30	52·44	52·58	52·73	52·87	53·14	53·28	53·42	53·56	53·70	53
54	53·29	53·43	53·57	53·72	53·86	54·14	54·28	54·43	54·57	54·72	54
55	54·28	54·42	54·56	54·71	54·86	55·15	55·29	55·44	55·58	55·73	55
56	55·26	55·41	55·56	55·71	55·86	56·15	56·29	56·45	56·59	56·74	56
57	56·25	56·40	56·55	56·70	56·85	57·15	57·30	57·45	57·60	57·76	57
58	57·24	57·39	57·54	57·69	57·85	58·15	58·30	58·46	58·61	58·77	58
59	58·22	58·38	58·53	58·69	58·85	59·16	59·31	59·47	59·62	59·78	59
60	59·21	59·37	59·52	59·68	59·84	60·16	60·32	60·47	60·63	60·79	60
61	60·20	60·36	60·52	60·68	60·84	61·16	61·32	61·48	61·64	61·81	61
62	61·19	61·35	61·51	61·67	61·84	62·16	62·33	62·49	62·65	62·82	62
63	62·17	62·34	62·50	62·67	62·83	63·17	63·33	63·50	63·67	63·84	63
64	63·16	63·33	63·49	63 66	63·83	64·17	64·34	64·51	64·68	64·85	64
65	64·15	64·32	64 49	64·66	64·83	65·17	65·34	65·51	65·69	65·86	65
66	65·13	65·31	65·48	65·65	65·82	66·17	66·35	66·52	66·70	66·88	66
67	66·12	66·30	66·47	66·64	66·82	67·18	67·35	67·53	67·71	67·89	67
68	67·10	67·29	67·46	67·64	67·82	68·18	68·36	68·54	68·72	68·90	68
69	68·09	68·28	68·45	68·63	68·82	69·18	69·36	69·54	69·73	69·91	69
70	69·08	69·26	69·44	69·63	69·82	70·18	70·37	70·55	70·74	70·92	70
71	70·07	70 25	70·43	70·62	70·81	71·19	71·37	71·56	71·75	71·94	71
72	71·05	71·24	71·43	71·62	71·81	72·19	72·38	72·57	72·76	72·95	72
73	72·04	72·23	72·42	72·61	72·81	73·19	73·38	73·57	73·77	73·97	73
74	73·03	73·22	73·41	73·61	73·80	74·19	74·39	74·58	74·78	74·98	74
75	74·01	74·21	74·40	74·60	74·80	75·20	75·39	75·59	75·79	75·99	75
76	75·00	75·20	75·40	75·60	75·80	76·20	76·40	76·60	76·80	77·01	76
77	75·99	76·19	76·39	76·59	76·79	77·20	77·40	77·60	77·81	78·02	77
78	76·97	77·18	77·38	77·58	77·79	78·20	78·41	78·61	78·82	79·03	78
79	77·96	78·17	78·37	78·58	78·79	79·21	79·41	79·62	79·83	80·04	79
80	78·94	79·16	79·36	79·58	79·79	80·21	80·42	80·63	80·84	81·06	80
81	79·93	80·15	80·35	80·57	80·79	81·21	81·42	81·64	81·85	82·07	81
82	80·92	81·14	81·35	81·56	81·78	82·21	82·43	82·65	82·87	83·09	82
83	81·91	82·13	82·34	82·56	82·78	83 22	83·44	83 66	83·88	84·10	83
84	82·90	83·12	83·34	83·56	83·78	84·22	84·44	84·66	84·89	85·11	84
85	83·88	84·11	84·33	84·55	84·78	85·22	85·45	85·67	85·90	86·13	85
86	84·87	85·10	85·32	85 55	85·78	86·22	86·46	86·67	86·91	87·14	86
87	85·85	86·08	86·31	86·54	86·77	87·23	87·46	87·68	87·92	88·15	87
88	86·84	87·07	87·30	87·54	87·77	88·23	88·47	88·69	88·93	89·17	88
89	87·82	88·06	88·29	88·53	88·77	89·23	89·47	89·70	89·94	90·18	89
90	88·81	89·05	89·29	89·52	89·77	90·23	90·48	90 71	90·95	91·19	90
91	89·80	90·04	90·28	90·52	90·76	91·24	91·48	91·72	91·96	92·21	91
92	90·79	91·03	91·27	91·51	91·76	92·24	92·49	92·73	92·97	93·22	92
93	91·77	92·02	92·26	92·51	92·76	93·24	93·49	93·74	93·98	94·23	93
94	92·76	93·01	93·26	93·50	93·75	94·24	94·49	94·74	94·99	95·24	94
95	93·74	94·00	94·25	94·50	94·75	95·25	95·50	95·75	96·00	96·26	95
96	94·73	94·98	95·24	95·49	95·75	96·25	96 51	96·76	97·01	97·27	96
97	95·72	95·97	96·23	96·49	96·75	97·25	97·51	97·77	98·02	98·29	97
98	96·70	96·96	97·22	97·48	97·74	98·25	98·52	98·77	99·03	99·30	98
99	97·69	97·95	98·21	98·48	98·74	99·26	99·52	99·78	100·04	100·31	99
100	98·68	98·95	99·21	99·47	99·74	100·26	100·53	100·79	101·05	101·32	100

TABLE 13.—FACTORS FOR REDUCING A TEMPERATURE

0° Centigrade, and 760 millimetres, or 32°

Centigrade.		0·0.	1·1.	2·2.	3·3.	4·4.	5·6.	6·7.	7·8.	8·9.
Fahrenheit.		32°.	34°.	36°.	38°.	40°.	42°.	44°.	46°.	48°.
In.	Milli-metres.									
27·5	698·5	·9191	·9154	·9116	·9079	·9043	·9007	·8972	·8936	·8899
27·6	701·0	·9224	·9188	·9149	·9112	·9076	·9039	·9005	·8969	·8932
27·7	703·6	·9258	·9221	·9183	·9145	·9109	·9072	·9037	·9001	·8964
27·8	706·1	·9291	·9254	·9215	·9179	·9142	·9105	·9070	·9034	·8996
27·9	708·6	·9325	·9288	·9249	·9212	·9174	·9138	·9102	·9067	·9029
28·0	711·2	·9358	·9321	·9282	·9244	·9208	·9170	·9135	·9099	·9061
28·1	713·7	·9391	·9354	·9315	·9278	·9241	·9208	·9167	·9131	·9093
28·2	716·3	·9425	·9387	·9348	·9310	·9273	·9236	·9200	·9164	·9125
28·3	718·8	·9458	·9421	·9382	·9344	·9306	·9269	·9233	·9197	·9158
28·4	721·3	·9491	·9454	·9415	·9377	·9339	·9301	·9265	·9229	·9190
28·5	723·9	·9525	·9487	·9448	·9410	·9372	·9334	·9298	9262	·9223
28·6	726·4	·9558	·9520	·9481	·9443	·9405	·9367	·9331	·9294	·9255
28·7	728·9	·9592	·9554	·9514	·9476	·9438	·9400	·9364	·9327	·9287
28·8	731·5	·9625	·9587	·9547	·9509	·9471	·9432	·9396	·9359	·9320
28·9	734·0	·9659	·9620	·9580	·9542	·9504	·9465	·9429	·9392	·9352
29·0	736·6	·9692	·9654	·9613	·9575	·9536	·9498	9462	·9424	·9385
29·1	739·1	·9725	·9687	·9647	·9608	·9569	·9531	·9494	9457	·9417
29·2	741·6	·9759	·9720	·9680	·9640	·9602	·9563	·9527	·9489	·9449
29·3	744·2	·9792	·9753	·9713	·9674	·9635	·9596	·9559	·9522	·9481
29·4	746·7	·9826	·9787	·9746	9707	·9668	·9629	9592	·9554	·9514
29·5	749·3	·9859	·9820	·9779	·9740	·9701	·9662	9624	9587	9546
29·6	751·8	·9893	·9853	·9812	·9773	·9733	·9694	·9657	9619	9578
29·7	754·3	·9926	·9887	·9845	·9806	·9766	·9727	·9690	9652	·9611
29·8	756·9	·9959	·9920	·9879	9839	·9800	·9760	·9722	·9684	·9643
29·9	759·4	·9993	·9954	·9912	·9872	·9832	·9793	·9755	·9717	·9676
30·0	762·0	1·0026	·9987	·9945	·9905	·9865	·9826	·9788	·9749	·9708
30·1	764·5	1·0060	1·0020	·9978	·9938	·9898	·9858	·9820	·9782	9740
30·2	767·0	1·0093	1·0053	1·0011	·9971	·9931	·9891	·9853	·9814	·9773
30·3	769·6	1·0126	1·0086	1·0044	1·0004	·9964	·9924	9885	·9846	·9805
30·4	772·1	1·0160	1·0120	1·0078	1·0037	·9997	·9957	9918	·9879	·9837
30·5	774·7	1·0194	1·0153	1·0111	1 0070	1·0030	·9989	9950	9911	·9870
30·6	777·2	1·0227	1·0186	1·0144	1·0103	1·0063	1·0022	·9983	9944	·9902
30·7	779·7	1·0260	1·0220	1·0177	1·0136	1·0096	1 0055	1·0016	·9976	·9935
30·8	782·3	1·0294	1·0253	1·0210	1·0169	1·0128	1·0087	1·0048	1·0009	·9967
30·9	784·8	1·0327	1·0286	1·0243	1·0202	1·0164	1·0120	1·0081	1·0041	1 0000
31·0	787·4	1·0360	1·0319	1·0276	1·0235	1·0194	1·0153	1·0114	1·0074	1·0032

GIVEN VOLUME OF GAS TO NORMAL AND PRESSURE.

Fahrenheit, and 29·92 inches barometric pressure.

Centigrade.		10·0.	11·1.	12·2.	13·3.	14·4.	15·6	16·7.	17·8.
Fahrenheit.		50°.	52°.	54°.	56°.	58°.	60°.	62°.	64°.
In.	Millimetres.								
27·5	698·5	·8867	·8832	·8797	·8763	·8728	·8695	·8661	·8628
27·6	701·0	·8900	·8864	·8829	·8795	·8760	·8726	·8693	·8660
27·7	703·6	·8932	·8897	·8861	·8827	·8792	·8758	·8724	·8691
27·8	706·1	·8964	·8928	·8893	·8859	·8823	·8790	·8756	·8722
27·9	708·6	·8996	8960	·8925	·8890	·8855	·8821	·8787	·8754
28·0	711·2	·9029	·8992	·8957	·8922	·8887	·8853	·8819	·8785
28·1	713·7	·9060	·9025	·8989	·8954	·8919	·8884	·8850	·8816
28·2	716·3	·9093	·9057	·9021	·8986	·8951	·8916	·8882	·8848
28·3	718·8	·9125	·9089	·9053	·9018	·8983	·8948	·8913	·8879
28·4	721·3	·9157	·9121	·9085	·9050	·9014	·8979	·8945	·8911
28·5	723·9	·9189	·9153	·9117	·9082	·9046	·9011	·8976	·8942
28·6	726·4	·9222	·9185	·9149	·9114	·9077	·9043	·9008	·8973
28·7	728·9	·9254	·9218	·9181	·9145	·9109	·9074	·9039	·9005
28·8	731·5	·9286	·9250	·9213	·9177	·9141	·9106	·9071	·9036
28·9	734·0	·9318	·9282	·9245	·9209	·9173	·9138	·9102	·9067
29·0	736·6	·9351	·9314	·9277	·9241	·9205	·9169	·9134	·9099
29·1	739·1	·9383	·9346	·9309	·9273	·9236	·9201	·9165	·9130
29·2	741·6	·9415	·9378	·9341	·9305	·9268	·9233	·9197	·9162
29·3	744·2	·9448	·9410	·9373	·9336	·9300	·9264	·9228	·9193
29·4	746·7	·9480	·9443	·9405	·9368	·9332	·9296	·9260	·9224
29·5	749·3	·9512	·9475	·9137	·9400	·9363	·9328	·9291	·9256
29·6	751·8	·9544	·9506	·9469	·9432	·9395	·9359	·9323	·9287
29·7	754·3	·9577	·9539	·9501	·9464	·9427	·9390	·9354	·9318
29·8	756·9	·9609	·9571	·9533	·9496	·9159	·9422	·9386	·9350
29·9	759·4	·9641	·9603	·9565	·9528	·9490	·9454	·9417	·9381
30·0	762·0	·9673	·9635	·9597	·9560	·9522	·9486	·9449	·9413
30·1	764·5	·9706	·9667	·9629	·9591	·9554	·9517	·9480	·9444
30·2	767·0	·9738	·9700	·9661	·9623	·9586	·9549	·9512	·9475
30·3	769·6	·9770	·9731	·9693	·9655	·9617	·9580	·9543	·9507
30·4	772·1	·9802	·9764	·9725	·9687	·9649	·9612	·9575	·9538
30·5	774·7	·9835	·9796	·9757	·9719	·9681	·9643	·9606	·9569
30·6	777·2	·9867	·9828	·9789	·9751	·9712	·9675	·9638	·9601
30·7	779·7	·9899	·9860	·9821	·9782	·9744	·9707	·9669	·9632
30·8	782·3	·9931	·9892	·9853	·9815	·9776	·9738	·9701	·9664
30·9	784·8	·9963	·9924	·9885	·9846	·9807	·9770	·9732	·9695
31·0	787·4	·9996	·9956	·9917	·9878	·9840	·9801	·9764	·9726

TABLE 13—*Continued.*

Centigrade.		18·9.	20.	21·1.	22·2.	23·3.	24·4.	25·6.	26·7.
Fahrenheit.		66°	68°.	70°.	72°.	74°.	76°.	78°.	80°.
In.	Millimetres.								
27·5	698·5	8595	·8563	·8530	·8498	·8466	·8435	·8403	·8372
27·6	701·0	·8626	·8594	·8561	·8529	·8497	·8465	·8434	·8403
27·7	703·6	·8658	·8625	·8592	·8560	·8528	·8496	·8464	·8433
27·8	706·1	·8689	·8656	·8623	·8591	·8559	·8527	·8495	·8463
27·9	708·6	·8720	·8687	·8654	·8622	·8589	·8557	·8525	·8494
28 0	711·2	·8751	·8718	·8685	·8653	·8620	·8588	·8556	·8524
28·1	713·7	·8783	·8750	·8716	·8684	·8651	·8619	·8587	·8555
28·2	716·3	·8814	·8781	·8747	·8714	·8682	·8649	·8617	·8585
28·3	718·8	·8845	·8812	·8778	·8745	·8713	·8680	·8648	·8616
28 4	721·3	·8876	·8843	·8809	·8776	·8743	·8711	·8678	·8646
28·5	723·9	·8908	·8874	·8840	·8807	·8774	·8741	·8709	·8677
28·6	726·4	·8939	·8905	·8872	·8838	·8805	·8772	·8739	·8707
28·7	728 9	·8970	·8936	·8903	·8869	·8836	·8803	·8770	·8738
28·8	731·5	·9002	·8968	·8934	·8900	·8866	·8833	·8800	·8768
28·9	734·0	·9033	·8999	·8965	·8931	·8897	·8864	·8831	·8798
29·0	736·6	·9064	·9030	·8996	·8962	·8928	·8895	·8862	·8829
29·1	739·1	·9095	·9061	·9027	·8993	·8959	·8925	·8892	·8859
29 2	741·6	·9127	·9092	·9058	·9023	·8990	·8956	·8923	·8890
29·3	744·2	·9158	·9123	·9089	·9054	·9020	·8987	·8953	·8920
29·4	746·7	·9189	·9154	·9120	·9085	·9051	·9017	·8984	·8951
29·5	749·3	·9220	·9186	·9151	·9116	·9082	·9048	·9014	·8981
29 6	751·8	·9252	·9217	·9182	·9147	·9113	·9079	·9045	·9012
29·7	754·3	·9283	·9248	·9213	·9178	·9144	·9109	·9076	·9042
29·8	756·9	·9314	·9279	·9244	·9209	·9174	·9140	·9106	·9072
29·9	759·4	·9345	·9310	·9275	·9240	·9205	·9171	·9137	·9103
30 0	762 0	·9377	·9341	·9306	·9271	·9236	·9201	·9167	·9133
30·1	764·5	·9408	·9372	·9337	·9302	·9267	·9232	·9198	·9164
30·2	767·0	·9439	·9403	·9368	·9333	·9297	·9263	·9228	·9194
30·3	769·6	·9470	·9435	·9399	·9363	·9328	·9293	·9259	·9225
30·4	772·1	·9502	·9466	·9430	·9394	·9359	·9324	·9289	·9255
30·5	774·7	·9533	·9497	·9461	·9425	·9390	·9355	·9320	·9286
30·6	777·2	·9564	·9528	·9492	·9456	·9421	·9385	·9351	·9316
30·7	779·7	·9595	·9559	·9523	·9487	·9451	·9416	·9381	·9346
30·8	782·3	·9627	·9590	·9554	·9518	·9482	·9447	·9412	·9377
30·9	784·8	·9658	·9621	·9585	·9549	·9513	·9477	·9442	·9407
31·0	787·4	·9689	·9653	·9616	·9580	·9544	·9508	·9473	·9438

TABLE 14.—VOLUMES OF WATER AT DIFFERENT TEMPERATURES. (Rossetti.)

Temp. °C.		Temp. °C.		Temp. °C.	
0	1	14	1·000556	40	1·007531
1	0·999947	15	1·000695	45	1·009541
2	0·999908	16	1·000846	50	1·011766
3	0·999885	17	1·001010	55	1·014100
4	0·999877	18	1·001184	60	1·016590
5	0·999883	19	1·001370	65	1·019302
6	0·999903	20	1·001567	70	1·022246
7	0·999938	21	1·001776	75	1·025410
8	0·999986	22	1·001995	80	1·028581
9	1·000048	23	1·002225	85	1·031894
10	1·000124	24	1·002465	90	1·035397
11	1·000213	25	1·002717	95	1·039094
12	1·000314	30	1·004061	100	1·042986
13	1·000429	35	1·005697		

TABLE 15.—REDUCTION OF WATER PRESSURE TO MERCURIAL PRESSURE.

aq.	Hg.	aq.	Hg.	aq.	Hg.	aq.	Hg.	aq.	Hg.
1	0·07	23	1·70	45	3·32	67	4·94	89	6·57
2	0·15	24	1·77	46	3·39	68	5·02	90	6·64
3	0·22	25	1·84	47	3·47	69	5·09	91	6·72
4	0·30	26	1·92	48	3·54	70	5·17	92	6·79
5	0·37	27	1·98	49	3·62	71	5·24	93	6·86
6	0·44	28	2·07	50	3·69	72	5·31	94	6·94
7	0·52	29	2·11	51	3·76	73	5·39	95	7·01
8	0·59	30	2·21	52	3·84	74	5·46	96	7·08
9	0·66	31	2·29	53	3·91	75	5·54	97	7·16
10	0·74	32	2·36	54	3·99	76	5·61	98	7·23
11	0·81	33	2·44	55	4·06	77	5·68	99	7·31
12	0·89	34	2·51	56	4·13	78	5·76	100	7·38
13	0·96	35	2·58	57	4·21	79	5·83	200	14·76
14	1·03	36	2·66	58	4·28	80	5·90	300	22·14
15	1·12	37	2·73	59	4·35	81	5·98	400	29·52
16	1·18	38	2·80	60	4·43	82	6·05	500	36·90
17	1·26	39	2·88	61	4·50	83	6·13	600	44·28
18	1·33	40	2·95	62	4·58	84	6·20	700	51·66
19	1·40	41	3·03	63	4·65	85	6·27	800	59·04
20	1·48	42	3·10	64	4·72	86	6·35	900	66·42
21	1·55	43	3·17	65	4·80	87	6·42	1000	73·80
22	1·62	44	3·25	66	4·87	88	6·49		

TABLE 16.—TENSION OF AQUEOUS VAPOUR.

Between −20° and +118° C. in Millimetres Mercury. (Magnus.)

T.	mm.	T.	mm.	T.	mm.
−20°	0·916	+5°	6·471	+30°	31·602
19	0·999	6	6·939	31	33·5
18	1·089	7	7·436	32	35·4
17	1·186	8	7·964	33	37·5
16	1·290	9	8·525	34	39·6
15	1·403	10	9·126	35	41·9
14	1·525	11	9·756	36	44·3
13	1·655	12	10·421	37	46·8
12	1·796	13	11·130	38	49·4
11	1·947	14	11·882	39	52·1
10	2·109	15	12·677	40	55·0
9	2·284	16	13·519	41	58·0
8	2·471	17	14·409	42	61·1
7	2·671	18	15·351	43	64·4
6	2·886	19	16·345	44	67·8
5	3·110	20	17·396	45	71·4
4	3·361	21	18·505	46	75·2
3	3·624	22	19·675	47	79·1
2	3·900	23	20·909	48	83·2
1	4·205	24	22·211	49	87·5
0	4·525	25	23·582	50	92·0
+1	4·867	26	25·026	51	96·6
2	5·231	27	26·547	52	101·5
3	5·619	28	28·148	53	106·6
4	6·032	29	29·832	54	111·9

TABLE 16—*Continued.*

T.	mm.	T.	mm.	T.	mm.
+55°	117·4	+77°	312·9	+99°	733·1
56	123·1	78	326·1	100	760·0
57	129·1	79	339·8	101	787·7
58	135·3	80	353·9	102	816·3
59	141·8	81	368·6	103	845·7
60	148·6	82	383·7	104	876·0
61	155·6	83	399·4	105	907·1
62	162·9	84	415·6	106	939·2
63	170·5	85	432·3	107	972·3
64	178·4	86	449·6	108	1006·3
65	186·6	87	467·5	109	1041·3
66	195·1	88	486·0	110	1077·3
67	204·0	89	505·0	111	1114·3
68	213·2	90	524·8	112	1152·3
69	222·7	91	545·1	113	1191·4
70	232·6	92	566·1	114	1231·7
71	242·9	93	587·8	115	1273·0
72	253·5	94	610·2	116	1315·5
73	264·6	95	633·3	117	1359·1
74	276·0	96	657·1	118	1403·9
75	287·9	97	681·7		
76	300·2	98	707·0		

TABLE 17.—TENSION OF AQUEOUS VAPOUR FOR TEMPERATURES FROM 40° C.

Temperature Centigrade.	Tension in mm. of Mercury.	Pressure in atmospheres.	Pressure per sq. cm. in kilos.
+40°	54·906	0·072	0·07465
45	71·391	0·094	0·09706
50	91·982	0·121	0·12505
55	117·478	0·154	0·15972
60	148·791	0·196	0·20323
65	186·945	0·246	0·25417
70	233·093	0·306	0·31692
75	288·517	0·380	0·39227
80	354·643	0·466	0·48217
85	433·041	0·570	0·58877
90	525·450	0·691	0·71440
95	633·778	0·834	0·86168
100	760·00	1·000	1·03330
105	906·41	1·193	1·23236
110	1075·37	1·415	1·46210
115	1269·41	1·673	1·72592
120	1491·28	1·962	2·02755
125	1743·88	2·294	2·37098
130	2030·28	2·671	2·76037
135	2353·73	3·097	3·20013
140	2717·63	3·575	3·69490
145	3125·55	4·112	4·24950
150	3581·23	4·712	4·86904
155	4088·56	5·380	5·55881
160	4651·62	6·120	6·32434
165	5274·54	6·940	7·17127
170	5961·66	7·814	8·10547
175	6717·43	8·838	9·13302
180	7546·39	9·929	10·2601
185	8453·23	11·122	11·4930
190	9442·70	12·424	12·8383
195	10519·73	13·841	14·3025
200	11688·96	15·380	15·8923
205	12955·66	17·047	17·6145
210	14324·80	18·848	19·4760
215	15801·33	20·791	21·4835
220	17390·00	22·881	23·6439
225	19097·04	25·127	25·9643
230	20926·40	27·534	28·4515

TABLE 17 — *Continued.* **TENSION OF AQUEOUS VAPOUR FOR TEMPERATURES FROM 40° F.**

Temperature Fahrenheit.	Tension in inches of Mercury.	Pressure in atmospheres.	Pressure in lbs. per square inch.
100°	1·918	·064	·941
110	2·577	·086	1·267
120	3·427	·114	1·676
130	4·502	·150	2·205
140	5·858	·196	2·883
150	7·546	·252	3·705
160	9·628	·322	4·734
170	12·18	·407	5·984
180	15·27	·510	7·498
190	19·01	·635	9·336
200	23·46	·784	11·53
210	29·92	1·000	14·706
220	35·01	1·170	17·19
230	42·34	1·415	20·80
240	50·89	1·701	25·01
250	60·81	2·032	29·87
260	72·27	2·415	35·50
270	85·41	2·855	41·97
280	100·4	3·356	49·34
290	117·5	3·927	57·73
300	136·8	4·572	67·22
310	158·6	5·301	77·94
320	183·1	6·120	89·98
330	210·5	7·035	103·4
340	241·1	8·058	118·5
350	275·0	9·198	135·2
360	312·6	10·45	153·6
370	354·0	11·83	173·9
380	399·6	13·35	196·3
390	449·6	15·02	220·8
400	504·4	16·86	247·9
410	563·9	18·84	277·0
420	628·8	21·01	309·9
430	699·2	23·37	343·6
440	775·3	25·91	380·9

TABLE 18.—TENSION OF AQUEOUS VAPOUR IN INCHES OF MERCURY FROM 1° TO 100° F.

Temperature Fahrenheit.	Inches of Mercury.	Temperature Fahrenheit.	Inches of Mercury.
1°	·046	36°	·212
2	·048	37	·220
3	·050	38	·229
4	·052	39	·238
5	·054	40	·247
6	·057	41	·257
7	·060	42	·267
8	·062	43	·277
9	·065	44	·288
10	·068	45	·299
11	·071	46	·311
12	·074	47	·323
13	·078	48	·335
14	·082	49	·348
15	·086	50	·361
16	·090	51	·374
17	·094	52	·388
18	·098	53	·403
19	·103	54	·418
20	·108	55	·433
21	·113	56	·449
22	·118	57	·465
23	·123	58	·482
24	·129	59	·500
25	·135	60	·518
26	·141	61	·537
27	·147	62	·556
28	·153	63	·576
29	·160	64	·596
30	·167	65	·617
31	·174	66	·639
32	·181	67	·661
33	·188	68	·685
34	·196	69	·708
35	·204	70	·733

TABLE 18—*Continued.*

Temperature Fahrenheit.	Inches of Mercury.	Temperature Fahrenheit.	Inches of Mercury.
71°	·759	86°	1·242
72	·785	87	1·282
73	·812	88	1·323
74	·840	89	1·366
75	·868	90	1·401
76	·897	91	1·455
77	·927	92	1·501
78	·958	93	1·548
79	·990	94	1·596
80	1·023	95	1·646
81	1·057	96	1·697
82	1·092	97	1·751
83	1·128	98	1·806
84	1·165	99	1·862
85	1·203	100	1·918

TABLE 19.—BOILING POINT OF WATER AT DIFFERENT BAROMETRIC PRESSURES.

Barometric Pressure.	Boiling Point.	Barometric Pressure.	Boiling Point.
mm.		mm.	
710	98·11	745	99·44
715	98·30	750	99·63
720	98·49	755	99·82
725	98·69	760	100·00
730	98·88	765	100·18
735	99·07	770	100·37
740	99·26	775	100·55

TABLE 20.—COMPARISON OF THE HYDROMETER DEGREES ACCORDING TO BAUMÉ AND TWADDELL, WITH THE SPECIFIC GRAVITIES.

B.	Tw.	Spec. Gravity.	B.	Tw.	Spec. Gravity.	B.	Tw.	Spec. Gravity.
0	0	1·000	15·4	24	1·120	29·3	51	1·255
0·7	1	1·005	16·0	25	1·125	29·7	52	1·260
1·0	1·4	1·007	16·5	26	1·130	30·0	52·6	1·263
1·4	2	1·010	17·0	26·8	1·134	30·2	53	1·265
2·0	2·8	1·014	17·1	27	1·135	30·6	54	1·270
2·1	3	1·015	17·7	28	1·140	31·0	54·8	1·274
2·7	4	1·020	18·0	28·4	1·142	31·1	55	1·275
3·0	4·1	1·022	18·3	29	1·145	31·5	56	1·280
3·4	5	1·025	18·8	30	1·150	32·0	57	1·285
4·0	5·8	1·029	19·0	30·4	1·152	32·4	58	1·290
4·1	6	1·030	19·3	31	1·155	32·8	59	1·295
4·7	7	1·035	19·8	32	1·160	33·0	59·4	1·297
5·0	7·4	1·037	20·0	32·4	1·162	33·3	60	1·300
5·4	8	1·040	20·3	33	1·165	33·7	61	1·305
6·0	9	1·045	20·9	34	1·170	34·0	61·6	1·308
6·7	10	1·050	21·0	34·2	1·171	34·2	62	1·310
7·0	10·2	1·052	21·4	35	1·175	34·6	63	1·315
7·4	11	1·055	22·0	36	1·180	35·0	64	1·320
8·0	12	1·060	22·5	37	1·185	35·4	65	1·325
8·7	13	1·065	23·0	38	1·190	35·8	66	1·330
9·0	13·4	1·067	23·5	39	1·195	36·0	66·4	1·332
9·4	14	1·070	24·0	40	1·200	36·2	67	1·335
10·0	15	1·075	24·5	41	1·205	36·6	68	1·340
10·6	16	1·080	25·0	42	1·210	37·0	69	1·345
11·0	16·6	1·083	25·5	43	1·215	37·4	70	1·350
11·2	17	1·085	26·0	44	1·220	37·8	71	1·355
11·9	18	1·090	26·4	45	1·225	38·0	71·4	1·357
12·0	18·2	1·091	26·9	46	1·230	38·2	72	1·360
12·4	19	1·095	27·0	46·2	1·231	38·6	73	1·365
13·0	20	1·100	27·4	47	1·235	39·0	74	1·370
13·6	21	1·105	27·9	48	1·240	39·4	75	1·375
14·0	21·6	1·108	28·0	48·2	1·241	39·8	76	1·380
14·2	22	1·110	28·4	49	1·245	40·0	76·6	1·383
14·9	23	1·115	28·8	50	1·250	40·1	77	1·385
15·0	23·2	1·116	29·0	50·4	1·252	40·5	78	1·390

N.B.—The Baumé degrees are calculated by the formula $d = \frac{144\cdot3}{144\cdot3 - n}$, where n is the degree on the Baumé scale and d the specific gravity. On this Baumé scale, water at 15° C. = 0° and sulphuric acid of 1·842 = 66°. This is the Baumé's hydrometer, mostly used on the Continent of Europe, but other scales are in use there as well, and quite another scale for Baumé's hydrometer is used in America.

TABLE 20—*Continued.*

B.	Tw.	Spec. Gravity.	B.	Tw.	Spec. Gravity.	B.	Tw.	Spec. Gravity.
40·8	79	1·395	50·9	109	1·545	59·5	140	1·700
41·0	79·4	1·397	51·0	109·2	1·546	59·7	141	1·705
41·2	80	1·400	51·2	110	1·550	60·0	142	1·710
41·6	81	1·405	51·5	111	1·555	60·2	143	1·715
42·0	82	1·410	51·8	112	1·560	60·4	144	1·720
42·3	83	1·415	52·0	112·6	1·563	60·6	145	1·725
42·7	84	1·420	52·1	113	1·565	60·9	146	1·730
43·0	84·8	1·424	52·4	114	1·570	61·0	146·4	1·732
43·1	85	1·425	52·7	115	1·575	61·1	147	1·735
43·4	86	1·430	53·0	116	1·580	61·4	148	1·740
43·8	87	1·435	53·3	117	1·585	61·6	149	1·745
44·0	87·6	1·438	53·6	118	1·590	61·8	150	1·750
44·1	88	1·440	53·9	119	1·595	62·0	150·6	1·753
44·4	89	1·445	54·0	119·4	1·597	62·1	151	1·755
44·8	90	1·450	54·1	120	1·600	62·3	152	1·760
45·0	90·6	1·453	54·4	121	1·605	62·5	153	1·765
45·1	91	1·455	54·7	122	1·610	62·8	154	1·770
45·4	92	1·460	55·0	123	1·615	63·0	155	1·775
45·8	93	1·465	55·2	124	1·620	63·2	156	1·780
46·0	93·6	1·468	55·5	125	1·625	63·5	157	1·785
46·1	94	1·470	55·8	126	1·630	63·7	158	1·790
46·4	95	1·475	56·0	127	1·635	64·0	159	1·795
46·8	96	1·480	56·3	128	1·640	64·2	160	1·800
47·0	96·6	1·483	56·6	129	1·645	64·4	161	1·805
47·1	97	1·485	56·9	130	1·650	64·6	162	1·810
47·4	98	1·490	57·0	130·4	1·652	64·8	163	1·815
47·8	99	1·495	57·1	131	1·655	65·0	164	1·820
48·0	99·6	1·498	57·4	132	1·660	65·2	165	1·825
48·1	100	1·500	57·7	133	1·665	65·5	166	1·830
48·4	101	1·505	57·9	134	1·670	65·7	167	1·835
48·7	102	1·510	58·0	134·2	1·671	65·9	168	1·840
49·0	103	1·515	58·2	135	1·675	66·0	168·4	1·842
49·4	104	1·520	58·4	136	1·680	66·1	169	1·845
49·7	105	1·525	58·7	137	1·685	66·3	170	1·850
50·0	106	1·530	58·9	138	1·690	66·5	171	1·855
50·3	107	1·535	59·0	138·2	1·691	66·7	172	1·860
50·6	108	1·540	59·2	139	1·695	67·0	173	1·865

TABLE 21.—MATHEMATICAL TABLES.

Circumference and area of circles, squares, cubes, square and cube roots.

n	πn ○	$\pi \frac{n^2}{4}$ ●	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
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

TABLE 21—*Continued.*

n	πn ○	$\pi \frac{n^2}{4}$ ●	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
4·8	15·080	18·096	23·04	110·592	2·1909	1·6869
4·9	15·391	18·857	24·01	117·649	2·2136	1·6985
5·0	15·708	19·635	25·00	125·000	2·2361	1·7100
5·1	16·022	20·428	26·01	132·651	2·2583	1·7213
5·2	16·336	21·237	27·04	140·608	2·2804	1·7325
5·3	16·650	22·062	28·09	148·877	2·3022	1·7435
5·4	16·965	22·902	29·16	157·464	2·3238	1·7544
5·5	17·279	23·758	30·25	166·375	2·3452	1·7652
5·6	17·593	24·630	31·36	175·616	2·3664	1·7758
5·7	17·907	25·518	32·49	185·193	2·3875	1·7863
5·8	18·221	26·421	33·64	195·112	2·4083	1·7967
5·9	18·535	27·340	34·81	205·379	2·4290	1·8070
6·0	18·850	28·274	36·00	216·000	2·4495	1·8171
6·1	19·164	29·225	37·21	226·981	2·4698	1·8272
6·2	19·478	30·191	38·44	238·328	2·4900	1·8371
6·3	19·792	31·173	39·69	250·047	2·5100	1·8469
6·4	20·106	32·170	40·96	262·144	2·5298	1·8566
6·5	20·420	33·183	42·25	274·625	2·5495	1·8663
6·6	20·735	34·212	43·56	287·496	2·5691	1·8758
6·7	21·049	35·257	44·89	300·763	2·5884	1·8852
6·8	21·363	36·317	46·24	314·432	2·6077	1·8945
6·9	21·677	37·393	47·61	328·509	2·6268	1·9038
7·0	21·991	38·485	49·00	343·000	2·6458	1·9129
7·1	22·305	39·592	50·41	357·911	2·6646	1·9220
7·2	22·619	40·715	51·84	373·248	2·6833	1·9310
7·3	22·934	41·854	53·29	389·017	2·7019	1·9399
7·4	23·248	43·008	54·76	405·224	2·7203	1·9487
7·5	23·562	44·179	56·25	421·875	2·7386	1·9574
7·6	23·876	45·365	57·76	438·976	2·7568	1·9661
7·7	24·190	46·566	59·29	456·533	2·7749	1·9747
7·8	24·504	47·784	60·84	474·552	2·7929	1·9832
7·9	24·819	49·017	62·41	493·039	2·8107	1·9916
8·0	25·133	50·266	64·00	512·000	2·8284	2·0000
8·1	25·447	51·530	65·61	531·441	2·8461	2·0083
8·2	25·761	52·810	67·24	551·368	2·8636	2·0165
8·3	26·075	54·106	68·89	571·787	2·8810	2·0247
8·4	26·389	55·418	70·56	592·704	2·8983	2·0328

TABLE 21—*Continued.*

n	πn ○	$\pi \frac{n^2}{4}$ ●	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
8·5	26·704	56·745	72·25	614·125	2·9155	2·0408
8·6	27·018	58·088	73·96	636·056	2·9326	2·0488
8·7	27·332	59·447	75·69	658·503	2·9496	2·0567
8·8	27·646	60·821	77·44	681·472	2·9665	2·0646
8·9	27·960	62·211	79·21	704·969	2·9833	2·0724
9·0	28·274	63·617	81·00	729·000	3·0000	2·0801
9·1	28·588	65·039	82·81	753·571	3·0166	2·0878
9·2	28·903	66·476	84·64	778·688	3·0332	2·0954
9·3	29·217	67·929	86·49	804·357	3·0496	2·1029
9·4	29·531	69·398	88·36	830·584	3·0659	2·1105
9·5	29·845	70·882	90·25	857·375	3·0822	2·1179
9·6	30·159	72·382	92·16	884·736	3·0984	2·1253
9·7	30·473	73·898	94·09	912·673	3·1145	2·1327
9·8	30·788	75·430	96·04	941·192	3·1305	2·1400
9·9	31·102	76·977	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
10·4	32·673	84·949	108·16	1124·864	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	3·3754	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

TABLE 21—*Continued.*

n	πn	$\pi \frac{n^2}{4}$	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
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	156·15	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
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	176·72	225·00	3375·000	3·8730	2·4662
15·1	47·438	179·08	228·01	3442·951	3·8859	2·4717
15·2	47·752	181·46	231·04	3511·808	3·8987	2·4772
15·3	48·066	183·85	234·09	3581·577	3·9115	2·4825
15·4	48·381	186·27	237·16	3652·264	3·9243	2·4879
15·5	48·695	188·69	240·25	3723·875	3·9370	2·4933
15·6	49·009	191·13	243·36	3796·416	3·9497	2·4986
15·7	49·323	193·59	246·49	3869·893	3·9623	2·5039
15·8	49·637	196·07	249·64	3944·312	3·9749	2·5092
15·9	49·951	198·56	252·81	4019·679	3·9875	2·5146

TABLE 21—*Continued.*

n	πn ○	$\pi \frac{n^2}{4}$ ●	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
16·0	50·265	201·06	256·00	4096·000	4·0000	2·5198
16·1	50·580	203·58	259·21	4173·281	4·0125	2·5251
16·2	50·894	206·13	262·44	4251·528	4·0249	2·5303
16·3	51·208	208·67	265·69	4330·747	4·0373	2·5355
16·4	51·522	211·24	268·56	4410·944	4·0497	2·5406
16·5	51·836	213·83	272·25	4492·125	4·0620	2·5458
16·6	52·150	216·42	275·56	4574·296	4·0743	2·5509
16·7	52·465	219·04	278·89	4657·463	4·0866	2·5561
16·8	52·779	221·67	282·24	4741·632	4·0988	2·5612
16·9	53·093	224·32	285·61	4826·809	4·1110	2·5663
17·0	53·407	226·98	289·00	4913·000	4·1231	2·5713
17·1	53·721	229·66	292·41	5000·211	4·1352	2·5763
17·2	54·035	232·35	295·84	5088·448	4·1473	2·5813
17·3	54·350	235·06	299·29	5177·717	4·1593	2·5863
17·4	54·664	237·79	302·76	5268·024	4·1713	2·5913
17·5	54·978	240·53	306·25	5359·375	4·1833	2·5963
17·6	55·292	243·29	309·76	5451·776	4·1952	2·6012
17·7	55·606	246·06	313·29	5545·233	4·2071	2·6061
17·8	55·920	248·85	316·84	5639·752	4·2190	2·6109
17·9	56·235	251·65	320·41	5735·339	4·2308	2·6158
18·0	56·549	254·47	324·00	5832·000	4·2426	2·6207
18·1	56·863	257·30	327·61	5929·741	4·2544	2·6256
18·2	57·177	260·16	331·24	6028·568	4·2661	2·6304
18·3	57·491	263·02	334·89	6128·487	4·2778	2·6352
18·4	57·805	265·90	338·56	6229·504	4·2895	2·6400
18·5	58·119	268·80	342·25	6331·625	4·3012	2·6448
18·6	58·434	271·72	345·96	6434·856	4·3128	2·6495
18·7	58·748	274·65	349·69	6539·203	4·3243	2·6543
18·8	59·062	277·59	353·44	6644·672	4·3359	2·6590
18·9	59·376	280·55	357·21	6751·269	4·3474	2·6637
19·0	59·690	283·53	361·00	6859·000	4·3589	2·6684
19·1	60·004	286·52	364·81	6967·871	4·3703	2·6731
19·2	60·319	289·53	368·64	7077·888	4·3818	2·6777
19·3	60·633	292·55	372·49	7189·057	4·3942	2·6824
19·4	60·947	295·59	376·36	7301·384	4·4045	2·6869
19·5	61·261	298·65	380·25	7414·875	4·4159	2·6916
19·6	61·575	301·72	384·16	7529·536	4·4272	2·6962
19·7	61·889	304·81	388·09	7642·373	4·4385	2·7008

TABLE 21—*Continued.*

n	πn ○	$\pi \frac{n^2}{4}$ ●	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
19·8	62·204	307·91	392·04	7762·392	4·4497	2·7053
19·9	62·518	311·03	396·01	7880·599	4·4609	2·7098
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	408·01	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	313·07	436·81	9129·329	4·5716	2·7545
21·0	65·973	316·36	441·00	9261·000	4·5826	2·7589
21·1	66·288	319·67	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	479·41	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
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

TABLE 21—*Continued.*

n	πn ○	$\pi\frac{n^2}{4}$ ●	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
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	4·9192	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	490·87	625·00	15625·000	5·0000	2·9241
25·1	78·854	494·81	630·01	15813·251	5·0099	2·9279
25·2	79·168	498·76	635·04	16003·008	5·0199	2·9318
25·3	79·482	502·73	640·09	16194·277	5·0299	2·9356
25·4	79·796	506·71	645·16	16387·064	5·0398	2·9395
25·5	80·111	510·71	650·25	16581·375	5·0497	2·9434
25·6	80·425	514·72	655·36	16777·216	5·0596	2·9472
25·7	80·739	518·75	660·49	16974·593	5·0695	2·9510
25·8	81·053	522·79	665·64	17173·512	5·0793	2·9549
25·9	81·367	526·85	670·81	17373·979	5·0892	2·9586
26·0	81·681	530·93	676·00	17576·000	5·0990	2·9624
26·1	81·996	535·02	681·21	17779·581	5·1088	2·9662
26·2	82·310	539·13	686·44	17984·728	5·1185	2·9701
26·3	82·624	543·25	691·69	18191·447	5·1283	2·9738
26·4	82·938	547·39	696·96	18399·744	5·1380	2·9776
26·5	83·252	551·55	702·25	18609·625	5·1478	2·9814
26·6	83·566	555·72	707·56	18821·096	5·1575	2·9851
26·7	83·881	559·90	712·89	19034·163	5·1672	2·9888
26·8	84·195	564·10	718·24	19248·832	5·1768	2·9926
26·9	84·509	568·32	723·61	19465·109	5·1865	2·9963
27·0	84·823	572·56	729·00	19683·000	5·1962	3·0000
27·1	85·137	576·80	734·41	19902·511	5·2057	3·0037
27·2	85·451	581·07	739·84	20123·648	5·2153	3·0074

TABLE 21—*Continued.*

n	πn ○	$\pi \frac{n^2}{4}$ ●	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
27·3	85·765	585·35	745·29	20346·417	5·2249	3·0111
27·4	86·080	589·65	750·76	20570·824	5·2345	3·0147
27·5	86·394	593·96	756·25	20796·875	5·2440	3·0184
27·6	86·708	598·29	761·76	21024·576	5·2535	3·0221
27·7	87·022	602·63	767·29	21253·933	5·2630	3·0257
27·8	87·336	606·99	772·84	21484·952	5·2725	3·0293
27·9	87·650	611·36	778·41	21717·639	5·2820	3·0330
28·0	87·965	615·75	784·00	21952·000	5·2915	3·0366
28·1	88·279	620·16	789·61	22188·041	5·3009	3·0402
28·2	88·593	624·58	795·24	22425·768	5·3103	3·0438
28·3	88·907	629·02	800·89	22665·187	5·3197	3·0474
28·4	89·221	633·47	806·56	22906·304	5·3291	3·0510
28·5	89·535	637·94	812·25	23149·125	5·3385	3·0546
28·6	89·850	642·42	817·96	23393·656	5·3478	3·0581
28·7	90·164	646·93	823·69	23639·903	5·3572	3 0617
28·8	90·478	651·44	829·44	23887·872	5·3665	3·0652
28·9	90·792	655·97	835·21	24137·569	5·3758	3·0688
29·0	91·106	660·52	841·00	24389·000	5·3852	3·0723
29·1	91·420	665·08	846·81	24642·171	5·3944	3·0758
29·2	91·735	669·66	852·64	24897·088	5·4037	3·0794
29·3	92·049	674·26	858·49	25153·757	5·4129	3·0829
29·4	92·363	678·87	864·36	25412·184	5·4221	3·0864
29·5	92·677	683·49	870·25	25672·375	5·4313	3·0899
29·6	92·991	688·13	876·16	25934·336	5·4405	3·0934
29·7	93·305	692·79	882·09	26198·073	5·4497	3·0968
29·8	93·619	697·47	888·04	26463·592	5·4589	3·1003
29·9	93·934	702·15	894·01	26730·899	5·4680	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
30·9	97·075	749·91	954·81	29503·629	5·5587	3·1380

TABLE 21—*Continued.*

n	πn ○	$\pi \frac{n^2}{4}$ ●	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
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	3·1549
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	789·21	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	824·49	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	5·7056	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	5·7447	3·2075
33·1	103·99	860·49	1095·61	36264·691	5·7532	3·2108
33·2	104·30	865·70	1102·24	36594·368	5·7619	3·2140
33·3	104·62	870·92	1108·89	36925·037	5·7706	3·2172
33·4	104·93	876·19	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	3·2424
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	5·8751	3·2522
34·5	108·38	934·82	1190·25	41063·525	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

TABLE 21—*Continued.*

n	πn ○	$\pi \frac{n^2}{4}$ ●	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
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
35·0	109·96	962·11	1225·00	42875·000	5·9161	3·2710
35·1	110·27	967·62	1232·01	43243·551	5·9245	3·2742
35·2	110·58	973·14	1239·04	43614·208	5·9326	3·2773
35·3	110·90	978·68	1246·09	43986·977	5·9413	3·2804
35·4	111·21	984·23	1253·16	44361·864	5·9497	3·2835
35·5	111·53	989·80	1260·25	44738·875	5·9581	3·2866
35·6	111·84	995·38	1267·36	45118·016	5·9665	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	5·9916	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	49017·896	6·0497	3·3202
36·7	115·30	1057·84	1346·89	49430·863	6·0580	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	6·0827	3·3322
37·1	116·55	1081·03	1376·41	51064·811	6·0909	3·3352
37·2	116·87	1086·87	1383·84	51478·848	6·0991	3·3382
37·3	117·18	1092·72	1391·29	51895·117	6·1073	3·3412
37·4	117·50	1098·58	1398·76	52313·624	6·1155	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	6·1318	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	6·1481	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	96623·104	6·1967	3·3737

TABLE 21—*Continued.*

n	πn ○	$\pi \frac{n^2}{4}$ ●	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
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	3·3797
38·7	121·58	1176·28	1497·69	57960·603	6·2209	3·3825
38·8	121·80	1182·37	1505·44	58411·072	6·2289	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
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	1213·01	1544·49	60698·457	6·2689	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	6·2928	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	6·3245	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	66430·126	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	67917·312	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	72511·719	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

TABLE 21—*Continued.*

n	πn ○	$\pi\frac{n^2}{4}$ ●	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
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
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	6·6333	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	6·7156	3·5595
45·2	142·00	1604·60	2043·04	92345·408	6·7231	3·5621
45·3	142·31	1611·71	2052·09	92959·677	6·7305	3·5648
45·4	142·63	1618·83	2061·16	93576·664	6·7379	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	6·7749	3·5805

TABLE 21—*Continued.*

n	πn ○	$\pi \frac{n^2}{4}$ ●	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
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	6·8117	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	6·8410	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	6·8556	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
47·3	148·60	1757·16	2237·29	105823·817	6·8775	3·6165
47·4	148·91	1764·60	2246·76	106496·424	6·8847	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	6·9137	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	6·9928	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

TABLE 21—*Continued.*

n	πn ○	$\pi \frac{n^2}{4}$ ●	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
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	191·63	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
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	210·48	3525·66	4489·00	300763·000	8·1854	4·0615
68·0	213·63	3631·69	4624·00	314432·000	8·2462	4·0817
69·0	216·77	3739·29	4761·00	328509·000	8·3066	4·1016
70·0	219·91	3848·46	4900·00	343000·000	8·3666	4·1213
71·0	223·05	3959·20	5041·00	357911·000	8·4261	4·1408
72·0	226·19	4071·51	5184·00	373248·000	8·4853	4·1602
73·0	229·33	4185·39	5329·00	389017·000	8·5140	4·1793
74·0	232·47	4300·85	5476·00	405224·000	8·6023	4·1983
75·0	235·62	4417·87	5625·00	421875·000	8·6603	4·2172
76·0	238·76	4536·47	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	4778·37	6084·00	474552·000	8·8318	4·2727
79·0	248·18	4901·68	6241·00	493039·000	8·8882	4·2908
80·0	251·32	5026·56	6400·00	512000·000	8·9443	4·3089
81·0	254·47	5153·01	6561·00	531441·000	9·0000	4·3267
82·0	257·61	5281·03	6724·00	551368·000	9·0554	4·3445
83·0	260·75	5410·62	6889·00	571787·000	9·1104	4·3621
84·0	263·89	5541·78	7056·00	592704·000	9·1652	4·3795

TABLE 21—*Continued.*

n	πn ○	$\pi\frac{n^2}{4}$ ●	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
85·0	267·03	5674·50	7225·00	614125·000	9·2195	4·3968
86·0	270·17	5808·81	7396·00	636056·000	9·2736	4·4140
87·0	273·32	5944·69	7569·00	658503·000	9·3274	4·4310
88·0	276·46	6082·13	7744·00	681472·000	9·3808	4·4480
89·0	279·60	6221·13	7921·00	704969·000	9·4330	4·4647
90·0	282·74	6361·74	8100·00	729000·000	9·4868	4·4814
91·0	285·88	6503·89	8281·00	753571·000	9·5394	4·4979
92·0	289·02	6647·62	8464·00	778688·000	9·5917	4·5144
93·0	292·17	6792·92	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	7088·23	9025·00	857375·000	9·7468	4·5629
96·0	301·59	7238·24	9216·00	884736·000	9·7980	4·5789
97·0	304·73	7389·83	9409·00	912673·000	9·8489	4·5947
98·0	307·87	7542·98	9604·00	941192·000	9·8995	4·6104
99·0	311·02	7697·68	9801·00	970299·000	9·9499	4·6261
100·0	314·16	7854·00	100000·00	1000000·000	10·0000	4·6416

Approximately $\sqrt{a^2 \pm b} = a \pm \frac{b}{2a}$ and $\sqrt[3]{a^3 \pm b} = a \pm \frac{b}{3a^2}$

TABLE 22.—FORMULÆ FOR MENSURATION OF AREAS AND SOLID CONTENTS.

1.—Triangle.

Area $= \frac{1}{2} \times$ base $\times$ height.

If all the sides, a, b, c, are known and half their sum is represented by s, so that $s = \frac{a+b+c}{2}$ then

$$A = \sqrt{s(s-a)(s-b)(s-c)}$$

2.—Circle.

Area of circle, if d = diameter, r = radius, and $\pi = 3·14159$

$$A = \frac{\pi}{4}d^2 = r^2\pi \quad . \; . \; . \quad \left(\frac{\pi}{4} = 0·7854\right)$$

$$d = 1·12838\sqrt{A}$$

TABLE 22—*Continued.*

Area of segment of circle of an arc of a^0

$$A = \left(\frac{a}{180}\pi - \sin a\right)\frac{r^2}{2}$$

Or, if d is the diameter and h the height of segment, calculate $\frac{h}{d}$ and find the value x, in the following table, corresponding to $\frac{h}{d}$; the square of the diameter multiplied by x, gives the area of the segment.

Area of segment $= xd^2$.

$\frac{h}{d}$	x	$\frac{h}{d}$	x	$\frac{h}{d}$	x	$\frac{h}{d}$	x
·01	·00133	·14	·06683	·27	·17109	·40	·29337
·02	·00375	·15	·07387	·28	·18002	·41	·30319
·03	·00687	·16	·08111	·29	·18905	·42	·31304
·04	·01054	·17	·08854	·30	·19817	·43	·32293
·05	·01468	·18	·09613	·31	·20737	·44	·33284
·06	·01924	·19	·10390	·32	·21667	·45	·34278
·07	·02417	·20	·11182	·33	·22603	·46	·35274
·08	·02944	·21	·11990	·34	·23547	·47	·36272
·09	·03501	·22	·12811	·35	·24498	·48	·37270
·10	·04087	·23	·13646	·36	·25455	·49	·38270
·11	·04701	·24	·14495	·37	·26418	·50	·39270
·12	·05338	·25	·15355	·38	·27386		
·13	·06000	·26	·16226	·39	·28359		

3.—Cone and Pyramid.

Solid content: $S = \frac{1}{3}$ base $\times$ height.

Area of convex surface of right cone: When s = side of cone $= \sqrt{r^2+h^2}$, where r = radius of base and h = height of cone, the area of convex surface will be

$$A = \pi r s.$$

TABLE 22—*Continued.*

4.—Cylinder.

Area of convex surface $A = 2\pi r h$.
Content of cylinder $S = \text{base} \times \text{height}$.

5.—Sphere.

Convex surface $A = 4\pi r^2 = 12{\cdot}56636 r^2$.
Surface of segment $A = 2\pi r h$, h = height of segment.
Solid content of sphere $S = \frac{4}{3} r^3 \pi = 4{\cdot}1888 r^3$.
Solid content of sphere $S = \frac{1}{6} \pi d^3 = 0{\cdot}5236 d^3$.
Radius $r = 0{\cdot}62035 \sqrt[3]{\text{content}}$.

Content of segment of sphere: If a is the radius of the sectional area, h the height of the segment, and r the radius of the sphere,

$$S = \frac{1}{6}\pi h(3a^2 + h^2)$$
$$= \frac{1}{3}\pi h^2(3r - h).$$

Solid content of spherical zone: If a and b are the respective radii of the two terminal surfaces, and h the height,

$$S = \frac{1}{6}\pi h(3a^2 + 3b^2 + h^2).$$

[TABLE 23.

TABLE 23.—HIGH TEMPERATURES, AS MEASURED WITH LE CHATELIER'S PYROMETER.

(Where no other observer is quoted, according to Le Chatelier's publications 1892, 1895, and 1900.)

	With blue cone.	Green cone. / °C.
Spirit lamp (Heraeus), about		800
Petroleum flame, about		1500
Bunsen burner (Lewes)—		
Top of inner cone	1090	1575
Middle of outer cone	1533	1630
Top	1175	1545
Margin	1333	1511
(At the level of the top of the inner cone.)		
Fusing point of white Swedish pig iron		1135
grey foundry pig iron		1220
ingot iron, with 3·1 per cent. C.		1475
ingot, half hard, 0·3 per cent. C.		1455
ingot steel, 0·9 per cent. C.		1410
silver		962
gold		1065
copper		1076
nickel		1496
platinum		1753
Bessemer converter		1580-1640
Siemens-Martin furnace		1420-1550
Siemens crucible steel furnace		1600
Revolving puddling furnace (final temperature)		1330

	°C.
Blast-furnace (grey Bessemer pig) at tuyeres	1930
iron, on tapping	1400-1520
Glass furnaces—pot furnace	1375
temp. of pot during refining	1310
temp. of pot during hot firing	1045
cistern furnace	1400
cistern furnace, temp. of glass	1310
Porcelain furnace, for hard porcelain (final temperature)	1400
Coal-gas, Siemen furnaces, top	1190
bottom	1045
retorts (final temperature)	975
fire gases at chimney	680
Annular brick kiln	1100
Electric incandescent lamps	1800-2100
light arc (absolute temp.)	4100
Fusing point of fireclay	1670-1700
Seger cone, No. 36 (Heraeus)	1705
No. 35	1685
No. 34	1670
No. 33	1650
No. 32	1635
No. 31	1618
No. 30	1605

TABLE 24.—SYMBOLS, MOLECULAR WEIGHTS, AND PERCENTAGE COMPOSITION.

Of Compounds which are of importance in the Inorganic Chemical Industries and in Technical Analysis.

Note.—The salts are arranged alphabetically according to their cations. The H_2O given in the percentage composition includes the water formed by the decomposition of hydrates and of the ammonium-ion.

Compounds.	Formula.	Molec. weight. O = 16.	Percentage Composition.
Aluminium chloride	$AlCl_3$	133·48	Al 20·30 ; Cl 79·70.
hydroxide	$Al(OH)_3$	78·12	Al_2O_3 65·41 ; H_2O 34·59.
oxide (alumina)	Al_2O_3	102·20	Al 53·03 ; O 46·97.
sulphate	$Al_2(SO_4)_3$	342·38	Al_2O_3 29·85 ; SO_3 70·15.
cryst.	$Al_2(SO_4)_3+18H_2O$	666·67	Al_2O_3 15·33 ; SO_3 36·03 ; H_2O 48·64.
Ammonia	NH_3	17·03	N 82·25 ; H 17·75.
alum	$Al(NH_4)(SO_4)_2+12H_2O$	453·45	Al_2O_3 11·27 ; NH_3 3·76 ; SO_3 35·31 ; H_2O 49·66.
carbonate	$(NH_4)HCO_3+(NH_4)CO_2+(NH_2)$	157·11	NH_3 32·52 ; CO_2 56·01 ; H_2O 11·47.
chloride	NH_4Cl	53·50	NH_3 31·83 ; HCl 68·17.
magnesium arsenate	$(NH_4)MgAsO_4+\frac{1}{2}H_2O$	190·33	MgO 21·18 ; As_2O_5 60·40 ; NH_3 8·95 ; H_2O 9·47.
magnesium phosphate, cryst.	$(NH_4)MgPO_4+6H_2O$	245·50	MgO 16·42 ; NH_3 6·94 ; P_2O_5 28·94 ; H_2O 47·70.
Ammonium nitrate	NH_4NO_3	80·05	NH_3 21·28 ; N_2O_5 67·47 ; H_2O 11·25.

TABLE 24—*Continued.*

Compounds.	Formula.	Molec. weight. O = 16.	Percentage Composition.
Ammonium phosphate	$(NH_4)_2HPO_4$	132·13	NH_3 25·78; P_2O_5 53·77; H_2O 20·45.
sodium phosphate	$(NH_4)HNaPO_4 + 4H_2O$	209·15	NH_3 8·14; Na_2O 14·83; P_2O_5 33·96; H_2O 43·07.
platinum chloride	$(NH_4)_2PtCl_6$	444·04	NH_3 7·46; Pt 43·96; Cl 47·91; H_2O 0·47.
sulphate	$(NH_4)_2SO_4$	132·14	NH_3 25·78; SO_3 60·59; H_2O 13·63.
thiocyanate	$(NH_4)CNS$	76·11	NH_3 22·38; H 1·32; CN 34·17; S 42·13.
Arsenic pentoxide	As_2O_5	229·92	As 65·21; O 34·79.
trioxide	As_2O_3	197·92	As 75·75; O 24·25.
trisulphide	As_2S_3	246·13	As 60·91; S 39·09.
Barium monoxide	BaO	153·37	Ba 89·57; O 10·43.
hydroxide	$Ba(OH)_2$	171·39	Ba 89·49; H_2O 10·51.
cryst.	$Ba(OH)_2 + 8H_2O$	315·51	BaO 48·62; H_2O 51·38.
carbonate	$BaCO_3$	197·37	BaO 77·71; CO_2 22·29.
chloride	$BaCl_2 + 2H_2O$	244·32	$BaCl_2$ 85·25; H_2O 14·75.
sulphate	$BaSO_4$	233·43	BaO 65·70; SO_3 34·30.
Calcium oxide (lime)	CaO	56·07	Ca 71·46; O 28·54.
hydroxide	$Ca(OH)_2$	74·09	CaO 75·68; H_2O 24·32.
carbonate	$CaCO_3$	100·07	CaO 56·03; CO_2 43·97.
chlorate	$Ca(ClO_3)_2$	206·99	CaO 27·09; Cl_2O_5 72·91.
chloride	$CaCl_2$	110·99	Ca 36·10; Cl 63·90.
cryst.	$CaCl_2 + 6H_2O$	219·09	$CaCl_2$ 50·66; H_2O 49·34.
hypochlorite	$Ca(OCl)_2$	142·99	CaO 39·21; Cl 49·60; O 11·19.
phosphate, primary	$CaH_4(PO_4)_2$	234·18	CaO 23·94; P_2O_5 60·67; H_2O 15·39.
secondary	$CaH(PO_4)$	136·12	CaO 41·19; P_2O_5 52·19; H_2O 6·62.

TABLE 24—*Continued.*

Compounds.	Formula.	Molec. weight. O=16.	Percentage Composition.
Calcium phosphate, tertiary	$Ca_3(PO_4)_2$	310·29	CaO 54·21 ; P_2O_5 45·79.
sulphate (anhydrite)	$CaSO_4$	136·13	CaO 41·19 ; SO_3 58·81.
hydrated (gypsum)	$CaSO_4-2H_2O$	172·16	CaO 32·57 ; SO_3 46·50 ; H_2O 20·93.
sulphide	CaS	72·13	Ca 55·55 ; S 44·45.
pentasulphide	CaS_5	200·37	Ca 20·00 ; S 80·00.
sulphite	$CaSO_3$	120·13	CaO 46·67 ; SO_2 53·33.
thiosulphate	CaS_2O_3	152·19	CaO 36·84 ; SO_2 42·09 ; S 21·07.
Carbon dioxide	CO_2	44·00	C 27·27 ; O 72·73.
monoxide	CO	28·00	C 42·86 ; O 57·14.
Chloric acid	$HClO_3$	84·47	Cl 41·98 ; O 47·36 ; H_2O 10·66.
Copper oxide	CuO	79·57	Cu 79·89 ; O 20·11.
chloride	$CuCl_2$	134·49	Cu 47·27 ; O 52·73.
sulphide (cuprous)	Cu_2S	159·20	Cu 79·86 ; S 20·14.
(cupric)	CuS	95·63	Cu 66·47 ; S 33·53.
sulphate	$CuSO_4-5H_2O$	249·71	CuO 31·87 ; SO_3 32·06 ; H_2O 36·07.
Ethylene	C_2H_4	28·03	C 85·62 ; H 14·38.
Hydrochloric acid	HCl	36·47	Cl 97·24 ; H 2·76.
Hypochlorous acid	HOCl	52·47	Cl 67·59 ; O 30·49 ; H 1·92.
anhydride	Cl_2O	86·92	Cl 81·59 ; O 18·41.
Iron oxide (ferric)	Fe_2O_3	159·68	Fe 69·94 ; O 30·06.
hydrated (ferric hydroxide)	$Fe(OH)_3$	106·86	Fe_2O_3 74·72 ; H_2O 25·28.
Iron chloride (ferrous)	$FeCl_2$	126·76	Fe 44·05 ; Cl 55·95.
cryst.	$FeCl_2+4H_2O$	198·82	$FeCl_2$ 63·75 ; H_2O 36·25.

TABLE 24—*Continued.*

Compounds.	Formula.	Molec. weight. O=16.	Percentage Composition.
Iron chloride (ferric)	$FeCl_3$	162·22	Fe 34·42; Cl 65·58.
bisulphide (pyrites)	FeS_2	119·96	Fe 46·55; S 53·45.
sulphate (ferrous)	$FeSO_4+7H_2O$	277·95	Fe 20·09; O 5·76; SO_3 28·80; H_2O 45·35.
Lead monoxide (litharge)	PbO	223·20	Pb 92·83; O 7·17.
oxide (red lead)	Pb_3O_4	685·60	Pb 90·67; O 9·33.
carbonate	$PbCO_3$	267·20	PbO 83·53; CO_2 16·47.
chloride	$PbCl_2$	278·12	Pb 74·50; Cl 25·50.
sulphate	$PbSO_4$	303·26	PbO 73·60; SO_3 26·40.
sulphide	PbS	239·26	Pb 86·60; S 13·40.
Magnesium oxide	MgO	40·32	Mg 60·32; O 39·68.
hydroxide	$Mg(OH)_2$	58·34	MgO 69·12; H_2O 30·88.
chloride	$MgCl_2$	95·24	Mg 25·54; Cl 74·46.
cryst.	$MgCl_2+6H_2O$	203·34	$MgCl_2$ 46·84; H_2O 53·16.
carbonate	$MgCO_3$	84·32	MgO 47·82; CO_2 52·18.
pyrophosphate	$Mg_2P_2O_7$	222·72	MgO 36·21; P_2O_5 63·79.
sulphate, cryst.	$MgSO_4+7H_2O$	246·49	MgO 16·36; SO_3 32·48; H_2O 51·16.
Manganese protoxide	MnO	70·93	Mn 77·44; O 22·56.
sesquioxide	Mn_2O_3	157·86	Mn 69·59; O 30·41.
dioxide	MnO_2	86·93	Mn 63·19; O 36·81.
Manganous manganic oxide	Mn_3O_4	228·79	Mn 72·03; O 27·97.
chloride	$MnCl_2$	125·85	Mn 43·65; Cl 56·35.
sulphate	$MnSO_4$	150·99	MnO 46·98; SO_3 53·02.
Mercurous chloride	$HgCl$	236·06	Hg 84·98; Cl 15·02.

TABLE 24—*Continued.*

Compounds.	Formula.	Molec. weight. O=16.	Percentage Composition.
Mercuric chloride	$HgCl_2$	271·52	Hg 73·88 ; Cl 26·12.
Methane	CH_4	16·03	C 74·85 ; H 25·15.
Nitrosulphonic acid (nitrososulphuric acid, chamber crystals)	$SO_2(OH)(ONO)$	127·08	SO_3 63·00 ; N_2O_3 29·91 ; H_2O 7·09.
Nitrous oxide	N_2O	44·02	N 63·65 ; O 36·35.
Nitric oxide	NO	30·01	N 46·68 ; O 53·32.
Nitrous anhydride	N_2O_3	76·02	N 36·86 ; O 63·14.
acid	NO_2H	47·02	N_2O_3 80·84 ; H_2O 19·16.
Nitric peroxide (tetroxide)	NO_2 or N_2O_4	46·01 92·02	N 30·45 ; O 69·55.
acid	NO_3H	63·02	N_2O_5 85·71 ; H_2O 14·29.
Pentathionic acid, *cf.* Sulphur.			
Phosphoric pentoxide	P_2O_5	142·08	P 43·69 ; O 56·31.
acid, ortho-	H_3PO_4	98·06	P_2O_5 72·44 ; H_2O 27·56.
pyro-	$H_4P_2O_7$	178·11	P_2O_5 79·77 ; H_2O 20·23.
meta-	HPO_3	80·05	P_2O_5 88·75 ; H_2O 11·25.
Platinum-hydrogen chloride	H_2PtCl_6	410·00	Pt 47·61 ; Cl 51·90 ; H 0·49.
Potassium oxide	K_2O	94·20	K 83·01 ; O 16·99.
hydroxide	KOH	56·11	K_2O 83·95 ; H_2O 16·05.
carbonate	K_2CO_3	138·20	K_2O 68·16 ; CO_2 31·84.
bicarbonate	$KHCO_3$	100·11	K_2O 47·05 ; CO_2 43·95 ; H_2O 9·00.
dichromate	$K_2Cr_2O_7$	294·20	K_2O 32·02; Cr_2O_3 67·98.
chlorate	$KClO_3$	122·56	K_2O 38·43 ; Cl 28·93 ; O 32·64.
chloride	KCl	74·56	K 52·44 ; Cl 47·56.
chromate	K_2CrO_4	194·20	K_2O 48·51 ; CrO_3 51·49.

TABLE 24—*Continued.*

Compounds.	Formula.	Molec. weight. O=16.	Percentage Composition.
Potassium cyanide	KCN	65·11	K 60·05; CN 39·95.
ferricyanide	$K_3Fe(CN)_6$	329·20	K 35·63; Fe 16·96; CN 47·41.
ferrocyanide	$K_4Fe(CN)_6+3H_2O$	422·35	K 37·03; Fe 13·22; CN 36·95; H_2O 12·80.
iodide	KI	166·02	K 23·55; I 76·45.
nitrate	KNO_3	101·11	K_2O 46·58; N_2O_5 53·42.
nitrite	KNO_2	85·11	K_2O 55·34; N_2O_3 44·66.
permanganate	$KMnO_4$	158·03	K_2O 29·80; Mn_2O_7 70·20.
phosphate	K_2HPO_4	174·25	K_2O 54·06; P_2O_5 40·77; H_2O 5·17.
platinum chloride	K_2PtCl_6	486·16	Pt 40·15; Cl 43·76; K 16·09 = (KCl 30·67).
silicate	K_2SiO_3	154·50	K_2O 60·97; SiO_2 39·03.
sulphate	K_2SO_4	174·26	K_2O 54·06; SO_3 45·94.
bisulphate	$KHSO_4$	136·17	K_2O 34·59; SO_3 58·80; H_2O 6·61.
sulphide	K_2S	110·26	K 70·92; S 29·08.
sulphite, cryst.	$K_2SO_3+2H_2O$	194·29	K_2O 48·48; SO_2 32·97; H_2O 18·55.
bisulphite	$KHSO_3$	120·17	K_2O 39·20; SO_2 53·30; H_2O 7·50.
thiocyanate	$KCNS$	97·17	K 40·24; CNS 59·76.
Potash alum	$KAl(SO_4)_2+12H_2O$	474·51	K_2O 9·93; Al_2O_3 10·77; SO_3 33·74; H_2O 45·56.
Selenious anhydride	SeO_2	111·20	Se 71·22; O 28·78.
Silicic anhydride (silica)	SiO_2	60·30	Si 46·93; O 53·07.
Silver bromide	$AgBr$	187·80	Ag 57·44; Br 42·56.
chloride	$AgCl$	143·34	Ag 75·26; Cl 24·74.
iodide	AgI	234·80	Ag 45·95; I 54·05.
nitrate	$AgNO_3$	169·89	Ag 63·50; NO_3 36·50.

TABLE 24—*Continued.*

Compounds.	Formula.	Molec. weight. O = 16.	Percentage Composition.
Silver sulphide	Ag_2S	247·82	Ag 87·06; S 12·94.
thiocyanate	$AgCNS$	165·96	Ag 65·00; CNS 35·00.
Sodium oxide	Na_2O	62·00	Na 74·19; O 25·81.
hydroxide	$NaOH$	40·01	Na_2O 77·48; H_2O 22·52.
aluminate	Na_3AlO_3	144·10	Na_2O 64·54; Al_2O_3 35·46.
	$Na_2Al_2O_4$	164·20	Na_2O 37·76; Al_2O_3 62·24.
borate	$Na_2B_4O_7 + 10H_2O$	381·96	Na_2O 16·24; B_2O_3 36·57; H_2O 47·19.
carbonate anhydrous	Na_2CO_3	106·00	Na_2O 58·49; CO_2 41·51.
decahydrated	$Na_2CO_3 + 10H_2O$	286·16	Na_2O 21·67; CO_2 15·38; H_2O 62·95.
bicarbonate	$NaHCO_3$	84·01	Na_2O 36·90; CO_2 52·38; H_2O 10·72.
chlorate	$NaClO_3$	106·46	Na_2O 29·12; Cl_2O_5 70·88.
chloride	$NaCl$	58·46	Na 39·34; Cl 60·66.
chromate	Na_2CrO_4	162·00	Na_2O 38·27; CrO_3 61·73.
bichromate	$NaHCrO_4$	140·01	Na_2O 22·14; CrO_3 71·42; H_2O 6·44.
hypochlorite	$NaOCl$	74·46	Na_2O 41·63; Cl_2O 58·37.
nitrate	$NaNO_3$	85·01	Na_2O 36·47; N_2O_5 63·53.
nitrite	$NaNO_2$	69·01	Na_2O 44·92; N_2O_3 55·08.
phosphate	$Na_2HPO_4 + 12H_2O$	358·24	Na_2O 17·31; P_2O_5 19·83; H_2O 62·86.
silicate	Na_2SiO_3	122·30	Na_2O 50·69; SiO_2 49·31.
sulphate	Na_2SO_4	142·06	Na_2O 43·64; SO_3 56·36.
cryst.	$Na_2SO_4 + 10H_2O$	322·22	Na_2O 19·24; SO_3 24·85; H_2O 55·91.
bisulphate	$NaHSO_4$	120·07	Na_2O 25·82; SO_3 66·68; H_2O 7·50.
sulphide	Na_2S	78·06	Na 58·93; S 41·07.
hydrogen sulphide	$NaHS$	56·07	Na_2S 69·61; H_2S 30·39.
sulphite, cryst.	$Na_2SO_3 + 7H_2O$	252·17	Na_2O 24·59; SO_2 25·40; H_2O 50·01.

TABLE 24—*Continued.*

Compounds.	Formula.	Molec. weight. O=16.	Percentage Composition.
Sodium bisulphite	$NaHSO_3$	104·07	Na_2O 29·79; SO_2 61·56; H_2O 8·65.
thiosulphate	$Na_2S_2O_3+5H_2O$	248·20	Na_2O 24·98; S 12·92; SO_2 25·81; H_2O 36·29.
Sulphur dioxide	SO_2	64·06	S 50·05; O 49·95.
trioxide	SO_3	80·06	S 40·04; O 59·96.
Sulphuric acid	H_2SO_4	98·08	SO_3 81·63; H_2O 18·37.
pyro-	$H_2S_2O_7$	178·14	H_2SO_4 55·06; SO_3 44·94.
Trithionic acid	$H_2S_3O_6$	194·20	SO_3 41·23; SO_2 32·99; S 16·51; H_2O 9·27.
Tetrathionic acid	$H_2S_4O_6$	226·26	SO_3 35·38; SO_2 28·31; S 28·34; H_2O 7·97.
Pentathionic acid	$H_2S_5O_6$	258·32	SO_3 30·99; SO_2 24·80; S 37·23; H_2O 6·98.
Sulphuretted hydrogen	H_2S	34·08	S 94·08; H 5·92.
Tin chloride (stannous)	$SnCl_2+2H_2O$	225·65	Sn 52·60; Cl 31·43; H_2O 15·97.
Water	H_2O	18·02	H 11·19; O 88·81.
Zinc oxide	ZnO	81·37	Zn 80·34; O 19·66.
chloride	$ZnCl_2$	136·29	Zn 47·96; Cl 52·04.
sulphate	$ZnSO_4$	161·43	ZnO 50·41; SO_3 49·59.
cryst.	$ZnSO_4+7H_2O$	287·54	ZnO 28·30; SO_3 27·84; H_2O 43·86.
sulphide	ZnS	97·43	Zn 67·09; S 32·91.

TABLE 25.—FACTORS FOR CALCULATING GRAVIMETRIC ANALYSES.

Substance weighed.	Substance to be determined.	Factor.	log
Ammonium.			
Ammonium chloride, NH_4Cl	Ammonia, NH_3 .	0·3184	0·50301 − 1
Ammonium platinum chloride, $(NH_4)_2PtCl_6$.	Ammonia, NH_3 .	0·0767	0·88488 − 2
	Nitrogen N . .	0·0631	0·80000 − 2
Arsenic.			
Arsenic trisulphide, As_2S_3 .	Arsenic, As . .	0·6092	0·78475 − 1
	Arsenic trioxide, As_2O_3	0·8042	0·90536 − 1
	Arsenic anhydride, As_2O_5	0·9342	0·97045 − 1
Ammonium magnesium arsenate, $Mg(NH_4)AsO_4 + \frac{1}{2}$ aq.	Arsenic, As . .	0·3939	0·59532 − 1
	Arsenic trioxide, As_2O_3	0·5200	0·71595 − 1
	Arsenic anhydride, As_2O_5	0·6039	0·78100 − 1
Barium.			
Barium sulphate, $BaSO_4$.	Barium oxide, BaO	0·6570	0·81755 − 1
Barium carbonate, $BaCO_3$.	Barium oxide, BaO	0·7770	0·89043 − 1
Barium silicofluoride, $BaSiF_6$	Barium oxide, BaO	0·5483	0·73906 − 1
Calcium.			
Calcium sulphate, $CaSO_4$.	Calcium oxide, CaO	0·4119	0·61478 − 1
Calcium carbonate, $CaCO_3$	Calcium oxide, CaO	0·5603	0·74843 − 1
Carbon.			
Barium carbonate, $BaCO_3$.	Carbon dioxide, CO_2	0·2229	0·34817 − 1
Calcium carbonate, $CaCO_3$.	Carbon dioxide, CO_2	0·4397	0·64315 − 1
Carbon dioxide, CO_2 . .	Carbon, C . .	0·2727	0·43568 − 1
Chlorine.			
Silver chloride, AgCl .	Chlorine, Cl . .	0·2474	0·39337 − 1
	Potassium chloride, KCl	0·5202	0·71614 − 1
	Sodium chloride, NaCl	0·4078	0·61049 − 1
	Hydrogen chloride, HCl	0·2544	0·40554 − 1
Copper.			
Cupric oxide, CuO . .	Copper, Cu . .	0·7989	0·90250 − 1
Cuprous sulphide, Cu_2S .	Copper, Cu . .	0·7986	0·90234 − 1
	Cupric oxide, CuO .	0·9996	0·99984 − 1
Hydrogen.			
Water, H_2O	Hydrogen, H . .	0·1119	0·04884 − 1
Iron.			
Ferric oxide, Fe_2O_3 . .	Iron, Fe . . .	0·6994	0·84473 − 1
	Ferrous oxide, FeO	0·8998	0·95415 − 1
Lead.			
Lead monoxide, PbO .	Lead, Pb . .	0·9283	0·96770 − 1
Lead sulphate, $PbSO_4$.	Lead, Pb . .	0·6833	0·83459 − 1
	Lead oxide, PbO .	0·7360	0·86688 − 1

TABLE 25—*Continued.*

Substance weighed.	Substance to be determined.	Factor.	log
Lead.			
Lead sulphide, PbS	Lead Pb	0·8660	0·93752 – 1
	Lead oxide, PbO	0·9329	0·96982 – 1
Lead, Pb	Lead oxide, PbO	1·0772	0·03230
Magnesium.			
Magnesium pyrophosphate, $Mg_2P_2O_7$	Magnesium oxide, MgO	0·3621	0·55881 – 1
Magnesium sulphate, $MgSO_4$	Magnesium oxide, MgO	0·3349	0·52497 – 1
Manganese.			
Mangano manganic oxide, Mn_3O_4	Manganese, Mn	0·7203	0·85749 – 1
Manganese sulphide, MnS	Manganese, Mn	0·6314	0·80034 – 1
	Manganous oxide, MnO	0·8154	0·91136 – 1
Nitrogen.			
Ammonium platinum chloride, $(NH_4)_2PtCl_6$	Nitrogen, N	0·0631	0·80003 – 2
Platinum, Pt	Nitrogen, N	0·1435	0·15693 – 1
Phosphorus.			
Magnesium pyrophosphate, $Mg_2P_2O_7$	Phosphorus, P	0·2787	0·44521 – 1
	Phosphorus pentoxide, P_2O_5	0·6380	0·80479 – 1
Potassium.			
Potassium chloride, KCl	Potassium oxide, K_2O	0·6317	0·80051 – 1
Potassium chloride	Potassium K	0·5244	0·71967 – 1
Potassium-platinum chloride, K_2PtCl_6 (reduction factors adopted at Stassfurt)	Potassium oxide	0·1930	0·28556 – 1
	Potassium chloride	0·3056	0·48515 – 1
	Potassium sulphate	0·3571	0·55279 – 1
Potassium sulphate	Potassium oxide	0·5406	0·73285 – 1
Potassium sulphate	Potassium	0·4488	0·65201 – 1
Sodium.			
Sodium sulphate, Na_2SO_4	Sodium oxide, Na_2O	0·4364	0·63992 – 1
Sodium carbonate, Na_2CO_3	Sodium oxide, Na_2O	0·5849	0·76708 – 1
Sodium chloride, NaCl	Sodium oxide, Na_2O	0·5303	0·72450 – 1
Sulphur.			
Barium sulphate, $BaSO_4$	Sulphur, S	0·1373	0·13780 – 1
	Sulphur dioxide, SO_2	0·2744	0·43843 – 1
	Sulphur trioxide, SO_3	0·3429	0·53522 – 1
	Sulphuric acid, H_2SO_4	0·4202	0·62340 – 1
	Sodium sulphate, Na_2SO_4	0·6086	0·78431 – 1
Zinc.			
Zinc oxide, ZnO	Zinc, Zn	0·8034	0·90492 – 1
Zinc sulphide, ZnS	Zinc, Zn	0·6709	0·82669 – 1
	Zinc oxide, ZnO	0·8352	0·92177 – 1

TABLE 26.—DENSITY OF GASES AND VAPOURS.

And Litre Weights at 0° C., and at a pressure of 760 mm.

grm. mol. of each gas = 22·412 litres. 1 litre of each gas = 0·04462 × its molecular weight. The spec. gravity of gases referred to atmospheric air as unity is = its molecular weight divided by 28·945, or = $\frac{34\cdot55 \times \text{molec. weight}}{1000}$.

Gas.	Formula.	Molecular Weight.	Weight of 1 litre in grams.		Density, air = 1.		Observer.
			Calculated.	Observed.	Calculated.	Observed.	
Acetylene	C_2H_2	26·02	1·1610	1·189	0·8989	0·9056	Leduc.
Ammonia	NH_3	17·03	0·7606	1·7708	0·5883	0·5962	Saussure.
Atmospheric air	...	...	1·2928	...	1·0000	...	...
Bromine	Br_2	159·84	7·1388	7·1418	5·5220	5·5243	(at 228°) Jahn.
Chlorine	Cl_2	70·92	3·1674	3·2191	2·4501	2·491	Treadwell.
Carbon monoxide	CO	28·00	1·2505	1·2503	0·9673	0·96716	Rayleigh, Leduc.
dioxide	CO_2	44·00	1·9651	1·9768	1·5201	1·52908	Guye.
Ethylene	C_2H_4	28·03	1·2519	1·2737	0·9683	0·9852	Saussure.
Hydrogen	H_2	2·02	0·0900	0·08987	0·06965	0·06952	Morley.
chloride	HCl	36·47	1·6289	1·6394	1·2598	1·2681	Scheuer.
Methane	CH_4	16·03	0·7159	0·7160	0·5538	0·5545	Baume, Perrot.
Nitrogen	N_2	28·02	1·2514	1·2505	0·9680	0·96727	Rayleigh, Leduc.
Nitrous oxide	N_2O	44·02	1·9660	1·9777	1·5208	1·5298	Guye.
Nitric oxide	NO	30·01	1·3403	1·3402	1·0368	1·0367	Guye.
peroxide	NO_2	46·01	2·0549	...	1·5895	...	...
	N_2O_4	92·02	4·1098	...	3·1790	...	...
Oxygen	O_2	32·00	1·4292	1·4292	1·1055	1·1055	Guye.
Sulphur	S_2	64·12	2·8610	...	2·2130	...	...
Sulphuretted hydrogen	H_2S	34·09	1·5226	1·5392	1·1777	1·1906	Baume, Perrot.
Sulphur dioxide	SO_2	64·07	2·8615	2·9266	2·2134	2·2638	Jaquerod, Pintza.
trioxide	SO_3	80·06	3·5722	...	2·7631	...	...
Water	H_2O	18·02	0·8040	...	0·6219	...	...

TABLE 27.—CALCULATION OF THE C.C. READ OFF IN GAS-VOLUMETRIC ANALYSIS, TO MILLIGRAMS OF THE SUBSTANCE REQUIRED.

N.B.—The data for this calculation are not the theoretically calculated, but the observed densities of the gases, according to Table 26.

c.c. at 0° and 760 mm.	1.	log	2.	3.	4.	5.	6.	7.	8.	9.
CO_2 = mg CO_2	1·9768	0.29597	3·9536	5·9304	7·9072	9·8840	11·8608	13·8376	15·8144	17·7912
CO_2 = mg $CaCO_3$	4·4968	0·65290	8·9936	13·4904	17·9872	22·4840	26·9808	31·4776	35·9744	40·4712
O = mg O .	1·4292	0·15509	2·8584	4·2876	5·7168	7·1460	8·5752	10·0044	11·4336	12·8628
(O = mg O)* .	0·7146	0·85406 − 1	1·4292	2·1437	2·8584	3·5730	4·2876	5·0022	5·7168	6·4314
O = mg MnO_2	3·8825	0·58912	7·7650	11·6475	15·5300	19·4125	23·2950	27·1775	31·0600	34·9625
O = mg Cl .	3·1675	0·50072	6·3350	9·5025	12·6700	15·8375	19·0050	22·1725	25·3408	28·5085
N = mg N .	1·2505	0·09709	2·5010	3·7515	5·0020	6·2525	7·5030	8·7535	10·0040	11·2545
N = mg NH_3 .	1·5200	0·18184	3·0400	4·5600	6·0800	7·6000	9·1200	10·6400	12·1600	13·6800
(N = mg N)† .	1·2818	0·10782	2·5636	3·8454	5·1272	6·4090	7·6908	8·9726	10·2544	11·5362
(N = mg NH_3)†	1·5582	0·19263	3·1164	4·6746	6·2328	7·7910	9·3492	10·9074	12·4656	14·0238
NO = mg N .	0·6256	0·79633 − 1	1·2513	1·8769	2·5024	3·1280	3·7536	4·3792	5·0048	5·6304
NO = mg NO .	1·3403	0·12720	2·6806	4·0209	5·3612	6·7015	8·0418	9·3821	10·7224	12·0627
NO = mg N_2O_3 .	1·6974	0·22979	3·3948	5·0922	6·7896	8·4870	10·1846	11·8818	13·5792	15·2766
NO = mg HNO_3	2·8143	0·44937	5·6286	8·4429	11·2572	14·0715	16·8858	19·7001	22·5144	25·3297
NO = mg $NaNO_3$	3·7963	0·57936	7·5926	11·3889	15·1852	18·9815	22·7778	26·5741	30·3704	34·1874
Cl = mg Cl .	3·2191	0·50773	6·4382	9·6573	12·8764	16·0955	19·3146	22·5337	25·7528	28·9719
H_2S = mg H_2S .	1·5392	0·18730	3·0784	4·6176	6·1568	7·6960	9·2352	10·7744	12·3136	13·8528

* In the case of the hydrogen peroxide methods, where only half of the oxygen liberated comes from the substance analysed.
† In the case of the azotometric methods, where the potassium-bromate method yields 2·5 per cent. too little nitrogen.

TABLE 28.—SOLUBILITY OF SALTS AND CERTAIN ELEMENTS.

Note.—The solubility is given in parts of the anhydrous salt dissolved by 100 parts of water, though the actual substance in equilibrium with the solution may be a hydrate.

100 parts of Water dissolve		At 0°.	At 15°.	At 30°.	At 50°.	At 70°.	At 100°.
SUBSTANCE.	SOLID PHASE.						
Alum, ammonia	$Al(NH_4)(SO_4)_2, 12H_2O$	2·6	5·5	9·1	15·9	27·0	109·7
potash	$AlK(SO_4)_2, 12H_2O$	3·0	5·0	8·4	17	36	154
Aluminium sulphate	$Al_2(SO_4)_3, 18H_2O$	31·3	34·9	40·4	52·1	66·2	89·1
Ammonium bicarbonate	NH_4HCO_3	11·9	17·3	27	...	...	...
bromide	NH_4Br	...	70	81	94	...	...
chloride	NH_4Cl	29·7	35·3	41·4	50·4	60·2	77·3
nitrate	NH_4NO_3	118	162	242	344	499	871
sulphate	$(NH_4)_2SO_4$	70·6	74·2	78·0	84·4	91·6	103·3
Barium chloride	$BaCl_2, 2H_2O$	31·6	34·5	38·2	43·6	49·4	58·8
hydroxide (wt. of BaO)	$Ba(OH)_2, 8H_2O$	1·5	2·85	5·0	11·7	31·9	...
nitrate	$Ba(NO_3)_2$	5·0	8·1	11·6	17·1	23·6	34·2
Boric acid (wt. of B_2O_3)	$B_2O_3, 3H_2O$	1·1	1·9	3·1	5·1	8·0	15·7
Bromine	$Br_2, 10H_2O$ (up to 6·2°)	2·37	...	3·44	3·52	...	...
Calcium carbonate	$CaCO_3$	...	0·0013	...	...	...	...
chloride	$CaCl_2, 6H_2O$	59·5	68	102	...	...	...
,,	$CaCl_2, 2H_2O$	...	...	...	...	141·7	159·0
hydroxide	$Ca(OH)_2$	0·131	0·129	0·113	0·096	0·075	...
nitrate	$Ca(NO_3)_2, 4H_2O$	93·1	115	...	...	...	...
sulphate	$CaSO_4, 2H_2O$	0·176	0·200	0·210	0·207	...	...
Cadmium sulphate	$8CdSO_4, 3H_2O$	75·5	76·1	77·5	80·2	...	...
	$CdSO_4, H_2O$	...	...	...	...	...	60·8
Chlorine	$Cl_2, 8H_2O$ (up to 28·7°)	0·51	1·3	...	...	...	...
Cupric chloride	$CuCl_2, 2H_2O$	70·6	75	80	...	...	...

TABLE 28—*Continued.*

100 parts of Water dissolve Substance.	Solid Phase.	At 0°.	At 15°.	At 30°.	At 50°.	At 70°.	At 100°.
Cupric nitrate	$Cu(NO_3)_2, 6H_2O$	81·8	ca. 105	...	...	...	...
	$Cu(NO_3)_2, 3H_2O$	...	...	ca. 155	ca. 160	ca. 192	ca. 250
sulphate	$CuSO_4, 5H_2O$	14·9	19·3	25·5	33·6	45·7	73·5
Ferric chloride *	$FeCl_3, 6H_2O$	74·4	87	106·8	...	...	...
	$FeCl_3$	...	...	...	...	...	536
Ferrous sulphate	$FeSO_4, 7H_2O$	15·6	23·9	33·0	48·5	...	...
	$FeSO_4, 4H_2O$	...	...	...	...	56·04	...
Iodic acid	HIO_3	287	307	329	376	446	...
Iodine	I_2	...	0·0276	0·0454	...	...	...
Lead chloride	$PbCl_2$	0·673	0·909	1·20	1·70	2·30	3·34
nitrate	$Pb(NO_3)_2$	36·5	48·4	60·7	78·7	97·7	127
sulphate	$PbSO_4$	...	0·004	...	...	...	...
Magnesium carbonate	$MgCO_3, 3H_2O$	...	0·10	...	...	...	...
chloride *	$MgCl_2, 6H_2O$	52·8	54	56	59	63	73
hydroxide	$Mg(OH)_2$	...	0·0008	...	...	...	...
sulphate *	$MgSO_4, 7H_2O$	26·0	33·3	40·9	...	...	...
Potassium bichromate	$K_2Cr_2O_7$	5·0	10·5	21	40	61	102
bicarbonate	$KHCO_3$	22·5	30·5	39·0	52·2	...	...
carbonate	$K_2CO_3, 2H_2O$	105	111	114	121	133	156
chlorate	$KClO_3$	3·3	6·0	10·1	19·7	32·5	56·0
chromate	K_2CrO_4	58·9	61·8	65·0	69·0	73·0	79·1
ferricyanide	$K_3Fe(CN)_6$	31	40	...	...	...	77·5
ferrocyanide	$K_4Fe(CN)_6, 3H_2O$	14	22	ca. 30	ca. 42	ca. 60	...
hydroxide	$KOH, 2H_2O$	97	107	126	...	...	...
	KOH, H_2O	...	...	...	140	ca. 152	178
iodide	KI	126	140	152	168	184	209
nitrate	KNO_3	13·3	25·7	45·8	85·5	138	246

* There are a number of hydrates and the solubility curves are somewhat complex.

TABLE 28—*Continued.*

100 parts of Water dissolve		At 0°.	At 15°.	At 30°.	At 50°.	At 70°.	At 100°.
SUBSTANCE.	SOLID PHASE.						
Potassium permanganate	$KMnO_4$	2·9	6·3	...	...	...	...
platinichloride	K_2PtCl_6	0·7	1·0	1·4	2·2	3·2	5·2
sulphate	K_2SO_4	7·35	10·0	13·0	16·5	19·7	24·1
Sodium biborate (borax)	$Na_2B_4O_7, 10H_2O$	1·1	2·0	3·9	10·5	...	...
	$Na_2B_4O_7, 5H_2O$	...	...	...	...	24·4	52·3
bicarbonate	$NaHCO_3$	6·9	8·9	11·1	14·5	..	...
bromide	$NaBr, 2H_2O$	79·5	87	97	116	...	...
	$NaBr$	...	...	...	...	118	120·5
carbonate	$Na_2CO_3, 10H_2O$	7·1	16·6	40·9	...	...	...
	Na_2CO_3, H_2O	...	...	...	47·5	45·8	45·1
chlorate	$NaClO_3$	82	91	...	...	...	204
chloride	$NaCl$	35·63	35·75	36·03	36·67	37·51	39·12
hydroxide *	$NaOH, 4H_2O$	42	...	...	...	...	...
	$NaOH, H_2O$	...	105	119	145	...	...
nitrate	$NaNO_3$	73	84	96	114	136	175
nitrite	$NaNO_2$	...	83·3	...	...	...	...
phosphate (ordinary)	$Na_2HPO_4, 12H_2O$	2·5	6·0	24·1	...	...	...
	$Na_2HPO_4, 7H_2O$	...	...	...	84	95	99
sulphate	$Na_2SO_4, 10H_2O$	5·0	13·2	40	...	...	...
	Na_2SO_4	..	...	...	46·8	44·5	42·7
sulphite	$Na_2SO_3, 7H_2O$	14·1	ca 24	...	...	...	...
thiosulphate	$Na_2S_2O_3, 5H_2O$	52	65	85	...	...	...
	$Na_2S_2O_3, 2H_2O$	...	...	...	170	232	266
Stannous chloride	$SnCl_2, 2H_2O$	84	270	...	...	...	...
Zinc chloride *	$ZnCl_2, 3H_2O$	208	...	...	...	...	...
sulphate *	$ZnSO_4, 7H_2O$	41·9	50·9	61	...	...	...

* There are a number of hydrates and the solubility curves are somewhat complex.

TABLE 29.—SOLUBILITY OF GASES IN WATER.

Column *a* gives the volume of gas (reduced to 0° and 760 mm.) dissolved by one volume of the liquid at the temperature indicated, if the partial pressure of the gas is = 760 mm. Hg.

Column *q* gives the weight of the substance in grams, dissolved by 100 gr. of the pure solvent, if the partial pressure of the gas + the vapour pressure of the liquid at the temperature indicated = 760 mm. Hg.

The letters following the name of the gas indicate the observer, viz., W. = Winkler; B. & B. = Bohr & Bock; F. = Fauser; R. = Raoult; S. = Schönfeld; R.-D. = Roscoe-Dittmar; R. = Roozeboom; B. = Bunsen.

T.	Oxygen, W.		Hydrogen, W.		Nitrogen, B. & B.		Chlorine, W.	
	a.	*q.*	*a.*	*q.*	*a.*	*q.*	*a.*	*q.*
0	·04890	·006948	·02148	·0001922	·02388	·002 977	...	...
1	·04759	·006758	·02126	·0001902	·02337	·002912	...	...
2	·04633	·006576	·02105	·0001882	·02288	·002843	...	...
3	·04512	·006401	·02084	·0001862	·02241	·002790	...	...
4	·04397	·006234	·02064	·0001843	·02196	·002732	...	...
5	·04286	·006074	·02044	·0001824	·02153	·002677	...	...
6	·04181	·005920	·02025	·0001806	·02111	·002624	...	...
7	·04080	·005775	·02007	·0001789	·02070	·002570	...	...
8	·03983	·005633	·01989	·0001772	·02031	·002520	...	...
9	·03891	·005499	·01972	·0001756	·01993	·002472	...	...
10	·03802	·005370	·01955	·0001739	·01956	·002424	3·095	·9969
11	·03718	·005248	·01940	·0001725	·01920	·002378	2·996	·9652
12	·03637	·005129	·01925	·0001710	·01885	·002333	2·900	·9344
13	·03560	·005011	·01911	·0001696	·01851	·002289	2·808	·9048
14	·03486	·004908	·01897	·0001682	·01818	·002246	2·720	·8766
15	·03415	·004804	·01883	·0001669	·01786	·002205	2·635	·8493
16	·03347	·004703	·01869	·0001654	·01755	·002164	2·553	·8230
17	·03283	·004609	·01856	·0001641	·01725	·002125	2·474	·7977
18	·03220	·004515	·01844	·0001630	·01698	·002089	2·399	·7736
19	·03161	·004428	·01831	·0001616	·01667	·002049	2·328	·7508
20	·03102	·004339	·01819	·0001604	·01639	·002012	2·260	·7291
21	·03044	·004253	·01805	·0001590	·01611	·001975	2·200	·7098
22	·02988	·004169	·01792	·0001575	·01584	·001940	2·143	·6916
23	·02934	·004088	·01779	·0001561	·01557	·001903	2·087	·6737
24	·02881	·004009	·01766	·0001548	·01530	·001868	2·035	·6570
25	·02831	·003932	·01754	·0001534	·01504	·001832	1·985	·6411
26	·02783	·003859	·01742	·0001522	·01478	·001798	1·937	·6257
27	·02736	·003787	·01731	·0001509	·01453	·001764	1·891	·6110
28	·02691	·003717	·01720	·0001497	·01428	·001731	1·848	·5973
29	·02649	·003653	·01709	·0001485	·01404	·001699	1·808	·5845
30	·02608	·003588	·01699	·0001470	·01380	·001666	1·769	·5722
35	·02440	·003315	·01666	·0001426	·01271	·001516	1·575	·5103
40	·02306	·003081	·01644	·0001385	·01182	·001386	1·414	·4589
45	·02187	·002860	·01624	·0001338	·01111	·001275	1·300	·4227
50	·02090	·002657	·01608	·0001288	·01061	·001184	1·204	·3927
60	·01946	·002274	·01600	·0001178	·01000	·001026	1·006	·3294
70	·01833	·001857	...	·0001021	...	...	0·848	·2792
80	·01761	·001381	...	·0000790	...	...	0·672	·2226
90	·01723	·000787	...	·0000461	...	...	0·380	·1268
100	·01700	·000000	...	·0000000	·01000	·000000	0·000	·0000

TABLE 29—*Continued.*

T.	Carbon monoxide, W.		Carbon dioxide, B. & B.		Hydrogen sulphide, F.		Ammonia, R.	
	a.	*q.*	*a.*	*q.*	*a.*	*q.*	*a.*	*q.*
0	0·03537	0·004397	1·713	0·3347	4·686	0·710	1298·9	98·7
1	0·03455	0·004293	1·646	0·3214	4·555	0·689	1220·2	92·7
2	0·03375	0·004192	1·584	0·3091	4·428	0·670	1154·7	87·7
3	0·03297	0·004092	1·527	0·2979	4·303	0·651	1100·9	83·6
4	0·03222	0·003997	1·473	0·2872	4·182	0·632	1053·0	79·9
5	0·03149	0·003904	1·424	0·2774	4·063	0·615	1019·5	77·3
6	0·03078	0·003814	1·377	0·2681	3·948	0·596	997·2	75·6
7	0·03009	0·003726	1·331	0·2590	3·836	0·579	974·9	73·9
8	0·02942	0·003641	1·282	0·2494	3·728	0·562	954·5	72·3
9	0·02878	0·003560	1·237	0·2401	3·622	0·546	933·0	70·6
10	0·02816	0·003481	1·194	0·2319	3·520	0·530	910·4	68·9
11	0·02757	0·003416	1·154	0·2240	3·421	0·515	888·0	67·2
12	0·02701	0·003333	1·117	0·2166	3·325	0·500	865·6	65·5
13	0·02646	0·003260	1·083	0·2099	3·232	0·485	843·2	63·7
14	0·02593	0·003188	1·050	0·2033	3·142	0·471	822·1	62·1
15	0·02543	0·003130	1·019	0·1971	3·056	0·458	802·4	60·6
16	0·02494	0·003065	0·985	0·1904	2·973	0·445	783·2	59·1
17	0·02448	0·003007	0·956	0·1845	2·893	0·433	764·1	57·6
18	0·02402	0·002943	0·928	0·1789	2·816	0·421	744·3	56·1
19	0·02360	0·002893	0·902	0·1736	2·742	0·409	725·8	54·7
20	0·02319	0·002839	0·878	0·1689	2·672	0·398	710·6	53·5
21	0·02281	0·002789	0·854	0·1641	...	...	690·2	51·9
22	0·02244	0·002739	0·829	0·1591	...	...	674·3	50·6
23	0·02208	0·002691	0·804	0·1541	...	...	661·0	49·6
24	0·02174	0·002647	0·781	0·1494	...	...	647·8	48·6
25	0·02142	0·002603	0·759	0·1450	...	...	634·6	47·6
26	0·02110	0·002560	0·738	0·1407	...	...	621·3	46·5
27	0·02080	0·002519	0·718	0·1367	...	...	608·1	45·5
28	0·02051	0·002479	0·699	0·1328	...	...	594·8	44·4
29	0·02024	0·002442	0·682	0·1293	...	...	...	...
30	0·01998	0·002405	0·665	0·1259	...	...	...	...
35	0·01877	0·002231	0·592	0·1106	...	...	...	...
40	0·01775	0·002076	0·530	0·0974	...	...	...	...
45	0·01690	0·001934	0·479	0·0862	...	...	...	...
50	0·01615	0·001797	0·436	0·0762	...	...	...	...
60	0·01488	0·001521	0·359	0·0577	...	...	...	...
70	0·01440	0·001276	...	...	...	...	...	...
80	0·01430	0·000981	...	...	...	...	...	...
90	0·01420	0·000568	...	...	...	...	...	...
100	0·01410	0·000000	...	...	...	...	...	...

TABLE 29—*Continued.*

T.	Sulphur dioxide, S.		Hydrogen chloride, R.-D.		Methane, W.	
	a.	*q.*	*a.*	*q.*	*a.*	*l.*
0	79·789	22·83	506·7	82·5	0·05563	0·003959
1	77·210	22·09	...	...	0·05401	0·003842
2	74·691	21·37	499·8	81·4	0·05244	0·003729
3	72·230	20·67	...	...	0·05093	0·003620
4	69·828	19·98	493·7	80·4	0·04946	0·003514
5	67·485	19·31	...	...	0·04805	0·003411
6	65·200	18·66	486·9	79·3	0·04669	0·003312
7	62·973	18·02	...	...	0·04539	0·003218
8	60·805	17·40	480·8	78·3	0·04413	0·003127
9	58·697	16·80	...	...	0·04292	0·003039
10	56·647	16·21	473·9	77·2	0·04177	0·002956
11	54·655	15·64	...	...	0·04072	0·002880
12	52·723	15·09	467·7	76·2	0·03970	0·002805
13	50·849	14·56	...	...	0·03872	0·002733
14	49·033	14·04	461·5	75·2	0·03779	0·002666
15	47·276	13·54	...	...	0·03690	0·002600
16	45·578	13·05	455·2	74·2	0·03606	0·002538
17	43·939	12·59	...	...	0·03525	0·002479
18	43·360	12·14	448·3	73·1	0·03446	0·002422
19	40·838	11·70	...	...	0·03376	0·002369
20	39·374	11·29	442·0	72·1	0·03308	0·002319
21	37·970	10·89	...	...	0·03243	0·002270
22	36·617	10·50	435·0	71·0	0·03180	0·002223
23	35·302	10·13	...	...	0·03119	0·002178
24	34·026	9·76	428·7	70·0	0·03061	0·002134
25	32·786	9·41	...	...	0·03006	0·002092
26	31·584	9·07	423·0	69·1	0·02952	0·002051
27	30·422	8·43	...	...	0·02901	0·002012
28	29·314	8·42	417·2	68·2	0·02852	0·001974
29	28·210	8·10	...	...	0·02806	0·001939
30	27·161	7·81	411·5	67·3	0·02762	0·001905
35	22·489	6·47	...	...	0·02546	0·001732
40	18·766	5·41	387·7	63·3	0·02369	0·001586
50	...	...	361·6	59·6	0·02134	0·001359
60	...	...	338·7	56·1	0·01954	0·001145
70	...	...	...	...	0·01825	0·000926
80	...	...	...	...	0·01770	0·000695
90	...	...	...	...	0·01735	0·000398
100	...	...	...	...	0·01700	0·000000

TABLE 29—*Continued.*

T.	Ethylene, W.		Acetylene, W.		Air, W.		Nitrous oxide, in Alcohol, B.
	a.	*q.*	*a.*	*q.*	*a.*		*a.*
0	0·226	0·0281	1·73	0·20	0·02881	...	4·1780
1	0·219	0·0272	1·68	0·19	0·02808	...	4·1088
2	0·211	0·0262	1·63	0·19	0·02738	...	4·0409
3	0·204	0·0254	1·58	0·18	0·02670	...	3·9741
4	0·197	0·0245	1·53	0·18	0·02606	...	3·9085
5	0·191	0·0237	1·49	0·17	0·02543	...	3·8442
6	0·184	0·0228	1·45	0·17	0·02482	...	3·7811
7	0·178	0·0221	1·41	0·16	0·02424	...	3·7192
8	0·173	0·0214	1·37	0·16	0·02369	...	3·6585
9	0·167	0·0207	1·34	0·15	0·02316	...	3·5990
10	0·162	0·0200	1·31	0·15	0·02264	...	3·5408
11	0·157	0·0194	1·27	0·15	0·02217	...	3·4838
12	0·152	0·0188	1·24	0·14	0·02171	...	3·4279
13	0·148	0·0183	1·21	0·14	0·02127	...	3·3734
14	0·143	0·0176	1·18	0·14	0·02085	...	3·3200
15	0·139	0·0171	1·15	0·13	0·02045	...	3·2678
16	0·136	0·0167	1·13	0·13	0·02005	...	3·2169
17	0·132	0·0162	1·10	0·13	0·01970	...	3·1672
18	0·129	0·0158	1·08	0·12	0·01935	...	3·1187
19	0·125	0·0153	1·05	0·12	0·01901	...	3·0714
20	0·122	0·0150	1·03	0·12	0·01869	...	3·0253
21	0·119	0·0146	1·01	0·12	0·01838	...	2·9805
22	0·116	0·0142	0·99	0·11	0·01808	...	2·9368
23	0·114	0·0139	0·97	0·11	0·01779	...	2·8944
24	0·111	0·0135	0·95	0·11	0·01751	...	2·8532
25	0·108	0·0131	0·93	0·11	0·01724	...	...
26	0·106	0·0129	0·91	0·10	0·01698	...	...
27	0·104	0·0126	0·89	0·10	0·01674	...	...
28	0·102	0·0123	0·87	0·10	0·01650	...	...
29	0·100	0·0121	0·85	0·10	0·01627	...	...
30	0·098	0·0118	0·84	0·09	0·01606	...	...
...	...	...	...	...	0·01503	...	...
...	...	...	...	...	0·01418	...	...
...	...	...	..	...	0·01297	...	...
...	...	...	...	...	0·01216	...	...
...	...	...	...	...	0·01156	...	...
...	...	...	...	...	0·01126	...	...
...	...	...	...	...	0·01113	...	...
...	...	...	...	...	0·01105	...	...

TABLE 30.—SPECIFIC GRAVITIES OF SOLIDS.

Alum, ammonium	1·626
potassium	1·724
Alum stone	2·8
Alumina, anhydrous	4·15
Aluminium, cast	2·56
wrought	2·67
Aluminium sulphate, cryst.	1·596
Ammonium nitrate	1·707
sulphate	1·77
chloride	1·528
Anhydrite ($CaSO_4$)	2·96
Anthracite	1·4-1·7
Antimony	6·7
Arsenic acid	4·250
Arsenious acid	3·884
Asbestos	2·45
Ash wood	0·7-0·8
Asphalt	1·1-1·2
Barium carbonate	4·56
chloride, cryst.	2·664
hydroxide, cryst.	1·66
sulphate (spar)	4·73
Basalt	2·8-3·2
Beech wood, dry	0·7-0·8
Bell metal	8·06
Birch wood, dry	0·7-0·8
Bismuth	9·85
Borate of magnesium (boracite)	2·9
Borax, crystallised	1·692
Boric acid, crystallised	1·479
fused	1·830
Brass	8·4-8·7
Bricks, ordinary	1·4-2·2
Brickwork	1·5-1·7
Brown coal, lignite	1·2-1·4
Calamine	4·1-4·5
Calcium carbonate	2·7
chloride, anhydrous	2·240
chloride, cryst.	1·612
phosphate	3·18
silicate	2·9
sulphate, anhydrous	2·927
Calcspar	2·72
Cannel coal	1·16-1·27
Cement	2·7-3·05
Charcoal, organic	1·57
wood	0·3-0·5
China clay, kaolin	2·21
Clay	1·8-2·6
Coal, porous	1·16-1·63
Coke, porous	0·4
Concrete	2·2
Copper, hammered	8·94
metallic, cast	8·726
oxide	6·43
pyrites	4·1-4·3
sulphate	2·27
Cryolite	2·96
Cuprous sulphide	5·97
Ebonite	1·38
Elm wood	0·58-0·67
Fat, animal	0·92
Felspar	2·5-2·6
Fibres, vegetable	1·51
Firebricks	1·85
Fir wood, dry	0·6
Flint	2·6-2·7
Glass, crystal, Bohem.	2·9-3·0
flint, English	3·4-3·44
green	2·642
plate	2·450
Glauber's salt, anhydrous	2·63
cryst.	1·52
Granite	2·5-2·9
Graphite	2·35
Gypsum, cast, dry	0·97
plaster-of-Paris	2·322
Hæmatite	4·9
Heavy spar	4·3-4·48
Ice (0°)	0·917
Iodine	4·948
Iron, carbonate	3·87
grey, cast	6·6-7·3
hydrated oxide	3·94
magnetic oxide	5·4
pyrites	5·18
pyrites, white	4·65-4·88
sesquioxide	5·22
sulphate, cryst.	1·904
white, cast	7·1-7·9

TABLE 30—*Continued.*

Iron, wrought . .	7·8-7.9	Potassium chloride .	1·945
Ivory	1·83-1·94	chromate .	2·603
Larch wood . .	0·44-0·5	hydroxide .	2·044
Lead, acetate, cryst. .	2·395	nitrate .	2·058
carbonate . .	6·47	sulphate .	2·66
cast . . .	11·3	Quartz	2·7
chloride . .	5·802	Resin	1·07
chromate . .	6·00	Rock salt . . .	2·1-2·2
nitrate . .	4·40	Rubber . . .	0·83
oxide . .	9·41	Sal-ammoniac . .	1·528
red . . .	8·62	Sand, damp . .	1·9-2·0
sulphate . .	6·169	dry . . .	1·4-1·6
sulphide . .	7·505	Sandstone . . .	1·9-2·5
Lignite . . .	1·2-1·4	Silver	10·6
Lime, burnt, quick- .	3·08	Silver chloride . .	5·501
Lime wood . . .	0·5	Slate	2·7
Litharge . . .	9·36	Sodium carbonate, anh.	2·509
Magnesia, calcined .	3·2	carbonate, cryst.	1·454
carbonate .	2·94	chloride . .	2·078
Magnesite . . .	2·9-3·1	hydroxide .	2·130
M gnesium chloride,		nitrate . .	2·226
cryst. . . .	1·558	sulphate . .	2·63
Magnesium sulph., cryst.	1·751	sulphide . .	2·471
Manganese native ore	4·7-5·0	thiosulphate .	1·736
peroxide .	2·94	Spruce . . .	0·52
Maple wood . .	0·5-0·6	Steel	7·80
Marble . . .	2·5-2·8	Steel, cast . . .	7·92
Nickel, cast . .	8·28	hardened . .	7·66
hammered .	8.67	Sugar	1·6
Oak, dry . . .	0·85-0·95	Sulphur, native . .	2·069
Phosphor bronze, cast	8·6	soft, amorphous	1·96
drawn	8·72	sticks, fresh .	1·98
Phosphorus, red .	2·106	sticks, old .	2·05
yellow .	1·826	Sulphuric anhydride .	1·97
Pine wood, red . .	0·5	Teak	0·80
white .	0·55	Tin, cast . . .	7·21-7·4
yellow .	0·76	hammered . .	7·475
Pitch	1·07	Vulcanite . . .	1·52
Platinum . . .	21·5	Willow wood . .	0·5-0·58
Poplar . . .	0·38	Witherite . . .	4·30
Porcelain . . .	2·1-2·5	Zinc, blende . .	3·9-4·2
Porphyry . . .	2·8	cast . . .	6·8
Potash, natural . .	2·3	oxide . . .	5·73
Potassium bisulphate .	2·277	rolled . . .	7·2
carbonate .	2·264	sulphate . .	2·036
chlorate .	2·35		

TABLE 31.—SPECIFIC GRAVITY OF LIQUIDS.

	Specific Gravity.	Temp.
Acetic anhydride	1·004	17°
Acetone	0·81	...
Alcohol	0·7939	12°·5
Acetic acid	1·064	17°
Bisulphide of carbon	1·272	...
Benzene	0·884	15°·5
Coal tar	1·15	15°
Ether	0·723	12°·5
Glycerine	1·260	15°
Linseed oil	0·9347	15°
Mercury	13·596	0°
Nitrogen peroxide (liquid)	1·45	...
Olive oil	0·917	15°
Petroleum	0·78-0·81	15°
Rapeseed oil	0·9136	15°
Sulphur dioxide (liquid)	1·45	20°
Sea-water	1·02-1·04	15°
Spirits of turpentine	0·865	15°

TABLE 32.—SPECIFIC GRAVITY AND PERCENTAGE OF SOLUTIONS SATURATED AT 15°.

The percentage refers to Anhydrous Salt in 100 solution.

	Temperature.	Percentage of Salt.	Specific Gravity.	Degrees Twaddell.
Ammonium chloride	15	26·30	1·0776	15·5
sulphate	19	50·00	1·2890	57·8
Barium chloride	15	25·97	1·2827	56·5
Calcium chloride	15	40·66	1·4110	82·2
Magnesium sulphate	15	25·25	1·2880	57·6
Potassium chloride	15	24·90	1·1723	34·4
carbonate	15	52·02	1·5708	114
nitrate	15	21·07	1·1441	28·8
sulphate	15	9·92	1·0831	16·6
Sodium chloride	15	26·395	1·2043	40·8
carbonate	15	14·35	1·1535	30·7
nitrate	19·5	46·25	1·3804	76
sulphate	15·0	11·95	1·1117	22·3

TABLE 33.—LINEAR EXPANSION OF SUBSTANCES ON HEATING.

By heating from 0° to 100° C. (32°-212° F.).

Aluminium	0·00218	1 : 459
Brass	0·001982	1 : 535
Bronze	0·001820	1 : 549
Charcoal from oak	0·001200	1 : 833
fir	0·00100	1 : 1000
Copper	0·001714	1 : 582
Glass, flint	0·000817	1 : 1219
white	0·000861	1 : 1161
green	0·000766	1 : 1305
Gold	0·001431	1 : 682
Iron, wrought	0·001235	1 : 812
cast	0·001144	1 : 901
Lead	0·002938	1 : 351
Marble of Carrara	0·000849	1 : 1178
St Beat	0·000418	1 : 2392
Mercury	0·0182	1 : 55
Nickel	0·001516	1 : 600
Platinum	0·000884	1 : 1132
Porcelain (Berlin)	0·000336	1 : 3000
Silver	0·001954	1 : 524
Solder, hard	0·002058	1 : 486
Steel, hardened	0·001240	1 : 807
not hardened	0·001079	1 : 927
Tin	0·002703	1 : 516
Water	0·015538	1 : 71·4
Zinc	0·001711	1 : 340

TABLE 34.—WEIGHT OF SUBSTANCES AS STORED.

Substance.	1 Cubic Metre Weighs	1 Cubic Foot Weighs	Tons per Cub. Foot.
	Kilo.	lb. avdp.	
Alkali waste (wet)	1268	79	·0352
Bicarbonate (ground)	986	61·5	·0274
Black ash (lumps)	962	60	·0268
Bleaching powder	721-834	45-52	·0216
Bricks	2100	131	·0584
Cement	1200	75	·0335
Cinders (ashes)	738	46	·0205
Clay, damp	1650	103	·0459
Clay, dry	1570	98	·0437
Coke (for filling towers)	417-534	26-33	·0131
Flints (for filling towers)	1600	100	·0446
Limestone and other building stones	2000	125	·0558
Limestone dust	1550	96·5	·0431
Limestone (small pieces)	1400	87·5	·0391
Manganese dioxide, native	2210	138	·0616
Mortar (lime and sand)	1800	112	·0500
Nitre	1310	81·5	·0364
Nitre cake (acid sulphate of soda)	1335	83	·0375
Pyrites, broken pieces	2500	156	·0696
burnt	1520	95	·0424
smalls	2340	146·5	·0654
Quicklime	1000	62·5	·0279
Quicklime (small lumps)	1058	66	·0295
Salt	689	43	·0192
Saltcake	1180	73·5	·0328
Sand, dry	1330	83	·0370
damp	1770	110	·0491
Sieved lime (for bleaching powder)	497-593	31-37	·0151
Soda ash (unground)	1195	74·5	·0332
Soda crystals	1010	63	·0281
Soda salts (Na_2CO_3, $10H_2O$) (drained)	810	50·5	·0225
Wood, beech logs	400	24·5	·0107
fir logs	330	20·5	·0091
oak logs	420	26	·0116

TABLE 35.—WEIGHT OF SHEET METAL.

Weight in lbs. of one Square Foot.

Thickness.	Wrought Iron.	Cast Iron.	Steel.	Copper.	Brass.	Lead.	Zinc.	Tin.	Gun-Metal.	Aluminium.
Inch.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.
$\frac{1}{16}$	2·53	2·34	2·55	2·89	2·73	3·71	2·34	2·41	2·73	0·86
$\frac{1}{8}$	5·05	4·69	5·10	5·78	5·47	7·42	4·69	4·81	5·46	1·72
$\frac{3}{16}$	7·58	7·03	7·66	8·67	8·20	11·13	7·03	7·22	8·19	2·58
$\frac{1}{4}$	10·10	9·38	10·21	11·76	10·94	14·83	9·38	9·63	10·9	3·45
$\frac{5}{16}$	12·63	11·72	12·76	14·45	13·67	18·54	11·72	12·0	13·7	4·31
$\frac{3}{8}$	15·16	14·06	15·31	17·34	16·41	22·25	14·06	14·4	16·4	5·18
$\frac{7}{16}$	17·68	16·41	17·87	20·23	19·14	25·96	16·41	16·8	19·1	5·97
$\frac{1}{2}$	20·21	18·75	20·42	23·13	21·88	29·67	18·75	19·3	21·9	6·91
$\frac{9}{16}$	22·73	21·09	22·97	26·02	24·61	33·38	21·09	21·7	24·6	7·76
$\frac{5}{8}$	25·27	23·44	25·52	28·91	27·34	37·08	23·44	24·0	27·4	8·64
$\frac{11}{16}$	27·79	25·78	28·07	31·80	30·08	40·79	25·78	26·4	30·1	9·49
$\frac{3}{4}$	30·31	28·13	30·63	34·69	32·81	44·50	28·13	28·8	32·8	10·36
$\frac{13}{16}$	32·84	30·47	33·18	37·58	35·55	48·21	30·47	31·2	35·5	11·22
$\frac{7}{8}$	35·87	32·81	35·73	40·47	38·28	51·92	32·81	33·6	38·2	12·09
$\frac{15}{16}$	37·90	35·16	38·28	43·36	41·02	55·63	35·16	36·0	40·9	12·95
1	40·42	37·50	40·83	46·25	43·75	59·33	37·50	38·5	43·7	13·82

TABLE 36.—CHEMICAL NAMES AND FORMULÆ OF COMMON CHEMICALS.

Common Name.	Chemical Name or Description.	Formula.
Abraum salts	Residue from Stassfurt salts	......
Acetic ether	Ethyl acetate	$CH_3 . COOC_2H_5$
Alabaster	Fine grained masses of gypsum	$CaSO_4, 2H_2O$
Aldehyde	Acetaldehyde	$CH_3 . CHO$
Alum	Potassium aluminium sulphate	$KAl(SO_4)_2, 12H_2O$
Alundum	Essentially fused alumina	Al_2O_3
Aniline	Amidobenzene	$C_6H_5 . NH_2$
Aniline salt	Aniline hydrochloride	$C_6H_5 . NH_2 . HCl$
Animal charcoal	......	Mixture of $Ca_3(PO_4)_2$ and C
Antifebrin	Acetanilide	$C_6H_5 . NHCOCH_3$
Antimony black	Antimony trisulphide	Sb_2S_3
Antimony vermilion	Antimony oxysulphide	$Sb_2S_3 . Sb_2O_3$
Antimony white	Antimonious oxide	Sb_2O_3
Antimony yellow	Basic lead antimoniate	$PbO . Sb_2O_5$
Aqua fortis	Concentrated nitric acid	HNO_3
Aqua regia	Nitric acid + hydrochloric acid	$HNO_3 + 3HCl$
Argol	Crude potassium bitartrate	$KHC_4H_4O_6$
Arsine	Arsenuretted hydrogen	AsH_3
Asphalt	Solution of pitch in heavy tar oils	......
Asphaltum	Natural pitch from Trinidad	......
Aspirin	Acetyl-salicylic acid	o-$C_6H_4(OCOCH_3)$ COOH
Azurite	Basic copper carbonate	$2CuCO_3 . Cu(OH)_2$
Baking soda	Sodium bicarbonate	$NaHCO_3$
Baryta	Barium oxide	BaO
Barytes	Native barium sulphate	$BaSO_4$
Bauxite	Hydrated alumina	Hydrated Al_2O_3
Benzine	Petrol	......
Benzol	Benzene	C_6H_6
Bichrome	Potassium bichromate	$K_2Cr_2O_7$
Black ash	Impure sodium carbonate	......
Black flux	Mixture of potassium carbonate and charcoal	......
Black Jack	Native zinc sulphide	ZnS
Black lead	Graphite	C
Blanc fixe	Barium sulphate	$BaSO_4$
Bleaching powder	Calcium chloro-hypochlorite	$CaOCl_2$

TABLE 36—*Continued.*

Common Name	Chemical Name or Description.	Formula.
Blue-john . . .	Fluorspar (calcium fluoride) . . .	CaF_2
Bluestone . . .	Copper sulphate . .	$CuSO_4 . 5H_2O$
Blue verditer . .	Basic copper carbonate .	$2CuCO_3 . Cu(OH)_2$
Blue vitriol . .	Copper sulphate . .	$CuSO_4 . 5H_2O$
Bog iron . . .	Hydrated ferric oxide .	Fe_2O_3, H_2O
Bone ash . . .	Impure calcium phosphate	mainly $Ca_3(PO_4)_2$
Bone black . .	Crude animal charcoal .	$Ca_3(PO_4)_2 + C$
Borax . . .	Sodium tetraborate . .	$Na_2B_4O_7 . 10H_2O$
B.O.V. . . .	Crude 70 per cent. sulphuric acid . .	......
Bremen blue . .	Basic copper carbonate .	$xCuCO_3 . yCu(OH)_2$
Brimstone . .	Sulphur	S
Burnt alum . .	Anhydrous potassium aluminium sulphate .	$K_2SO_4 . Al_2(SO_4)_3$
Burnt lime . .	Calcium oxide . . .	CaO
Butter of antimony .	Antimony trichloride .	$SbCl_3$
Cadmium yellow .	Cadmium sulphide . .	CdS
Calamine . . .	Zinc carbonate . .	$ZnCO_3$
Caliche . . .	Impure sodium nitrate .	$NaNO_3$
Calomel . . .	Mercurous chloride . .	Hg_2Cl_2
Cane sugar . .	Sucrose	$C_{12}H_{22}O_{11}$
Carbolic acid . .	Phenol	C_6H_5OH
Carbon black . .	Carbon from American natural gas . . .	C
Carbonic acid . .	Carbon dioxide . .	CO_2
Carborundum . .	Silicon carbide . .	SiC
Cassel Yellow . .	Basic lead chloride . .	Approx. $PbCl_2 + 7PbO$
Cassiterite . .	Native stannic oxide .	SnO_2
Ceruse . . .	Basic lead carbonate .	$2PbCO_3 . Pb(OH)_2$
Celluloid . . .	Dinitro-cellulose with camphor . . .	......
Chalk . . .	Calcium carbonate . .	$CaCO_3$
Chili saltpetre . .	Sodium nitrate . .	$NaNO_3$
China clay . .	Aluminium silicate . .	$Al_2O_3 . 2SiO_2 . 2H_2O$
Chinese red . .	Basic lead chromate .	$PbCrO_4 . PbO$
Chinese white . .	Zinc oxide . . .	ZnO
Chloride of lime .	Bleaching powder . .	$CaOCl_2$
Chrome alum . .	Potassium chromium sulphate . . .	$K_2SO_4 . Cr_2(SO_4)_3 24H_2O$
Chrome green . .	Chromium oxide . .	Cr_2O_3
Chrome red . .	Basic lead chromate .	$PbCrO_4 . PbO$
Chrome yellow . .	Lead chromate . .	$PbCrO_4$
Cinnabar . . .	Mercuric sulphide . .	HgS
Cobalt black . .	Cobalt oxide . . .	CoO

TABLE 36—*Continued.*

Common Name.	Chemical Name or Description.	Formula.
Cobalt green	Cobalt zincate	$CoO . ZnO$
Copperas	Ferrous sulphate	$FeSO_4 . 7H_2O$
Corrosive sublimate	Mercuric chloride	$HgCl_2$
Corundum	Aluminium oxide	Al_2O_3
Cream of tartar	Potassium hydrogen tartrate	$KHC_4H_4O_6$
Cresylic acid	Mixture of *o*- *m*- and *p*-cresol	$C_6H_4(CH_3)OH$
Derby red	Basic lead chromate	$PbCrO_4 . PbO$
Derbyshire spar	Fluorspar (calcium fluoride)	CaF_2
Dextrose	Glucose	$C_6H_{12}O_6$
Dutch liquid	Ethylene chloride	$C_2H_4Cl_2$
Eau-de-Javelle	Potassium hypochlorite solution	$KClO$
Eau-de-Labarraque	Sodium hypochlorite solution	$NaClO$
Emerald green	Copper aceto-arsenite	$Cu(C_2H_3O_2)_2 . 3CuAs_2O_4$
Emery	Ferric oxide and corundum	$Fe_2O_3 + Al_2O_3$
Epsom salts	Magnesium sulphate	$MgSO_4 . 7H_2O$
Ferro-prussiate	Potassium ferrocyanide	$K_4Fe(CN)_6$
Firedamp	Gas escaping from coal, mainly methane	......
Flowers of sulphur	Sulphur	S
Fluorspar	Calcium fluoride	CaF_2
Formalin	40 per cent. aqueous solution of formaldehyde	$H . CHO$
Freezing salt	Crude sodium chloride	$NaCl$
Fruit sugar	Fructose	$C_6H_{12}O_6$
Fulminating mercury	Mercuric fulminate	$HgC_2O_2N_2$
Fuming oil of vitriol	Fuming sulphuric acid	A solution of SO_3 in H_2SO_4
Gasoline	American for petrol	......
Glauber's salt	Sodium sulphate	$Na_2SO_4 . 10H_2O$
Golden sulphide	Antimony pentasulphide	Sb_2S_5
Grape sugar	Glucose	$C_6H_{12}O_6$
Green verditer	Basic copper carbonate	$CuCO_3 . Cu(OH)_2$
Green vitriol	Ferrous sulphate	$FeSO_4 . 7H_2O$
Gun cotton	Cellulose trinitrate	$C_6H_7O_2(NO_3)_3$
Gypsum	Calcium sulphate	$CaSO_4 . 2H_2O$
Heavy spar	Native barium sulphate	$BaSO_4$
Hexamine	Hexamethylene tetramine	$C_6H_{12}N_4$
Horn silver	Silver chloride	$AgCl$

TABLE 36—*Continued.*

Common Name.	Chemical Name or Description.	Formula.
Hypo	Sodium thiosulphate	$Na_2S_2O_3 . 5H_2O$
Iceland spar	Pure native calcium carbonate	$CaCO_3$
Indian red	Ferric oxide	Fe_2O_3
Invert sugar	Glucose and fructose	......
Iron mordant	Ferric sulphate	$Fe_2(SO_4)_3$
Ivory black	Purified bone char	$Ca_3(PO_4)_2$ and C
Kaolin	Aluminium silicate	$Al_2O_3 . 2SiO_2 . 2H_2O$
Kerosene	American term for paraffin oil	......
Killed spirits of salt	Solution of zinc chloride	$ZnCl_2$
King's yellow	Arsenic sulphide	As_2S_3
Kish	Graphite scales from blast furnaces	C
Lævulose	Fructose	$C_6H_{12}O_6$
Lampblack	Impure oily carbon	......
Lanolin	Cholesterol	$C_{27}H_{46}O$
Laughing gas	Nitrous oxide	N_2O
Lemon chrome	Barium chromate	$BaCrO_4$
Lime	Calcium oxide	CaO
Limeshells	Calcium oxide	CaO
Limestone	Calcium carbonate	$CaCO_3$
Litharge	Lead monoxide	PbO
Lithopone	Zinc sulphide + barium sulphate	$ZnS + BaSO_4$
Liver of sulphur	Mixed potassium sulphides	......
Loadstone	Magnetic iron oxide	Fe_3O_4
Lunar caustic	Silver nitrate	$AgNO_3$
Lye	Solution of sodium hydroxide	NaOH
Magnesia	Magnesium oxide	MgO
Magnesite	Magnesium carbonate	$MgCO_3$
Malachite	Basic copper carbonate	$CuCO_3 . Cu(OH)_2$
Marble	Calcium carbonate	$CaCO_3$
Marsh gas	Methane	CH_4
Massicot	Lead monoxide	PbO
Metol	Photographic developer	......
Microcosmic salt	Sodium ammonium hydrogen phosphate	$Na(NH_4)HPO_4 . 4H_2O$
Milk of lime	Calcium hydroxide	$Ca(OH)_2$
Milk of magnesia	Magnesium hydroxide	$Mg(OH)_2$
Milk of sulphur	Precipitated sulphur	S
Milk sugar	Lactose	$C_{12}H_{22}O_{11}$
Mineral white	Native calcium sulphate	$CaSO_4, 2H_2O$
Minium	Lead tetroxide	Pb_3O_4

TABLE 36—*Continued.*

Common Name.	Chemical Name or Description.	Formula.
Mixed acid	Mixture of concentrated sulphuric and nitric acids	......
Mosaic gold	Stannic sulphide	SnS_2
Moulder's blacking	Ground coke or coal	......
Muriate of ammonia	Ammonium chloride	NH_4Cl
Muriatic acid	Hydrochloric acid	HCl
Naples Yellow	Basic lead pyro-antimonate	......
Natron	Sodium carbonate	$Na_2CO_3 . 10H_2O$
Nitre	Potassium nitrate	KNO_3
Nitre cake	Sodium sulphate and bisulphate	$Na_2SO_4 + NaHSO_4$
Nitro-lime	Calcium cyanamide	$CaCN_2$
Nitrous ether	Ethyl nitrite	$C_2H_5NO_2$
Nordhausen acid	Fuming sulphuric acid	$H_2SO_4 + SO_3$
Norge saltpetre	Basic calcium nitrate	$Ca(OH)(NO_3)$
Oil of bitter almonds	Benzaldehyde	$C_6H_5 . CHO$
Oil of mirbane	Nitrobenzene	$C_6H_5 . NO_2$
Oil of mustard	Allyl isothiocyanate	$C_3H_5 . CNS$
Oil of vitriol	Concentrated sulphuric acid	H_2SO_4
Oil of wintergreen	Methylsalicylate	$o\text{-}C_6H_4(OH)COOCH_3$
Olefiant gas	Ethylene	C_2H_4
Oleum	Fuming sulphuric acid	$H_2SO_4 + SO_3$
Orpiment	Arsenic sulphide	As_2S_3
Paris green	Copper aceto-arsenite	$Cu(C_2H_3O_2)_2 . 3CuAs_2O_4$
Pearl ash	Potassium carbonate	K_2CO_3
Perhydrol	Trade name for hydrogen peroxide	H_2O_2
Permanent white	Barium sulphate	$BaSO_4$
Petroleum ether	Petrol	......
Petroleum spirit	Petrol	......
Phenic acid	Phenol	C_6H_5OH
Phosgene	Carbonyl chloride	$COCl_2$
Picric acid	*sym*-Trinitrophenol	$C_6H_2(NO_2)_3OH$
Pink salt	Stannic ammonium chloride	$(NH_4)_2SnCl_6$
Plaster of Paris	Calcium sulphate	$CaSO_4 . \frac{1}{2}H_2O$
Plumbago	Graphite	C
Potash	Potassium hydroxide	KOH
Precipitated chalk	Calcium carbonate	$CaCO_3$
Prussian blue	Ferric ferrocyanide	$Fe_4[Fe(CN)_6]_3$
Prussic acid	Hydrocyanic acid	HCN
Putty powder	Stannic oxide	SnO_2
Pyrites	Iron disulphide	FeS_2
Pyroligneous acid	Crude acetic acid	$CH_3 . COOH$

TABLE 36—*Continued.*

Common Name.	Chemical Name or Description.	Formula.
Pyroligneous spirit	Methyl alcohol	CH_3OH
Pyrolusite	Manganese dioxide	MnO_2
Quick lime	Calcium oxide	CaO
Quicksilver	Mercury	Hg
Quinol	Hydroquinone	$p-C_6H_4(OH)_2$
Realgar	Arsenic disulphide	As_2S_2
Rectified spirit	Ethyl alcohol, 90 per cent.	......
Red lead	Lead tetroxide	Pb_3O_4
Red liquor	Impure ferric chloride solution	......
Red oxide	Mainly ferric oxide	Fe_2O_3
Red prussiate of potash	Potassium ferricyanide	$K_3Fe(CN)_6$
Rochelle salt	Potassium sodium tartrate	$KNaC_4H_4O_6 . 4H_2O$
Rock oil	Petroleum	......
Rock salt	Native sodium chloride	......
Rongalite	Sodium formaldehyde sulphoxylate	$NaOS . O . CH_2OH$
Rouge	Ferric oxide	......
R.O.V.	Crude concentrated sulphuric acid	......
Saccharin	Benzoic sulphimide	$o\text{-}C_6H_4\langle\begin{smallmatrix}SO_2\\CO\end{smallmatrix}\rangle NH$
Salammoniac	Ammonium chloride	NH_4Cl
Salol	Phenyl salicylate	$o\text{-}C_6H_4(OH)COOC_6H_5$
Salt cake	Impure sodium sulphate	......
Salt of amber	Succinic acid	$C_4H_6O_4$
Salt of lemon, Salt of sorrel	Potassium hydrogen oxalate	$KHC_2O_4 . H_2O$
Salt of tartar	Potassium carbonate	K_2CO_3
Saltpetre	Potassium nitrate	KNO_3
Salvarsan	3·3′-Diamino-4·4′-dihydroxy-arsenobenzene dihydrochloride	$As_2[C_6H_3(OH)(NH_2)]_2 . 2HCl$
Satin white	Calcium sulphate	$CaSO_4, 2H_2O$
Scheele's green	Copper hydrogen arsenite	$CuHAsO_3$
Slaked lime	Calcium hydroxide	......
Smelling salt	Ammonium carbonate	Mainly $(NH_4)_2CO_3$
Snow white	Zinc oxide	ZnO
Soda	Sodium carbonate	$Na_2CO_3 . 10H_2O$
Soda water	Water charged with CO_2	......
Sodium hyposulphite	Sodium thiosulphate	$Na_2S_2O_3 . 5H_2O$
Soft soap	Formerly potash soap, now many substitutes	......

TABLE 36—*Continued.*

Common Name.	Chemical Name or Description.	Formula.
Soluble glass . .	Sodium silicate . .	Na_2SiO_3
Spirit of hartshorn .	Ammonia solution . .	NH_4OH
Spirit of salt . .	Hydrochloric acid . .	HCl
Spirit of wine . .	Ethyl alcohol . . .	C_2H_5OH
Sugar of lead . .	Lead acetate . . .	$Pb(CH_3 . COO)_2, 3H_2O$
Sulphuric ether .	Diethyl ether . . .	$(C_2H_5)_2O$
Tartar . . .	Crude potassium bitartrate . . .	$KHC_4H_4O_6$
Tartar emetic . .	Potassium antimonyl tartrate	$K(SbO)C_4H_4O_6 . \frac{1}{2}H_2O$
Tetralin . . .	Tetrahydronaphthalene .	$C_{10}H_{12}$
Thermit . . .	Mixture of iron oxide and aluminium . . .	......
Tin salt . . .	Stannous chloride . .	$SnCl_2, 2H_2O$
Tin stone . . .	Native stannic oxide .	SnO_2
Tin white . . .	Stannic hydroxide . .	$Sn(OH)_4$
T.N.T. . . .	Trinitrotoluene . .	$C_6H_2(CH_3)(NO_2)_3$ (1 . 2 . 4 . 6)
Toluol . . .	Toluene	$C_6H_5 . CH_3$
Turnbull's blue . .	Ferrous ferricyanide .	$Fe_3[Fe(CN)_6]_2$
Ultramarine yellow .	Barium chromate . .	$BaCrO_4$
Vanillin . . .	Methyl ether of protocatechualdehyde . .	$C_6H_3 \begin{cases} CHO & 1 \\ OCH_3 & 3 \\ OH & 4 \end{cases}$
Vaseline . . .	Purified low-melting paraffin . . .	$(C_{19}H_{40}$ to $C_{21}H_{44})$
Venetian red . .	Ferric oxide . . .	Fe_2O_3
Verdigris . . .	Basic copper acetate .	$2Cu(C_2H_3O_2)_2 + CuO$
Vermilion . . .	Red mercuric sulphide .	HgS
Vitriol . . .	Sulphuric acid . .	H_2SO_4
Washing soda . .	Sodium carbonate . .	$Na_2CO_3 . 10H_2O$
Water glass . .	Solution of sodium silicates	......
White arsenic . .	Arsenious oxide . .	As_2O_3
White lead . .	Basic lead carbonate .	$2PbCO_3 + Pb(OH)_2$
White vitriol . .	Zinc sulphate . . .	$ZnSO_4 . 7H_2O$
Whiting . . .	Calcium carbonate . .	$CaCO_3$
Wood alcohol . .	Methyl alcohol . .	CH_3OH
Wood naphtha . .	Crude methyl alcohol .	CH_3OH
Wood spirit . .	Methyl alcohol . .	CH_3OH
Yellow prussiate of potash . . .	Potassium ferrocyanide .	$K_4Fe(CN)_6 . 3H_2O$
Zinc vitriol . .	Zinc sulphate . . .	$ZnSO_4 . 7H_2O$
Zinc white . .	Zinc oxide . . .	ZnO

TABLE 37.—COMPOSITION OF COMMON ALLOYS.

		m.p.t.
Aluminium bronze	90 Cu, 10 Al	1000°
Argozoil	14 Ni, 54 Cu, 28 Zn, 2 Pb, 2 Sn	...
Babitt metal	90 Sn, 7 Sb, 3 Cu	...
Bell metal	77-85 Cu, 15-23 Sn	...
Benedict metal	14-16 Ni, 84-86 Cu	...
Brass (for casting)	33 Zn, 67 Cu	...
(sheet)	36-46 Zn, 54-64 Cu (sometimes Pb, Sn)	...
(naval brass)	37 Zn, 62 Cu, 1 Sn	...
Brittania metal	5-8 Sb, trace Pb; remainder Sn	...
Bronze coinage (old)	95 Cu, 4 Sn, 1 Zn	...
(present)	95½ Cu, 3 Sn, 1½ Zn	...
Cast iron (white)	3 combined C, 0·1 free C, traces Si, S, P, Mn; remainder Fe	...
(grey)	0·9 combined C, 2·8 free C, traces Si, S, P, Mn; remainder Fe	...
Constantan	40 Ni, 60 Cu	1290°
Delta metal	40 Zn, 1-2 Fe; remainder Cu	...
Dental alloy (1st quality)	66 Ag, 33 Pt	...
(2nd quality)	75 Ag, 25 Pt	...
Ferro-chrome	60-68 Cr, 2-5 C, 30-38 Fe	...
manganese	40-80 Mn, 5-8 C, 12-55 Fe	...
nickel	25-75 Ni, 1 C, 24-74 Fe	...
silicon	10-50 Si; remainder Fe	...
German silver	50-60 Cu, 10-30 Ni, 20-30 Zn	1100°
Gold coinage (British)	22 Au, 2 Cu or Ag	...
Gun metal	90 Cu, 10 Sn	...
metal	80-95 Cu, 5-18 Sn, 0-15 Zn, 0-10 Pb	...
Illium	60·6 Ni, 6·4 Cu, 21·1 Cr, 4·7 Mo, 2·1 W	1300°
Invar	35 Ni, 0·5 Mn, 0·5 C, 64 Fe	1425°
Magnalium	90 Al, 10 Mg	...
Manganin	4-40 Ni, 60-80 Cu, 1-12 Mn	...
Monel metal	60 Ni, 33 Cu, 6·5 Fe, 0·5 Al	1360°
Muntz metal	40 Zn, 60 Cu	...
Newton's metal	18·75 Sn, 31·35 Pb, 50 Bi	94·5°
Nichrome	60 Ni, 14 Cr, 15 Fe	...
Nickel coinage	Usually 25 Ni, 75 Cu	...
Nickelin	32 Ni, 55-70 Cu, 0-13 Zn	...
Pewter	79 Sn, 20 Pb, 1 Sb	...

TABLE 37—*Continued.*

		m.p.t.
Phosphor bronze (for strength)	91-92 Cu, 7·4-8·7 Sn, 0·3-0·6 P	...
(for bearings)	10-15 Sn, 1·0 P, 10 Sb or Pb; remainder Cu . . .	...
Platinite	46 Ni, 0·15 C; remainder Fe	...
Platinoid	60 Cu, 14 Ni, 24 Zn, 1-2 W .	...
Rose's metal	25 Sn, 25 Pb, 50 Bi . .	95°
Silver coinage (old) . . .	92·5 Ag, 7·5 Cu	...
(new). . .	50·0 Ag, 50·0 Ni	...
Solder (hard)	25-50 Sn, 50-75 Pb . .	...
(soft)	67 Sn, 33 Pb	182°
Speculum metal . . .	68 Cu, 32 Sn	...
Stainless steel	10-15 Cr, 0·5 C, 85-90 Fe .	...
Stellite (a "stainless steel") .	75 Co, 25 Cr (usually traces W)	...
Stereotype metal . . .	112 Pb, 3 Sn, 18 Sb . .	...
Tantiron	84 Fe, 15 Si, 1 C	...
Type metal	15-20 Sb, 80-85 Pb; often little Sn or Bi . . .	...
Wood's alloy	12 Cd, 50 Bi, 25 Pb, 13 Sn .	60·5°

TABLE 38.—ACID-RESISTING CEMENTS.

Cottrell (**Nitric Acid and Nitrates**) recommends the following:—

Silicate Cement (Hard) for permanent joints. Coarse white asbestos powder made into a stiff dough with silicate of soda (Sp. Gr. 1·250).

Rust Cement for permanent iron to iron connections. 5 lbs. iron filings, 1 oz. sal ammoniac, 2 oz. flowers of sulphur, and sufficient water to make the mixture feel just damp.

Soft Putty for joints exposed to nitric acid or its vapour. Mix thoroughly 40 parts white asbestos powder, 8 parts blue asbestos fibre, 10 parts china clay, 2½ parts tallow and 21 parts of boiled linseed oil.

TABLE 39.—FREEZING MIXTURES.

Substances.	Parts by Weight.	Temp. falls From	Temp. falls To
1. Sodium sulphate Ammonium nitrate Dilute nitric acid	6 5 4	10°	−25°
2. Ammonium chloride Potassium nitrate Water	5 5 16	10°	−12°
3. Sodium sulphate Dilute nitric acid	3 2	10°	−10°
4. Sodium sulphate Ammonium chloride Potassium nitrate Dilute nitric acid	6 4 2 4	10°	−23°
5. Sodium chloride Snow	1 3	0°	−18°
6. Ammonium chloride Potassium nitrate Water	1 1 1	8°	−24°
7. Dilute nitric acid Snow	1 1	14°	−35°
8. Sodium sulphate Hydrochloric acid	8 5	10°	−18°
9. Ammonium nitrate Water	1 1	10°	−16°
10. Potassium hydroxide Snow	4 3	0°	−37°
11. Dilute nitric acid Dilute sulphuric acid Snow	1 1 2	0°	−40°
12. Dilute sulphuric acid Snow	1 1	5°	−41°
13. Calcium chloride Snow	3 2	0°	−33°
14. Calcium chloride Snow	2 1	0°	−42°

TABLE 40.—SPECIFIC HEATS.

(*a*) Of Solids and Liquids.

Aluminium . .	0·2220	Iron (cast) . . .	0·1050
Alcohol . . .	0·547	(wrought) . .	0·1081
Antimony . . .	0·0495	Lead	0·0309
Ashes . . .	0·20	Limestone (marble) .	0·21
Bismuth . . .	0·0303	Mercury . . .	0·0334
Brass	0·0917	Nickel . . .	0·109
Bricks . . .	0·22	Oil (lubricating) .	0·40
Cement . . .	0·19	Platinum . . .	0·0324
Carbon (wood) . .	0·1653	Sandstone . . .	0·22
(graphite .	0·1604	Slag	0·18
(diamond) .	0·1042	Silver . . .	0·0559
Copper . . .	0·0936	Steel	0·1070
Glass (for thermometers)	0·1988	Sulphur . . .	0·1764
Gypsum . . .	0·20	Sulphuric acid . .	0·332
Granite . . .	0·20	Tin	0·0552
Gold	0·0316	Zinc	0·0935

(*b*) Of Gases and Vapours for Constant Pressures between the Temperatures of 0° and 200° C. (Langen and Regnault.)

	Cal. per 1 kg.	Cal. per 1 cb.m.		Cal. per 1 kg.	Cal. per 1 cb.m.
Atmospheric air .	0·2389	0·3082	Carbon monoxide	0·2466	0·3082
Oxygen . .	0·2158	0·3082	Methane . .	0·5930	0·4241
Nitrogen . .	0·2459	0·3082	Ethylene . .	0·4040	0·5053
Hydrogen .	3·452	0·3082	Sulphur dioxide .	0·1544	0·4413
Carbon dioxide .	0·2092	0·4109	Aqueous vapour .	0·4542	0·3654

TABLE 41.—MELTING POINTS (OF COMMON SUBSTANCES).

	Degrees Cent.
Alcohol (ethylic)	-130
Aluminium	657
Ammonia	-75
Antimony	630
Asphalt	100
Benzene (pure)	6
Bismuth	268
Boric acid	186
Brass	900
Bromine	-70
Bronze	900
Cadmium	321
Carbon dioxide	-79
Cobalt	1190
Colophonium	135
Copper	1083
Cupric chloride	498
Cuprous chloride	434
Fat, ox	40
sheep	42
pig	27
Fluorspar *	1330-1378
Glass free from lead	1200
„ containing lead	1000
Gold	1063
Iron, cast, white	1075-1135
grey	1200-1250
wrought	1500
Iodine	113
Lead	327
oxide	954
chloride	498
Magnesium	650
Mercury	39·4
Mercuric chloride *	287-293
Naphthalene	79
Nickel	1452
Nitric acid	-50
oxide	-148·8 to -167
Nitric tetroxide	-11
Nitrous oxide	-102

* The statements found in literature vary between these limits.

TABLE 42.—BOILING POINTS.

	Degrees Centigrade.
Acetone	56
Alcohol, absolute	78
Aldehyde	21
Ammonia, anhydrous	−33·7
nitrate, satur. solution	240
Barium chloride, satur. solution	104·4
Benzene	80·4
Bromine	63·0
Calcium chloride, satur. solution	260
66 per cent. solution	156
33 per cent. solution	128
nitrate, satur. solution	151
Carbon dioxide	−78
disulphide	46
Chlorine	−33·6
Ether	35
Hydrochloric acid, 20·2 per cent. HCl	110
Iodine	184·4
Methylic alcohol	60
Mercury	356
Naphthalene	218
Nitric acid, very concentrated	86
specific gravity 1·42	121
Nitrous anhydride	3·5

TABLE 42—*Continued.*

	Degrees Centigrade.
Nitrous oxide	−88
Nitric peroxide	20
Potassium chloride, satur. solution	108·5
chlorate, satur. solution	104·4
acetate, satur. solution	161
carbonate, satur. solution	133·5
nitrate, satur. solution	115
sulphate, satur. solution	102·1
Sodium chloride, satur. solution	108·8
acetate, satur. solution	125
carbonate, satur. solution	105
phosphate, satur. solution	106·6
nitrate, satur. solution	120
Sulphur	444·4
Sulphuric acid, H_2SO_4	326
anhydride α	15
β	50
Sulphur dioxide	−10
Toluene	111
Xylenes	136-141
Turpentine, spirits of	160
Zinc	916

SPECIAL PART

I. RULES FOR SAMPLING.

A.—Fuel.*

Take a shovelful of each wheelbarrow, basket, etc., throw it into a cask or tub. Coarsely grind up the whole without delay, mix the contents, spread them out in a flat, square heap, divide this diagonally into four quadrants, remove two opposite quadrants, grind up the other two more finely and mix them again, and continue in this manner until the weight has been reduced to about ¼ cwt. Put this into a tin box, which is soldered up and sent to the testing-laboratory. There this sample is ground again, mixed up, and divided into twelve or sixteen portions in the manner of a chess-board. Take out a teaspoonful from each of these portions and grind them in a porcelain mortar to a powder as fine as dust. This powder is kept in a stoppered bottle, and is well mixed up before taking out a fresh sample for testing.

For separate *moisture tests*, a number of samples are taken during the first sampling, and kept in air-tight vessels.

B.—Ores and Minerals (Pyrites, Manganese, Salt, etc.).

(a) *Smalls, slack, salt, or other substances not requiring to be crushed.*—Take a sample of about 1 lb. of each weighing-tub, cart, or the like, by means of a scoop, so as to obtain about the same quantity each time. Of railway trucks, which are tipped directly into the warehouse, take three samples, one from the middle and one from each end.† All these single samples are put in a cask and kept covered, to prevent the evaporation of moisture. When the large sample is taken, empty the contents of the cask on a level, clean, and hard place, spread it flat, heap it up in a cone at the centre by going regularly round with a spade; spread this heap again flat, and take a sample of about a quarter of the mass, by taking out with a spade two strips crossing each other at right angles, and adding a little from the centre of each remaining

* According to the rules laid down for the German Official tests of steam-boilers and steam-engines.

† At some factories very unsatisfactory results have been obtained with this mode of sampling; they prefer that described later on (in *b*), viz., taking a certain number of entire tubs, barrows, or carts as sample.

quadrant. Treat this reduced sample exactly like the larger one, so that a third sample of about 5 lbs. is obtained. Mix this again thoroughly, and fill it into four (or more) wide-necked bottles of 4 ounces capacity, placed close together on a sheet of paper, so that a portion of each handful gets into each of the four bottles. When these are full, they are at once closed with tight-fitting corks; these are cut off straight above the necks of the bottles and well covered with sealing wax, putting on the seals of both buyer and seller, or any other party concerned. The mixing and filling must be done as quickly as possible, in order to prevent the evaporation, or, on the other hand, the absorption of appreciable quantities of moisture during the operation.

The above sample bottles are handed over to the laboratory chemist, who has to pulverise their contents till they pass *completely* through a sieve with holes 1 mm. (= $\frac{1}{25}$ in.) wide; no coarse material must be left behind. From this, after thorough mixing, a smaller sample is taken and reduced to the degree of division necessary for analysis, by grinding in a steel or agate mortar, in the case of softer substances in a porcelain mortar. Manganese samples should not be treated in iron mortars. Moisture is estimated in an unground portion of the sample.

(b) *Ores in pieces requiring to be crushed.*—Large-sized samples must be taken if the lumps of the ore are very coarse. If the pieces are not above the size of an apple, and not too unequal, it is sufficient to take a sample from each tub, etc., as in (a), but with a shovel or scoop holding about 10 lbs. In the case of larger lumps, and of very unequal sizes, it is preferable to tip every tenth or twentieth tub or cart into a separate place, where the whole average sample is collected. In any case, the proportion between the large and small pieces must be represented as accurately as possible in the average sample. This is then crushed to the size of a walnut, either by hand or by machinery, leaving no larger lumps behind. The crushed material is thoroughly mixed by turning it over with a spade several times; it is then spread out in a flat heap and a smaller sample of about $\frac{1}{4}$ cwt. is taken, by lifting out two strips crossing each other at right angles, adding something from the centre of each remaining quadrant. The reduced sample is crushed further, either in a large metal mortar, or preferably with a sledge hammer on a flanged cast-iron plate about 3 ft. square, bedded on a solid foundation; the latter process is much cleaner and more convenient than grinding in a mortar. The coarse portions are sifted out by a riddle of $\frac{1}{8}$-in. holes and crushed again, till all has passed through. The product is reduced as in (a), by mixing, etc., to a quantity of 2 or 4 lbs., from which the sample bottles are filled as described above.

C.—Chemicals.

Saltcake, *soda ash*, etc., if in bulk, are sampled as in No. 1, (a). If packed in casks, each third, fifth, or tenth cask, according to the size of the parcel, is bored at one of its bottoms and sampled by means of an *auger* (Fig. 1), which is inserted up to the centre of the cask, turning it round its axis all the while. The single cask samples are put into a large wide-mouthed bottle, as drawn, till the sampling is over. Then empty the whole on to a large sheet of paper, mix thoroughly, crush any lumps with a spatula, and fill

Fig. 1.

the 4-ounce bottles, previously prepared, exactly as described in No. 1 as for ores, observing the simple rules for corking and sealing.

Bleaching powder, *potash*, and any other substances which are liable to be quickly spoilt in contact with the air by attracting moisture, or from other reasons, are treated like the foregoing substances, but operating with the greatest possible speed, and keeping the large bottles for collecting the cask samples well closed. The sampling is still more safely performed by taking away the upper end of the cask, removing the top layer to a depth of about 2 inches, taking a handful of the material from the interior as far as it is possible to reach in, which should be nearly to the centre of the cask, and placing it in the large bottles. In this

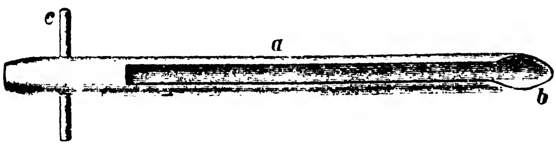

Fig. 2.

way there is the least contact with air. Or else a sample auger is employed, like that shown in Fig. 2. It is made of a piece of gas-pipe of 1½-inch bore, cut open for part of its length, so that a longitudinal slot of 1 inch width, *a*, is formed. One side of the slot is sharpened, as well as the tip *b*, which is driven into the bleaching powder, etc. The upper part of the pipe is left uncut, and is provided with a handle, *c*. Before introducing the auger the cask is well shaken up; then it is placed in an upright position and the auger is driven in as deeply as possible, in case of need by the aid of a hammer. This is done either after opening the cask, or by boring a hole in the end, which is afterwards closed by a piece of tin, with paper underneath. After driving in the auger, it is turned several times round its axis, so that it cuts through the bleaching powder with its sharp side and is thus filled. The sample drawn out is put on paper, and is crushed as quickly as possible, preferably by means of a small hand-roller; it is then mixed and spread out flat. Small samples are finally taken from various parts by means of a spatula, as quickly as possible, and are put into bottles, which are tightly closed and kept in a dark place. Bleaching powder samples should be always tested with as little delay as possible.

Caustic Soda.—Since the samples absorb moisture and carbonic acid on their surface, even in well-closed bottles, the outer opaque crust must be removed by scraping before weighing out the samples (*cf.* p. 209). It should be borne in mind that the centre of the drum is of weaker strength than the remainder, because the foreign salts accumulate in the portion which remains liquid the longest. The average strength is best represented by the portions next to the bottom and sides of the drum, which solidify quickest. This is most conveniently done while the contents are still in the liquid state. For the control of the manufacture itself it is best to take samples out of every pot during the time its contents are ladled out, from the top, the centre, and the bottom. These are poured out on to a metal plate, where they quickly solidify. The centre sample is the most important one for judging the quality of the pot.

Solid sulphuric anhydride cannot be sampled directly for analysis. An auger cannot be employed, as the mass is too firm and tough; melting the mass in the drums themselves is out of the question, on account of the clouds of fumes. The following process is, therefore, employed:—A large sample of the solid anhydride is mixed with so much exactly analysed "monohydrated" sulphuric acid that an acid of about 70 per cent. is formed, which is liquid at ordinary temperatures. This mixture is made in a stoppered bottle, and is gently heated to 30° or 40° C., the stopper being loosely put in until the solution is complete, and a small sample then taken out by means of Lunge and Rey's glass-tap pipette (p. 172).

II. THE PREPARATION OF STANDARD SOLUTIONS.

As mentioned in the preface, the author has assumed that the user of this handbook is a qualified chemist working in a well-appointed works laboratory. The book is not intended to be used as a students' text-book, but, in order to prevent misunderstanding as to the units and conventions adopted, some notes regarding standard solutions, indicators, etc., have been included. Fuller particulars, with details of procedure, will be found in text-books, such as Cumming and Kay's *Quantitative Chemical Analysis.*

Standard Solutions.—Any solution of accurately known composition is called a standard solution.

Normal Solution.—A solution which contains one gram-equivalent of the reacting substance per litre of solution is called a *normal* solution. The gram-equivalent of a substance is the weight of the substance, in grams, which is chemically equivalent to 1·008 g. of hydrogen.

A normal solution of an oxidising agent is one which is capable of yielding 8 g. of "available" oxygen per litre. One litre of a normal solution of an oxidising agent will therefore oxidise 1·008 g. of hydrogen with formation of water.

The Unit of Volume.

The instruments used in volumetric work are graduated in cubic centimetres. The true cubic centimetre is the volume of a cube whose sides are 1 cm. in length. For analytical purposes, it may be taken as equal to the volume of 1 g. of water (as weighed in a vacuum) at 4°.

Measuring instruments are sometimes graduated in terms of Mohr's unit. This unit is often incorrectly called a cubic centimetre, but is actually the volume occupied by a quantity of water (at 15° or 17·5°) which, when weighed in air with brass weights, has an apparent weight of 1 g. This unit (at 15°) is 0·2 per cent. larger than the true cubic centimetre.

RATIO OF WEIGHT TO VOLUME OF WATER, WEIGHED IN AIR WITH BRASS WEIGHTS.

Temperature.	Weight of 1 c.c. in grams.	Volume in c.c. occupied by 1 gram.	Temperature.	Weight of 1 c.c. in grams.	Volume in c.c. occupied by 1 gram.
10°	0·9987	1·0013	21°	0·9970	1·0030
11°	86	14	22°	67	33
12°	85	15	23°	65	35
13°	83	17	24°	63	37
14°	82	18	25°	60	40
15°	81	19	26°	57	43
16°	79	21	27°	55	45
17°	77	23	28°	52	48
18°	76	24	29°	49	51
19°	74	26	30°	46	54
20°	72	28	31°	43	57

Measuring instruments, as bought, are often inaccurate. In order to calibrate a vessel, one requires to know

(1) the weight of water which will occupy 1 c.c. at the given temperature,

(2) the corrections to be applied for the weight of air displaced by the water and by the brass weights respectively.

In the table on p. 107 these corrections have been introduced.

Use of English Weights and Measures.

The metric system of weights and measures is now almost universally used in analytical work. It is to be regretted, however, that in England it is still usual to specify quantities in the old-fashioned, unscientific English units, *e.g.* grains per gallon or grains per cubic foot.

The analyst is recommended in all such cases to use metric weights and measures, and convert the results by calculation. As there are, however, still laboratories in which the "English system" is used, the following notes may be useful.

The unit of weight of the English system is the grain. All normal solutions are prepared so that 1000 grains by volume (100 decems) contain one equivalent of the reagent in grains, and consequently all normal solutions prepared on the English system are identical in concentration with those prepared on the metric system.

English burettes usually hold 1000 grains, and are divided into 100 parts of 10 grains each, called one decem. The decem corresponds to the cubic centimetre. As, however, this unit, the decem, is ten times the unit of weight, the following rules must be observed when any of the data are to be changed from the metric to the English system :—

Instead of litre read 10,000 grains.
,, cubic centimetre read decem, or ten times the number of grains.
,, grams read ten times the number of grains.

If, for instance, we are told to prepare a standard solution of permanganate by dissolving 15·820 g. of potassium permanganate in 1 litre of water, and that 1 c.c. of such a solution corresponds to 0·028 g. of iron, we obtain a solution of equal strength by dissolving 158·20 grains in 10,000 grains of water, and 1 decem of this solution corresponds to 0·28 grain of metallic iron. The reader should substitute ten times as many grains for the number of grams, ten times as many grains, or an equal number of decems, for the number of cubic centimetres, and 10,000 grains for each litre. Where we are directed to measure out by means of a pipette 50 c.c., we take 500 grains instead, etc.; but when speaking of the number of cubic centimetres on the burette, we substitute exactly the same number of decems.

It will also be useful to remember that:

Grams per litre	= grains per 1000 grains.
,, ,,	= ounces per 1000 ounces.
,, ,,	= ounces per cubic foot (approximately).
Grams per litre $\div$ 16	= lbs. per cubic foot.
Grams per litre $\times$ 70	= grains per 70,000 grains.
,, ,, ,,	= grains per gallon.
0·4375 $\times$ grams per cub. metre	= grains per cubic foot.
Kilograms per cubic metre	= lbs. per 1000 lbs.
,, ,, ,,	= lbs. per 16 cubic feet.
$\frac{\text{Kilograms per cubic metre}}{16}$	= lbs. per cubic foot.
16 $\times$ cub. metres per kilogram	= cubic feet per lb.
Kilograms per square metre	= 0·205 lb. per square foot.
Kilograms per sq. metre $\times$ 4·89	= lbs. per square foot.

As 1 gallon of any dilute aqueous solution weighs approximately 70,000 grains, it is a close approximation to take

Parts per gallon = parts per 70,000.

STANDARD SOLUTIONS IN COMMON USE.

A.—Normal Acid and Alkali.

The only acids in common use as standard acids are sulphuric acid and hydrochloric acid, and of these hydrochloric acid has the wider range of utility. Normal hydrochloric acid has no tendency to lose the free acid but, if exposed to the air, becomes more concentrated.

As standard alkalis, the most useful are sodium hydroxide, sodium carbonate, and barium hydroxide. It is essential that a standard alkali solution should always be used with the indicator used when it was standardised.

Indicators.—The indicators commonly used in acidimetry and alkalimetry are litmus, methyl orange, phenolphthalein, and methyl red.

Indicators for acid and alkali are substances which exhibit a marked change of colour at or near the neutral point. Usually the colour change does not occur at the point of true neutrality and the change occurs at different points with different indicators. This does not affect the accuracy of the results, provided a suitable indicator is used under correct conditions.

Strong Acids and Strong Bases.—If acids and bases are free from carbonates and sulphides, any indicator may be used if the concentration of the standard solution is not less than 0·2 normal. With more dilute solutions, methyl red or phenolphthalein should be used.

Weak Acids with Strong Bases.—Use phenolphthalein.

Weak Bases with Strong Acids.—Use methyl red.

Carbonates and Sulphides with Strong Acids.—This can be done with cold solutions using methyl orange as indicator. Methyl red or litmus can be used if the titration is carried out at the boiling point of the solution.

For convenience, the above and some further information is given below under the headings of the various indicators.

Litmus.—Although this was at one time the universal indicator, it is nowadays more satisfactory to use other indicators. Litmus is variable in quality and, unless a purified product (azolitmin) is used, the results are often unsatisfactory. It may be used for strong acids and alkalis, but is inaccurate if carbonates are present. It can be used for the estimation of ammonia with a strong acid. It can also be used in the estimation of carbonates, bicarbonates and sulphides if the solution be boiled. Sulphide will bleach the litmus but more litmus can be added towards the end of the titration.

Methyl Orange.—This is the most useful indicator for the titration of carbonates, bicarbonates, sulphides, silicates, borates, and arsenites. If more than traces of carbonate are present, the solution should be boiled when nearing the neutral point and then cooled before completing the titration.

Methyl orange cannot be used for the titration of weak acids. It can be used for titrating ammonia, but methyl red is better.

Phenolphthalein.—This is the most useful indicator for the titration of weak acids, such as acetic acid, with a strong base. It should be used only with strong bases free from carbonate. Organic acids insoluble in water can often be titrated in an alcohol-water solution using this indicator. Phenolphthalein is useless for ammonia or in presence of ammonium salts. With carbonates of the alkalis, it indicates neutrality roughly at the bicarbonate stage.

Methyl Red.—This is the best indicator for the titration of ammonia or solutions containing ammonium salts. It is more sensitive and gives a sharper end-point than methyl orange with very dilute solutions of strong acids and bases. It is useless for weak acids. It is less sensitive than litmus or phenolphthalein to carbonic acid. and the amount present in an ordinary solution of sodium hydroxide does not affect this indicator.

As basis of Alkalimetry and Acidimetry, we employ *chemically pure sodium carbonate.* This is tested for purity by dissolving 5 g. in water, which ought to yield a perfectly clear, colourless solution; if, after acidifying this solution with pure nitric acid, no opalescence is caused by barium chloride, or silver nitrate, the salt may be taken as sufficiently pure. Before using it, the sodium carbonate must be heated in a platinum crucible (or if this is not available a porcelain basin). This is half-filled with the carbonate and is placed on a sand-bath, the sand reaching to the same level outside as the carbonate inside. A thermometer is put in, which at the same time serves as a stirrer. The temperature is raised to 270° to 300° for about half an hour, with frequent stirring; the contents are then emptied hot into a stoppered weighing-bottle, which is kept in a desiccator up to the time of weighing. Then weigh off, for normal acid, four portions of about 2 g. each into the beakers in which the titration is to take place; for one-fifth normal acid the single portions ought not to exceed 0·4 g. The balance ought to turn to at least 0·2 mg.

As normal acid we prefer *hydrochloric acid*, which has the following advantages over sulphuric and oxalic acid, viz.: 1st, it is more generally applicable, *e.g.*, for alkaline earths; 2nd, its strength, after being fixed by pure sodium carbonate, can be accurately checked by silver nitrate, far more accurately than that of sulphuric acid by barium chloride; 3rd, it does not change on keeping, like oxalic acid.

Normal HCl (36·47 g. HCl per litre) is prepared as follows:— Dilute pure hydrochloric acid to 1·020 specific gravity (4 Tw.). Such an acid will be rather too strong. Fill a burette with this acid, and titrate with it one of the weighed samples of sodium carbonate, the weight of which is w grams. Suppose that x c.c. of this acid are required. As the acid is sure to be too strong, x will always be smaller than $\frac{w}{0{\cdot}053}$, and we shall have to add to every x c.c. of the acid $\frac{w}{0{\cdot}053} - x$ c.c. of water, and if the total quantity of acid of specific gravity 1·020 amounts to V c.c., the amount of water to be added thereto to render it correct will be n c.c., where $n = V\left(\frac{w}{0{\cdot}053\,x} - 1\right)$. For one-fifth normal acid the above factor would be $= \frac{w}{0{\cdot}0106}$.

If accurate normal alkali is at hand, it may be similarly employed for examining the provisional acid, and then adjusting it to the normal strength.

In any case, the mixed normal acid must be checked by titrating new samples of sodium carbonate, when x ought to $= \frac{w}{0{\cdot}053}$. A further check is afforded by estimating the chlorine gravimetrically by silver nitrate; 10 c.c. (= 0·3647 HCl) ought to yield 1·4334 g. AgCl.

The ordinary *indicator* in alkalimetry and acidimetry used to be tincture of litmus, which must be kept in open vessels to avoid its being spoiled. When employing litmus, the liquid to be tested must be kept boiling for some time, in order to expel all CO_2, and normal acid must be added as long as, on further boiling, the colour changes back from red to purple, or blue. This prolonged boiling causes some alkali to be dissolved from most kinds of glass, which makes the tests inaccurate. A test with litmus rarely lasts less than half an hour, usually more. Phenolphthalein has exactly the same drawbacks. Even the action of the carbon dioxide contained in the air, which comes into contact with the liquid on cooling, may cause trouble in very accurate work. On the other hand, a test is finished in a few minutes, if litmus is replaced by a very dilute solution of *methyl orange;* but in this case the liquids must not be hot, but at the ordinary temperature, and only mineral acids, not oxalic acid, may be employed. The cold solution of sodium carbonate is coloured just perceptibly yellow by adding a drop or two of the solution of methyl orange, preferably by means of a pipette; if the colour is too intense, it will cause the transition into red on neutralisation to be less sharp. CO_2 does not act in the least upon methyl orange; a change of colour only takes place when all Na_2CO_3 has been decomposed. When the Na_2CO_3 has been exactly converted into NaCl, a tinge of brown or red appears in the faintly yellow solution. This is the end-point. Exactly the same course is followed in titrating acids with caustic soda solution; in this case also the reading is taken at the brownish transition colour, before the change to yellow has taken place. The results obtained in this way are identical with those obtained by the *proper* application of litmus or phenolphthalein, that is, working with these indicators under complete exclusion of air, with prolonged boiling, and in porcelain or silver vessels. The great advantage of methyl orange over the last-named indicators is the saving of time, the working at ordinary temperatures, and the possibility of employing glass vessels without any danger of error caused by the use of this material.

Another advantage of methyl orange is that it is not affected by *sulphuretted hydrogen* (which destroys litmus); hence it can be employed, *e.g.*, for the direct titration of black-ash liquors. *Sulphur dioxide* acts upon it like the stronger mineral acids, but only to the extent of one-half of its equivalent; that is, the point of neutrality is reached when the compound $NaHSO_3$ has been formed. In the presence of *nitrous acid* methyl orange is gradually destroyed, but it is quite easy to employ it even in this case by proceeding as described on p. 162.

It is generally agreed that methyl orange is the best indicator for titrating *bases* by means of strong mineral acids, and this holds good also for the titration of the *strong acids*—sulphuric, hydrochloric, and nitric acid. In these cases, indeed, its advantage over litmus or phenolphthalein is even more marked, because a slight percentage of CO_2 in the standard alkali employed has no effect. But *organic acids* cannot be titrated with methyl orange.

Some authors have proposed, in lieu of methyl orange, the unsulphonated compound, dimethylaminoazobenzene, but this is only soluble in alcohol, and cannot be recommended. This is also the case with ethyl orange.

To prepare *standard alkali*, dissolve about 50 g. of the best commercial caustic soda in 1 litre of pure water and titrate 50 c.c. of this solution with standard acid. More than 50 c.c. of acid will be required; we call this x c.c. The fraction $\frac{5000}{x}$ shows the number of c.c. of the first solution, which must be diluted with pure water to 1 litre in order to obtain a really normal alkali. The solution thus prepared is again checked by titration with normal acid.

The normal alkali, when intended to be used with litmus, should be as free as possible from carbonate, and should be protected against absorption of CO_2 from the air, because otherwise the change of colour does not take place sufficiently rapidly and markedly in cold solutions. A solution of sodium hydroxide *entirely* free from carbonate is difficult to prepare and to preserve when in constant use. When employing methyl orange as an indicator, an ordinary caustic soda solution may be employed without any special precautions. The caustic soda employed should not contain more than a very small proportion of alumina; ordinary strong caustic nearly always fulfils this condition, or it may even be replaced by a solution of 53·00 g. pure sodium carbonate in 1 litre water, which is employed cold, and which yields as accurate results as NaOH, no notice being taken of the CO_2 which escapes with effervescence. The general use of this solution is, however, inconvenient on account of the efflorescence on the burettes, necks of bottles, etc. Weaker (*e.g.*, fifth-normal, or even seminormal) solutions do not have this drawback.

All standard solutions must be prepared and employed as nearly as possible at a certain *temperature*. Mohr prescribes 15°; some prefer 18° C., as being more suitable for laboratories. When the solutions have stood for some time in bottles, a little water is evaporated and recondensed in the upper part of the bottles; the contents must then be properly mixed by shaking.

If the temperature of the laboratory differs more than 2° or 3° from that employed for preparing the standard solutions, a correction should be made by means of the following table. In order to reduce the volumes read off at $t°$ to 15°, deduct per 100 c.c. the following amounts:—

$t°$	c.c.	$t°$	c.c.
15	0	23	0·135
16	0·013	24	0·156
17	0·027	25	0·179
18	0·043	26	0·202
19	0·059	27	0·227
20	0·076	28	0·252
21	0·095	29	0·278
22	0·114	30	0·305

B.—Potassium Permanganate.

The ordinary solution is decinormal, *i.e.*, it yields 0·0008 g. oxygen per c.c. It serves, *e.g.*, for estimating nitrous acid in sulphuric acid, for testing the nitrogen acids in the chamber exits, for testing manganese ore, for testing Weldon mud, etc.

The solution is made by dissolving pure crystallised potassium permanganate, and is then quite stable, if protected from dust and direct sunlight. Dissolve 3·161 g. of pure permanganate in 1 litre of cold water. (Do not heat the solution, and do not grind the crystals.) Keep the solution in a dark place and free from dust. If any sediment forms in the solution at any time, reject it. Store in a bottle with a glass stopper.

None of the methods formerly employed for standardising permanganate (by means of metallic iron, or oxalic acid, or hydrogen peroxide, etc.) is entirely free from objections. No such objection exists to the employment of *pure sodium oxalate*, first proposed by Sorensen. This salt need only be kept for a few hours in a drying oven at 100°, and then allowed to cool in a desiccator over calcium chloride. Dissolve about 0·26 g. of this (exactly weighed) in about 200 c.c. water, heated to 60°-70°, add dilute sulphuric acid, and run in the permanganate solution from a burette, first quickly, then drop by drop, until a permanent red colour is produced. If a be the weight of sodium oxalate, b the c.c. of permanganate solution used, the fraction $\frac{29{\cdot}851\,a}{b}$ gives the quantity of oxygen given off per c.c. of the permanganate solution.

If a brown precipitate (of MnO_2) should be formed during the titration, the experiment must be rejected, but this occurs only when the solutions are too concentrated or too hot (*i.e.* above 70°).

Permanganate is best employed in a burette with a lateral hollow glass-tap. Any change in its titre (due to dust, etc.) is perceptible by a deposition of MnO_2 in the bottle. It is advisable to check the solution once every three months.

Permanganate can be used with perfect accuracy in the presence of free hydrochloric acid, if the solutions contain a considerable quantity of manganese salts; in other cases the same effect is produced by adding, say 1 g. of manganese sulphate free from iron.

C.—Iodine.

Weigh exactly 12·692 g. of pure resublimed iodine (either bought as such, or prepared by grinding up commercial iodine with 10 per cent. of potassium iodide and resubliming) on a balance turning at least with 1 mg.; put it into a litre flask containing a concentrated solution of 15 to 18 g. KI, close the flask, agitate till the iodine is completely dissolved, and fill up to the mark. This decinormal solution is checked by the arsenite solution (p. 115). Both solutions ought to be precisely equivalent, c.c. per c.c.

For estimating very small quantities of sodium sulphide a special iodine solution is sometimes made, by dissolving 3·2515 g. of pure iodine with 5 g. of potassium iodide in a litre, to correspond to 0·001 g. Na_2S per c.c.

Solutions of iodine, especially the more dilute ones, keep a long time in well-stoppered bottles in a cool place, but they ought to be checked once a month by the arsenite solution.

Preparation of the Starch Solution.—Grind up 3 g. potato starch with a little water to a homogeneous paste; introduce this gradually into 300 g. of boiling water, contained in a porcelain dish, and continue the boiling till an almost clear liquid has been produced. Allow this to settle in a tall beaker, pour the clear portion through a filter, and saturate it with common salt. This solution, when kept in a cool place, is stable for some time; as soon as fungoid growths are noticed in it, it is thrown away.

A very convenient form of soluble starch is that made by Zulkowsky's method, by heating 100 parts of concentrated glycerine with 6 parts of starch to 190° C. for about an hour, pouring into water, precipitating the soluble starch by alcohol, and filtering. This starch is kept in the state of a thick paste, not allowed to dry, and a small quantity is taken out for each test by means of a glass rod. There are also other forms of soluble starch, *e.g.*, "ozone-starch."

D.—Sodium Arsenite.

This serves for standardising the iodine solution, and as its volumetrical complement, especially in testing bleaching powder. Employ commercial pure powdered arsenious acid: test its purity by subliming a little from a small dish into a watch-glass, when no yellow sublimate of As_2S_3 (which volatilises more easily than As_2O_3) should result initially; on heating more strongly it should leave no residue. Before use the powdered As_2O_3 is kept for some time over sulphuric acid in a desiccator, and can then be weighed out without any special precautions, since it is not hygroscopic. For preparing a decinormal solution, weigh out exactly 4·948 g. As_2O_3, dissolve it in a little hot solution of caustic soda, neutralise with dilute sulphuric acid (using phenolphthalein as indicator), add a solution of about 20 g. sodium bicarbonate in 500 c.c. water, and dilute on cooling to 1000 c.c. This solution is quite stable, and equivalent to 0·003546 g. chlorine or 0·012692 g. iodine per c.c.

If really pure and dry arsenious acid has been employed, the above solution will be correct at once. But when preparing large quantities, it ought to be checked by grinding up 0·5 g. iodine with 0·1 g. potassium iodide, heating this mixture in a small dish on a sand-bath or upon an asbestos board till abundant vapours arise, covering with a dry watch-glass, allowing the major portion, but not the whole, of the iodine to sublime into the watch-glass, covering this with a second watch-glass which fits air-tight upon the former, and has been weighed with it, and weighing. Slip the watch-glasses into a solution of 1 g. of potassium iodide (free from iodate), in 10 g. water, wait a little till the iodine is dissolved, dilute with 100 c.c. water, and titrate with the arsenite solution. When the colour is only a light yellow, add a little starch solution, and titrate exactly till the blue colour has just vanished. The c.c., of arsenite solution used, multiplied by 0·012692, ought to correspond exactly with the weight of iodine taken. Or the dry, sublimed iodine is transferred directly from the upper watch-glass into a tared stoppered weighing-bottle, weighed, and dissolved in KI solution in the same bottle.

E.—Silver Nitrate.

Weigh out exactly 16·989 g. of pure crystallised silver nitrate, preferably kept in a desiccator for a few hours, and dissolve in 1 litre. This gives a decinormal solution, corresponding per c.c. to 0·003546 g. Cl, or 0·003647 g. HCl, or 0·005846 g. NaCl. By dissolving 2·906 g. $AgNO_3$ in 1 litre, a solution is obtained corresponding to 0·001 g. NaCl per c.c.

Ammoniacal silver solution, for Lestelle's estimation of alkaline sulphides, is obtained by dissolving 13·818 g. of pure silver in pure nitric acid, adding 250 c.c. of ammonia, and diluting to 1 litre. Each c.c. of this corresponds to 0·005 g. Na_2S.

F.—Copper Sulphate.

Copper solution, for testing ferrocyanide, is obtained by dissolving 12·486 g. pure crystallised, non-effloresced, cupric sulphate, in 1 litre water.

G.—Oxalic Acid.

Oxalic acid solution is employed for testing the "base" of Weldon mud, and caustic soda or lime in the presence of carbonate.

Dissolve 63·03 g. pure, non-effloresced, crystallised oxalic acid in 1 litre water, and check with normal alkali. This solution is not quite stable, especially when exposed to daylight; nor can it be employed for alkalimetry, when using methyl orange as an indicator.

III. FUEL AND FURNACES.

A.—Fuel.

The following tests should be applied in the case of lignite, peat, coal, and coke. The method of sampling is described on p. 103.

1. *Moisture.*—Heat 100 to 200 g. of coal to 110° (not above), for two hours, preventing access of air as much as possible. At a higher temperature the result might be too high, owing to escape of volatile matters, or too low, owing to a partial oxidation. The sample should be broken up quickly into pieces not smaller than a bean, otherwise too much water would evaporate during the process. Lignite and peat are heated to 100° for five or six hours, and repeatedly weighed, till no further diminution of weight takes place. Coke is heated to 110° for two hours.

All other tests are made with *air-dried* material. The average sample is weighed before taking the samples for the tests; it is then spread out in a thin layer and allowed to lie in ordinary dry air for forty-eight hours. It is then weighed again, and the results obtained with such air-dried fuel are calculated on the original (undried) material.

2. *Residual Coke (Fixed Carbon).*—One g. of finely powdered coal is placed in a platinum crucible at least 1¼ in. deep, weighing from 20 to 30 g., provided with a tightly fitting cover. The crucible should then be heated by means of an ordinary Bunsen burner, the flame of which should not be less than 7 in. high. The crucible should be supported on a triangle of thin platinum wire, and it should be so placed that the space between the bottom of the crucible and the top of the burner is 2·5 to 3 in. The heating ought not to last longer than a few minutes, but must be continued as long as any appreciable quantity of inflammable matter escapes. The surface of the crucible cover should then be clean, but its lower side should be covered with carbon. If the flame be smaller, or the crucible be supported by a stout wire triangle, the yield of coke will be too high. The results should always be calculated upon coal or coke free from ash, in order to render them comparative. Good coal for reverberatory furnaces should yield from 60 to 70 per cent. of coke.

3. *Ash.*—This estimation is very simple for lignite or peat; coke requires a very high temperature; coal which cakes presents most difficulty. This type of coal must be powdered very finely, and heated up gradually, so that the volatile matters may escape before the powder can form a cake. If an analysis is only occasionally required, 2 to 5 g. of finely ground coal is heated in a platinum crucible, which is fitted in a hole into a stoneware

slab, or, better, in a fused-silica plate (Fig. 3). This is placed in a slanting position on a tripod stand. The slab serves to separate the air required for oxidation from the gases of the burner, and greatly hastens the combustion, which is thus completed in two hours, whereas without the slab it frequently remains incomplete even after eight or ten hours' heating. It is not advisable to use a blowpipe, because the chance of mechanical loss is thereby greatly increased. If determinations have to be made frequently, it is preferable to effect the combustion in a muffle furnace, or still more quickly in a platinum boat placed in a heated porcelain tube, through which a current of oxygen is passed. When using the latter, the coal or coke should be broken into small pieces, and not ground fine, or else the oxygen does not come sufficiently into contact with the lower strata.

Where frequent tests have to be made, several platinum dishes can be placed in a muffle at the same time. It is best to cover the dishes or boats at first by a mica plate and to remove this only when the gases have been driven off, after which the ignition is continued, until no more black spots are visible and the weight remains constant.

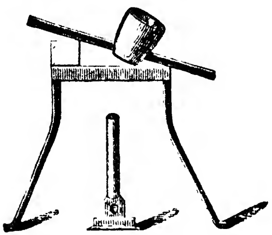

FIG. 3.

4. *Sulphur* (Eschka's method).—Mix 0·5 to 1 g. of the finely ground coal with 1½ times its weight of an intimate mixture of 2 parts of well-burnt magnesia and 1 part of anhydrous sodium carbonate. The magnesia and sodium carbonate should be tested for traces of sulphate before use, and only pure reagents used. The mixture is made in a platinum crucible by means of a glass rod, and the crucible, without putting on the cover, is heated in an inclined position, in such manner that only its lower portion attains a red heat. This is most conveniently done by placing it in a fused silica plate, provided with a hole, as shown in Fig. 3. The combustion of the sulphides to sulphates should be promoted by frequent stirring with a thick platinum wire; it will be finished in about an hour, during which time the grey colour of the mixture mostly passes into yellow, red, or brown. The calcined mass is covered with hot water, and bromine water is added until the liquid shows a slight yellow colour. Then heat the whole to boiling, decant the liquid through a filter, and wash the residue with hot water. Add hydrochloric acid to the aqueous solution, boil till all the bromine has been removed and the liquid has been decolorised, and add a solution of barium chloride, drop by drop, always at a boiling heat, until the precipitation is complete.

Even if the gas employed for heating the crucible should contain a notable quantity of sulphur, no error is caused if the products of combustion are kept away from the contents of the crucible by the silica shield as shown in the figure. One part $BaSO_4$ indicates 0·1374 part S.

5. *The calorific power* of fuel can be estimated by ascertaining the percentage of carbon and hydrogen, according to the ordinary methods of elementary analysis, and calculating the results according to Dulong's formula. In the case of coal it is necessary to take account of the volatile sulphur—that is, that which is determined by heating in a current of oxygen, passing the gases through neutralised hydrogen peroxide, and titrating the sulphuric acid formed. If the percentage of C, H, and (volatile) S, and that of the moisture (W), is known, the percentage of the oxygen is expressed by the equation :—

$$O = 100 - (C + H + S + W + \text{ash}).$$

The nitrogen contained in the coal may be neglected. The calorific power of the coal, expressed in gram-calories, is then

$$= 81\,C + 290\left(H - \frac{O}{8}\right) + 25\,S - 6\,W.$$

A direct estimation of the heating power of fuel can be made by means of the calorimetric bomb, of which a description is given in *Tech. Meth.*, vol. i., p. 340 (second edition).

B.—Furnaces.

1. *Chimney Gases.*—In these, CO_2, O, CO, and N (the latter by difference) are most conveniently estimated by the Orsat apparatus, shown in Fig. 4. This consists of a gas-burette, A, connected with the water-filled level-bottle, B, by means of a rubber tube. A is filled to the zero point with water, and by lowering B gas is aspirated, either from the supply tube C or from the absorption pipettes, D, E, F. The gas is forced into each of these pipettes by opening its special tap and raising B. For reading the volume of gas in A, the bottle B must be held in such a position that the level of water is the same in A and B.

The absorption pipettes are charged as follows :—Tube D receives 110 c.c. of caustic potash solution of specific gravity 1·20 to 1·28. This absorbs CO_2, and can serve for a long time. Tube E serves for absorbing the oxygen by means of very thin sticks of phosphorus, kept under water. This tube, when not in use, should be protected from the light by a covering of black paper. Any tarry matters getting into this tube render the phosphorus inactive, and must therefore be kept out by filtering the gas before entering into C, through asbestos, cotton-wool, or other suitable material. The absorption of the oxygen by the phosphorus only sets in at 16° C., better at 18° C. In case the room is at a lower temperature, the vessel E must be cautiously warmed up by a spirit-lamp. In tube F the carbon monoxide is absorbed. For this purpose a solution is prepared by shaking up in a closed bottle 250 g. cuprous chloride with a solution of 250 g. ammonium chloride in 750 c.c. water. When completed, a spiral of copper wire, reaching from top to bottom, is introduced into

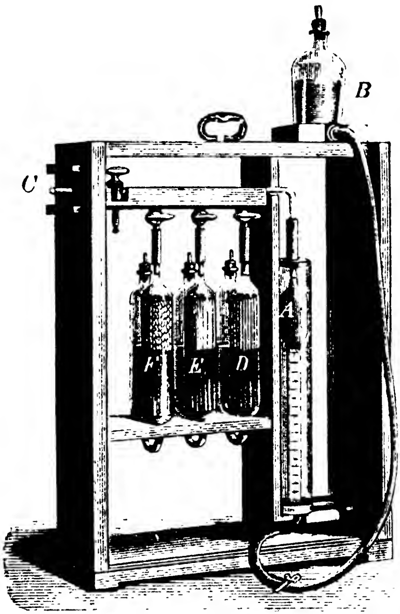

FIG. 4.

the stock bottle. This bottle is always kept well closed when not in use. Before charging tube F, 3 vols. of the solution from the stock bottle are mixed with 1 vol. ammonia, specific gravity 0·905. One c.c. of this mixture ought to absorb 16 c.cm. CO, but this requires prolonged shaking. The reagent in F must be frequently renewed; if this is neglected, it may even yield up some CO to gases containing too little of it. The reagent in F also absorbs ethylene, but this gas does not occur in chimney gases. Since the solution in F also absorbs oxygen, the latter must always be removed before employing pipette F.

For daily use it is often sufficient to test merely for CO_2, by means of the caustic potash solution in pipette D.

For the testing of acidity in flue gases, see p. 142.

Checking the Working of Furnaces.—The estimation of CO_2 in the chimney gases, if combined with an observation of temperature, checks both the efficiency of a furnace or boiler and the daily work of the firemen, according to a formula worked out by Lunge (*Zsch. f. angew. Chem.*, 1889, p. 240). A consecutive number, say from 10 to 15 tests for CO_2, are made by an Orsat apparatus in the flue leading from the furnace to the chimney, and the mean volume percentage of CO_2 found is called n. At the same time, a thermometer with very long stem, tightly inserted in the testing hole in such manner that its bulb is well within the flue, but with the scale outside, is observed at frequent intervals, and the mean temperature of the gases is called t', that of the air outside t. c is the specific heat of a cubic metre of CO_2, expressed in gram-calories; c' that of N or O (see below). The total volume of exit gases produced by the combustion of 1 kg. of carbon burnt on the grate is $= 1{\cdot}854 + 1{\cdot}854\left(\frac{100-n}{n}\right)$ cubic metres, and the loss of heat in the exit gases, expressed in gram-calories:—

$$L = 1{\cdot}854\,(t'-t)\,c + 1{\cdot}854\,(t'-t)\left(\frac{100-n}{n}\right)c'.$$

The loss, expressed in per cent. of the heat theoretically given out by the carbon, is:—

$$\frac{100\,L}{8080}$$

The value of c' may be assumed for all temperatures $= 0{\cdot}31$; that of c varies with the temperature, and must be taken as follows:—

If t' is	below	150° C.,	$c = 0{\cdot}41$.
,,	between	150-200°	$= 0{\cdot}43$.
,,	,,	200-250°	$= 0{\cdot}44$.
,,	,,	250-300°	$= 0{\cdot}45$.
,,	,,	300-350°	$= 0{\cdot}46$.

Note.—The observations of n and t' must be made several times in succession, and the average value taken as final. For accurate investigations several series of tests must be made at different times of the day.

Instruments have been devised for a continuous approximate check of the percentage of CO_2 in chimney gases, such as Arndt's Œconometer.

2. *Gas from Producers* (*Generators*).—In producer gas usually only CO_2 and CO are estimated by means of Orsat's apparatus, as described, p. 120. Any ethylene present in the producer gas would

be absorbed and estimated together with the CO. *Hydrogen* can be estimated in the residue from absorbing CO_2, CO, C_2H_4, and O, by mixing it with a measured volume of air, and passing the mixture over gently heated platinum or palladium asbestos.* The estimation is conveniently done in Lunge's modification of Orsat's apparatus, Fig. 5. The indicating letters correspond to those in Fig. 4, but there is an additional U-tube, G, connected

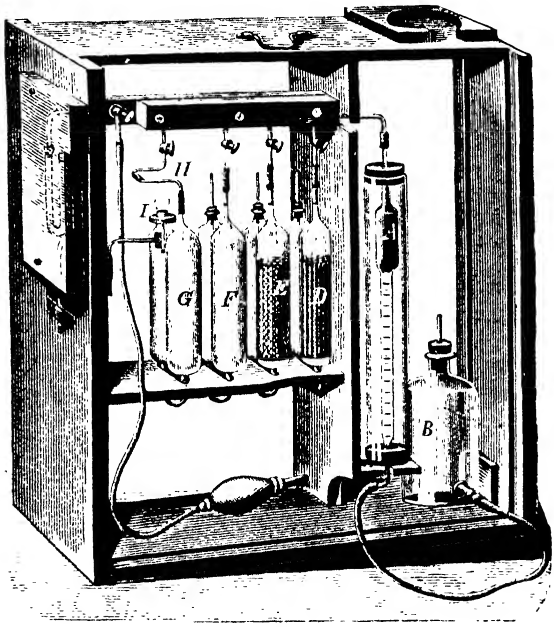

FIG. 5.

with a capillary, H, of refractory glass. H contains platinum or palladium asbestos and can be heated by the small spirit lamp, I, turning on a pivot. The U-tube G is filled with water. The gas freed from CO_2, CO, C_2H_4, and O (if this be present) is mixed in the gas-burette A with as much air as the space will allow, and

* This can be obtained ready-made or is prepared by soaking a few threads of long soft asbestos in a strong solution of platinum or palladium chloride, mixed with a saturated solution of sodium formate and enough sodium carbonate to produce an alkaline reaction. After an hour's soaking the asbestos is dried completely in a water-bath, whereby the metal is precipitated in a very minute state of division. The soluble lasts are then washed out by hot water and the asbestos is again dried.

a reading is taken. This air will suffice for a quantity of hydrogen corresponding to $\frac{4}{10}$ of the employed volume of air (*i.e.*, twice the volume of oxygen contained in that air). If more H be present, which will only occur in the case of "water gas," either less than 100 c.c. of gas must be employed at the commencement for the analysis, or the residual gas is mixed with oxygen instead of with air. The capillary tube H is heated very gently by means of the lamp I, and the gaseous mixture is quickly passed once through it into G and back again, when one end of the platinum asbestos should become red hot. The residual gas is again measured and $\frac{2}{3}$ of the diminution in volume calculated as hydrogen. If methane (marsh gas, CH_4) is to be estimated, the residue from the last operation is mixed with more air and burnt by means of

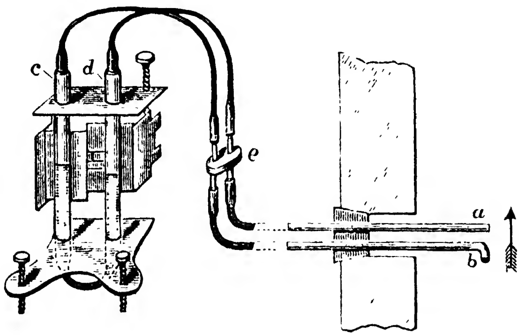

Fig. 6.

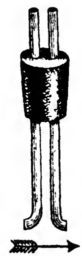

Fig. 7.

an electrically heated palladium or platinum wire, enclosed in a capillary tube. If a capillary platinum tube is employed, filled with a few platinum wires, so as to leave a very small space for the gases to pass through, the electric heating may be replaced by that of a broad gas flame, producing a strong red heat.

3. *Speed of Draught.*—A convenient apparatus for measuring this in chemical works, where any fine mechanism would soon be ruined, is Fletcher's anemometer, based upon the movement of a column of ether in a U-tube (described in Lunge-Cumming's *Acid and Alkali*, vol. ii., p. 136). Fig. 6 shows this in the simpler form, leaving out the microscopes, which are quite unnecessary for reading the divisions of the scale or the vernier. The ends of the glass tubes *a b* should be placed rather less than one-sixth of the diameter of the flue from its inner wall. The straight end of *a* ought to be as exactly parallel as possible to the

direction of the draughts; the end of *b* ought to be exactly at a right angle to this, so that the current blows straight into it. Without this precaution a mistake is made, which is avoided by the arrangement shown in Fig. 7, and proposed by Hurter, viz., employing tubes with ends bent in opposite directions. The tubes *a b* communicate with the ether tube *c d*; the draught causes the ether to rise in *a* by aspiration and to fall in *b* by the pressure of the air blowing into the tube. The difference of level between *c* and *d* is read off by means of the scale and vernier. The sliding disc *e* is then turned through 180°, whereby the currents are reversed. There will now be a difference of levels in the opposite direction, but equal in amount to the first, if the observation is correct. The sum of these two differences is the "anemometer reading" given in the tables.

The following tables show the application of the readings of the Anemometer for calculating the speed of draughts, both for instruments graduated on the inch scale and for those on the metrical scale.

a.—TABLE TO SHOW THE SPEED OF CURRENTS OF AIR.

At a temperature of 15° C. = 60° F.; Barometer, 760 mm. = 29·92 inches.

A.—Readings in Inches.

Anemometer Reading. Inches.	Speed. Feet per Second.	Anemometer Reading. Inches.	Speed. Feet per Second.	Anemometer Reading Inches.	Speed Feet per Second.	Anemometer Reading. Inches.	Speed. Feet per Second.
·01	2·855	·16	11·42	·32	16·15	·95	27·83
·02	4·038	·17	11·77	·34	16·65	1·00	28·55
·03	4·945	·18	12·11	·36	17·13	1·25	31·93
·04	5·710	·19	12·45	·38	17·60	1·50	34·97
·05	6·384	·20	12·77	·40	18·06	1·75	37·77
·06	6·993	·21	13·08	·45	19·15	2·00	40·37
·07	7·554	·22	13·39	·50	20·18	...	...
·08	8·075	·23	13·70	·55	21·17	...	...
·09	8·565	·24	13·99	·60	22·12	...	...
·10	9·028	·25	14·28	·65	23·02	...	...
·11	0·469	·26	14·56	·70	23·89	...	...
·12	9·891	·27	14·84	·75	24·73	...	...
·13	10·29	·28	15·11	·80	25·54	...	...
·14	10·68	·29	15·38	·85	26·32	...	...
·15	11·06	·30	15·64	·90	27·08	...	...

B.—Readings in Millimetres.

Reading.	Speed.	Reading.	Speed.	Reading.	Speed.	Reading.	Speed.	Reading.	Speed.	Reading.	Speed.
mm.	m.	mm.	m.	mm.	m.	mm.	m.	mm.	m.	mm.	m.
0·1	0·575	1·4	2·040	2·7	2·833	5·0	3·855	10·0	5·452	19·0	7·515
0·2	0·771	1·5	2·111	2·8	2·885	5·2	3·931	10·5	5·586	20 0	7·710
0·3	0·944	1·6	2·181	2·9	2·935	5·4	4·006	11·0	5·718	21	7·900
0·4	1·090	1·7	2·248	3·0	2·986	5·6	4·080	11·5	5·846	22	8·086
0·5	1·205	1·8	2·313	3·2	3·077	5·8	4·152	12·0	5·972	23	8·268
0·6	1·341	1·9	2·376	3·4	3·179	6·0	4·223	12·5	6·095	24	8·446
0·7	1·442	2·0	2·438	3·6	3·271	6·5	4·395	13·0	6·216	25	8·620
0·8	1·560	2·1	2·498	3·8	3·361	7·0	4·561	13·5	6·334	30	9·443
0·9	1·636	2·2	2·557	4·0	3·448	7·5	4·721	14·0	6·450	35	10·199
1·0	1·724	2·3	2·615	4·2	3·460	8·0	4·876	15·0	6·667	40	10·903
1·1	1·808	2·4	2·671	4·4	3·616	8·5	5·026	16·0	6·896	45	11·565
1·2	1·889	2·5	2 726	4·6	3·698	9·0	5·172	17·0	7·108	50	12·190
1·3	1·966	2·6	2·779	4·8	3·777	9·5	5·314	18·0	7·314		

β.—CORRECTIONS FOR TEMPERATURE.

Column *a* shows the temperature of the chimney or flue, column *b* the factor for multiplying the figure found in Table *a* in order to arrive at the real speed of the current of gas.

A.—Readings in Degrees Fahrenheit.

Fahr. *a.*	*b.*	*a.*	*b*	*a.*	*b.*	*a.*	*b.*
0	1·0634	90	0·9723	180	0·9012	380	0·7865
5	1·0577	95	0·9679	185	0·8977	400	0·7763
10	1·0520	100	0·9636	190	0·8943	425	0·7663
15	1·0464	105	0·9593	195	0·8909	450	0·7556
20	1·0409	110	0·9551	200	0·8875	475	0·7454
25	1·0355	115	0·9509	210	0·8808	500	0·7356
30	1·0302	120	0·9468	220	0·8743	525	0·7261
35	1·0250	125	0·9428	230	0·8680	550	0·7171
40	1·0198	130	0·9388	240	0·8614	575	0·7085
45	1·0148	135	0·9348	250	0·8557	600	0·7000
50	1·0098	140	0·9309	260	0·8497	650	0·6841
55	1·0049	145	0·9270	270	0·8438	700	0·6691
60	1·0000	150	0·9232	280	0·8380	750	0·6552
65	0·9952	155	0·9194	290	0·8324	800	0·6420
70	0·9905	160	0·9156	300	0·8269	850	0·6297
75	0·9858	165	0·9119	320	0·8163	900	0·6181
80	0·9812	170	0·9083	340	0·8060	950	0·6070
85	0·9767	175	0·9047	360	0·7960	1000	0·5964

B.—Readings in Degrees Centigrade.

a. t° C.	b.	a. t° C.	b.	a. t° C.	b.	a. t° C.	b.	a. t° C.	b.	a. t° C.	b.
·10	1·046	18	0·995	42	0·956	66	0·922	140	0·835	260	0·735
· 5	1·036	20	0·991	44	0·953	68	0·919	150	0·825	270	0·728
0	1·027	22	0·988	46	0·950	70	0·916	160	0·815	280	0·721
2	1·023	24	0·985	48	0·947	75	0·909	170	0·806	290	0·715
4	1·020	26	0 981	50	0·944	80	0·903	180	0·797	300	0·709
6	1·016	28	0 978	52	0·941	85	0·897	190	0·788	320	0·697
8	1·012	30	0·975	54	0·938	90	0·890	200	0·780	340	0·685
10	1·009	32	0·972	56	0·935	95	0·884	210	0·772	360	0·676
12	1·005	34	0·968	58	0·933	100	0·878	220	0·764	400	0·654
14	1·003	36	0·965	60	0·930	110	0·867	230	0·756	450	0·631
15	1·000	38	0·962	62	0·927	120	0·856	240	0·749	500	0·603
16	0 998	40	0·959	64	0·924	130	0·845	250	0·742		

A very simple and cheaper instrument is Seger's Differential Anemometer, Fig. 8. The U-tube A is surmounted by two enlargements, B and C. D is a sliding scale, adjustable by slits *a a* and screw-pins *b b*. The tube is filled with two non-miscible liquids of nearly equal specific gravity; for instance, paraffin oil and dilute spirits of wine (coloured). The line of contact, at X, is the zero point of the scale D. If an aspirating force is acting on the surface of the liquid in C, the level of the liquid will be raised in C, and the point X will be lowered in a multiplied ratio, corresponding to the difference in the sectional areas of the narrow part of A and the enlargements in C, say 1 : 20.

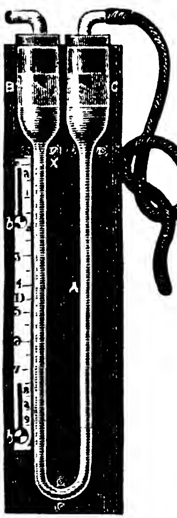

Fig. 8.

C. Temperature.

The measurement of temperatures up to about 300° calls for no special remark, as the ordinary mercurial thermometers are always used. For higher temperatures a large number of *pyrometers* have been constructed. All of these are unreliable after prolonged use, many of them even from the very beginning, and they require a frequent control of their indications by calorimetric methods. Among these "empirical" pyrometers those mostly used are: Gauntlett's (up to 900° C. or 1600° F.), Steinle and Hartung's graphite pyrometer (up to 1200° C.), and Klinghammer's

Thalpotasimeter. In many cases Prinsep's metallic alloys, of definite fusing points, and Seger's cones, do good service; the fusing points corresponding to the commercial forms of the Seger cones have been given on p. 61.

The calorimetric control can be effected by any of the well-known calorimeters, such as Mahler's or Fischer's, but is a somewhat difficult and complicated operation, and the working of the air pyrometer is even more so.

Most of the drawbacks formerly connected with pyrometry have been removed by the construction of Le Chatelier's *Thermo-electric Pyrometer*. Its working part is shown in Fig. 9. It consists of a thermocouple, composed of a wire *a* of pure platinum, and a wire *b* of an alloy of 90 parts of platinum + 10 parts of rhodium, soldered to the former. These wires are insulated by

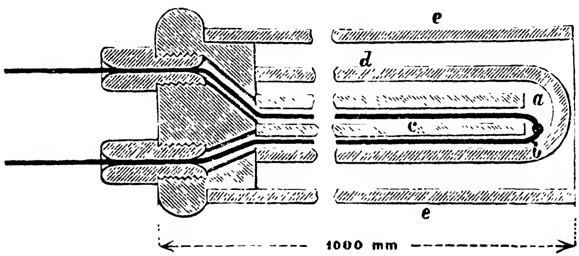

FIG. 9.

porcelain tubes *c*, *d*, about 3 feet long, and protected on the outside, against heating gases, by the iron pipe *e e*. The wires are connected with platinum or copper wires, leading to a galvanometer, and the indications of the needle of the latter show the temperature at the point where *a* and *b* are soldered together. The temperature scale marked on the galvanometer is fixed by comparing it with an air pyrometer at the works where the instruments are made.

The following rules must be observed for the use of this pyrometer. The galvanometer should be placed in a horizontal position and so as to be protected against mechanical oscillations, preferably on a wall-bracket, and this may be at some distance from the pyrometer itself—*e.g.* in the manager's office. Before moving the galvanometer from its place, the needle should be always arrested. After fixing it on its bracket, the arresting-screw is cautiously loosened, until the needle begins to move. If it does not point to zero after being placed in a horizontal position, this must be effected by moving the adjusting screws. The electric resistance of the conducting wire should not appreciably exceed 1 ohm; up to distances of about 300 feet this will be attained by employing insulated copper wire of $\frac{1}{12}$-inch thickness. The junction of the couple with the conducting wires ought not to be much above the ordinary temperature. If one of the wires should break, the contact can be re-established by twisting the ends tightly together for a length of about $\frac{1}{3}$ inch; it is preferable to fuse them together in an oxyhydrogen flame. If the temperature within the furnace does not exceed 1000°, the pyrometer may be left permanently inside; for higher temperatures, which would cause the iron pipe to soften and to burn away too rapidly, the pyrometer should be taken out and introduced merely for taking an observation, which may be done ten minutes afterwards. Even then it is best to provide a fireclay slab on which the instrument can rest. Le Chatelier's pyrometer may be employed for temperatures up to 1500 C. For higher temperatures, up to 2100°, W. C. Heræus (Hanau, Germany) has constructed a thermo-couple, consisting of a wire of pure iridium, fused to another wire of an alloy of 90 parts iridium + 10 ruthenium.

For such high temperatures Wanner's pyrometer is now frequently used. It allows a photometric comparison of the polarised light from a small electric lamp with that of the furnace, etc., to be tested, by means of an instrument like a telescope; it is easy to handle, and is serviceable for approximately measuring temperatures above 1500°, where Le Chatelier's pyrometer cannot be employed. It is also more convenient than the latter for estimating temperatures inside the furnace at some distance from the front of the furnaces. (Supplied by Townson & Mercer, London.)

D.—Feed-Water for Steam-Boilers, etc.

1. *Hardness.*—The English degrees of hardness are based on the unit of 1 part $CaCO_3$, or its equivalent of $MgCO_3$, in 70,000 parts of water (grains to the gallon). The French degrees signify each 1 part $CaCO_3$ (or $MgCO_3$) in 100,000 water, the German degrees that of 1 part CaO (or MgO) in 100,000 water.

The testing for hardness was formerly mostly effected by Clark's soap test. The methods to be described here are both simpler and more accurate than the soap test.

(*a*) *Temporary Hardness* (alkalinity) is that which is removed by prolonged boiling, by which operation nearly all the $CaCO_3$ and some of the $MgCO_3$ is precipitated. This can be estimated with sufficient approximation by testing the water alkalimetrically, employing $\frac{1}{5}$ normal hydrochloric acid and methyl orange as indicator, at the ordinary temperature, until the first reddish tint appears. When employing 200 c.c. of the water for this test, the number of c.c. of $\frac{1}{5}$ normal acid used, multiplied by 3·5, indicates the English degrees of temporary hardness (for French degrees multiply by 5, for German degrees by 2·8).

Where feed-water, purified by means of sodium carbonate, is tested in this way, an error may be caused by the presence of an excess of Na_2CO_3, which makes the hardness appear too high. In such cases the 200 c.c. of water employed should be boiled in a porcelain dish for some time, the precipitated carbonates removed by filtration, and the filtrate titrated as above. The acid then used corresponds to the Na_2CO_3 and a little unprecipitated $MgCO_3$.

(b) *Total Hardness.*—Add to 200 c.c. of the feed-water hydrochloric acid in slight excess, boil down to about 50 c.c.; wash this into a 100 c.c. flask, neutralise exactly with caustic soda solution, employing methyl orange as indicator; add 20 c.c. of a mixture of equal volumes of $\frac{1}{5}$ normal caustic soda solution and $\frac{1}{5}$ normal sodium carbonate solution, boil, allow to cool, fill up the flask to the 100 c.c. mark with distilled water, pour through a dry filter, and estimate the unsaturated alkali in 50 c.c. of the filtrate by $\frac{1}{5}$ normal hydrochloric acid and methyl orange. Multiply the c.c. of acid used by 2, and deduct this from 20; the remainder $= a$ shows the alkali consumed for precipitating the alkaline earths contained in 200 c.c. of water. The total hardness is hence $= 3{\cdot}5a$ in English degrees, $5a$ in French, $2{\cdot}8a$ in German degrees. This process is accurate also in presence of magnesia. By deducting the degrees of alkalinity found in a from the total hardness found in b, the *permanent hardness* is obtained—*i.e.* that which is caused by calcium sulphate.

Water having a total hardness of less than 8° (English) is considered as *soft*, from 8° to 15° as *moderately hard*, above 15° as *hard*.

(c) *Residue on Evaporation.*—In the case of water containing but little MgO, a convenient check for the total hardness—*i.e.* the sum of alkalinity a and permanent hardness b—is afforded by evaporating 500 c.c. down to dryness, heating to decompose the organic matter, moistening with a solution of CO_2 in distilled water, and drying at 110°. Since the degrees of hardness are all calculated for CaO, the value of c will not be quite equal to $a + b$, if any considerable quantity of magnesia is present, and this indirectly proves the presence of more magnesia than usual.

2. *Estimation of the Reagents* (*lime water and sodium carbonate*) *required for Purifying Water.*—Add to 500 c.c. of the water 10 c.c. of a $\frac{1}{5}$ normal sodium carbonate solution, evaporate to dryness, take up the residue with a small quantity of water, filter through a small filter, wash till there is no further alkaline reaction, and estimate the unconsumed sodium carbonate in the filtrate plus washings by titrating with methyl orange and $\frac{1}{5}$ normal hydrochloric acid. If a c.c. of $\frac{1}{5}$ normal sodium carbonate are used in the titration, then $2a \times 0{\cdot}0106$ shows the grams of pure *sodium carbonate* required per litre of the water for removing the calcium sulphate—*i.e.* the *permanent* hardness.

The amount of *lime water* required for removing the *temporary* hardness is estimated as follows:—To 500 c.c. of water add 100 c.c. of clear lime water, after having previously determined its percentage of CaO by titrating with $\frac{1}{5}$ normal hydrochloric acid and phenolphthalein (methyl orange is not applicable in this case, because this would indicate also the $CaCO_3$ present in small quantities along with $Ca(OH)_2$, which would be wrong). Heat the mixture during half an hour in a covered flask (to keep out CO_2), allow to cool, pour through a dry filter, and titrate, without delay, 500 c.c. of the filtrate. The HCl now used, increased by one-fifth (since the original 500 c.c. of water had been brought to 600 c.c.), shows the quantity of lime not used up. By deducting this from the CaO originally contained in 100 c.c. of the lime water, the quantity of CaO required for destroying the temporary hardness of $\frac{1}{2}$ litre of the water to be tested is ascertained.

IV. SULPHURIC ACID MANUFACTURE.

A.—Brimstone.

1. *Moisture.*—This should be estimated by drying an average sample of 100 g. at 70° for a few hours, in an oven or water-bath. The sample must be prepared without losing any moisture during the operation; the brimstone for this purpose must, therefore, not be ground, but only coarsely crushed, as quickly as possible.

2. *Bituminous Substances* (Fresenius).—Remove the sulphur by heating the sample for some time a little over 200°, taking care that it does not take fire, weigh the residue, and deduct the ash found in No. 3.

3. *Ash.*—Burn 10 g. in a porcelain dish and weigh the residue. Some samples of brimstone contain carbonaceous matter. In this case (which is easily recognised by the appearance of the sample) the flame must be removed immediately after the sulphur has been burned, and before the carbon has taken fire, so that the latter is not calculated as sulphur.

4. *Arsenic.*—Treat 10 g. brimstone with dilute ammonium hydroxide at 70° to 80°, in order to dissolve the As_2S_3, filter, neutralise the filtrate exactly with dilute nitric acid, and titrate with decinormal silver nitrate solution, until a drop gives a brown colour with a solution of neutral potassium chromate. Each c.c. of the silver nitrate solution indicates 0·041 per cent. As_2S_3. If the arsenic should be present as ferric or calcium arsenate (this never occurs in the case of native brimstone, but it may do so in the case of sulphur recovered from Leblanc soda residue), the sample must be extracted with carbon disulphide, the residue oxidised by aqua regia, and the sulphur estimated as in pyrites (see below).

5. *Direct Estimation of the Total Sulphur* (Pfeiffer).—Shake a weighed sample of powdered sulphur with exactly four times the

quantity of pure carbon disulphide, filter, reduce the temperature to 15°, and ascertain the specific gravity of the solution. The following table (abridged from the original) shows the number of parts of sulphur dissolved by 100 parts by weight of CS_2 at 15° for various specific gravities found :—

Specific Gravity.	Sulphur Dissolved.	Specific Gravity.	Sulphur Dissolved.	Specific Gravity.	Sulphur Dissolved.
1·2708	0·0	1·3087	8·5	1·3426	17·0
1·2731	0·5	1·3108	9·0	1·3445	17·5
1·2754	1·0	1·3129	9·5	1·3463	18·0
1·2779	1·5	1·3150	10·0	1·3481	18·5
1·2800	2·0	1·3170	10·5	1·3500	19·0
1·2833	2·5	1·3190	11·0	1·3517	19·5
1·2857	3·0	1·3211	11·5	1·3536	20·0
1·2870	3·5	1·3231	12·0	1·3553	20·5
1·2894	4·0	1·3251	12·5	1·3571	21·0
1·2916	4·5	1·3271	13·0	1·3587	21·5
1·2938	5·0	1·3291	13·5	1·3605	22·0
1·2960	5·5	1·3311	14·0	1·3622	22·5
1·2982	6·0	1·3330	14·5	1·3640	23·0
1·3003	6·5	1·3350	15·0	1·3657	23·5
1·3024	7·0	1·3369	15·5	1·3674	24·0
1·3045	7·5	1·3388	16·0	1·3692	24·5
1·3066	8·0	1·3408	16·5	1·3709	25·0

6. *Selenium* is found by fusing a sample with potassium nitrate, dissolving the mass in hydrochloric acid, and treating with sulphur dioxide, which precipitates the selenium.

7. *The degree of fineness* of ground brimstone is estimated in France by means of Chancel's sulphurimeter, *i.e.* a glass tube, closed at one end, provided with a glass stopper at the other, and graduated in 100 parts. In this, the ground brimstone is shaken up for some time with pure, anhydrous ether, and after allowing the tube to rest in a vertical position, the number of divisions occupied by the brimstone is read off (degrees Chancel).

B.—Spent Oxide of Gas-works.

The Spent Oxide Association advise the following procedure :—

Sampling.

Samples sent for quotation purposes are often assumed to represent bulk deliveries. This is almost impossible to be the case, as the bulk of the oxide may subsequently dry further or become damper owing to exposure. It is also possible that portions of the heap of oxide which contain more or less sulphur may have become covered up and not included in the sample, however carefully taken. The spent oxide should, therefore, for invoicing purposes, be again sampled during loading and the greatest care taken to obtain correct proportions of lumps and fines, as these may contain different percentages of sulphur.

When deliveries are being made, daily samples are to be taken from every cart or wagon and collected in an air-tight receptacle. It cannot be too strongly emphasised that samples must not be allowed to lie about exposed to the risk of drying, but must be mixed, ground, and bottled each day. When the delivery of the parcel is completed, all the daily samples are to be at once mixed and broken down, and for this purpose coning and quartering is the best method. The well-mixed oxide is poured several times on to a given centre; this ensures an even distribution of both lumps and fines in the form of a cone. The cone is then flattened and quartered. Two opposite quarters are discarded and the remainder again mixed, coned, and quartered until the quantity is reduced to a convenient amount. This is now crushed until it will all pass through a ¼-inch mesh sieve, and at once bottled.

The above operation must be carried out as quickly as possible to avoid alteration in the moisture content of the sample.

Samples should be of at least ½ lb., and must be packed in air-tight bottles or tins; no other receptacle may be used. In taking the necessary samples, one must always be sealed and retained for reference.

Before carrying out the analysis, the whole of the sample is further intimately mixed and broken down and reduced to about 100 g., which is ground so that the whole quantity passes through a 20-mesh sieve.

Analysis.

Moisture.—Five g. are dried for three hours at 100° in a water oven. The loss of weight found on cooling and reweighing represents the moisture.

Sulphur and Tar.—The dried residue from the moisture determination is to be extracted for two hours in a Soxhlet's apparatus with freshly distilled carbon bisulphide. The carbon bisulphide is then distilled off, the flask cautiously blown out with air and dried for two hours at 100° in the water oven. The flask is then placed on a hot sand-bath until the sulphur has just fused, care being taken that no loss by overheating and volatilisation takes place. After the flask has cooled completely it is again carefully blown out with dry air and again weighed.

Estimation of the Sulphur.—Fifteen c.c. of concentrated (95 per cent.) sulphuric acid are poured on to the sulphur and tar in the flask, and the whole is heated for two hours at 100°

in a water oven. After cooling, the contents of the flask are diluted with water, filtered, washed free from acid, and dried. The dried filter paper with contents is placed in a Soxhlet's tube and again extracted with carbon bisulphide. The bisulphide is distilled off, and the residue fused exactly as described above.

The following alternative method gives reliable results and expedites the extraction by CS_2:—

Place the 5 g. of dried spent oxide in a beaker with 25 c.c. of strong sulphuric acid and heat for four hours at 100°. Carefully dilute with distilled water, filter and wash free from acid, dry and extract with CS_2 in the usual way. Only one extraction with the solvent is necessary.

See also Spent Oxide, p. 243.

C.—Pyrites.

The average sample is taken and reduced according to the rules given on p. 103. Two samples are customary. (1) Coarsely ground for moisture; (2) finely ground for quality. For this purpose, the ore is reduced to an impalpable powder, by grinding it first in a steel, and then in an agate mortar, and is kept in well-sealed bottles.

1. *Moisture.*—The coarsely ground pyrites is dried at 105° C. until the weight remains constant.

2. *Quality.*—For the following tests, the finely ground average sample in a well-sealed bottle (not the dried sample) is employed. The analytical results are calculated for dry pyrites, for which reason a special estimation of moisture is made in the finely ground average sample.

Sulphur (Lunge's method).—About 0·5 g. of pyrites is treated with 10 c.c. of a mixture of 3 vols. nitric acid (spec. grav. 1·4) and 1 vol. strong hydrochloric acid, both ascertained to be absolutely free from sulphuric acid, in a 300 c.c. beaker, which is covered with a watch-glass to avoid any loss by spurting. At first, the acid is allowed to act in the cold, but the reaction is completed by heating upon a water-bath. The separation of a little free sulphur is observed sometimes when the temperature exceeds 60° C., and must be oxidised by adding a little potassium chlorate. Evaporate to dryness on a water-bath, add 5 c.c. hydrochloric acid, evaporate once more (no nitrous fumes should escape now), add 1 c.c. concentrated hydrochloric acid and 100 c.c. of hot water, filter through a small filter, and wash with hot water. The insoluble residue may be dried, ignited and weighed. It may contain, in addition to silica and silicates, the sulphates of barium, lead, and even calcium, the sulphur of which, being non-available, is purposely neglected. (*N.B.*—If this residue is not to be estimated, the filtration need not be carried out, and the elimination of the iron by precipitation with ammonia may be proceeded with as soon as all the nitric acid has been driven off, but for very accurate work, the removal is recommended.)

The filtrate and washings are saturated with ammonia, avoiding much excess (5 to 7 c.c. strong ammonia after neutralisation is sufficient), and kept at 60 to 70° C. for about 15 minutes before filtration. (The solution should still smell of ammonia, for if this is removed by boiling, some basic sulphate is precipitated.) The ferric hydroxide precipitate is filtered off and washed. This can be done in from half an hour to one hour, by employing the following precautions:—(1) Filter hot and wash on the filter with hot water, avoiding channels in the mass by churning up the whole precipitate thoroughly each time with the water; (2) employ sufficiently dense, but rapid, filtering paper; (3) use funnels, made exactly at an angle of 60°, whose tube is not too wide and is filled *completely* by the liquid running through. A filter pump also gives satisfactory results with the usual precautions.

The precipitate is washed until about 1 c.c. of the washings shows no turbidity on adding barium chloride solution, even after standing a few minutes. (If there is any doubt, the ferric hydroxide should be dissolved in hydrochloric acid and re-precipitated with excess of ammonia again. The two filtrates are then mixed. The complete absence of basic sulphates can be confirmed by drying the precipitated ferric hydroxide, fusing it with pure sodium carbonate and testing the aqueous solution of the melt for sulphates.)

If the filtrate and washings exceed 300 c.c., they should be concentrated by evaporation. The solution is neutralised by adding pure hydrochloric acid until methyl orange is just reddened, and then 1 c.c. of strong hydrochloric acid is added in excess. Then heat to boiling; remove the burner and add 20 c.c. of a boiling hot 10 per cent. solution of barium chloride, while stirring vigorously. The barium chloride solution is measured off roughly in a test tube provided with a mark, and boiled in the same tube; it is then poured into the hot liquid *all at once*, not drop by drop. An error is introduced by this procedure owing to the absorption of some barium chloride by the barium sulphate precipitate; but this just compensates with the loss caused by the slight solubility of barium sulphate in the hot solution containing free hydrochloric acid and ammonium chloride. A large excess of barium chloride must be avoided, or the results will turn out too high.

The precipitate is allowed to settle for about half an hour, and is then washed three or four times by decantation, with 100 c.c. of boiling water, until the liquid ceases to give an acid reaction. The precipitate is transferred to a filter, washed free from chloride, dried, ignited and weighed. It should be a perfectly white and loose powder. One part of it is equal to 0·1373 sulphur.

3. *Copper*—(Method of the Duisburg Copper Co.).—Of the powdered pyrites, dried at 100° C., 5 g. is gradually dissolved in 60 c.c. of nitric acid, spec. grav. 1·2, in a flask placed in a slanting position. When the first violent reaction is over, the flask is heated and the evaporation continued until thick, white fumes of sulphuric acid escape. Dissolve the dry residue in 50 c.c. hydrochloric acid, spec. grav. 1·19, add 2 g. sodium hypophosphite, dissolved in 5 c.c. water, for the purpose of removing the arsenic and reducing the ferric chloride, boil for some time, then add an excess of concentrated hydrochloric acid, diluted with about 300 c.c. hot water, pass hydrogen sulphide into the liquid, separate the precipitate from the liquid by filtration, and wash it well. Pierce the filter paper with a glass rod, wash the precipitate back into the precipitating flask, dissolve the sulphides adhering to the filter and the principal portion of the precipitate by means of nitric acid, and evaporate the contents of the flask to dryness on the water-bath. Treat the residue with nitric acid and water, neutralise with ammonia, and add sulphuric acid in slight excess. After the liquid has cooled down, separate the clear liquid from the insoluble lead sulphate, etc., wash out the flask and filter with water containing a little sulphuric acid, add to the filtrate 3 to 8 c.c. nitric acid, spec. grav. 1·4, and precipitate the copper electrolytically. From the ascertained percentage of copper deduct 0·01 per cent. for bismuth and antimony.

4. *Lead* remains in the residue from the treatment with aqua regia (No. 2) or nitric acid (No. 3), as lead sulphate. This is extracted from the residue (preferably that from the nitric acid treatment) by heating with a concentrated solution of ammonium acetate. The solution is evaporated, with addition of a little pure sulphuric acid, the evaporation completed in a porcelain crucible, and the residue dried and ignited. One part $PbSO_4$ = 0·6829 Pb.

5. *Zinc* is sometimes estimated in pyrites, because the sulphur combined with it is hardly recoverable in the pyrites burners. The following method of Messrs Hassreidter and Prost should be employed in this case, in lieu of Schaffner's method described subsequently for zinc blende, because in the case of pyrites the presence of iron renders gravimetric preferable to volumetric analysis:—Dissolve 1 g. pyrites in aqua regia, as described on p. 133, expel the nitric acid, take up the residue with about 20 c.c. concentrated hydrochloric acid, dilute with water, treat the acid solution with H_2S in order to precipitate lead, etc., filter, expel the H_2S from the filtrate by boiling, and oxidise the liquid with aqua regia. When cooled down, add ammonium carbonate until the precipitate formed redissolves but slowly, then add ammonium acetate, boil for a short time, and filter the liquid from the

precipitated basic ferric sulphate. As this contains a little zinc, dissolve it in hydrochloric acid, precipitate it again as above, and repeat this treatment until no more zinc is found in the filtrate. The united filtrates are concentrated by evaporation. Then precipitate the zinc in the hot solution by H_2S, allow to stand for twenty-four hours, pour off the clear liquid, filter, wash the ZnS, dissolve it (without removing the filter) in dilute HCl, boil off the H_2S, precipitate with sodium carbonate, wash the $ZnCO_3$, dry and ignite it. One part $ZnO = 0{\cdot}8034$ Zn. For very accurate work the SiO_2, Fe_2O_3, and Al_2O_3 retained in the ZnO should be estimated and deducted, but this is very rarely necessary.

6. *The Carbonates* (of Ca, etc.) are sometimes estimated in pyrites, because they convert a certain quantity of sulphur into sulphate. Since their quantity is always small, the CO_2 is estimated directly by expelling with strong acids, and is easily estimated gravimetrically by absorbing it in soda-lime, etc., or, more quickly, by decomposing a weighed quantity with hydrochloric acid in an evacuated vessel and measuring the CO_2 evolved in a Hempel pipette.

7. *Arsenic.*—Reich's method, modified by M'Cay :—Decompose 0·5 g. pyrites by concentrated nitric acid in a porcelain crucible, remove the free acid by evaporation, but not to complete dryness, add 4 g. sodium carbonate, heat on the sand-bath until the mass is quite dry, add 4 g. potassium nitrate, and heat until the mass has fused quietly for ten minutes. After cooling, wash it with hot water, acidulate the filtered solution with a little nitric acid, heat for some time till all CO_2 is expelled, add silver nitrate, and neutralise carefully with dilute ammonia. The precipitate formed contains all the arsenic as Ag_3AsO_4. Dissolve it in dilute nitric acid, and either estimate the silver volumetrically by ammonium thiocyanate (Volhard's method), or evaporate the solution in a porcelain dish, dry, and weigh the residue. One part $Ag_3AsO_4 = 0{\cdot}1620$ As, or 1 part $Ag = 0{\cdot}2316$ As.

8. *Selenium.*—Twenty to 30 g. of pyrites are dissolved in hydrochloric acid (spec. grav. 1·19) and potassium chlorate. After filtering from gangue, the iron is reduced to the ferrous state by means of zinc, more hydrochloric acid is added, the solution boiled and the selenium precipitated by stannous chloride. Since it may contain arsenic, it is collected on an asbestos filter, dissolved in potassium iodide, and reprecipitated by hydrochloric acid and sulphur dioxide.

D.—Burnt Pyrites (Cinders).

1. *Sulphur.*—Mix exactly 2 g. sodium bicarbonate of known alkalimetric value in a nickel crucible of 20 or 30 c.c. capacity, intimately with 3·207 g. of ground cinders, by means of a glass rod

flattened at the end. Heat the crucible by a small gas-flame, the point of which reaches just to the bottom of the crucible, for ten minutes. Stir the mass up again, heat it again for fifteen minutes by a stronger flame, but not to the fusing point. During the heating the crucible should be covered, and no stirring should take place during this time to prevent the escaping CO_2 from carrying away any dust. Empty the contents of the crucible into a porcelain dish, wash it out with water, add a concentrated solution of sodium chloride, free from magnesium chloride and perfectly neutral (without this addition it is difficult to avoid some ferric oxide passing through the filter later on), boil for ten minutes, filter, wash the insoluble residue till there is no alkaline reaction, allow the filtrate, etc, to cool down, and titrate it with methyl orange and normal hydrochloric acid (1 c.c. = 0·05300 Na_2CO_3, indicating 0·01604 S). If we call the number of c.c. of the acid required by 2 g. bicarbonate $= a$, and the c.c. of acid used for titrating $= b$, the percentage of sulphur in the cinders corresponds to $\frac{a-b}{2}$.

2. *Copper* is estimated as in fresh pyrites, but the solution of 1 g. of the sample is effected by hydrochloric acid with only a few drops of nitric acid, and *no* deduction for Bi and Sb is made from the electrolytically estimated Cu.

3. *Iron.*—Dissolve 0·5 g. cinders in concentrated hydrochloric acid by prolonged heating; reduce the boiling solution by zinc, free from iron, or more conveniently by stannous chloride, the excess of the latter being removed by a little mercuric chloride solution; pour the solution thus obtained into a half-litre of water, to which about 2 g. manganous sulphate has been added, and which has been just reddened by one or two drops of potassium permanganate. Determine the iron by titrating with decinormal potassium permanganate, each c.c. of which indicates 0·005584 g., or in 0·5 g. cinders 1·117 per cent. Fe.

E.—Zinc Blende.

1. *Total Sulphur.*—Decompose 0·5 of the finely ground sample by pure fuming nitric acid, cooling the beaker until the first violent reaction is over, and add hydrochloric acid, drop by drop, gently heating, until the decomposition is finished. Remove the iron by precipitation with ammonia, as in the case of pyrites (p. 134), and precipitate the sulphate by adding the requisite quantity of the dilute hot solution of barium chloride, all at once, in which case the $BaSO_4$ remaining in solution is just compensated by the $BaCl_2$ carried down with the precipitate (compare p. 134).

2. *Zinc.*—The following modification of Schaffner's method is employed at the Rhenish and Belgian zinc works, as com-

municated to the author by Messrs Hassreidter and Prost:—Treat 2·5 g. of the finely ground blende (dried at 100° C.) in a 250 c.c. Erlenmeyer flask with 12 c.c. fuming nitric acid, first without heating, then heating gently until no more red vapours come off. Add 20 to 25 c.c. concentrated hydrochloric acid, evaporate to dryness on a sand-bath, dissolve in 5 c.c. hydrochloric acid and a little water, heat for some time, add 50 or 60 c.c. water, and heat to 60 or 70° C. until everything except gangue and sulphur has passed into solution. Pass a moderate current of H_2S into the solution, and gradually add, with continuous stirring, 50 to 100 c.c. water, until all Pb and Cd have been precipitated. This will be recognised by the fact that the bubbles of gas evolved are transparent. Any excessive dilution or too much prolonged treatment with H_2S must be avoided. Filter and wash with 100 c.c. sulphuretted hydrogen water, to which 5 c.c. hydrochloric acid has been added, until a drop of the filtrate gives no reaction for zinc with ammonium sulphide. Boil the filtrate and washings (together about 300 c.c.) in order to expel the H_2S (test by lead paper), and oxidise the ferrous salt by adding 5 c.c. concentrated nitric acid and 10 c.c. hydrochloric acid. When partially cooled down, put the solution into a half-litre flask, add 100 c.c. ammonia (spec. grav. 0·9 to 0·91) and 10 c.c. of a cold saturated solution of ammonium carbonate, shake well and allow to cool. This solution we call A.

In the meantime an ammoniacal zinc solution of known strength, the "titre," is prepared by dissolving a quantity of chemically pure zinc, approximately equal to that contained in the ore, in another half-litre flask, in 5 c.c. nitric acid + 20 c.c. hydrochloric acid, adding 250 c.c. water, 100 c.c. ammonia, and 10 c.c. of ammonium carbonate solution, shaking up and allowing to stand till cool. (If manganese be present, add 10 c.c. hydrogen peroxide before adding the ammonia.) This solution we call B. When all is cool, fill both flasks up to the mark, and filter the solution A (made from the ore) through a dry pleated filter. For the titration itself take from each of the solutions A and B 100 c.c., run this into stout glass cylinders ("battery glasses") and dilute each with 200 c.c. water. The titration is effected by a concentrated solution of commercial crystallised sodium sulphide, diluted with ten or twenty times its volume of water and indicating per c.c. 0·005 to 0·010 g. Zn. This solution is placed in two 50 c.c. burettes, standing side by side, and is run by turns into the zinc solutions A and B. At first 2 or 3 c.c. less than is ultimately required is run in. Agitate the solutions and place at the same time a drop of each, by means of a thin glass rod, on to a strip of sensitive lead paper. After the action has lasted fifteen or twenty seconds, blow away the drops by means of a small wash-bottle and continue the addition of Na_2S, until both drops, after acting for the same time, produce a slight but distinct brownish colour of the same intensity. If too much liquid has been used in these drop tests, the titration must be repeated once or twice; at all events, the final reaction must take place equally in both glasses, and the readings must be accurate to 0·05 c.c.

If we call the quantity of pure zinc weighed out as "titre" *a*, that of the c.c. sodium sulphide solution used for the "titre" *b*, and the c.c. used for 100 c.c. of the ore solution (=0·5 g. ore) *c*, the expression $\frac{40\,ac}{b}$ gives the percentage of zinc in the ore.

For exact estimations, a quantity of ferric chloride, equal to the content of iron in the ore, is added to the "titre," in order to meet the objection that the ferric hydroxide may carry down a little zinc.

Some blendes, containing a large proportion of silicates, obstinately resist the ordinary methods of testing (Jensch, *Zsch. f. angew. Chem.*, 1894, p. 155).

3. *Lead.*—The sulphides precipitated in No. 2 are, if necessary, digested with a concentrated solution of sodium sulphide; then dilute, filter, wash the residue, dissolve it (together with the filter) in nitric acid (spec. grav. 1·20), filter, add an excess of sulphuric acid, evaporate to dryness, and weigh the lead as sulphate. One part $PbSO_4$=0·6831 Pb.

4. *Lime* and *Magnesia* are estimated, because they form sulphates in the roasting process. Digest 2·5 g. blende with 50 c.c. dilute sulphuric acid (1 : 10), with application of heat, decant the clear portion; repeat this treatment once or twice, wash the residue, expel the H_2S from the filtrates by boiling, oxidise with bromine water, precipitate with ammonium carbonate, and in the filtrate precipitate first the calcium by ammonium oxalate (weigh this as CaO after strongly igniting), and in the filtrate from this the magnesium by ammonium phosphate (compare p. 175).

5. *Arsenic* is estimated as described on p. 136.

6. *Carbon Dioxide* may be estimated as in pyrites, pp. 136 and 137. This is useful, even when CaO and MgO are estimated, since blende contains sometimes ferrous and zinc carbonate.

7. *Available Sulphur.*—From the total sulphur found in No. 1 deduct:

For each part of	Pb	found in	No. 3,	0·1550	part.
,, ,,	CaO	,,	,, 4,	0·5715	,,
,, ,,	MgO	,,	,, 4,	0·7944	,,

The remainder indicates the sulphur available for the manufacture of sulphuric acid. The S of $BaSO_4$, etc., remains in the residue from the dissolving process.

F.—Cinders from Blende.

1. *Sulphur* (according to Lunge and Stierlin, *Zsch. f. angew. Chem.*, 1906, p. 26).—The process is carried out as described for pyrites cinders on p. 136, but 2 g. ground potassium chlorate is added to the mixture. The bottom of the crucible should finally be at a red heat, but the contents should merely frit together, not fuse entirely. The crucible must be covered during the heating, and its contents must not be stirred up. The calculation is as on p. 137—that is, the percentage of S $= \frac{a-b}{2}$.

An addition of potassium chlorate is already required in the case of cinders from iron pyrites containing much zinc. In case the cinders contains upwards of 6 per cent. S, the mixture should be: 1·603 g. cinders, 2·000 g. $NaHCO_3$, 4·0 g. $KClO_3$, 2 - 3 g. ferric oxide (free from S). The percentage of sulphur is then $= a - b$, where a is the c.c. of normal acid corresponding to the 2·000 g. bicarbonate, b the c.c. of acid required for titration after the heating.

This process is also applicable to fresh (unroasted) blende, by using the following mixture: 0·3207 g. blende, 2·000 g. $NaHCO_3$, 2 g. $KClO_3$, 2 g. Fe_2O_3; percentage of $S = 5\ (a - b)$.

A crude test is made by the foreman at the works, in this manner: he heats a sample of the cinders with 10 c.c. hydrochloric acid (1:2 water) in a flask, holding in its neck a strip of paper soaked in a neutral or faintly alkaline solution of lead acetate, and he judges of the more or less complete state of roasting by the depth of the brown colour developed on the paper.

2. *Zinc*, as on p. 135.

G.—Gases.

I. Chamber Process.

1. *Burner Gases.*—(*a*) SO_2 is estimated by Reich's method. The gas is aspirated through a solution of iodine, contained in a wide-necked 200 c.c. bottle, and coloured blue by starch solution, till the colour is just discharged. This bottle is connected with a larger bottle, converted into an aspirator by having a tap near the bottom, or by a siphon with a pinchcock. Water is run from this into a graduated 250 c.c. jar. The iodine bottle is shaken up during the aspiration, and at the moment when the colour is discharged, the tap of the aspirator is closed and the volume of water in the jar is read off. It is equal to the volume of the water run out, increased by that of the SO_2 absorbed. The absorbing-bottle is charged with 10 c.c. of a decinormal solution of iodine (12·692 g. iodine per litre, preparation and valuation as on p. 114), along with about 50 c.c. of water, a little starch solution, and a little sodium bicarbonate. The above quantity of iodine is = 0·03203 g. SO_2 = 10·93 c.c. at 0° C. and a pressure of

760 mm. The latter figure, multiplied by 100 and divided by 10·93 c.c. + the volume of the water run out, yields the percentage of SO_2 in the gas by volume.

This calculation is saved by the following table, in which the 10·93 c.c. are taken into account.

Cubic Centimetres. Water Collected.	Volume per cent. SO_2 in Kiln Gas.	Cubic Centimetres. Water Collected.	Volume per cent. SO_2 in Kiln Gas.
80·1	12·0	125·7	8·0
84·1	11·5	134·8	7·5
88·4	11·0	145·2	7·0
93·2	10·5	157·2	6·5
98·4	10·0	171·2	6·0
104·1	9·5	187·8	5·5
110·5	9·0	207·8	5·0
117·7	8·5		

In this no notice is taken of temperature and barometer. If these are to be observed, the volume read off is reduced to 0° and 760 mm. by the Tables 12 and 13, and then looked up in the above table.

(*b*) Since Reich's test takes no account of the SO_3 always present in burner gases, it is preferable to estimate the *total acids* (SO_2+SO_3), either along with the test (*a*) or exclusively. This is performed in the same apparatus, but the absorbing-bottle is preferably provided with a gas entrance tube, closed at the bottom and perforated by numerous pinholes, through which the gas issues in small bubbles. The gas is passed through a solution of decinormal sodium hydroxide, coloured by phenolphthalein, until the colour is just discharged. The calculation is made as for pure SO_2, employing the table given in (*a*) (Lunge, *Zsch. f. angew. Chem.*, 1890, p. 563).

In both cases—(*a*) and (*b*)—an error is sometimes caused by arsenious oxide collecting in the aspirating tube; this is avoided by filtering the gases through asbestos.

2. *Chamber Gases.*—In these, *sulphur dioxide* and *nitrous gases* are estimated (as described by Raschig, *Zsch. angew. Chem.*, 1909, xxii., p. 1182) by means of a Reich apparatus (p. 140), charged with 10 c.c. decinormal iodine solution, 100 c.c. water, a little starch solution, and 10 c.c. of a cold saturated solution of sodium acetate. The estimation is performed as described on p. 140, taking care that no droplets of sulphuric acid get into the iodine solution, which is effected by passing the chamber gases through glass wool. The calculation of SO_2 is effected as described *supra*. In order to estimate the nitrous gases, add, after estimating the SO_2, a drop of phenolphthalein solution

to the decolorised solution, and titrate with decinormal caustic soda solution up to the appearance of a red colour. From the number of c.c. used deduct 10 c.c. for the hydriodic acid and 10 c.c. for the sulphuric acid formed, according to the equation: $SO_2 + I_2 + 2H_2O = H_2SO_4 + 2HI$. The c.c. of decinormal soda solution, used over and above these 20 c.c., indicate nitric or nitrous acid.

3. *Chamber Exit Gases.*—(a) *Oxygen.* Before estimating this, the acids are removed from the gas by washing with a solution of potassium or sodium hydroxide. Single samples can be taken at odd times during the day, but it is recommended to take an average sample for the whole day, by aspirating at least 10 or 20 litres of gas, and analysing a portion of this. The estimation of oxygen is best made by moist phosphorus in an Orsat apparatus with two absorbing tubes, one of which is filled with potassium hydroxide solution for removing the acids, the other with small pieces of phosphorus. The manipulation is exactly as in testing flue gases, but it should be observed that the temperature must be at least 16°, better 18° C., otherwise the tube must be warmed a little.

(b) *Sulphur and Nitrogen Acids.*—The different acid compounds of sulphur and nitrogen are estimated together, whatever their degree of oxidation. A continuous test over twenty-four hours is taken of the gases escaping from the exit pipes of the Gay-Lussac towers, aspirating at least one cubic foot per hour by means of any aspirator acting at a constant rate and recording the volume of gas = V by means of gauging the aspirator or by a gas meter. The volume V is reduced to 0° C. and 760 mm. pressure (= 32° F. and 29·92 inches*) by the Tables 12 and 13, and is called V^1. In order to allow comparisons, the number of cubic feet of chamber space per pound of sulphur burnt and passing into the chambers is recorded, excluding towers, but including tunnels, the amount of sulphur being taken by the weekly average, each firm to state the distance of the testing hole from the point at which the gases leave the Gay-Lussac towers. The absorption apparatus consists of four bottles or tubes, containing not less than 100 c.c. of absorbing liquid each, with a depth of at least 3 inches in each bottle, the aperture of inlet tubes not to exceed $\frac{1}{50}$ inch in diameter, and to be measured by a standard wire. The first three bottles each contain 100 c.c. of normal caustic soda solution (40·01 g. per litre), the fourth 100 c.c. distilled water. The caustic soda used must be free from nitrogen acids. The gases are tested (1) for total acidity, stated in grains of SO_3 per cubic foot of gas, or in grams per cubic metre; (2) sulphur acids; (3) nitrogen acids, both stated in grains of S and N per cubic foot (or grams per cubic metre). The

* The law prescribes the cubic feet to be measured at 60° F. and 30 inches, which necessitates the use of other tables or factors than those mentioned in the text; but the difference is hardly perceptible, and certainly within the limits of experimental error.

analysis is carried out as follows :—The contents of the four bottles are united, taking care not to unnecessarily augment the bulk of the liquids, and are divided into three equal parts, one of which is reserved for accidents, etc. The first part is titrated with normal sulphuric acid (49·04 g. H_2SO_4 per litre), to ascertain total acidity. The number of cubic centimetres of acid necessary for neutralisation is called x. The second part of the liquid is gradually poured into a warm solution of potassium permanganate, strongly acidified with pure sulphuric acid. A small excess of permanganate must be present, and must be afterwards reduced by the addition of a few drops of sulphurous acid solution, until only a faint red tint is visible. Now all nitrogen acids are present as HNO_3, but no excess of SO_2. The HNO_3 is estimated by its action on $FeSO_4$. Twenty-five c.c. of a solution, containing per litre 100 g. crystallised ferrous sulphate and 100 c.c. pure sulphuric acid (the same solution which is used for estimating MnO_2, p. 182), are put into a flask, 20 c.c. to 25 c.c. pure concentrated sulphuric acid is added, the mixture is allowed to cool, and the other mixture, treated with permanganate, etc., is added. The flask is closed by a cork with glass tubes. A current of CO_2 passes through and issues beneath the surface of some water, to prevent entrance of air. First, all the air is expelled in this way by means of an apparatus giving a constant current of CO_2; then the solutions are introduced, and the contents of the flask are heated to boiling, till the dark colour produced by the formation of NO has changed to a clear light yellow. This takes from a quarter of an hour to one hour, according to the quantity of HNO_3 present and that of the sulphuric acid added. The unoxidised ferrous sulphate is titrated by a seminormal permanganate solution (yielding 0·004 g. oxygen per cubic centimetre—compare p. 114). The cubic centimetres used $= y$. Since the titre of the iron solution changes somewhat quickly, it should be tested daily by taking out 25 c.c. with the same pipette as is used for the above operation, and ascertaining the amount of permanganate required for oxidising it $= z$ c.c. The data required are found by the following equations :—

1. *Total Acidity* in grams per cubic metre =

$$SO_3 = \frac{0{\cdot}120(100 - x)}{V^1}$$

2. *Sulphur* in grams per cubic metre =

$$S = \frac{0{\cdot}008(600 - 6x - z + y)}{V^1}$$

3. *Nitrogen* in grams per cubic metre =

$$N = \frac{0{\cdot}007(z - y)}{V^1}$$

1. *Total Acidity* in grains per cubic foot =

$$SO_3 = \frac{1{\cdot}852(100 - x)}{V^1}$$

2. *Sulphur* in grains per cubic foot =

$$S = \frac{0{\cdot}12346(600 - 6x - z + y)}{V^1}$$

3. *Nitrogen* in grains per cubic foot =

$$N = \frac{0{\cdot}10803(z - y)}{V^1}$$

The legal limit for total acidity in the lead-chamber process is 4 grains of SO_3 per cubic foot, before admixture with air, smoke, or other gases; for the contact process, the "best practicable means" are to be adopted.*

In lieu of the above process, it is customary in works practice, and for the purposes of the Alkali Act, to estimate the total acidity in the chamber exit gases, by means of the bellows aspirator, as described under chimney-testing, on p. 176.

The Technical Index to the Alkali Reports (1919), pp. 46-47, should be consulted for detailed information on this subject.

The test is carried out as follows:—

About 300 c.c. of distilled water with 5 to 10 c.c. of neutral hydrogen peroxide ("10 volume H_2O_2") is introduced into the bellows. The gases are drawn from the exit pipe through a glass tube, and are washed thoroughly after each aspiration by shaking the contents of the aspirator vigorously. When a sufficient

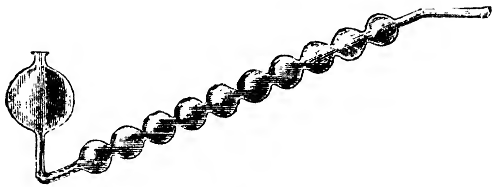

FIG. 10.

volume of gas has been withdrawn (½ cubic foot is usually enough), any acid which may have condensed in the glass tube is washed back into the bellows and the liquid then transferred to a porcelain dish and titrated with $\frac{N}{2}$ sodium carbonate solution, using methyl orange as indicator.

N.B.—Hydrogen peroxide should be kept in a cool place and protected from the action of light; for this purpose bottles of a brown or deep green colour should be used, not blue or colourless ones. (See Dr T. L. Bailey's report on experiments on the action of light on hydrogen peroxide in the 46th Annual Report, 1909, p. 110.)

(c) *Nitric Oxide* (NO) may be present in the exit gases after passing through the absorbing-bottles. If it is to be estimated, an absorption-tube (Fig. 10) † is interposed between the tubes of the apparatus described above and the aspirator. This tube contains 30 c.c. of seminormal permanganate and 1 c.c. of sulphuric acid, spec. grav. 1·25. The gas is passed through for twenty-

* Alkali Act, 1906.

† This shape of bulb-tubes has been found to be far superior to any other form of absorption-tubes tried.

four hours, and the tube then emptied and washed out. Now add 50 c.c. ferrous sulphate solution, corresponding to 2 z permanganate (compare last paragraph), and retitrate the decolorised liquid with permanganate. The quantity of the latter now used is called u. The NO has consumed $(30+u-2z)$ c.c. permanganate, which is equal—

In grams of nitrogen per cubic metre of the volume V^1.	In grains of nitrogen per cubic foot.
$N = \frac{0{\cdot}007\,(30+u-2z)}{3V^1}$	$N = \frac{0{\cdot}10803\,(30+u-2z)}{3V^1}$

II. Contact Process.

1. The *Entering Gases* are analysed like those of the Chamber Process (pp. 140 and 141).

2. The *Catalysed Gases* are passed through a measured quantity of iodine solution and then through a vessel containing thiosulphate solution. The non-consumed iodine is retitrated by thiosulphate, and the total acidity is ascertained by baryta solution or by decinormal soda solution, with phenolphthalein as indicator, making the same deduction as prescribed in the Reich-Raschig method (p. 141). If the c.c. of 1/10 N iodine solution consumed are designated by a, and those of 1/10 N soda solution (or baryta solution) by b, the formula $x = 0{\cdot}003203a$ indicates the quantity of non-catalysed SO_2, and $y = 0{\cdot}004\,(b-2a)$ that of the SO_3, formed. The yield of SO_3 in volume per cent. is shown by the formula :—

$$\frac{(b-2a)100}{b-a}.$$

H.—Sulphuric Acid.

1. *Specific Gravity.*—The specific gravity tables of sulphuric acid refer, of course, to *chemically pure* acid. Since, in the case of high-grade acids, the impurities always present in commercial acids quite sensibly increase the specific gravity, the table in the case of acids over 90 per cent. H_2SO_4 should only be employed for the private use of the works, but *sales should always be effected on the basis of a real analysis*, as described later on under No. 12, p. 162.

The following tables have been recalculated by the editor from the data of Domke and Bein, who investigated the density and expansion of sulphuric acid on behalf of the *Normaleichungs-kommission* at Berlin. There are many variations in these recalculated figures from those given in the last edition of this book.

1. SPECIFIC GRAVITY OF SULPHURIC ACID.

Degrees Twaddell.	Specific gravity d 15°/4°.	100 parts by weight contain		Kilos H_2SO_4 per litre.	1 Cubic foot of acid	
		SO_3.	H_2SO_4.		weighs lb. avoir.	contains lb. H_2SO_4.
1	1·005	0·69	0·84	0·0084	62·74	0·53
2	1·010	1·28	1·57	0·0159	63·05	0·99
3	1·015	1·89	2·31	0·0234	63·37	1·46
4	1·020	2·48	3·04	0·0310	63·68	1·94
5	1·025	3·10	3·79	0·0388	63·99	2·42
6	1·030	3·70	4·53	0·0467	64·30	2·91
7	1·035	4·31	5·27	0·0546	64·61	3·40
8	1·040	4·90	6·00	0·0624	64·93	3·90
9	1·045	5·49	6·72	0·0702	65·24	4·38
10	1·050	6·08	7·44	0·0781	65·55	4·88
11	1·055	6·66	8·15	0·0860	65·86	5·37
12	1·060	7·24	8·86	0·0939	66·18	5·86
13	1·065	7·81	9·56	0·1018	66·49	6·36
14	1·070	8·39	10·26	0·1098	66·80	6·86
15	1·075	8·96	10·96	0·1178	67·11	7·36
16	1·080	9·53	11·66	0·1259	67·42	7·86
17	1·085	10·09	12·35	0·1340	67·74	8·37
18	1·090	10·65	13·03	0·1420	68·05	8·87
19	1·095	11·21	13·71	0·1501	68·36	9·37
20	1·100	11·76	14·39	0·1583	68·67	9·88
21	1·105	12·32	15·07	0·1665	68·98	10·40
22	1·110	12·86	15·73	0·1746	69·30	10·90
23	1·115	13·40	16·40	0·1829	69·61	11·42
24	1·120	13·95	17·07	0·1912	69·92	11·93
25	1·125	14·49	17·73	0·1995	70·23	12·45
26	1·130	15·03	18·39	0·2078	70·55	12·97
27	1·135	15·56	19·04	0·2161	70·86	13·49
28	1·140	16·09	19·69	0·2245	71·17	14·01
29	1·145	16·62	20·34	0·2329	71·48	14·54
30	1·150	17·15	20·98	0·2413	71·79	15·06
31	1·155	17·67	21·62	0·2497	72·11	15·59
32	1·160	18·19	22·26	0·2582	72·42	16·12
33	1·165	18·72	22·90	0·2668	72·73	16·66
34	1·170	19·24	23·54	0·2754	73·04	17·19
35	1·175	19·75	24·17	0·2840	73·35	17·73
36	1·180	20·27	24·80	0·2926	73·67	18·27
37	1·185	20·78	25·43	0·3013	73·98	18·81
38	1·190	21·29	26·05	0·3100	74·29	19·35
39	1·195	21·81	26·68	0·3188	74·60	19·90
40	1·200	22·31	27·30	0·3278	74·92	20·45
41	1·205	22·82	27·92	0·3364	75·23	21·00
42	1·210	23·17	28·53	0·3452	75·54	21·55
43	1·215	23·82	29·15	0·3542	75·85	22·11
44	1·220	24·32	29·76	0·3631	76·16	22·67
45	1·225	24·82	30·37	0·3720	76·48	23·23
46	1·230	25·32	30·98	0·3810	76·79	23·79

SPECIFIC GRAVITY OF SULPHURIC ACID—*Continued.*

Degrees Twaddell.	Specific gravity d 15°/4°.	100 parts by weight contain		Kilos H_2SO_4 per litre.	1 Cubic foot of acid	
		SO_3.	H_2SO_4.		weighs lb. avoir.	contains lb. H_2SO_4.
47	1·235	25·81	31·58	0·3900	77·10	24·35
48	1·240	26·30	32·18	0·3990	77·41	24·91
49	1·245	26·79	32·78	0·4081	77·72	25·48
50	1·250	27·28	33·38	0·4172	78·04	26·05
51	1·255	27·77	33·98	0 4264	78·35	26·62
52	1·260	28·25	34·57	0·4356	78·66	27·19
53	1·265	28·74	35·17	0·4449	78·97	27·77
54	1·270	29·23	35·76	0·4515	79·29	28·35
55	1·275	29·71	36·35	0·4635	79·60	28·93
56	1·280	30·19	36·94	0·4728	79·91	29·52
57	1·285	30·67	37·52	0·4821	80·22	30·10
58	1·290	31·14	38·10	0·4919	80·53	30·68
59	1·295	31·61	38·68	0·5009	80·85	31·27
60	1·300	32·08	39·25	0·5102	81·16	31·85
61	1·305	32·56	39·83	0·5198	81·47	32·45
62	1·310	33·02	40·40	0·5292	81·78	33·04
63	1·315	33·48	40·97	0·5388	82·09	33·63
64	1·320	33·94	41·53	0·5482	82·41	34·22
65	1·325	34·40	42·09	0·5577	82·72	34·82
66	1·330	34·86	42·65	0·5672	83 03	35·41
67	1·335	35·31	43·20	0·5767	83·34	36·00
68	1·340	35·76	43·75	0·5862	83·66	36·60
69	1·345	36·21	44·30	0·5958	83·97	37·20
70	1·350	36·66	44·85	0·6055	84·28	37·80
71	1·355	37·10	45·39	0·6150	84·59	38·40
72	1·360	37·54	45·93	0·6246	84·90	39·00
73	1·365	37·97	46·46	0·6342	85·22	39·59
74	1·870	38·40	46·99	0·6438	85·53	40·19
75	1·375	38·84	47·52	0·6534	85·84	40·79
76	1·380	39·26	48·04	0·6629	86·15	41·39
77	1·385	39·69	48·56	0·6726	86·47	41·99
78	1·390	40·10	49·07	0·6821	86·78	42·58
79	1·395	40·53	49·59	0·6918	87·09	43·19
80	1·400	40·95	50·10	0·7014	87·40	43·79
81	1·405	41·36	50·61	0·7111	87·71	44·39
82	1·410	41·78	51·12	0·7208	88·03	45·00
83	1·415	42·89	51·62	0·7304	88·34	45·60
84	1·420	42·60	52·12	0·7401	88·65	46·20
85	1·425	43·01	52·62	0·7498	88·96	46·81
86	1·430	13·41	53·11	0·7595	89·27	47·41
87	1·435	43·81	53·60	0·7692	89·59	48·02
88	1·440	44·21	54·09	0·7780	89·90	48·63
89	1·445	44·61	54·58	0·7887	90·21	49·24
90	1·450	45·00	55·06	0·7984	90·52	49·84
91	1·455	45·39	55·54	0·8081	90·84	50·45
92	1·460	45·79	56·02	0·8179	91·15	51·06

SPECIFIC GRAVITY OF SULPHURIC ACID—*Continued.*

Degrees Twaddell.	Specific gravity d 15°/4°.	100 parts by weight contain SO_3.	100 parts by weight contain H_2SO_4.	Kilos H_2SO_4 per litre.	1 Cubic foot of acid weighs lb. avoir.	1 Cubic foot of acid contains lb. H_2SO_4
93	1·465	46·18	56·50	0·8277	91·46	51·67
94	1·470	46·56	56·97	0·8375	91·77	52·28
95	1·475	46·95	57·44	0·8472	92·08	52·89
96	1·480	47·33	57·91	0·8571	92·40	53·51
97	1·485	47·71	58·38	0·8669	92·71	54·12
98	1·490	48·10	58·85	0·8769	93·02	54·74
99	1·495	48·48	59·32	0·8868	93·33	55·36
100	1·500	48·86	59·78	0·8967	93·64	55·98
101	1·505	49·23	60·24	0·9066	93·96	56·60
102	1·510	49·61	60·70	0·9166	94·27	57·22
103	1·515	49·99	61·16	0·9266	94·58	57·85
104	1·520	50·35	61·61	0·9365	94·89	58·46
105	1·525	50·73	62·07	0·9466	95·21	59·09
106	1·530	51·10	62·52	0·9566	95·52	59·72
107	1·535	51·47	62·97	0·9666	95·83	60·34
108	1·540	51·83	63·42	0·9767	96·14	60·97
109	1·545	52·20	63·87	0·9868	96·45	61·60
110	1·550	52·56	64·31	0·9968	96·77	62·23
111	1·555	52·92	64·75	1·0069	97·08	62·86
112	1·560	53·28	65·19	1·0170	97·39	63·49
113	1·565	53·64	65·63	1·0271	97·70	64·12
114	1·570	54 01	66·08	1·0375	98·01	64·77
115	1·575	54·37	66·52	1·0477	98 33	65·41
116	1·580	54·73	66 96	1·0580	98·64	66·05
117	1·585	55·09	67·40	1·0683	98·95	66·69
118	1·590	55·44	67·83	1·0785	99·26	67·33
119	1·595	55·79	68·26	1·0887	99·58	67·97
120	1·600	56·14	68 69	1·0990	99·89	68·61
121	1·605	56·49	69·12	1·1094	100·20	69·26
122	1·610	56·84	69·55	1·1198	100·51	69·91
123	1·615	57·19	69·98	1·1302	100·82	70·56
124	1 620	57·46	70·41	1·1406	101·14	71·21
125	1·625	57·89	70·83	1·1510	101·45	71·86
126	1·630	58·25	71·27	1·1617	101·76	72·52
127	1·635	58·60	71·70	1·1723	102·07	73·19
128	1·640	58·95	72·13	1·1829	102·38	73·85
129	1·645	59·30	72·55	1·1934	102·70	74·51
130	1·650	59·64	72·97	1·2040	103·01	75·17
131	1·655	59·99	73·40	1·2148	103·32	75·84
132	1·660	60·33	73·82	1·2254	103·63	76·50
133	1·665	60·68	74·24	1·2361	103·95	77·17
134	1·670	61·02	74·66	1·2468	104·26	77·84
135	1·675	61·37	75·09	1·2578	104·57	78·52
136	1·680	61·71	75·51	1·2686	104·88	79·20
137	1·685	62·06	75·93	1·2794	105·19	79·87
138	1·690	62·41	76·36	1·2905	105·51	80·56

SPECIFIC GRAVITY OF SULPHURIC ACID—*Continued.*

Degrees Twaddell.	Specific gravity d 15°/4°.	100 parts by weight contain		Kilos H_2SO_4 per litre.	1 Cubic foot of acid	
		SO_3.	H_2SO_4		weighs lb. avoir.	contains lb. H_2SO_4.
139	1·695	62·75	76·78	1·3014	105·82	81·25
140	1·700	63·10	77·21	1·3126	106·13	81·94
141	1·705	63·45	77·63	1·3236	106·44	82·63
142	1·710	63·80	78·06	1·3348	106·75	83·33
143	1·715	64·15	78·49	1·3461	107·07	84·04
144	1·720	64·50	78·92	1·3574	107·38	84·74
145	1·725	64·85	79·35	1·3688	107·69	85·45
146	1·730	65·21	79·79	1·3804	108·00	86·18
147	1·735	65·57	80·23	1·3920	108·32	86·90
148	1·740	65·94	80·68	1·4038	108·63	87·64
149	1·745	66·31	81·14	1·4159	108·94	88·39
150	1·750	66·69	81·60	1·4280	109·25	89·15
151	1·755	67·08	82·07	1·4403	109·56	89·92
152	1·760	67·46	82·54	1·4527	109·88	90·69
153	1·765	67·85	83·02	1·4653	110·19	91·48
154	1·770	68·24	83·50	1·4779	110·50	92·27
155	1·775	68·68	84·03	1·4915	110·81	93·12
156	1·780	69·11	84·56	1·5052	111·12	93·97
157	1·785	69·57	85·12	1·5194	111·44	94·86
158	1·790	70·03	85·69	1·5338	111·75	95·76
159	1·795	70·53	86·30	1·5491	112·06	96·71
160	1·800	71·04	86·92	1·5646	112·37	97·67
161	1·805	71·60	87·61	1·5814	112·69	98·72
162	1·810	72·21	88·35	1·5991	113·00	99·83
163	1·815	72·87	89·16	1·6182	113·310	101·03
164	1·820	73·59	90·04	1·6387	113·62	102·31

DENSITY OF SOLUTIONS CONTAINING ABOVE 90 PER CENT. OF SULPHURIC ACID.

Per cent. H_2SO_4 .	91	92	93	94	95
Density d. $\frac{15^\circ}{4^\circ}$.	1·8248	1·8293	1·8331	1·8363	1·8388
Per cent. H_2SO_4 .	96	97	98	99	100
Density d. $\frac{15^\circ}{4^\circ}$.	1·8406	1·8466	1·8411	1·8393	1·8357

2. TABLE FOR REDUCING THE SPECIFIC GRAVITIES OF SULPHURIC ACID OF VARIOUS STRENGTHS TO ANY OTHER TEMPERATURE (DEGREES C.).

0°.	5°.	10°.	15°.	20°.	25°.	30°.	35°.	40°.	45°.	50°.
1·857	1·852	1·846	1·840	1·835	1·830	1·825	1·821	1·816	1·811	1·806
1·847	1·841	1·836	1·830	1·825	1·820	1·815	1·810	1·805	1·800	1·795
1·837	1·831	1·825	1·820	1·815	1·809	1·804	1·799	1·794	1·789	1·784
1·827	1·821	1·815	1·810	1·805	1·799	1·793	1·788	1·783	1·778	1·773
1·817	1·811	1·805	1·800	1·794	1·788	1·783	1·777	1·772	1·766	1·761
1·807	1·801	1·796	1·790	1·784	1·778	1·773	1·767	1·762	1·756	1·751
1·797	1·791	1·786	1·780	1·774	1·768	1·763	1·757	1·752	1·746	1·741
1·786	1·781	1·776	1·770	1·765	1·759	1·754	1·748	1·743	1·737	1·732
1·776	1·770	1·765	1·760	1·755	1·749	1·744	1·738	1·733	1·728	1·723
1·765	1·760	1·755	1·750	1·745	1·740	1·735	1·730	1·725	1·720	1·715
1·754	1·750	1·745	1·740	1·735	1·730	1·726	1·721	1·716	1·711	1·706
1·744	1·740	1·735	1·730	1·725	1·720	1·716	1·711	1·706	1·701	1·696
1·734	1·730	1·725	1·720	1·715	1·710	1·706	1·701	1·696	1·691	1·686
1·724	1·720	1·715	1·710	1·705	1·700	1·696	1·691	1·686	1·681	1·676
1·714	1·710	1·705	1·700	1·695	1·690	1·686	1·681	1·676	1·671	1·667
1·704	1·700	1·695	1·690	1·685	1·680	1·676	1·671	1·666	1·661	1·656
1·694	1·690	1·685	1·680	1·675	1·670	1·666	1·661	1·656	1·651	1·646
1·684	1·680	1·675	1·670	1·665	1·660	1·656	1·651	1·646	1·641	1·637
1·674	1·670	1·665	1·660	1·655	1·650	1·646	1·641	1·636	1·632	1·628
1·664	1·660	1·655	1·650	1·645	1·640	1·636	1·632	1·627	1·622	1·618
1·654	1·650	1·645	1·640	1·635	1·631	1·626	1·622	1·617	1·612	1·608
1·644	1·640	1·635	1·630	1·625	1·621	1·616	1·612	1·607	1·602	1·598
1·634	1·630	1·625	1·620	1·615	1·611	1·606	1·602	1·597	1·592	1·588
1·624	1·620	1·615	1·610	1·605	1·601	1·596	1·592	1·587	1·582	1·578
1·614	1·610	1·605	1·600	1·595	1·591	1·586	1·582	1·577	1·572	1·568
1·604	1·600	1·595	1·590	1·585	1·581	1·576	1·572	1·567	1·562	1·558
1·594	1·589	1·584	1·580	1·575	1·570	1·566	1·562	1·558	1·553	1·548
1·584	1·579	1·574	1·570	1·566	1·561	1·556	1·552	1·548	1·543	1·539
1·574	1·569	1·564	1·560	1·556	1·552	1·547	1·543	1·539	1·534	1·530
1·563	1·558	1·554	1·550	1·546	1·542	1·538	1·534	1·530	1·525	1·521
1·552	1·548	1·544	1·540	1·536	1·532	1·528	1·524	1·520	1·516	1·512
1·542	1·538	1·534	1·530	1·526	1·522	1·518	1·514	1·510	1·506	1·502
1·532	1·528	1·524	1·520	1·516	1·512	1·508	1·504	1·500	1·497	1·492
1·522	1·518	1·514	1·510	1·506	1·502	1·498	1·494	1·490	1·486	1·482
1·512	1·508	1·504	1·500	1·496	1·492	1·488	1·484	1·480	1·476	1·472
1·502	1·498	1·494	1·490	1·486	1·482	1·478	1·474	1·470	1·466	1·462
1·492	1·488	1·484	1·480	1·476	1·472	1·468	1·465	1·461	1·457	1·453
1·482	1·478	1·474	1·470	1·466	1·462	1·458	1·455	1·451	1·447	1·443
1·472	1·468	1·464	1·460	1·456	1·452	1·448	1·445	1·442	1·438	1·434
1·462	1·458	1·454	1·450	1·446	1·442	1·438	1·435	1·432	1·429	1·425
1·452	1·448	1·444	1·440	1·436	1·432	1·429	1·426	1·423	1·420	1·416
1·442	1·438	1·434	1·430	1·426	1·422	1·419	1·416	1·413	1·409	1·405
1·432	1·428	1·424	1·420	1·416	1·413	1·410	1·406	1·402	1·398	1·394
1·422	1·418	1·414	1·410	1·406	1·403	1·399	1·396	1·392	1·388	1·384
1·412	1·408	1·404	1·400	1·396	1·393	1·389	1·386	1·382	1·378	1·374
1·402	1·398	1·394	1·390	1·386	1·383	1·379	1·375	1·372	1·368	1·364
1·392	1·388	1·384	1·380	1·376	1·373	1·370	1·365	1·362	1·359	1·355
1·382	1·378	1·374	1·370	1·366	1·363	1·360	1·355	1·352	1·349	1·346
1·372	1·368	1·364	1·360	1·356	1·353	1·350	1·347	1·344	1·340	1·336
1·362	1·358	1·354	1·350	1·346	1·343	1·340	1·337	1·334	1·330	1·326

TABLE 2—*Continued.*

55°.	60°.	65°.	70°.	75°.	80°.	85°.	90°.	95°.	100°.
1·801	1·796	1·792	1·787	1·782	1·778	1·774	1·770	1·766	1·762
1·790	1·787	1·781	1·776	1·770	1·766	1·762	1·757	1·752	1·748
1·779	1·774	1·769	1·764	1·759	1·754	1·749	1·744	1·739	1·734
1·767	1·762	1·757	1·752	1·747	1·741	1·736	1·731	1·726	1·721
1·755	1·750	1·744	1·739	1·734	1·729	1·724	1·719	1·714	1·708
1·746	1·741	1·735	1·730	1·725	1·720	1·715	1·710	1·705	1·700
1·736	1·731	1·726	1·721	1·716	1·712	1·707	1·702	1·697	1·692
1·727	1·722	1·717	1·712	1·707	1·702	1·697	1·693	1·688	1·683
1·718	1·713	1·708	1·703	1·698	1·693	1·688	1·684	1·679	1·674
1·710	1·705	1·700	1·695	1·699	1·685	1·681	1·676	1·671	1·667
1·702	1·697	1·692	1·688	1·683	1·678	1·674	1·669	1·664	1·660
1·692	1·687	1·683	1·678	1·673	1·668	1·664	1·659	1·654	1·650
1·682	1·677	1·673	1·668	1·663	1·659	1·654	1·649	1·644	1·640
1·672	1·667	1·663	1·658	1·653	1·649	1·644	1·639	1·635	1·630
1·662	1·657	1·653	1·648	1·644	1·639	1·634	1·630	1·625	1·620
1·652	1·647	1·642	1·638	1·634	1·630	1·625	1·620	1·615	1·610
1·642	1·637	1·632	1·628	1·624	1·620	1·615	1·611	1·606	1·602
1·633	1·628	1·623	1·619	1·615	1·611	1·606	1·602	1·597	1·593
1·623	1·619	1·614	1·610	1·606	1·602	1·597	1·593	1·588	1·584
1·614	1·610	1·605	1·600	1·596	1·592	1·588	1·583	1·579	1·575
1·604	1·600	1·595	1·591	1·586	1·582	1·578	1·574	1·570	1·565
1·594	1·590	1·585	1·581	1·577	1·573	1·569	1·565	1·561	1·556
1·584	1·580	1·576	1·572	1·568	1·564	1·560	1·556	1·552	1·547
1·574	1·570	1·566	1·562	1·558	1·554	1·550	1·546	1·542	1·537
1·564	1·560	1·556	1·552	1·548	1·544	1·540	1·536	1·531	1·527
1·554	1·550	1·545	1·541	1·537	1·533	1·529	1·525	1·521	1·516
1·544	1·539	1·535	1·531	1·527	1·523	1·519	1·515	1·510	1·506
1·535	1·531	1·526	1·522	1·518	1·513	1·509	1·505	1·501	1·496
1·526	1·522	1·517	1·513	1·509	1·504	1·500	1·496	1·492	1·487
1·517	1·513	1·509	1·504	1·500	1·495	1·491	1·487	1·483	1·478
1·508	1·504	1·500	1·495	1·491	1·486	1·482	1·478	1·473	1·469
1·498	1·494	1·490	1·485	1·481	1·476	1·472	1·468	1·463	1·459
1·488	1·484	1·480	1·476	1·472	1·467	1·462	1·458	1·453	1·449
1·478	1·474	1·470	1·466	1·462	1·457	1·452	1·448	1·443	1·438
1·468	1·464	1·460	1·455	1·451	1·446	1·442	1·438	1·433	1·428
1·458	1·454	1·450	1·442	1·441	1·437	1·433	1·429	1·424	1·419
1·449	1·445	1·441	1·436	1·432	1·428	1·424	1·419	1·414	1·410
1·439	1·435	1·431	1·427	1·423	1·418	1·414	1·409	1·405	1·401
1·430	1·426	1·422	1·418	1·413	1·409	1·405	1·400	1·396	1·392
1·421	1·417	1·413	1·409	1·404	1·400	1·396	1·391	1·387	1·383
1·412	1·407	1·403	1·399	1·395	1·391	1·386	1·382	1·378	1·374
1·401	1·397	1·393	1·389	1·385	1·380	1·376	1·372	1·368	1·364
1·390	1·386	1·382	1·378	1·374	1·370	1·366	1·362	1·358	1·353
1·380	1·376	1·372	1·368	1·364	1·360	1·356	1·352	1·348	1·343
1·370	1·366	1·362	1·358	1·354	1·350	1·346	1·342	1·338	1·333
1·360	1·356	1·352	1·348	..	..	..	..	..	..
1·351	1·346	1·342	1·338	..	..	..	..	..	..
1·342	1·337	1·334	1·329	..	..	..	..	..	..
1·332	1·327	1·323	1·319	..	..	..	..	..	..
1·322	1·317	1·314	1·310	..	..	..	..	..	..

TABLE 2—*Continued.*

0°.	5°.	10°.	15°.	20°.	25°.	30°	35°	40°	45°.	50°.
1·352	1·348	1·344	1·340	1·336	1·333	1·330	1·327	1·324	1·320	1·316
1·341	1·337	1·333	1·330	1·327	1·324	1·321	1·318	1·314	1·310	1·306
1·330	1·326	1·323	1·320	1·317	1·314	1·311	1·308	1·304	1·301	1·297
1·320	1·316	1·313	1·310	1·307	1·304	1·301	1·298	1·294	1·291	1·287
1·310	1·306	1·303	1·300	1·297	1·294	1·291	1·288	1·284	1·281	1·277
1·300	1·296	1·293	1·290	1·287	1·284	1·280	1·277	1·274	1·270	1·267
1·290	1·286	1·283	1·280	1·277	1·274	1·270	1·267	1·264	1·260	1·256
1·280	1·276	1·273	1·270	1·267	1·264	1·260	1·257	1·254	1·250	1·246
1·270	1·266	1·263	1·260	1·257	1·254	1·251	1·248	1·245	1·241	1·237
1·260	1·256	1·253	1·250	1·247	1·244	1·241	1·238	1·235	1·231	1·227
1·250	1·246	1·243	1·240	1·237	1·234	1·230	1·227	1·224	1·220	1·217
1·240	1·236	1·233	1·230	1·227	1·224	1·220	1·217	1·214	1·210	1·207
1·230	1·226	1·223	1·220	1·217	1·214	1·210	1·207	1·204	1·200	1·197
1·220	1·216	1·213	1·210	1·206	1·204	1·200	1·197	1·194	1·190	1·187
1·210	1·206	1·203	1·200	1·196	1·193	1·190	1·186	1·183	1·180	1·176
1·200	1·196	1·193	1·190	1·186	1·183	1·180	1·176	1·173	1·169	1·165
1·190	1·186	1·183	1·180	1·176	1·173	1·170	1·166	1·163	1·159	1·155
1·180	1·176	1·173	1·170	1·166	1·163	1·160	1·156	1·153	1·149	1·146
1·169	1·166	1·163	1·160	1·157	1·153	1·150	1·147	1·144	1·141	1·138
1·159	1·156	1·153	1·150	1·147	1·143	1·140	1·137	1·134	1·131	1·128
1·149	1·146	1·143	1·140	1·137	1·134	1·131	1·128	1·125	1·122	1·119
1·138	1·135	1·133	1·130	1·127	1·125	1·122	1·119	1·116	1·113	1·110
1·128	1·125	1·123	1·120	1·118	1·115	1·112	1·110	1·107	1·104	1·102
1·118	1·115	1·113	1·110	1·108	1·105	1·102	1·100	1·097	1·094	1·092
1·108	1·105	1·103	1·100	1·097	1·094	1·092	1·090	1·087	1·084	1·082
1·098	1·095	1·093	1·090	1·087	1·084	1·082	1·080	1·077	1·074	1·072
1·088	1·085	1·083	1·080	1·077	1·074	1·072	1·070	1·067	1·064	1·062
1·078	1·075	1·073	1·070	1·067	1·064	1·062	1·060	1·057	1·054	1·052
1·068	1·065	1·063	1·060	1·057	1·054	1·052	1·050	1·048	1·044	1·042
1·058	1·055	1·053	1·050	1·047	1·044	1·042	1·040	1·038	1·034	1·032
1·048	1·045	1·043	1·040	1·037	1·034	1·032	1·030	1·028	1·024	1·022
1·038	1·035	1·033	1·030	1·027	1·024	1·022	1·020	1·018	1·014	1·012
1·028	1·025	1·023	1·020	1·017	1·014	1·012	1·010	1·008	1·004	1·002
1·018	1·015	1·013	1·010	1·007	1·004	1·002	1·000	0·998	0·994	0·992

TABLE 2—*Continued.*

55°.	60°.	65°.	70°.	75°.	80°.	85°.	90°.	95°.	100°.
1·312	1·308	1·304	1·300	..	..	..	..	..	..
1·302	1·298	1·294	1·290	..	..	..	..	..	..
1·293	1·289	1·284	1·280	..	..	..	..	..	..
1·283	1·279	1·274	1·270	..	..	..	..	..	..
1·273	1·269	1·265	1·260	..	..	..	..	..	..
1·263	1·259	1·255	1·250	..	..	..	..	..	..
1·252	1·248	1·244	1·240	..	..	..	..	..	..
1·242	1·238	1·234	1·230	..	..	..	..	..	..
1·233	1·228	1·224	1·220	..	..	..	..	..	..
1·223	1·218	1·214	1·210	..	..	..	..	..	..
1·210	1·209	1·204	1·200	..	..	..	..	..	..
1·204	1·200	1·195	1·190	..	..	..	..	..	..
1·194	1·190	1·185	1·180	..	..	..	..	..	..
1·183	1·179	1·175	1·170	..	..	..	..	..	..
1·172	1·168	1·164	1·160	..	..	..	..	..	..
1·162	1·158	1·154	1·150	..	..	..	..	..	..
1·152	1·148	1·144	1·140	..	..	..	..	..	..
1·143	1·139	1·135	1·131	..	..	..	..	..	..
1·135	1·131	1·127	1·123	..	..	..	..	..	..
1·125	1·122	1·118	1·114	..	..	..	..	..	..
1·116	1·113	1·109	1·106	.	..	..	..	..	..
1·107	1·104	1·100	1·097	..	..	..	..	..	..
1·099	1·096	1·092	1·088	..	..	..	..	..	..
1·089	1·086	1·082	1·078	..	..	..	..	..	..
1·079	1·075	1·072	1·068	..	..	..	..	..	..
1·069	1·065	1·062	1·058	..	..	..	..	..	..
1·059	1·055	1·052	1·048	..	..	..	..	..	..
1·049	1·045	1·042	1·038	..	..	..	..	..	..
1·036	1·035	1·032	1·028	..	..	..	..	..	..
1·039	1·025	1·022	1·018	..	..	..	..	..	..
1·019	1·015	1·012	1·008	..	..	..	..	..	..
1·009	1·005	1·002	0·998	..	..	..	..	..	..
0·999	0·995	0·992	0·988	..	..	..	..	..	..
0·989	0·985	0·982	0·978	..	..	..	..	..	..

3. SPECIFIC GRAVITIES OF COMMERCIAL (NORDHAUSEN) OIL OF VITRIOL.

(Messel, *Journ. Soc. Chem. Ind.*, 1885, p. 573.

Specimens.	Percentage of SO_3.	Specific Gravity.	
		At 80° F. = 26·6° C.	At 60° F. = 15·5° C.
Liquid	8·3	1·842	1·852
Do.	30·0	1·930	1·940
Crystalline mass, resembling nitre .	40·0	1·956	1·970
Do. do.	44·5	1·961	1·975
Do. do.	46·2	1·963	1·977
...	59·4	1·980	1·994
Liquid	60·8	1·992	2·006
Do.	65·0	1·992	2·006
Do.	69·4	2·002	2·016
Crystallised	72·8	1·984	1·988
Do.	80·0	1·959	1·973
Do.	82·0	1·953	1·967

4. FREEZING AND MELTING POINTS OF SULPHURIC ACID.*

Specific Gravity at 15°.	Freezing Point.	Melting Point.
1·671	Liquid at −20°	...
1·691	Liquid at −20°	...
1·712	Liquid at −20°	...
1·727	−7·5°	−7·5°
1·732	−8·5°	−8·5°
1·749	−0·2°	+4·5°
1·767	+1·6°	+6·5°
1·778	+8·5°	+8·5°
1·790	+4·5°	+8·0°
1·807	−9·0°	−6·0°
1·822	Liquid at −20°	...
1·840	Liquid at −20°	...

* Lunge, *Berichte d. deutsch. chem. Ges.*, 1881, s. 2649.

5. BOILING POINTS OF SULPHURIC ACID.

(Lunge, *Ber. d. d. chem. Ges.*, 11, 370.)

Per Cent. H_2SO_4.	Specific Gravity.	Boiling Point.	Per Cent. H_2SO_4.	Specific Gravity.	Boiling Point.	Per Cent. H_2SO_4.	Specific Gravity.	Boiling Point.
		Degrees.			Degrees.			Degrees.
5	1·031	101	56	1·459	133	82	1·758	218·5
10	1·069	102	60	1·503	141·5	84	1·773	227
15	1·107	103·5	62·5	1·530	147	86	1·791	238·5
20	1·147	105	65	1·557	153·5	88	1·807	251·5
25	1·184	106·5	67·5	1·585	161	90	1·818	262·5
30	1·224	108	70	1·615	170	91	1·824	268
35	1·265	110	72	1·639	174·5	92	1·830	274·5
40	1·307	114	74	1·661	180·5	93	1·834	281·5
45	1·352	118·5	76	1·688	189	94	1·837	288·5
50	1·399	124	78	1·710	199	95	1·840	295
53	1·428	128·5	80	1·733	207			

Monohydrate (100 per cent.) boils at 338° (Marignac).

6. BOILING POINTS OF OLEUM (FUMING SULPHURIC ACID).

Per cent. free SO_3.	Per cent. total SO_3.	Boiling Point °C.	Barometric Pressure, mm.
3·64	82·3	212	759
9·63	83·4	170	759
26·23	86·45	125	759
42·84	89·5	92	759
63·20	93·24	60	759
97·2	99·5	43	759

7. TOTAL VAPOUR PRESSURE OF SULPHURIC

Percentage H_2SO_4 Temperature.	24·92.	30·46.	35·54.	41·01.	48·37.	54·24.	62·81.	70·78
55° C	95·5	86·8	78·2	...	...	...	...	...
60	120·7	111·0	100·1	84·2	59·8	44·1	...	...
65	153·7	140·6	126·8	107·4	79·0	57·3	...	...
70	192·7	176·6	159·5	136·5	100·4	74·0	35·4	...
75	240·2	219·8	199·0	171·6	126·4	94·1	45·9	...
80	295·1	271·3	245·0	211·8	157 8	118·1	58·0	...
85	363·3	332·8	301·5	261·3	195·9	146·4	73·6	...
90	439·1	403·4	366·0	317·2	241·2	182·9	92·3	35·5
95	532·6	488·2	445·4	386·0	293·5	223·8	115·8	44·8
100	640·8	589·9	537·7	465·8	355·6	267·4	140·0	57·0
105	759·6	762·7	646·2	560 2	429·8	325·5	171·5	71·0
	(104·3)	(107·11)						
110	...	...	757·2	670·2	515·4	391·9	210·8	89·0
			(109·56)					
115	...	...	...	749·4	621·9	470·9	255·3	...
				(113·21)				
120	...	...	...	...	754·0	561·8	308·0	140·4
					(120·82)			
125	...	...	...	...	...	662·6	368·5	171·3
130	...	...	...	...	...	753·7	438·3	205·2
						(128·7)		
135	...	...	...	...	...	...	517·6	246·3
140	...	...	...	...	...	...	612·8	291·2
145	...	...	...	...	...	...	745·0	355·4
							(145·85)	
150	...	...	...	...	...	...	...	426·9
155	...	...	...	...	...	...	...	501·5
160	...	...	...	...	...	...	...	589·0
165	...	...	...	..	...	...	...	740·05
								(166·47)
170	...	...	...	...	...	...	...	...
175	...	...	...	...	...	...	...	...
180	...	...	...	...	...	...	...	...
185	...	...	...	...	...	...	...	...
190	...	...	...	...	...	...	...	...
195	...	...	...	...	...	...	...	...
200	...	...	...	...	...	...	...	...
205	...	...	...	...	...	...	...	...
210	...	...	...	...	...	...	...	...
215	...	...	...	...	...	...	...	...
220	...	...	...	...	...	...	...	...
225	...	...	...	...	...	...	...	...
230	...		...	...	...	...	...	...
		...						
235	...	...	...	...	...	...	...	...

8. SPECIFIC GRAVITIES AND PERCENTAGE OF FUMING OIL OF VITRIOL (OLEUM) AT DIFFERENT TEMPERATURES.

Density at					SO_3 Per Cent.
15°.	20°.	25°.	30°.	35°.	
1·8417	1·8371	1·8323	1·8287	1·8240	76·67
1·8427	1·8378	1·8333	1·8295	1·8249	77·49
1·8428	1·8388	1·8351	1·8302	1·8255	78·34
1·8437	1·8390	1·8346	1·8300	1·8257	79·04
1·8427	1·8386	1·8351	1·8297	1·8250	79·99
1·8420	1·8372	1·8326	1·8281	1·8234	80·46
1·8398	1·8350	1·8305	1·8263	1·8218	80·94
1·8446	1·8400	1·8353	1·8307	1·8262	81·37
1·8509	1·8466	1·8418	1·8371	1·8324	81·91
1·8571	1·8522	1·8476	1·8432	1·8385	82·17
1·8697	1·8647	1·8595	1·8545	1·8498	82·94
1·8790	1·8742	1·8687	1·8640	1·8592	83·25
1·8875	1·8823	1·8767	1·8713	1·8661	83·84
1·8942	1·8888	1·8833	1·8775	1·8722	84·12
1·8990	1·8940	1·8890	1·8830	1·8772	84·33
1·9034	1·8984	1·8930	1·8874	1·8820	84·67
1·9072	1·9021	1·8950	1·8900	1·8845	84·82
1·9095	1·9042	1·8986	1·8932	1·8866	84·99
1·9121	1·9053	1·8993	1·8948	1·8892	85·14
1·9250	1·9193	1·9135	1·9082	1·9023	85·54
1·9290	1·9236	1·9183	1·9129	1·9073	85·68
1·9368	1·9310	1·9250	1·9187	1·9122	85·88
1·9447	1·9392	1·9334	1·9279	1·9222	86·51
1·9520	1·9465	1·9402	1·9338	1·9278	86·72
1·9584	1·9528	1·9466	1·9406	1·9340	87·03
1·9632	1·9573	1·9518	1·9457	1·9398	87·46
cryst.	cryst.	1·9740	1·9666	1·9740	88·00

The above table is only intended for control in works, but not for commercial purposes, because the specific gravity is anything but a certain guide for the percentage of Nordhausen acid, and altogether fails as such, for strengths just below the monohydrate. The table was not made for chemically pure acids, but for commercial acid.

9. FUSING POINTS* OF SULPHURIC ACID AND OF NORDHAUSEN OIL OF VITRIOL. (KNIETSCH.)

Sulphuric Acid.				Nordhausen Oil of Vitriol.	
Percentage of SO_3 (as H_2SO_4).	Fusing Point. °C.	Percentage of SO_3 (as H_2SO_4).	Fusing Point. °C.	Percentage of *free* SO_3.	Fusing Point. °C.
Per cent.		Per cent.		Per cent.	
1 SO_3	− 0·6	69 SO_3	+ 7·0	0 SO_3	+ 10·0
2 ,,	− 1·0	70 ,,	+ 4·0	5 ,,	+ 3·5
3 ,,	− 1·7	71 ,,	− 1·0	10 ,,	− 4·8
4 ,,	− 2·0	72 ,,	− 2·0	15 ,,	− 11·2
5 ,,	− 2·7	73 ,,	− 16·2	20 ,,	− 11·0
6 ,,	− 3·6	74 ,,	− 25·0	25 ,,	− 0·6
7 ,,	− 4·4	75 ,,	− 34·0	30 ,,	+ 15·2
8 ,,	− 5·3	76 } 66°	− 32·0	35 ,,	+ 26·0
9 ,,	− 6·0	77 } Bé	− 33·0	40 ,,	+ 33·8
10 ,,	− 6·7	78 }	− 16·5	45 ,,	+ 34·8
11 ,,	− 7·2	79 ,,	− 5·2	50 ,,	+ 28·5
12 ,,	− 7·9	80 ,,	+ 3·0	55 ,,	+ 18·4
13 ,,	− 8·2	81 ,,	+ 7·0	60 ,,	+ 0·7
14 ,,	− 9·0	82 ,,	+ 8·2	65 ,,	+ 0·8
15 ,,	− 9·3	83 ,,	− 0·8	70 ,,	+ 9·0
16 ,,	− 9·8	84 ,,	− 9·2	75 ,,	+ 17·2
17 ,,	− 11·4	85 ,,	− 11·0	80 ,,	+ 22·0
18 ,,	− 13·2	86 ,,	− 2·2	85 ,,	+ 33·0 (27)†
19 ,,	− 15·2	87 ,,	+ 13·5	90 ,,	+ 34·0 (25)
20 ,,	− 17·1	88 ,,	+ 26·0	95 ,,	+ 36·0 (26)
21 ,,	− 22·5	89 ,,	+ 34·2	100 ,,	+ 40·0 (15)
22 ,,	− 31·0	90 ,,	+ 34·2		
23 ,,	− 40·1	91 ,,	+ 25·8		
... ,, }	below	92 ,,	+ 14·2		
... ,, }	− 40	93 ,,	+ 0·8		
61 ,,	− 40·0	94 ,,	+ 4·5		
62 ,,	− 20·0	95 ,,	+ 14·8		
63 } 60°	− 11·5	96 ,,	+ 20·3		
64 } Bé	− 4·8	97 ,,	+ 29·2		
65 ,,	− 4·2	98 ,,	+ 33·8		
66 ,,	+ 1·2	99 ,,	+ 36·0		
67 } 62°	+ 8·0	100 ,,	+ 40·0		
68 } Bé	+ 8·0				

* "Fusing Point" is understood to be the temperature to which the mercury of the thermometer, dipping into the solidifying liquid, rises and at which it remains *constant*. It should be noticed that *large* quantities of Nordhausen oil of vitriol, such as exist in transportation vessels, frequently do not behave in accord with the above data, because during the carriage and storage a separation often takes place in the acid, crystals of a different concentration being formed, which of course possess a correspondingly different fusing point.

† The figures in parentheses signify the fusing points of *freshly* made Nordhausen oil of vitriol, which has not polymerised.

10. PERCENTAGE OF SO_3 IN OLEUM.

Per cent. Free SO_3.	Equivalent per cent. H_2SO_4.	Per cent. Total SO_3.	Per cent. Free SO_3.	Equivalent per cent. H_2SO_4.	Per cent. Total SO_3.	Per cent. Free SO_3.	Equivalent per cent. H_2SO_4.	Per cent. Total SO_3.
0	100·00	81·63	34	107·65	87·88	68	115·30	94·12
1	100·23	81·82	35	107·88	88·06	69	115·53	94·31
2	100·45	82·00	36	108·10	88·25	70	115·75	94·49
3	100·68	82·18	37	108·33	88·43	71	115·98	94·67
4	100·90	82·37	38	108·55	88·61	72	116·20	94·86
5	101·13	82·55	39	108·78	88·80	73	116·43	95·04
6	101·35	82·73	40	109·00	88·98	74	116·65	95·22
7	101·58	82·92	41	109·23	89·16	75	116·88	95·41
8	101·80	83·10	42	109·45	89·35	76	117·10	95·59
9	102·03	83·29	43	109·68	89·53	77	117·33	95·78
10	102·25	83·47	44	109·90	89 71	78	117·55	95·96
11	102·48	83·65	45	110·13	89·90	79	117·78	96·14
12	102·70	83·84	46	110·35	90 08	80	118·00	96·33
13	102·93	84·02	47	110·58	90·27	81	118·23	96·51
14	103·15	84·20	48	110·80	90·45	82	118·45	96·69
15	103·38	84·39	49	111·03	90·63	83	118·68	96·88
16	103·60	84·57	50	111·25	90·82	84	118·90	97·06
17	103·83	84·76	51	111·48	91·00	85	119·13	97·24
18	104·05	84·94	52	111·70	91·18	86	119·35	97·43
19	104·28	85·12	53	111·93	91·37	87	119·58	97·61
20	104·50	85·31	54	112·15	91·55	88	119·80	97·80
21	104·73	85·49	55	112·38	91·73	89	120·03	97·98
22	104·95	85·67	56	112·60	91·92	90	120·25	98·16
23	105·18	85·86	57	112·83	92·10	91	120·48	98·35
24	105 40	86·04	58	113·05	92·29	92	120·70	98·53
25	105·63	86·22	59	113·28	92·47	93	120·93	98·71
26	105·85	86·41	60	113·50	92·65	94	121·15	98·90
27	106·08	86·59	61	113·73	92·84	95	121·38	99·08
28	106·30	86·78	62	113·95	93·02	96	121·60	99·28
29	106·53	86·96	63	114·18	93·20	97	121·83	99·45
30	106·75	87·14	64	114·40	93·39	98	122·05	99·63
31	106·98	87·33	65	114·63	93·57	99	122·28	99·82
32	107·20	87·51	66	114·85	93·76	100	122·50	100·00
33	107·43	87·69	67	115·08	93·94	...	...	...

11. SPECIFIC GRAVITY OF LIQUID SULPHUR DIOXIDE.

Temp.	Sp. Gr.	Temp	Sp. Gr.	Temp.	Sp. Gr.
−20°	1·485	10°	1·409	35°	1·344
−10°	1·460	15°	1·396	40°	1·326
−5°	1·448	20°	1·383	50°	1·296
0°	1·435	25°	1·369	60°	1·263
5°	1·422	30°	1·356	...	...

12. SPECIFIC GRAVITY OF SULPHUROUS ACID SOLUTIONS. (Pellett.)

Sulphurous acid in 100 c.c	Specific Gravity.	Sulphurous acid in 100 c.c.	Specific Gravity.
1	1·0075	4	1·0300
2	1·0150	5	1·0375
3	1·0225	6	1·0450

13. The Quantitative Examination of Sulphurous Acid and Sulphites.

The quantitative estimation of free sulphurous acid is made by titration with standard hydroxide, using either phenolphthalein or methyl orange as indicator, but not litmus. With phenolphthalein, the colour change to red is reached when the normal salt Na_2SO_3 is formed, so that 1 c.c. of normal alkali corresponds to 0·03203 g. SO_2, but with methyl orange, the change to yellow is reached at the formation of $NaHSO_3$, so that 1 c.c. of normal alkali corresponds to 0·06406 g. SO_2.

The reducing property of sulphuric acid serves also as a basis for its estimation. The method consists in running the acid into a decinormal iodine solution, 1 c.c. of which indicates 0·003203 g. SO_2.

A combination of the two methods of estimation enables the percentage of normal sulphite, acid sulphite, and free sulphurous acid present in a solution to be estimated.

14. The Quantitative Examination of Free Sulphuric Acid.

The quantitative examination of free sulphuric acid is made by titrating a weighed quantity. It is not sufficiently accurate to measure the acid by a pipette, etc., especially in the case of concentrated acid. The titration is performed by means of standard sodium hydroxide solution, and the results are expressed in terms of H_2SO_4.

Weigh from 2 to 3 g. acid in a glass-tap pipette (Fig. 14, p. 172), after cleaning the latter on the outside; run its contents into at least 100 c.c. water, and weigh the pipette again, *without* washing it out. This enables another pipette full of acid to be taken and tested, without washing and drying the instrument, and so forth. The same procedure is also very well adapted for slightly fuming mixtures of sulphuric and nitric acid, and for Nordhausen oil of vitriol (*cf.* p. 171).

The standard sodium hydroxide solution is "normal," *i.e.* containing 0·04001 g. NaOH per c.c. It is controlled by means of standard hydrochloric acid (0·03647 g. HCl per c.c.), the strength of which has been fixed by pure sodium carbonate.

As indicator, methyl orange is used always in the cold, and so much only is taken that the colour produced is just visible. Nitrous acid destroys this colouring matter, but ordinary commercial acid never contains sufficient to cause any trouble, and even "nitrous vitriol" or fuming nitric acid can be treated with methyl orange, if the indicator is added (or renewed) shortly before the last quantity of alkali has been added; or else an excess of alkali is added, then methyl orange, and titrated back. Nitrous acid behaves towards methyl orange like the strong mineral acids; that is, the change of colour takes place when the compound $NaNO_2$ has been formed.

15. Examination of Sulphuric Acid for other Substances.

(a) *Nitrous Acid* (Nitrososulphuric Acid) is titrated with seminormal permanganate. This can be done without loss of NO by manipulating as follows (Lunge, *Berliner Berichte*, x., 1075):—Put the nitrous vitriol into a burette fitted with a glass tap, run it slowly into a measured quantity of permanganate, diluted with five times its volume of tepid water (30° C. to 40° C.), and agitate continuously till the colour just vanishes. Sometimes during this process a little manganese dioxide is separated, which makes it difficult to recognise the end of the reaction; but this is avoided by keeping the temperature not above 40° and by diluting the permanganate, say to 200 c.c. (The same method holds good for the analysis of *sodium nitrite*, but in this case the permanganate solution must be previously acidulated to such an extent that the $NaNO_2$ solution is immediately decomposed

TABLE FOR ESTIMATING NITROUS VITRIOL.

Employ 50 c.c. of seminormal permanganate. The results are expressed as HNO_3 and $NaNO_3$. The column *y* refers to acid of 140° Tw. as unit :—

Acid consumed.	HNO_3.		$NaNO_3$.		Acid consumed.	HNO_3.		$NaNO_3$.	
y. c.c.	*a*. g. per litre.	*b*. per cent.	*a*. g. per litre.	*b*. per cent.	*y*. c.c.	*a*. g. per litre.	*b*. per cent.	*a*. g. per litre.	*b*. per cent.
10	78·75	4·61	106·29	6·22	36	21·88	1·28	29·53	1·73
11	71·59	4·19	96·63	5·65	37	21·28	1·24	28·72	1·68
12	65·63	3·84	88·58	5·18	38	20·72	1·21	27·97	1·64
13	60·58	3·54	81·76	4·78	39	20·19	1·18	27·25	1·59
14	56·25	3·29	75·92	4·44	40	19·69	1·15	26·53	1·55
15	52·50	3·07	70·86	4·14	41	19·21	1·12	25·83	1·51
16	49·22	2·88	66·43	3·88	42	18·75	1·10	25·31	1·48
17	46·32	2·71	62·52	3·65	43	18·27	1·07	24·66	1·44
18	43·75	2·56	59·05	3·45	44	17·90	1·05	24·16	1·41
19	41·45	2·42	55·95	3·27	45	17·76	1·02	23·57	1·38
20	39·38	2·30	53·15	3·11	46	17·12	1·00	23·11	1·35
21	37·50	2·19	50·61	2·96	47	16·72	0·978	22·57	1·32
22	35·80	2·09	48·32	2·83	48	16·41	0·960	22·15	1·30
23	34·24	2·00	46·21	2·70	49	16·01	0·938	21·65	1·27
24	32·81	1·92	44·28	2·59	50	15·75	0·921	21·26	1·24
25	31·50	1·84	42·52	2·49	55	14·32	0·837	19·33	1·13
26	30·29	1·77	40·88	2·39	60	13·13	0·768	17·72	1·04
27	29·17	1·71	39·37	2·30	65	12·12	0·709	16·36	0·957
28	28·13	1·65	37·97	2·22	70	11·25	0·658	15·18	0·888
29	27·16	1·59	36·66	2·14	75	10·50	0·614	14·17	0·829
30	26·25	1·54	35·43	2·07	80	9·85	0·576	13·29	0·777
31	25·40	1·49	34·28	2·00	85	9·26	0·542	12·50	0·731
32	24·61	1·44	33·22	1·94	90	8·73	0·511	11·78	0·689
33	23·86	1·40	32·20	1·88	95	8·29	0·485	11·19	0·654
34	23·16	1·35	31·26	1·83	100	7·88	0·461	10·64	0·622
35	22·50	1·32	30·37	1·78					

N.B.—The figures in column *a* also indicate 0·01 lb. avoirdupois per gallon, or nearly ounces per cubic foot.

when run into the permanganate.) Each cubic centimetre of the permanganate indicates 0·009502 g. N_2O_3, hence more or less of it is employed, according as to whether an acid containing more or less N_2O_3 is titrated. For chamber acid, employ at most 5 c.c.; for good Gay-Lussac acid, up to 50 c.c. of permanganate. If the quantity of permanganate is called x, and that of the vitriol consumed for decolorising it y, the quantity of N_2O_3 present in grams per litre of acid is :—

$$\frac{9{\cdot}502x}{y}$$

Calculated as $\quad HNO_3 = \dfrac{15{\cdot}75x}{y}$

as $\quad NaNO_3 = \dfrac{21{\cdot}253x}{y}$

The preceding table, p. 163, saves the calculation for all cases in which $x=50$. The column y gives the number of cubic centimetres of nitrous vitriol used, a the percentage in grams per litre, and b the percentage by weight, for acid of 140° Tw. (For other strengths the percentage by weight is calculated by dividing the figures of column a by $10 \times$ specific gravity.)

(b) *Total Nitrogen Acids.*—These are contained in sulphuric acid as N_2O_3, or more correctly as nitrososulphuric acid, $SO_2(OH)(ONO)$, and HNO_3. NO can be present only in minute quantity, and only in absence of HNO_3. N_2O_4 is decomposed by sulphuric acid into nitrososulphuric and nitric acid. The estimation made according to (a) only indicates N_2O_3. The total nitrogen acids are converted into NO by shaking up the nitrous vitriol with mercury; the quantity of NO formed is estimated by volume (Crum's reaction). This is done by Lunge's *Nitrometer*, Fig. 41, p. 165. Fill the graduated limb a with mercury by raising the level tube b; put the three-way tap so that it communicates with any of the openings; run the nitrous vitriol into the top cup of a from a 1 c.c. pipette graduated in $\frac{1}{100}$ c.c., employing only 0·5 c.c. of very strong, but up to 5 c.c. of very weak nitrous vitriol; lower the level tube, open the tap carefully so that the vitriol runs in without any air entering; pour 2 or 3 c.c. of pure strong sulphuric acid, free from nitrogen compounds, into the cup; let this acid enter the nitrometer, and repeat the washing of the cup with 1 or 2 c.c. of pure acid. Start the evolution of gas by taking the tube a out of the clamp, inclining it several times till almost horizontal, and suddenly righting it again, so that mercury and acid are well mixed; shake for one or two minutes till no more gas is evolved. Place the tubes so that the mercury in b is as much higher than that in a as is required for balancing the acid in a; this requires 1 mm. of Hg for $6\frac{1}{2}$ mm. of acid. An exact reading can only be obtained when the gas has attained the temperature of the room and all froth has subsided. Read off the volume of the gas, also a thermometer hung up close by, and the barometer. In order to check the levelling, open the tap, when the level of *a* should not change. If it rises, the pressure has been in excess, and the reading must be increased a little, say by 0·1 c.c. If it sinks, the reverse is the case, *i.e.* always in the opposite sense to the change of level. Another plan is, to put a little acid into the cup before opening the tap. This will be sucked in if the pressure was too low, or raised if too high. With adroit manipulation the reading can then soon be corrected. Finally, lower the graduated tube *a*, lest any air should enter on opening the tap; open the tap, raise the tube *b*,

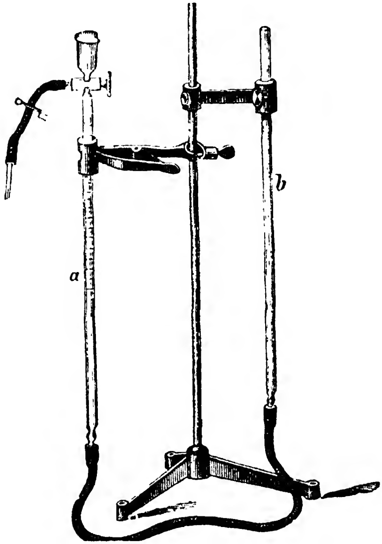

FIG. 11.

force the gas and all acid into the cup, and turn the tap so that the acid flows through into a vessel held below; the last portions are drawn off by blotting-paper. The nitrometer is then ready for the next experiment.

A test must always be made to see whether the glass tap is gas-tight. It will hardly remain so without greasing it occasionally with vaseline, but this ought to be done very slightly, so as to avoid any grease getting into the bore, for if the grease comes in contact with acid, troublesome froth is formed.*

* Such froth may also be formed in the presence of too much water, by the separation of mercuric sulphate, but this hardly ever happens in the case of nitrous vitriol, and even in the analysis of sodium nitrate only when the description given for the estimation is not properly adhered to.

This process is interfered with by the presence of sulphurous acid, the best test for which is the smell. To remove it, the acid is stirred up with a very small quantity of powdered potassium permanganate. Any great excess of this acid makes the process very troublesome and inaccurate.

In highly concentrated acids a notable quantity (up to 3 per cent. by volume) of NO may be dissolved; therefore a little water must be added to such acids in the nitrometer, sufficient to reduce their strength to about 90 per cent. H_2SO_4. The volume of NO read off is reduced to 0° C. and 760 mm. (32° F. and 29·92 in.) by means of the tables, pages 20 *et seq.*, and calculated for the nitrogen compounds present by the table on this page, in which column *a* gives milligrams, *b* per cent. by weight, when employing 1 c.c. acid of 140° Tw.

c.c. NO read off.	*a.* Absolute weight, mg.	*b.* Per cent. by weight, when employing 1 c.c. acid of 140° Tw. in the Nitrometer.
Nitrogen, N_2	0·6256	0·0366
Nitric oxide, NO	1·3403	0·0784
Nitrogen trioxide, N_2O_3	1·6974	0·0993
Nitric acid, real, HNO_3	2·8143	0·1646
Sodium nitrate, $NaNO_3$	3·7963	0·2221
Potassium nitrate, KNO_3	4·5176	0·2642

(Multiples of these figures are given in Table 27, p. 73.)

Nitrometers (and gas-volumeters) should of course be obtained from a reliable dealer, so that the correctness of the graduations and the tightness of the taps can be depended upon.

The reduction to 0° and 760 mm. can be effected without thermometer and barometer, and without the use of any tables, by means of Lunge's *Gas-volumeter*, Fig. 12, which serves also for numerous other analytical operations. It consists of the gas-measuring tube A, the reduction tube B, and the level tube C, all connected by thick rubber tubing with the three-way tube *a*. B and C are held in two arms of the same clamp, so as to be each either individually movable in its own arm, or both together by means of the common clamp. Tube A may be an ordinary nitrometer with three-way tap and funnel; it is, however, best employed merely as a gas-measuring tube, and for some purposes this tube is made to hold upwards of 100 c.c., in which case the upper portion is in the shape of a bulb, the division beginning below this, say, at 90 or 100 c.c. The most convenient shape, which serves both for small and large quantities of gas, is a tube possessing a bulb in the middle, and graduated above this from 0 (at the tap) to 40 c.c., below the bulb from 100 to 140 c.c. A two-way tap, *g*, allows communication either with the straight outlet tube *h*, or with the right-angle tube *e*.

Instead of carrying out the decomposition in tube A, it is decidedly preferable to employ for this purpose a separate tube D, provided with a two-way tap *f*, a funnel *d*, and an outlet tube *c*, corresponding to the tube *e* on A. D has its own

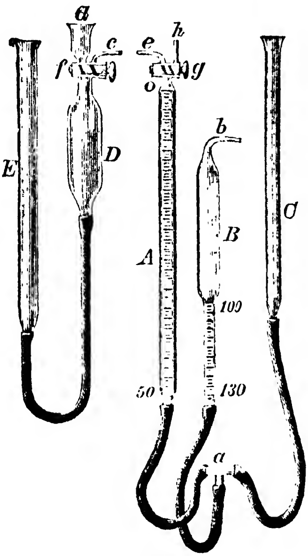

FIG. 12.

level tube E. All these tubes are held in clamps, which can be moved up and down on the two bars of a heavy iron stand.

The "reduction tube" B is enlarged at the top, and the narrow portion below is graduated from 100 to 125 c.c. in $\frac{1}{10}$ c.c. It contains a volume of dry air which at 0° and 760 mm. pressure would occupy exactly 100 c.c. This is obtained by taking, once for all, a reading of the thermometer and the barometer, and calculating what would be the volume of 100 c.c. of dry air under the prevailing atmospheric conditions. In reading the barometer, a deduction must be made for the expansion of the mercury, viz., 1 mm. between 0°

and 12°, 2 mm. between 13° and 19°, 3 mm. between 20° and 25°. For calculating the volume of 100 c.c. air at "normal conditions" from the observed temperature t and the barometric reading b (corrected as above), we have the formula :—

$$V = \frac{100(273+t)760}{273b}$$

A drop of concentrated sulphuric acid is previously introduced through the open end of b, most conveniently by suction After setting the level in B to the point indicated by the equation, the capillary end of b is sealed by fusing it up; in order to prevent the heat from expanding the air in B, a cardboard shield is put between the flame and B.

This is avoided by replacing the open capillary tube b by Lunge's "beaker-tap" (*Ber.*, 1892, p. 3157), and still better by Göckel's gas-tap with annular mercury seal.

The "laboratory vessel" or "decomposition tube" D, in which the reaction is carried out, is provided with the fittings of an ordinary nitrometer, viz., the three-way tap f, the cup d, the lateral outlet c, and the special level tube E. It holds about 150 c.c. and is not graduated. Mercury is poured in through E. By raising E, the vessel D is completely filled with mercury, till it begins to run out at c. The tap f is shut, the end of c closed by a glass or rubber cap, and the nitrous vitriol placed in d; this is sucked into D, then some pure acid sucked in, to wash the cup and tap, tap f closed (no bubbles of air must remain below it!), and the decomposition brought about in the usual manner by shaking the vitriol with the mercury, to evolve all the nitrogen acids as NO. The tubes D and A are then brought opposite to each other (A having been previously filled, by raising C, with mercury till it flows out at e); c and e are joined by a short piece of rubber tubing till they touch, so that no air remains in the space between; C is lowered, E raised, and by cautiously opening tap f, the NO contained in D is transferred into A. As soon as all the gas is in A, and the acid following it has filled the narrow tube e, tap g is closed. Now tube C is raised till the mercury in B has risen to the mark 100, and B and C are simultaneously moved up or down, as may be required, till the levels in A and B coincide, that in B being still at 100 c.c. Since the air in B is now compressed to the point which it would occupy in the dry state at 0° and 760 mm., and the gas in A is placed under exactly the same pressure (the temperature of these two parallel tubes being presumably the same), the reading in A gives the volume of NO reduced to the same conditions of 0° and 760 mm. The temperature in A and B must be exactly the same; this is ensured by the conductivity of the mercury, but in the case of large quantities of NO it is necessary to wait at least ten minutes before finally adjusting the levels.

If only one gas-volumeter is available, and that is adjusted for *moist* gases (as is required for other purposes), it may be used also for dry gases, but it is then necessary to avoid any sulphuric acid passing from D into A, and to suck a drop of water into A, before transferring the gas into it from D. Another way for measuring *dry* gases with a *moist* reduction tube is as follows :—observe the temperature ; take the tension of aqueous vapour corresponding to this from the table, p. 36 $= f$, and adjust the mercury in the measuring tube A higher by f mm. than in the reduction tube B, where as usual, the mercury is adjusted by means of the level tube C to the point marking 100·00 c.c. If, on the other hand, a reduction tube has been prepared for *dry* gases, by introducing a drop of concentrated acid, it may be used for *moist* gases (as in the testing of manganese ore, bleaching powder, potassium permanganate, etc.), by adjusting the mercury in A f mm. lower than in B.

(c) *Relative Proportions of the three Nitrogen Acids.*—In order to find from the result of the permanganate titration and from the estimation of total nitrogen in the nitrometer (as NO) the relative proportions of N_2O_3, N_2O_4, and HNO_3 in a mixture of all three nitrogen acids absorbed by sulphuric acid, we may employ the following formula :—

a = c.c. NO found in the nitrometer.
b = c.c. O, calculated from the permanganate titration.

(1 c.c. O = 1·4292 mg. ; 1 c.c. seminormal permanganate = 0·004 g. = 2·7975 c.c. oxygen.)

x = vols. NO, corresponding to the N_2O_3 present.
y = ,, NO, ,, ,, N_2O_4 ,,
z = ,, NO, ,, ,, HNO_3 ,,

If $4b$ be $> a$,

$$x = 4b - a\ ;\ y = 2(a - 2b),\ \text{or} = a - x.$$

If $4b$ be $< a$,

$$y = 4b\ ;\ z = a - 4b.$$

(d) *Qualitative Test for Traces of Nitrogen Acids.*—These can be detected by means of diphenylamine. Dissolve a few grams of diphenylamine in 100 parts of pure sulphuric acid. This acid should be completely free from nitrogen oxides, and can be made so, if not at hand, by boiling with a trace of ammonium sulphate. Dilute the acid with $\frac{1}{10}$th volume of water before dissolving the diphenylamine. This solution may be employed at once, or kept, as it keeps quite well. Pour about 2 c.c. of the vitriol to be tested into a test-tube, and add about 1 c.c. of the diphenylamine solution so that the layers mix only gradually. In the case of dilute acids, or other lighter liquids, proceed in the opposite manner. The slightest traces of nitrogen acids are detected by the appearance of a brilliant blue colour at the area of contact of the liquids.

The smallest traces of nitrous acid are detected, even in the presence of nitric acid, by the reagent proposed by Griess, as modified by Ilosvay and by Lunge. This reagent is prepared by (1) dissolving 0·5 g. sulphanilic acid in 150 c.c. dilute acetic acid; (2) boiling 0·1 g. solid α-naphthylamine with 20 c.c. water, pouring the colourless liquid off from the purple residue, and mixing it with 150 c.c. dilute acetic acid. The two solutions are united, and can thus be kept for an indefinite time in a bottle, well protected against air (which often contains traces of nitrogen acids). Add a few c.c. of this solution to the solution to be tested, and heat to 70° or 80°. If as little as 1 part nitrous acid be present in 1000 million parts of the liquid, a red colour is formed in about one minute. More concentrated solutions of HNO_3, say 1 : 1000, do not yield the blue colour, but a yellow solution.

In the presence of selenium the diphenylamine test fails, as Se gives the same reaction as nitrogen acids. In that case test for somewhat large quantities of nitrogen acids by the decoloration of indigo solution; for traces, by the reddening of a solution of brucine sulphate.

(e) *Selenium* in sulphuric acid can be recognised by adding to the acid a strong solution of ferrous sulphate, when a brownish-red precipitate will make its appearance, which cannot be confused with the colour produced by NO. It can also be recognised by the green colour, produced in a solution of codein.

(f) *Examination for Lead.*—Dilute the acid, if concentrated, with an equal volume of water and twice its volume of alcohol. Allow the mixture to stand for some time, filter any precipitate of $PbSO_4$, wash it with dilute alcohol, and dry and ignite in a porcelain crucible, burning the filter separately. 1 g. $PbSO_4$=0·6829 g. Pb.

(g) *Examination for Iron.*—Boil the acid, if free from nitrogen, with a drop of nitric acid to oxidise the iron. Dilute a little, allow to cool, and add a solution of potassium thiocyanate. A red colour proves the presence of iron. If there is not too little, it can be quantitatively estimated in another sample by heating with pure zinc (free from iron), pouring off from the zinc, washing the latter, allowing to cool, and titrating with permanganate. This is best employed as $\frac{1}{20}$th normal, indicating 0·002792 g. Fe per cubic centimetre. Not less than 50 c.c. of the acid should be taken for this test, as it generally contains very little iron.

The smallest traces of iron can be estimated colorimetrically (Lunge, *Zsch. f. angew. Chem.*, 1896, p. 3).

(h) *Arsenic* is detected qualitatively by the well-known methods of Marsh or of Reinsch. For quantitative estimation dilute 20 c.c. of the acid with water, and treat with a current of SO_2, until there is a strong smell of the gas. This reduces As_2O_5 to As_2O_3, but it requires a long time and a considerable excess of

SO_2. Now drive off this excess by heating and passing in a current of CO_2, neutralise exactly with Na_2CO_3 and a little $NaHCO_3$, add starch and titrate with decinormal iodine. 1 c.c. of the iodine solution indicates 0·00495 g. As_2O_3. (Any considerable proportion of iron should be previously removed.)

(i) *Chlorides.*—Boil 10 c.c. of the acid in a flask, pass the vapours on to the surface of a little water, contained in a flask, and estimate the absorbed HCl acidimetrically, or after neutralising with Na_2CO_3, by titrating with decinormal silver nitrate (p. 174).

16. Analysis of Fuming Sulphuric Acid (Oleum) and of Sulphuric Anhydride.

Although other tests are often carried out (among which that for arsenic is the most usual) the estimation most frequently made is that of the total acidity.

The substance is either weighed in glass bulbs or in a glass-tap tube. The former are very thin bulbs of about 2 cm. diameter, ending on each side in a capillary tube. Melt the acid, if solid, till it is completely homogeneous, and suck 3 g. to 5 g. into the bulb, which ought to be half-filled with it. The sucking is best done by means of a bottle closed with a rubber cork, through which passes a tightly fitting glass tap, connected at its free end with a rubber tube. Suction is applied to the latter, the tap closed, the rubber tube drawn over one of the capillary ends of the weighing bulb, and by opening the tap a sufficient quantity of acid admitted into the bulb. The tube is cleaned outside, and one of the capillary ends is sealed off. The other end can be left open without fear of any loss of SO_3 or attraction of moisture during weighing. The weighing is best done on a small platinum crucible with two nicks, on which the ends of the bulb can rest. If the latter should be accidentally broken, the acid runs into the crucible, not on to the balance. Put the bulb, after weighing, open end downwards into a small Erlenmeyer flask, into the neck of which it ought to fit exactly (Fig. 13), and which contains so much water that the capillary tube dips well into it, to prevent any loss of SO_3 on mixing the acid with water. Break off the other point, allow the acid to run out, squirt a few drops of water into the upper capillary, and ultimately rinse the whole bulb tube by repeated aspiration of water. Dilute the liquid to 500 c.c. and take 50 c.c. for each test. This is done with $\frac{1}{5}$ normal sodium carbonate solution (1 c.c.$=$0·008007 g. SO_3), and methyl

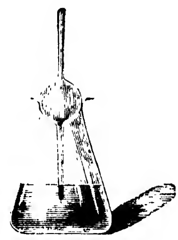

FIG. 13.

orange as indicator. From the acidity found, that due to SO_2 is deducted, which is ascertained by titrating another sample with iodine.

Lunge and Rey's glass-tap pipette (Fig. 14) (the taps of which must be tight without greasing!) is more convenient than the bulb tube. Shut the lower tap *c*, open the upper tap *a*, apply suction (with the mouth) at *d*, and shut *a* whilst sucking. Immerse the point *e* in the acid to be tested, and open *c*; the partial vacuum in bulb *b* suffices for drawing up enough acid, which must not be allowed to reach the tap *c*. Shut *c*, clean the point *e*, put the pipette in the outer glass vessel *f*, and weigh. Take the pipette out of *f*, place it point downwards in water, and slowly run out the contents. Then squirt some water from above into *b*, allow to stand for a moment, and rinse thoroughly with water.

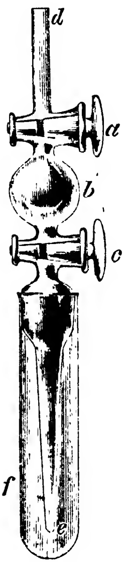

FIG. 14.

The strongest fuming oil of vitriol cannot be run directly into water without loss. Such oil of vitriol is weighed out in small glass bulbs, as described above; both ends are sealed up, the bulb is placed in a bottle containing a considerable quantity of water, the stopper put in, the bulb broken by shaking the bottle, and after waiting a little the solution titrated.

Solid products of this class must be melted by moderate heating; they then remain long enough in the liquid state to complete the weighing and running out without being heated again. But products which are not far removed from real SO_3 in composition would give out too much vapour in this operation. Such products are weighed out in a stoppered bottle, and mixed in this with a known and exactly analysed quantity of monohydrate, at a temperature of 30° to 40° C. This ought to produce a mixture containing about 70 per cent. SO_3 which will remain liquid at ordinary temperatures.

If only 0·5 to 1 g. of acid has been weighed off, titrate directly. This is more accurate than diluting and titrating only part of the liquid, but the latter method cannot be avoided when a larger quantity of acid has been weighed.

The acidimetric determination, of course, indicates the total percentage of acid. From this we must deduct in the first instance any SO_2 present. This is estimated in the usual way by decinormal iodine, and for each c.c. of this 0·05 c.c. normal sodium carbonate solution is deducted (since with methyl orange the colour changes when SO_2 has passed into $NaHSO_3$). If we call the c.c. of normal sodium carbonate used $= n$, those of decinormal iodine used for the same quantity of oil of vitriol $= m$, the acidity due to $H_2SO_4 + SO_3$ is $= (n - 0{\cdot}05\ m)\ 0{\cdot}040035\ SO_3$. To the SO_3 thus found add the SO_2 (calculated $= 0{\cdot}0032035\ m$), and assume the residue to be water.* By multiplying this H_2O by 4·445, we obtain the quantity of SO_3 combined with it to form H_2SO_4, and by deducting this from the total SO_3 acidity, that of the *free* SO_3.

PLANT TEST FOR FREE TRIOXIDE IN OLEUM.

Curtis and Miles have described a simple test which can be applied by a workman on the plant. The apparatus required is of the simplest kind—an earthenware jug or mug holding about a pint, two glass cylinders each holding 200 c.c., and a thermometer, which is preferably protected by sealing into a light iron case perforated with holes at the lower end.

To carry out the test, measure 200 c.c. of sulphuric acid (92·5 to 94·5 per cent.) into the mug and have ready 200 c.c. of oleum in the cylinder. Take the temperature of each, and then quickly pour the oleum into the acid, stirring vigorously all the time. Note the maximum temperature of the mixture, and calculate the increase, I, as follows :—

$$I = t_{\text{mixture}} - \frac{t_{\text{acid}} + t_{\text{oleum}}}{2}$$

Reference to the table below gives the percentage of free anhydride :—

Increase of Temp. I.	Per cent. SO_3.	Increase of Temp. I.	Per cent. SO_3.	Increase of Temp. I.	Per cent. SO_3.	Increase of Temp. I.	Per cent. SO_3.
1	...	11	5·9	21	12·1	31	18·7
2	0·0	12	6·5	22	12·8	32	19·4
3	0·6	13	7·2	23	13·4	33	20·1
4	1·3	14	7·8	24	14·1	34	20·8
5	2·0	15	8·5	25	14·7	35	21·4
6	2·6	16	9·7	26	15·4	36	22·0
7	3·2	17	9·1	27	16·0	37	22·7
8	3·9	18	10·3	28	16·7	38	23·4
9	4·6	19	10·9	29	17·4	39	24·1
10	5·3	20	11·5	30	18·0	40	24·7

The results from this table are correct to within ±0·5 per cent. The strength of the sulphuric acid may vary from 92·5 to 94·5 per cent. but should not go outside these limits.

* In case any weighable quantity of solid impurities is present, this must also, of course, be deducted.

V. SALTCAKE AND HYDROCHLORIC ACID.

A.—Salt (Common Salt, Rock-Salt.)

1. *Moisture.*—Ignite 5 g. of salt in a covered platinum crucible (to prevent loss by spirting); heat first quite gradually, then for some minutes, up to a low red heat. If the sample is too damp, or if several samples are to be tested at the same time, weigh off the 5 g. samples in flat-bottomed Erlenmeyer flasks, with funnels on, heat a number of these on a sand-bath for three or four hours to 140° or 150° (without funnel), and allow them to cool with the funnel in, which saves the use of a desiccator. Afterwards the small remainder of chemically combined water may be removed by heating on a wire-gauze, but this is mostly unnecessary.

2. *Insoluble matter.*—Dissolve 5 g., filter the insoluble matter, wash, dry, and ignite.

3. *Chlorine.*—Weigh off 5·846 g. of the moist salt, dissolve it, and dilute to 500 c.c.; take out 25 c.c. by means of a pipette, add so much of a solution of neutral potassium chromate that the liquid is distinctly yellow, and titrate with decinormal silver solution. Add the silver solution from a 50 c.c. burette, till the precipitate, even after agitation, shows a distinct but faint pink colour. 0·2 c.c. is deducted from the number of cubic centimetres of silver solution used, as being required for producing the colour. The remainder, multiplied by 2, gives the percentage of NaCl in the salt. In lieu of potassium chromate, sodium arsenate may be employed as indicator. This is even more sensitive, and *no* deduction from the silver solution used should be made in this case.

4. *Lime.*—Dissolve 5 g. of the salt in water, if necessary with the aid of a little HCl. When analysing impure rock-salt, the treatment with dilute HCl must be continued for some time, in order to dissolve all $CaSO_4$. It is also necessary to filter off any clay, etc., but non-argillaceous salt ought to dissolve completely, excepting any grains of sand and the like. In the clear solution precipitate the lime with ammonia and ammonium oxalate, allow to stand for twelve hours, filter the precipitate through a fine filter-paper in a well-shaped funnel (*cf.* p. 134), wash, dry, and ignite it in a platinum crucible till it is completely converted into CaO. This is done by first gently heating till the calcium oxalate is decomposed, and then igniting at nearly a white heat for twenty minutes, either over a gas blowpipe or, more conveniently, in a Hempel's gas-oven or over a Muencke burner. One part CaO is equal to 2·4281 $CaSO_4$, and is calculated as such.

5. *Sulphates.*—Dissolve 10 g. of the salt in tepid water, with addition of a little hydrochloric acid. Dilute to 1 litre, filter through a dry pleated filter, and precipitate 250 c.c. (=2·5 g. salt) by barium chloride (*cf.* p. 134). The sulphate is usually calculated as $CaSO_4$.

6. *Magnesium Chloride* may be titrated directly by drying the salt, extracting it with absolute alcohol, filtering, evaporating off the alcohol from the filtrate (which contains nothing but $MgCl_2$), and titrating with silver nitrate.

B.—Saltcake (Sulphate of Soda).

(*N.B.*—Nos. 1 and 2 are sufficient for the daily checking of the manufacture; the others are employed for saltcake when bought and sold.)

1. *Free Acid.*—Dissolve 20 g. saltcake, dilute to 250 c.c., take out 50 c.c. with a pipette, add methyl orange, and titrate with standard sodium carbonate to the point of neutralisation. Each cubic centimetre of the standard alkali is equal to 1 per cent. SO_3. The total acidity is calculated as SO_3, including HCl and $NaHSO_4$. (If litmus were employed as indicator, the presence of salts of iron and alumina would cause trouble in the titration; with methyl orange this is not the case.)

2. *Sodium Chloride.*—Take another 50 c.c. of the solution made for the test No. 1, add the same quantity of standard alkali as used for this test, so that the acid is exactly neutralised, then a little neutral potassium chromate, and titrate with decinormal silver solution, as in A, 3. Each cubic centimetre of silver solution (after deducting 0·2 from the whole) is equal to 0·1462 per cent. NaCl. Or else employ a solution containing 2·906 g. $AgNO_3$ per litre and indicating 0·001 g. NaCl per cubic centimetre. This would, in the present case, indicate 0·025 per cent. NaCl per cubic centimetre.

3. *Iron.*—Dissolve 10 g. of sulphate in water, reduce the iron salts to the ferrous state by a little sulphuric acid and zinc, and titrate with potassium permanganate.

4. Residue, insoluble in water, is estimated as usual, if present.

5. *Lime.*—Dissolve 10 g. in water, if necessary with a little HCl; add NH_4Cl and NH_3, precipitate with ammonium oxalate, ignite, and weigh as CaO. If any appreciable quantity of Fe_2O_3 has been found, this must be deducted.

6. *Magnesia* is precipitated in the filtrate from No. 5 by ammonium phosphate; allow to stand for twenty-four hours; filter, wash with dilute ammonia, dry, ignite, and weigh the magnesium pyrophosphate, of which 1 part=0·3621 MgO.

7. *Alumina.*—The solution of the saltcake is precipitated by ammonia (free from CO_2). The precipitate is ignited and weighed.

Deducting the weight of Fe_2O_3 found in No. 3, the remainder is $= Al_2O_3$.

8. *Sodium Sulphate* (*direct estimation*).—Dissolve 1 g. of the saltcake; precipitate any lime together with ferric oxide, etc., as in No. 5; filter; evaporate the filtrate to dryness after adding a few drops of pure sulphuric acid; ignite; repeat this after adding a small piece of ammonium carbonate, and weigh. Deduct from this weight (1) the NaCl found in test No. 2, calculated for Na_2SO_4 (1·0000 NaCl = 1·2151 Na_2SO_4, or each cubic centimetre of decinormal silver solution employed in test No. 2 = 0·001776 g. Na_2SO_4); (2) the MgO found in test No. 6 calculated as $MgSO_4$ (1·000 MgO = 2·9859 $MgSO_4$). The remainder is equal to the sodium sulphate actually present in 1 g. saltcake.

C.—Chimney-Testing.

Act of Parliament.—By the Alkali Works Regulation Act of 1906, it is enacted that "Every alkali work shall be carried on in such a manner as to secure the condensation to the satisfaction of the chief inspector, (*a*) of the muriatic acid gas evolved in such work to the extent of 95 per centum, and to such an extent that in each cubic foot of air, smoke, or chimney gases escaping from the works into the atmosphere, there is not contained more than *one-fifth part of the grain* [=0·457 g. per cubic metre] of muriatic acid; (*b*) of the acid gases of sulphur and nitrogen which are evolved in the process of the manufacture of sulphuric acid in that work to such an extent that the total acidity of such gases in each cubic foot of residual gases after completion of the process, and *before* admixture with air, smoke, or other gases, does not exceed what is equivalent to *four grains* of sulphuric anhydride; (*c*) in the residual gases from the concentration or distillation of sulphuric acid, the total acidity of gases in each cubic foot must not exceed the equivalent of 1½ grain of sulphuric anhydride."

Hydrochloric Acid in Chimney Gases.—In order to ascertain the HCl in chimney gases, an aspirator is used known as Fletcher's flexible aspirator, or bellows. This aspirator is supposed to draw at one aspiration one-tenth of a cubic foot. It is not safe to trust to this supposed capacity, and moreover the capacity of a new aspirator varies for some time. To ascertain the real capacity, fill a very large beaker or other cylindrical vessel with water, and invert it under water. Completely fill the aspirator with air, and expel this air into the inverted beaker. Mark the point to which the beaker is filled when the water inside the beaker is level with that outside. Measure the capacity of the beaker to that mark; say it contains V cubic centimetres of water.

Then the number of aspirations which must be made with this aspirator in order to draw 1 cubic foot of air is :—

$$N = \frac{28290}{V};$$

or if the capacity of the beaker is measured in grains :—

$$N = \frac{436485}{V}.$$

N will usually be a mixed number, but the nearest integral number is substituted, and it will be safest to substitute the next higher integral number. Thus, if N be found 9·3, it will be safest to consider 10 as the number of aspirations necessary to draw 1 cubic foot. The aspirator must be air-tight. The gas is withdrawn from the chimney through a glass tube, which should be sufficiently long to reach a considerable distance into the chimney, say 6 feet. The glass tube should be of at least ½ in. diameter, otherwise the aspiration is tedious. In flues where the temperature is too high for glass, a porcelain tube may be employed. The bellows and tube are washed with distilled water until the washings give no reaction with silver nitrate. 100 or 200 cubic centimetres of distilled water, free from chloride, are then charged into the bellows, and after each aspiration the gas is well washed by shaking the contents of the aspirator violently. When the number N of aspirations has been made, some water is forced into the glass tube, and allowed to flow back into the bellows to wash out any acid which may have condensed in the tube. The liquid is then transferred into a porcelain dish (or into a beaker standing on a porcelain slab). If the liquid is so highly charged with soot that it would be impossible to recognise the change of colour, it must be filtered through a filter previously washed free from chlorides. The liquid is then oxidised by adding sufficient hydrogen peroxide to oxidise the sulphur dioxide to sulphuric acid; the total acidity is then determined by titration with standard alkali, using methyl orange as indicator. The chloride in the neutralised solution is then determined by titration with centinormal silver nitrate using potassium chromate as indicator.

Sometimes black or green precipitates are formed which render the endpoint a matter of uncertainty. The Alkali Inspectors recommend the following procedure to ensure freedom from "black" tests :—

After titration with sodium carbonate for total acidity, about 0·5 g. of calcium or magnesium carbonate is added, followed by 5 to 10 drops of ferric sulphate solution (5 per cent.); stir for one minute, decant and filter the solution, and titrate with centinormal silver nitrate in the usual way.

The "grains per cubic foot" in the gas is found by multiplying the cubic centimetres of centinormal silver nitrate solution used by 0·05633.

M

D.—Hydrochloric Acid.

1. SPECIFIC GRAVITY OF PURE HYDROCHLORIC ACID AT 15° C. COMPARED WITH WATER AT 4°, AND REDUCED TO VACUUM. (Lunge and Marchlewski.)

Degrees Twaddell.	Specific Gravity at $\frac{15°}{4°}$ in vacuo.	100 parts by weight correspond to parts by weight of HCl.	Acid of spec. gravity 1·1425 = 28·5° Tw.	Acid of spec. gravity 1·152 = 30·4° Tw.	1 litre contains g. of HCl.	1 cubic foot contains lbs. of HCl.
0	1·000	0·16	0·57	0·53	1·6	0·10
1	1·005	1·15	4·08	3·84	12	0·75
2	1·010	2·14	7·60	7·14	22	1·37
3	1·015	3·12	11·80	10·41	32	1·99
4	1·020	4·13	14·67	13·79	42	2·62
5	1 025	5·15	18·30	17·19	53	3·30
6	1·030	6·15	21·85	20·53	64	3·99
7	1·035	7·15	25·40	23·87	74	4·61
8	1·040	8·16	28·99	27·24	85	5·30
9	1·045	9·16	32·55	30·58	96	5·98
10	1·050	10·17	36·14	33·95	107	6·67
11	1·055	11·18	39·73	37·33	118	7·35
12	1·060	12·19	43·32	40·70	129	8·04
13	1·065	13·19	46·87	44·04	141	8·79
14	1·070	14·17	50·35	47·31	152	9·48
15	1·075	15·16	53·87	50·62	163	10·16
16	1·080	16·15	57·39	53·92	174	10·85
17	1·085	17·13	60·87	57·19	186	11·59
18	1·090	18·11	64·35	60·47	197	12·28
19	1·095	19·06	67·73	63·64	209	13·03
20	1·100	20·01	71·11	66·81	220	13·71
21	1·105	20·97	74·52	70·01	232	14·46
22	1·110	21·92	77·89	73·19	243	15·15
23	1·115	22·86	81·23	76·32	255	15·90
24	1·120	23·82	84·64	79·53	267	16·65
25	1·125	24·78	88·06	82·74	278	17·33
26	1·130	25·75	91·50	85·97	291	18·14
27	1·135	26·70	94·88	89·15	303	18·89
28	1·140	27·66	98·29	92·35	315	19·64
29	1·145	28·61	101·67	95·52	328	20·45
30	1·150	29·57	105·08	98·73	340	21·20
31	1·155	30·55	108·58	102·00	353	22·01
32	1·160	31·52	112·01	105·24	366	22·82
33	1·165	32·49	115·46	108·48	379	23·63
34	1·170	33·46	118·91	111·71	392	24·44
35	1·175	34·42	122·32	114·92	404	25·19
36	1·180	35·39	125·76	118·16	418	26·06
37	1·185	36·31	129·03	121·23	430	26·81
38	1·190	37·23	132·30	124·30	443	27·62
39	1·195	38·16	135·61	127·41	456	28·43
40	1·200	39·11	138·98	130·58	469	29·24

2. INFLUENCE OF TEMPERATURE ON THE SPECIFIC GRAVITY OF HYDROCHLORIC ACID.

0°.	5°.	10°.	15°.	20°.	25°.	30°.	35°.	40°.	45°	50°
1·168	1·165	1·163	1·160	1·157	1·154	1·152	1·149	1·147	1·144	1·142
1·158	1·155	1·153	1·150	1·147	1·145	1·142	1·139	1·137	1·134	1·132
1·148	1·145	1·143	1·140	1·137	1·134	1·132	1·129	1·127	1·125	1·123
1·138	1·135	1·133	1·130	1·127	1·125	1·122	1·119	1·117	1·114	1·112
1·128	1·125	1·123	1·120	1·117	1·115	1·112	1·110	1·108	1·106	1·103
1·118	1·115	1·113	1·110	1·107	1·105	1·103	1·101	1·099	1·097	1·094
1·108	1·105	1·103	1·100	1·097	1·095	1·092	1·090	1·088	1·086	1·084
1·098	1·095	1·093	1·090	1·087	1·085	1·082	1·080	1·077	1·075	1·073
1·088	1·085	1·083	1·080	1·077	1·075	1·073	1·070	1·068	1·066	1·064
1·078	1·075	1·073	1·070	1·068	1·065	1·063	1·061	1·059	1·057	1·055
1·068	1·065	1·063	1·060	1·058	1·055	1·053	1·050	1·048	1·046	1·044
1·058	1·055	1·053	1·050	1·048	1·045	1·043	1·040	1·038	1·035	1·033
1·048	1·045	1·043	1·040	1·037	1·035	1·032	1·030	1·027	1·025	1·022
1·038	1·035	1·033	1·030	1·027	1·024	1·022	1·019	1·017	1·014	1·012
1·028	1·025	1·023	1·020	1·017	1·014	1·012	1·009	1·007	1·004	1·002
1·018	1·015	1·013	1·010	1·007	1·004	1·002	0·999	0·997	0·994	0·992

55°.	60°.	65°.	70°.	75°.	80°.	85°.	90°.	95°.	100°.
1·140	1·138	1·136	1·133	1·131	1·129	1·127	1·125	1·123	1·121
1·130	1·128	1·126	1·123	1·121	1·119	1·116	1·114	1·112	1·110
1·120	1·118	1·116	1·113	1·111	1·108	1·106	1·104	1·102	1·099
1·109	1·107	1·104	1·102	1·100	1·097	1·095	1·093	1·090	1·088
1·101	1·099	1·096	1·094	1·091	1·089	1·086	1·084	1·081	1·079
1·093	1·090	1·088	1·085	1·083	1·080	1·078	1·075	1·073	1·070
1·082	1·080	1·078	1·076	1·073	1·071	1·069	1·066	1·064	1·061
1·071	1·069	1·067	1·065	1·063	1·061	1·059	1·057	1·055	1·053
1·062	1·060	1·058	1·056	1·054	1·053	1·051	1·049	1·047	1·045
1·053	1·051	1·049	1·048	1·046	1·044	1·043	1·041	1·039	1·037
1·042	1·040	1·038	1·036	1·034	1·033	1·031	1·029	1·027	1·025
1·031	1·029	1·027	1·025	1·023	1·021	1·019	1·017	1·015	1·013
1·020	1·018	1·016	1·014	1·011	1·009	1·007	1·005	1·003	1·001
1·010	1·008	1·005	1·003	1·001	0·999	0·997	0·995	0·993	0·991
1·000	0·998	0·995	0·993	0·991	0·989	0·987	0·985	0·983	0·981
0·990	0·988	0·985	0·983	0·981	0·979	0·977	0·975	0·973	0·971

3. ANALYSIS OF HYDROCHLORIC ACID.

(a) *Estimation of* HCl.—Measure off, by means of an accurate pipette, 10 c.c. of the acid, the specific gravity of which should be known, dilute to 200 c.c., take out 10 c.c. Or else employ a glass-tap pipette, as described on p. 172 for fuming sulphuric acid; in this case its contents are run into water and employed directly for titration. Add sodium carbonate, free from chloride, till the reaction is neutral or faintly alkaline. This point will be hit quickly, and without the loss of many drops for testing, if the percentage of the acid is ascertained from its specific gravity by the table (p. 178) and the corresponding quantity of sodium carbonate solution is run in from a burette. Now add a little neutral potassium chromate, and titrate with decinormal silver solution till a faint pink colour is produced (*cf.* p. 174). Deduct 0·2 c.c. from the silver solution employed; the remainder, multiplied by 72·94 and divided by the specific gravity of the acid, indicates its percentage of HCl. This test would fail in the presence of metallic chlorides, which are, however, hardly ever present in appreciable quantity in ordinary hydrochloric acid. The free HCl can also be ascertained by estimating the total acidity and deducting therefrom that due to sulphuric acid, making allowance for any sodium sulphate present.

(b) *Estimation of Sulphuric Acid.*—Neutralise the acid almost, but not quite, with sodium carbonate free from sulphate, and precipitate the sulphuric acid by barium chloride, as on p. 134. If the acid be partially saturated with NH_3, or not saturated at all, the result is too low. Each part of $BaSO_4$ is equal to 0·3430SO_3.

(c) *Estimation of Iron.*—Reduce this to ferrous iron by digesting the acid for a short time with a rod of zinc free from iron, wash the rod, dilute the whole with water, add some manganous chloride or sulphate (in order to counteract the action of HCl on permanganate), and titrate with a twentieth normal solution of potassium permanganate, each cubic centimetre of which indicates 0·002792 g. Fe. In case of SO_2 being present, this must first be oxidised to sulphuric acid, before reducing the ferric salt and titrating.

(d) *Free Chlorine.*—Introduce a sample of the acid into a flask, remove the air from the empty space by CO_2; shake the acid with a strip of clean metallic copper. The latter is converted into chloride by the free chlorine, and the copper thus dissolved can be detected by potassium ferrocyanide, etc. This will show the smallest traces of chlorine. For ordinary purposes it is sufficient to heat the acid gently and hold a strip of KI starch paper in the vapour; this will at once turn blue in the presence of free Cl.

(e) *Sulphur Dioxide.*—Oxidise with permanganate, or iodine, or H_2O_2 to sulphuric acid, estimate the total H_2SO_4 now present as in No. 2, and deduct the quantity there found; the remainder $=SO_2$.

(f) *Arsenic.*—Reduce all to trichloride by passing in SO_2 for some time, and precipitate by H_2S as As_2S_3. Wash the precipitate, dissolve it on the filter in ammonia, evaporate the solution in a glass or porcelain dish, dry at 100°, and weigh. One part As_2S_3 $=0·6091$ As $=0·8041$ As_2O_3.

VI. BLEACHING POWDER AND CHLORATE OF POTASH MANUFACTURE.

A.—Natural Manganese Ore.

1. *Manganese Dioxide.*—Weigh 1·0866 g. of manganese ore, ground as fine as possible, and dried for some time at 100° C.; put it into the flask (Fig. 15) closed by a rubber (Bunsen) valve, or, preferably, into a flask provided with a Contat-Göckel bulb (Fig. 16), which has been half-filled with a concentrated solution of sodium carbonate; put into the flask 75 c.c. (in three portions with a 25 c.c. pipette) of a solution containing

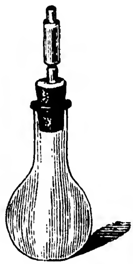

FIG. 15.

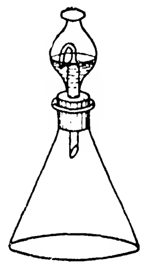

FIG. 16.

100 g. pure crystallised ferrous sulphate and 100 c.c. pure concentrated sulphuric acid, diluted to 1 litre, and standardised on the same day by means of the same 25 c.c. pipette, with decinormal potassium permanganate. Close the flask with its cork or valve, and heat till the manganese is completely decomposed, leaving a light-coloured residue. On cooling, the valve must act properly, which will be seen by the collapsing of the rubber tube, Fig. 15, or by the running in of sodium carbonate solution, Fig. 16. After complete cooling add 200 c.c. of water, and titrate with potassium permanganate to a faint pink coloration. Deduct the quantity of permanganate required from that corresponding to the 75 c.c. of iron solution; the remainder indicates for each cubic centimetre 0·02173 g., equal to 2 per cent. MnO_2.

2. *Carbon Dioxide* is estimated gravimetrically by expelling it with dilute sulphuric or nitric acid and absorbing it with soda-lime, by means of the apparatus and process described fully in Cumming and Kay's *Quantitative Analysis* (5th Edition), pp. 215 and 219.

3. *Estimation of the Hydrochloric Acid required for Decomposing the Ore.*—Dissolve 1 g. of manganese ore in a flask provided

with a reflux condenser in 10 c.c. of ordinary strong hydrochloric acid the titre of which is known, employing heat as far as necessary. Allow the solution to cool, and add standard alkali till reddish-brown flakes of ferric hydroxide appear, which do not redissolve on agitation. Calculate the standard alkali corresponding to the acid employed for dissolving the ore, and deduct the quantity thus found from the 10 c.c. first employed.

B.—Recovered Manganese Mud and Weldon Liquors.

1. MnO_2 *in Weldon Mud.*—Standardise an acid iron solution (100 g. pure crystallised ferrous sulphate + 100 c.c. pure concentrated sulphuric acid in 1 litre) by seminormal potassium permanganate, by diluting 25 c.c. of the former with 100 c.c. or 200 c.c. of cold water, and adding the permanganate from a stopcock burette, till, on agitating, the pink colour is not discharged immediately, but remains at least for half a minute. Subsequent decolorisation is not taken into account. This test should be made once each day. Call the cubic centimetres of permanganate employed x. Now, put another 25 c.c. of the iron solution into a beaker. Take 10 c.c. of manganese mud out of the well-shaken bottle (mere stirring does not ensure a proper mixture) containing it; wash the pipette outside, run its contents into the beaker containing the iron solution, and wash the mud remaining inside into the same beaker. When all has dissolved, on agitating, add 100 c.c. of water, and titrate by potassium permanganate. The number of cubic centimetres now used we call y. The quantity of MnO_2 in grams per litre of mud equals $2{\cdot}173\ (x-y)$.

2. *Total Manganese of the Mud, expressed in Grams of theoretically possible* MnO_2 *per Litre.*—Take 10 c.c. of the mud, with the same precautions as in test No. 1. Boil with strong hydrochloric acid till all chlorine is driven off; saturate the excess of acid by ground marble or precipitated calcium carbonate; add a concentrated filtered solution of bleaching powder; boil a few minutes till the colour turns a decided pink, and the excess of bleaching powder can be smelt, and again destroy the pink colour by adding alcohol drop by drop. All manganese is now present as MnO_2; filter and wash. The filtrate should not produce any brown colour with a bleaching-powder solution, which would show the presence of Mn in solution. Continue the washing till starch and KI do not give any reaction. Transfer the filter with the precipitate into 25 c.c. of the acid iron solution employed in test No. 1. If all MnO_2 is not dissolved, add another 25 c.c. of iron solution; dilute with 100 c.c. of water, and titrate with permanganate. Calculation as in No. 1.

3. *Estimation of the "Base," i.e. the Monoxides, etc., of the Mud which combine with* HCl *without yielding Free Chlorine.*—Dilute 25 c.c., or in case of a very rich base 50 c.c., of normal oxalic acid (63·03 g. crystallised oxalic acid in 1 litre) to 100 c.c.; heat to 60°-80° C., add 10 c.c. manganese mud by means of a pipette, with the precautions stated in No. 1, and agitate till the colour of the precipitate is no longer yellowish but pure white, which ought to take place very soon at the above temperature. Dilute to 202 c.c. (2 c.c. correspond to the volume of the precipitate, and are marked on the neck of the 200 c.c. flask); pour through a dry filter, and titrate 100 c.c. of the filtrate with standard alkali, employing phenolphthalein as indicator. (Methyl orange is not applicable for oxalic acid.) Call the number of cubic centimetres of standard alkali used, z. The oxalic acid serves (1) for reducing the MnO_2 with formation of MnO and CO_2; (2) for saturating the MnO thus formed; (3) for saturating the monoxides originally present, *i.e.* the base. The oxalic acid not thus used is equal to $2z$. The acid used for reducing MnO_2 is equal to that used for neutralising the MnO formed, and both amounts together are equal to the value $x-y$ obtained by the MnO_2 test, since the oxalic acid is normal and the permanganate half normal. The amount of oxalic acid consumed by the bases of the mud is found by deducting from the total acid used that required for the MnO_2 $(x-y)$, and that which was not neutralised at all by the mud $=2z$, therefore in all $x-y-2z$. The "base" is equal to the ratio of this value to that found in test No. 1, viz., $\frac{x-y}{2}$.

It is, therefore, if 25 c.c. of oxalic acid had been employed, equal to:

$$\frac{50-2x-4z+2y}{x-y} = \left(\frac{50-4z}{x-y}\right) - 2;$$

or, if 50 c.c. had been employed, equal to:—

$$\left(\frac{100-4z}{x-y}\right) - 2.$$

C.—Limestone.

1. *Insoluble Matter.*—Dissolve 1 g. in hydrochloric acid, filter the residue, wash, dry, and ignite. In the presence of appreciable quantities of organic matter, weigh the filter after drying at 100°, and ignite afterwards. The difference is calculated as organic matter.

2. *Lime.*—Dissolve 1 g. in 25 c.c. normal hydrochloric acid and titrate with normal alkali. Deduct the volume of the latter used from 25 and multiply the remainder by 2·8 to find the percentage of CaO, or by 5 to find that of $CaCO_3$. (*N.B.*—Here

MgO is calculated as CaO. This is admissible for most limestones employed in alkali and bleaching-powder making, because they contain but little MgO; otherwise the MgO or $MgCO_3$ found as in No. 3 must be deducted.)

3. *Magnesia* need only be estimated in limestone used for manganese recovery. Dissolve 2 g. of limestone in HCl, precipitate the CaO by NH_3 and ammonium oxalate, and precipitate the magnesia in the filtrate by sodium phosphate (*cf.* p. 175).

4. *Iron* is usually estimated only in limestone used for bleaching-powder making. Dissolve 2 g. in HCl, reduce by zinc, dilute, add some manganese solution free from iron, and titrate by permanganate (*cf.* p. 170).

D.—Quicklime.

1. *Free* CaO.—Weigh 100 g. of an average sample carefully taken, slake it completely, put the milk into a half-litre flask, fill up to the mark, shake well, take 100 c.c. out, run it into a half-litre flask, fill up, mix well, and employ 25 c.c. of the contents, equal to 1 g. quicklime, for the test. Titrate by normal oxalic acid and phenolphthalein as indicator, adding the acid *very slowly* and shaking well after each addition. The colour is changed when all free lime has been saturated and before the $CaCO_3$ is attacked. One c.c. normal HCl = 0·02804 g. CaO.

2. *Carbon Dioxide.*—Titrate CaO and $CaCO_3$ together by dissolving in an excess of standard hydrochloric acid and titrating back with standard alkali. By deducting the CaO estimated as in No. 1 the quantity of $CaCO_3$ is obtained. For very accurate estimations the CO_2 is expelled by HCl, absorbed in soda-lime, and weighed. (See Cumming and Kay's *Quantitative Analysis*, (5th Edition), pp. 215 and 219.)

E.—Slaked Lime.

1. *Water.*—Weigh about 1 g. in a stoppered glass tube, and heat it gradually in a platinum crucible, at last to a strong red heat (*cf.* p. 174); allow to cool in the exsiccator, and weigh. The loss of weight is equal to $H_2O + CO_2$.

2. *Carbon Dioxide* is estimated as above in D, 2.

3. *Estimation of the percentage of Caustic Lime in Milk of Lime by means of the specific gravity* (Blattner).—Thin milk of lime is poured into the cylinder and the reading of the hydrometer is taken quickly, before the lime subsides. For thick milk of lime employ a somewhat wide cylinder, put the hydrometer in without using any force and turn the cylinder slowly round, so that it receives a slight shaking, until the hydrometer ceases to sink. The following table is from Blattner's data for 15°.

TABLE SHOWING AMOUNT OF LIME IN MILK OF LIME.

Degrees Twaddell.	Grms. CaO per litre.	Lbs. CaO per cubic foot.	Degrees Twaddell.	Grms. CaO per litre.	Lbs. CaO per cubic foot.
2	11·7	0·7	28	177	11·1
4	24·4	1·5	30	190	11·9
6	37·1	2·3	32	203	12·7
8	49·8	3·1	34	216	13·5
10	62·5	3·9	36	229	14·3
12	75·2	4·7	38	242	15·1
14	87·9	5·5	40	255	15·9
16	100	6·3	42	268	16·7
18	113	7·1	44	281	17·6
20	126	7·9	46	294	18·4
22	138	8·7	48	307	19·2
24	152	9·5	50	321	20·0
26	164	10·3			

The editor would recommend that a table similar to the above be made by each user for his own use. Widely different results were obtained using lime from different sources.

F.—Bleaching Powder.

1. *Available Chlorine (Penot's Method).*—Weigh 7·092 g. of the sample, previously well mixed; grind it with a little water in a porcelain mortar (the lip of which has been greased a little underneath) till a completely homogeneous thin paste has been obtained; dilute with more water, wash the whole into a litre flask, fill up to the mark, and take for each test 50 c.c.=0·3546 g. bleaching powder, having shaken up the flask immediately before. Run into the above, with continuous agitation, an alkaline decinormal arsenite solution, containing 4·948 g. As_2O_3 per litre till the expected point is not very far off. Then place a drop of the mixture on to a piece of filter paper, moistened with a starch solution containing potassium iodide. If there is very much chlorine left, a brown spot will be produced; if less chlorine, the spot will be blue. According to the depth of this colour more or less arsenite solution is run in, and the above test is repeated till the paper is coloured hardly perceptibly, or not at all. Each cubic centimetre of the arsenite solution indicates 1 per cent. available chlorine.

2. *Comparison of the Percentage of Bleaching Powder with the French (Gay-Lussac) Degrees.*—The latter are understood to mean the number of litres of chlorine gas at 0° C. and 760 mm. pressure which can be given off by 1 kilogram of bleaching powder.

French Degrees	Per cent. Chlorine.	French Degrees.	Per cent. Chlorine	French Degrees.	Per cent. Chlorine.	French Degrees.	Per cent. Chlorine.
63	20·28	81	26·07	99	31·87	116	37·34
64	20·60	82	26·40	100	32·10	117	37·66
65	20·92	83	26·72	101	32·51	118	37·99
66	21·25	84	27·04	102	32·83	119	38·31
67	21·57	85	27·31	103	33·16	120	38·63
68	21·89	86	27·36	104	33·48	121	38·95
69	22·21	87	28·01	105	33·80	122	39·27
70	22·55	88	28·33	106	34·12	123	39·51
71	22·86	89	28·65	107	34·47	124	39·92
72	23·18	90	28·97	108	34·78	125	40·24
73	23·50	91	29·29	109	35·09	126	40·56
74	23·82	92	29·62	110	35·41	127	40·88
75	24·14	93	29·94	111	35·73	128	41·20
76	24·47	94	30·26	112	36·05	129	41·53
77	24·79	95	30·53	113	36·38	130	41·85
78	25·11	96	30·90	114	36·70	131	42·17
79	25·40	97	31·23	115	37·02	132	42·49
80	25·75	98	31·55				

3. *Testing the Atmosphere of the Chambers for Chlorine before opening them.*—In England a maximum of $2\frac{1}{2}$ grains chlorine per cubic foot is prescribed before the chamber may be opened. This is ascertained by the apparatus, Fig. 17. A is a rubber pressure ball holding about 100 c.c., B a hole in its mouthpiece, D a glass tube reaching nearly to the bottom of the glass jar E; its lower end is contracted so that only a thin needle can pass through. E is charged with 25 c.c. of a solution, so prepared that ten bulbfuls (A) of gas containing $2\frac{1}{2}$ grains of chlorine per cubic foot will just colour the liquid by separation of iodine. The content of the chamber gas in grains of chlorine per cubic foot is inversely as the number of bulbfuls required to colour the solution. The solution is prepared by diluting 64·0 c.c. of decinormal sodium arsenite solution (see p. 115), adding 25 g. potassium iodide, 5 g. precipitated calcium carbonate, 6 to 10 drops of ammonia, and diluting the whole to 1 litre. For a test, take 25 c.c. of this solution, add a little starch solution, introduce the outer end of D into the bleaching powder chamber 2 feet above the bottom, compress A and close the hole B by a finger, whereupon the pressure on A is

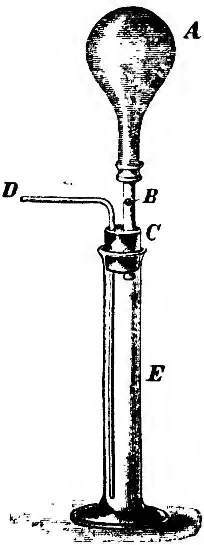

Fig. 17.

relieved. By the expansion of the rubber ball A chamber air is aspirated into the liquid contained in E. Note the number of times the ball A must be employed as described, before the liquid is coloured by the separation of iodine. According to the prescribed limit, this number should be at least 10.

A more accurate method for determining the chlorine is given in Lunge-Keane, *Techn. Methods*, vol. i. (2nd Edition), p. 597.

G.—Electrolytic Chlorine.

Examination for Carbon Dioxide.—Chlorine gas produced by means of gas carbon electrodes may contain up to 12 per cent. carbon dioxide. This CO_2 is estimated by Ferchland's process, as modified in Lunge's laboratory.

A dry Bunte burette, the content of which (from tap to tap = v) is exactly known, is filled with the chlorine by passing this through for some time, the gas passing in from below, so as to rise regularly below the lighter air. When filled with the chlorine gas under atmospheric pressure, the burette is fixed in a clamp in a vertical position, and a level tube is attached by means of a strong rubber tube, filled with mercury to the bottom tap, which has a single bore. The rubber tube must be entirely filled with mercury, so that no air can get into the burette, and it is secured against slipping off by iron wire. When the bottom tap of the burette is opened, mercury enters into the burette and absorbs the chlorine, at first rather quickly, but later on its surface is covered by a pellicle, which precludes further action. Then the bottom tap is closed, and by agitating the burette the complete absorption of the chlorine is effected. The sides of the burette are thereby covered with a non-transparent layer, and a mixture of mercurous chloride and mercury floats on the top of the mercury, which prevent reading off the volume. When the absorption of the chlorine is finished, open the bottom tap, put the level of the mercury approximately equal in the burette and the level tube, and allow ten or fifteen minutes for the equalisation of the temperature. Now put 1 c.c. saturated solution of sodium chloride into the top beaker, and allow this to enter the burette by lowering the level tube. This causes the pulverulent mixture on the top of the mercury to subside, and an easily readable surface to be formed. Then adjust the levels for atmospheric pressure, as described in the case of the nitrometer (p. 165) and read the volume of gas = a. Now introduce a little concentrated solution of potassium hydroxide through the funnel into the burette, absorb the CO_2 by shaking, re-establish atmospheric

PRESSURE AND SPECIFIC GRAVITY OF LIQUID CHLORINE. (Knietsch).

Temperature.	Pressure.	Specific Gravity.	Mean coefficient of expansion.
−88°	37·5 mm. Hg.	...	
−85	45·0 ,,	...	
−80	62·5 ,,	1·6602	
−75	88·0 ,,	1·6490	
−70	118 ,,	1·6382	
−65	159 ,,	1·6273	
−60	210 ,,	1·6167	
−55	275 ,,	1·6055	0·001409
−50	350 ,,	1·5945	
−45	445 ,,	1·5830	
−40	560 ,,	1·5720	
−35	705 ,,	1·5589	
−33·6	760 ,,	1·5575	
−30	1·20 atm.	1·5485	
−25	1·50 ,,	1·5358	
−20	1·84 ,,	1·5230	
−15	2·23 ,,	1·5100	0·001793
−10	2·63 ,,	1·4965	
− 5	3·14 ,,	1·4830	
± 0	3·66 ,,	1·4690	
+ 5	4·25 ,,	1·4548	0·001978
+10	4·95 ,,	1·4405	
+15	5·75 ,,	1·4273	0·002030
+20	6·62 ,,	1·4118	
+25	7·63 ,,	1·3984	0·002190
+30	8·75 ,,	1·3815	
+35	9·95 ,,	1·3683	0·002260
+40	11·50 ,,	1·3510	
50	14·70 ,,	1·3170	0·002690
60	18·60 ,,	1·2830	
70	23·00 ,,	1·2430	0·003460
80	28·40 ,,	1·2000	
90	34·50 ,,		
100	41·70 ,,		
110	50·80 ,,		
120	60·40 ,,		
130	71·60 ,,		
146	93·50 ,,	Critical	Point

pressure, and read the new volume of gas $= b$. The formula $\frac{(a-b)\,100}{v}$ shows the percentage of CO_2 in the crude chlorine gas. No correction for vapour tension of water need be made in this case if concentrated solutions have been used.

H.—Chlorate of Potash.

1. *Chlorate Liquors* contain calcium chlorate and chloride, but these are calculated as potassium salts for the sake of convenience.

(a) *Chlorate* is estimated both in order to check the work and to calculate the necessary addition of KCl. Measure 2 c.c. of liquor in an accurate pipette, run it into a flask (Fig. 15, p. 181, add a little hot water and one drop of alcohol, boil (without the valve) till all smell of chlorine and the pink colour have disappeared, allow to cool, add 25 c.c. of the strongly acid ferrous sulphate solution (*cf.* p. 181, and requiring a c.c. of seminormal permanganate), close the flask with its valve, and boil for ten minutes. After cooling, titrate with seminormal permanganate. The number of cubic centimetres required to produce a faint pink $= b$. The liquor then contains calcium chlorate equivalent to 5·105 $(a-b)$ g. $KClO_3$ per litre, and it will theoretically require an amount of 3·106 $(a-b)$ g. of pure KCl per litre.

(b) *Chloride* is estimated in order to check the work, and is therefore calculated as KCl, although present as $CaCl_2$. Treat 1 c.c. of liquor as above, to destroy the free chlorine and pink colour, allow to cool, add a little neutral potassium chromate, and titrate with decinormal silver nitrate (as described p. 174). Each cubic centimetre of the latter indicates chloride equivalent to 7·456 g. KCl per litre.

2. *Commercial Chlorate of Potash* is only tested for chlorides, calculated as KCl. As their quantity is very small, it is advisable to dissolve 50 g. of the salt in water absolutely free from chlorine, and to test with decinormal silver nitrate, as in 1 (b). Each cubic centimetre of this solution $=$ 0·007456 g. KCl $=$ 0·015 per cent. KCl.

I.—Bleach Liquors.

These are tested like Bleaching Powder, p. 185.

Electrolytic Bleach Liquor, see p. 209.

VII.—ANALYSIS OF COMMERCIAL SODA ASH.

When merely the *available alkali* (alkalimetrical degree) has to be ascertained, it is convenient to weigh out 15·5 g., to dissolve in a 500 c.c. flask, and to take for each test 50 c.c. (in Germany, without filtering; in England, sometimes with, sometimes without). In this case each cubic centimetre of standard acid indicates 0·03100 g. Na_2O, or just 2 per cent. of available alkali (Na_2O). The standard acid is normal hydrochloric acid, containing 36·468 g. HCl per litre, and is standardised both with pure sodium carbonate and with silver nitrate. The indicator is either litmus (in which case the solution has to be boiled for some time) or more conveniently methyl orange (which is used with cold solutions).

If the percentage of alkali is to be calculated in terms of Na_2CO_3, as is usual in Germany and other countries, 2·6500 g. is weighed out, dissolved, and titrated (without filtering) with normal hydrochloric acid, each c.c. of which indicates 2 per cent. Na_2CO_3 in this case. In Germany the samples are ignited before weighing, and the percentage is always stated for soda ash in this dry state.

For a *complete* analysis of commercial soda ash 50 g. are dissolved in warm water.

1. *The Insoluble Residue* is filtered and washed, the filtrate and washings are diluted up to 1 litre, and the following tests are made with this solution.

2. *Sodium Carbonate* is found by titrating 20 c.c. (equal to 1 g. of soda ash) with normal HCl, deducting the amount of No. 3. That of No. 4 is always too small to consider in this case.

3. *Sodium Hydroxide* is estimated by adding to 50 c.c. of the solution, contained in a 100 c.c. flask, an excess of barium chloride. Add water to 100 c.c. and allow precipitate to settle. Take 50 c.c., without filtering, and titrate with standard acid (*e.g.*, decinormal hydrochloric acid), using methyl orange as indicator.

4. *Sodium Sulphide.*—100 c.c. (equal to 5 g. of ash) are titrated with ammoniacal silver nitrate containing 13·818 g. Ag per litre, and indicating 0·005 g. Na_2S per cubic centimetre. Heat the soda liquor to boiling, add ammonia, and run in the silver solution from a burette divided in $\frac{1}{10}$ c.c., till no further black precipitate of Ag_2S is produced. In order to observe this more accurately the liquid is filtered towards the end of the operation, and the titration is continued if necessary. This filtration is repeated several times. Each cubic centimetre of silver solution indicates 0·1 per cent. of Na_2S in the alkali.

5. *Sodium Sulphite.*—Acidulate 100 c.c. (equal to 5 g. soda ash) with acetic acid, add starch solution, and titrate with iodine till a blue colour appears. A decinormal iodine solution corresponds to 0·006304 g. Na_2SO_3 per cubic centimetre (in this case 0·126 per cent.). From this should be deducted the amount corresponding to test No. 4; 1 c.c. of the silver solution can be regarded as equal to 1·3 c.c. of the decinormal, or equal to 5·0 c.c. of the weaker iodine solution.

6. *Sodium Sulphate.*—Acidulate 20 c.c. of the solution (equal to 1 g. soda ash) with hydrochloric acid, precipitate with barium chloride, as on p. 134, and weigh the $BaSO_4$, of which 1·000 part is equal to 0·6086 part Na_2SO_4.

7. *Sodium Chloride.*—Neutralise 20 c.c. (equal to 1 g. soda ash) exactly with nitric acid, preferably by adding exactly as many cubic centimetres normal nitric acid from a burette as had been used in test No. 1; then add neutral potassium chromate, and titrate with decinormal silver nitrate as described on p. 174. Each cubic centimetre of this corresponds to 0·005846 g. NaCl.

8. *Iron.*—Neutralise 100 c.c. (equal to 5 g. soda ash) with sulphuric acid free from iron, reduce with zinc free from iron (p. 170), and titrate with $\frac{1}{20}$ normal potassium permanganate, of which each cubic centimetre corresponds to 0·002793 g. Fe, or in this case 0·0559 per cent. Fe.

9. *Sodium Silicate* is not present in appreciable quantities in ordinary soda ash, but always in the ash recovered from the liquor used in the manufacture of wood "cellulose." It is estimated by acidulating 20 c.c. (equal to 1 g. soda ash) with HCl, filtering the SiO_2, drying, and igniting. 1 g. $SiO_2 = 2·028$ g. Na_2SiO_3.

10. *Table for comparing French, German, and English Commercial Alkalimetrical Degrees.*—The French or Descroizilles degrees mean the quantity of real sulphuric acid, H_2SO_4, neutralised by 100 parts of soda ash. The German degrees express the available alkali in terms of sodium carbonate, Na_2CO_3. In England some works invoice in actual percentage of soda, Na_2O, as found in the first column of the following tables. The Newcastle test is based on the equivalent 32 for Na_2O, or 59·26 degrees for pure Na_2CO_3, and invoices fractions of degrees.

FRENCH, GERMAN, AND ENGLISH COMMERCIAL ALKALIMETRICAL DEGREES.

Real Soda. Na_2O.	German degrees. Na_2CO_3.	New-castle degrees.	French degrees.	Real Soda. Na_2O.	German degrees. Na_2CO_3.	New-castle degrees.	French degrees.
0·5	0·86	0·51	0·79	20·5	35·06	20·77	32·40
1	1·71	1·01	1·58	21	35·91	21·27	33·19
1·5	2·57	1·52	2·37	21·5	36·77	21·78	33·98
2	3·42	2·03	3·16	22	37·62	22·29	34·77
2·5	4·28	2·54	3·95	22·5	38·48	22·80	35·56
3	5·13	3·04	4·74	23	39·33	23·30	36·35
3·5	5·99	3·55	5·53	23·5	40·19	23·81	37·14
4	6·84	4·05	6·32	24	41·04	24·31	37·93
4·5	7·70	4·56	7·11	24·5	41·90	24·82	38·72
5	8·55	5·06	7·90	25	42·75	25·32	39·51
5·5	9·41	5·57	8·69	25·5	43·61	25·83	40·30
6	10·26	6·08	9·48	26	44·46	26·34	41·09
6·5	11·12	6·59	10·27	26·5	45·32	26·85	41·88
7	11·97	7·09	11·06	27	46·17	27·35	42·67
7·5	12·83	7·60	11·85	27·5	47·03	27·86	43·46
8	13·68	8·10	12·64	28	47·88	28·36	44·25
8·5	14·54	8·61	13·43	28·5	48·74	28·37	45·04
9	15·39	9·12	14·22	29	49·59	29·38	45·83
9·5	16·25	9·63	15·01	29·5	50·45	29·89	46·62
10	17·10	10·13	15·81	30	51·30	30·39	47·42
10·5	17·96	10·64	16·60	30·5	52·16	30·90	48·21
11	18·81	11·14	17·39	31	53·01	31·41	49·00
11·5	19·67	11·65	18·18	31·5	53·87	31·91	49·79
12	20·52	12·17	18·97	32	54·72	32·42	50·88
12·5	21·38	12·68	19·76	32·5	55·58	32·92	51·37
13	22·23	13·17	20·55	33	56·43	33·43	52·16
13·5	23·09	13·68	21·34	33·5	57·29	33·94	52·95
14	23·94	14·18	22·13	34	58·14	34·44	53·74
14·5	24·80	14·69	22·92	34·5	59·00	34·95	54·53
15	25·65	15·19	23·71	35	59·85	35·46	55·32
15·5	26·51	15·70	24·50	35·5	60·71	35·96	56·11
16	27·36	16·21	25·29	36	61·56	36·47	56·90
16·5	28·22	16·73	26·08	36·5	62·42	36·98	57·69
17	29·07	17·22	26·87	37	63·27	37·48	58·48
17·5	29·93	17·73	27·66	37·5	64·13	37·98	59·27
18	30·78	18·23	28·45	38	64·98	38·50	60·06
18·5	31·64	18·74	29·24	38·5	65·84	39·00	60·85
19	32·49	19·25	30·03	39	66·69	39·51	61·64
19·5	33·35	19·76	30·82	39·5	67·55	40·02	62·43
20	34·20	20·26	31·61	40	68·40	40·52	63·22

FRENCH, GERMAN, AND ENGLISH COMMERCIAL ALKALIMETRICAL DEGREES—*Continued.*

Real Soda. Na_2O.	German degrees. Na_2CO_3.	New-castle degrees.	French degrees.	Real Soda. Na_2O.	German degrees. Na_2CO_3.	New-castle degrees.	French degrees.
40·5	69·26	41·03	64·01	60·5	103·46	61·30	95·63
41	70·11	41·54	64·81	61	104·31	61·80	96·42
41·5	70·97	42·04	65·60	61·5	105·17	62·31	97·21
42	71·82	42·55	66·39	62	106·02	62·82	98·00
42·5	72·68	43·06	67·18	62·5	106·88	63·32	98·79
43	73·53	43·57	67·97	63	107·73	63·83	99·58
43·5	74·39	44·07	68·76	63·5	108·59	64·33	100·37
44	75·24	44·58	69·55	64	109·44	64·84	101·16
44·5	76·10	45·08	70·34	64·5	110·30	65·35	101·95
45	76·95	45·69	71·13	65	111·15	65·85	102·74
45·5	77·81	46·10	71·92	65·5	112·01	66·36	103·53
46	78·66	46·60	72·71	66	112·86	66·87	104·32
46·5	79·52	47·11	73·50	66·5	113·72	67·37	105·11
47	80·37	47·62	74·29	67	114·57	67·88	105·90
47·5	81·23	48·12	75·08	67·5	115·43	68·39	106·69
48	82·08	48·63	75·87	68	116·28	68·89	107·48
48·5	82·94	49·14	76·66	68·5	117·14	69·40	108·27
49	83·79	49·64	77·45	69	117·99	69·91	109·06
49·5	84·65	50·15	78·24	69·5	118·85	70·41	109·85
50	85·50	50·66	79·03	70	119·70	70·92	110·64
50·5	86·36	51·16	79·82	70·5	120·56	71·43	111·43
51	87·21	51·67	80·61	71	121·41	71·93	112·23
51·5	88·07	52·18	81·40	71·5	122·27	72·44	113·02
52	88·92	52·68	82·19	72	123·12	72 95	113·81
52·5	89·78	53·19	82·98	72·5	123·98	73·45	114·60
53	90·63	53·70	83·77	73	124·83	73·96	115·39
53·5	91·49	54·20	84·56	73·5	125·69	74·47	116·18
54	92·34	54·71	85·35	74	126.54	74·97	116·97
54·5	93·20	55·22	86·14	74·5	127·40	75·48	117·76
55	94·05	55·72	86·93	75	128·25	75·99	118·55
55·5	94·91	56·23	87·72	75·5	129·11	76·49	119·34
56	95·76	56·74	88·52	76	129·96	77·00	120·13
56·5	96·62	57·24	89·31	76·5	130·82	77·51	120·92
57	97·48	57·75	90·10	77	131·67	78·01	121·71
57·5	98·33	58·26	90·89	77·5	132·53	78·52	122·50
58	99·18	58·76	91·68				
58·5	100·04	59·72	92·47				
59	100·89	59·77	93·26				
59·5	101·75	60·28	94·05				
60	102·60	60·79	94·84				

SPECIFIC GRAVITIES OF SOLUTIONS OF SODIUM CARBONATE AT 15° C.

Specific gravity.	Degrees Twaddell.	Degrees Baumé.	Per cent. by weight.		1 cubic metre contains kilog.	
			Na_2CO_3.	Na_2CO_3, 10 aq.	Na_2CO_3.	Na_2CO_3, 10 aq.
1·000	0	0	0·00	0·00	0·00	0·00
1·005	1	0·7	0·45	1·21	4·52	12·16
1·010	2	1·4	0·91	2·46	9·19	24·85
1·015	3	2·1	1·39	3·75	14·11	38·06
1·020	4	2·7	1·90	5·13	19·38	52·33
1·025	5	3·4	2·35	6·34	24·09	64·99
1·030	6	4·1	2·82	7·61	29·05	78·38
1·035	7	4·7	3·27	8·82	33·84	91·29
1·040	8	5·4	3·74	10·09	38·90	104·94
1·045	9	6·0	4·21	11·36	43·99	118·71
1·050	10	6·7	4·70	12·68	49·35	133·14
1·055	11	7·4	5·17	13·95	54·54	147·17
1·060	12	8·0	5·65	15·24	59·89	161·54
1·065	13	8·7	6·15	16·59	65·50	176·68
1·070	14	9·4	6·63	17·89	70·94	191·42
1·075	15	10·0	7·08	19·10	76·11	205·33
1·080	16	10·6	7·56	20·40	81·65	220·32
1·085	17	11·2	8·03	21·67	87·13	235·12
1·090	18	11·9	8·48	22·88	92·43	249·39
1·095	19	12·4	8·90	24·01	97·46	262·91
1·100	20	13·0	9·31	25·12	102·41	276·32
1·105	21	13·6	9·80	26·44	108·29	292·16
1·110	22	14·2	10·27	27·71	114·00	307·58
1·115	23	14·9	10·75	29·00	119·86	323·35
1·120	24	15·4	11·22	30·27	125·66	339·02
1·125	25	16·0	11·67	31·49	131·29	354·26
1·130	26	16·5	12·17	32·83	137·52	370·98
1·135	27	17·0	12·64	34·10	143·46	387·04
1·140	28	17·7	13·08	35·29	149·11	402·31
1·145	29	18·3	13·50	36·42	154·58	417·01
1·150	30	18·8	13·94	37·61	160·31	432·52
1·155	31	19·3	14·34	38·69	165·63	446·87

SPECIFIC GRAVITIES OF CONCENTRATED SOLUTIONS OF SODIUM CARBONATE AT 30° C.*

Specific gravity at 30°.	Degrees Twaddell.	Degrees Baumé.	Per cent. by weight.		1 cubic metre contains kilog.	
			Na_2CO_3.	Na_2CO_3, 10 aq.	Na_2CO_3.	Na_2CO_3, 10 aq.
1·310	62	34·2	28·08	75·76	367·85	992·46
1·305	61	33·7	27·66	74·63	360·96	973·92
1·300	60	33·3	27·25	73·52	354·25	955·76
1·295	59	32·8	26·84	72·41	347·58	937·71
1·290	58	32·4	26·42	71·28	340·82	919·51
1·285	57	32·0	26·00	70·15	334·10	901·43
1·280	56	31·5	25·60	69·07	327·68	884·10
1·275	55	31·1	25·18	67·94	321·05	866·24
1·270	54	30·6	24·74	66·75	314·20	847·73
1·265	53	30·2	24·28	65·51	307·14	828·70
1·260	52	29·7	23·85	64·35	300·51	810·81
1·255	51	29·3	23·43	63·21	294·05	793·29
1·250	50	28·8	23·03	62·14	287·88	776·75
1·245	49	28·4	22·63	61·06	281·74	760·20
1·240	48	27·9	22·22	59·95	275·53	743·38
1·235	47	27·4	21·80	58·82	269·23	726·43
1·230	46	26·9	21·37	57·66	262·85	709·22
1·225	45	26·4	20·96	56·55	256·76	692·73
1·220	44	26·0	20·55	55·44	250·71	676·37
1·215	43	25·5	20·12	54·28	244·46	659·50
1·210	42	25·0	19·67	53·07	238·01	642·15
1·205	41	24·5	19·26	51·96	232·08	626·12
1·200	40	24·0	18·83	50·80	225·96	609·60
1·195	39	23·5	18·42	49·70	220·42	594·22
1·190	38	23·0	18·00	48·56	214·20	577·84
1·185	37	22·5	17·55	47·35	207·97	561·10
1·180	36	22·0	17·09	46·11	201·66	544·10
1·175	35	21·4	16·62	44·84	195·29	526·87
1·170	34	20·9	16·16	43·60	189·07	510·12
1·165	33	20·3	15·70	42·36	182·91	493·49
1·160	32	19·8	15·25	41·14	176·90	477·22
1·155	31	19·3	14·84	40·04	171·40	462·46
1·150	30	18·8	14·42	38·91	165·83	447·47
1·145	29	18·3	14·02	37·83	160·53	433·15
1·140	28	17·7	13·61	36·72	155·15	418·61

* This temperature has been specially chosen, because the higher concentrations of sodium carbonate cannot exist in solution at lower temperatures.

INFLUENCE OF TEMPERATURE ON THE SPECIFIC

0° C.	5°.	10°.	15°.	20°.	25°	30°.	35°.	40°	45°	50°.
..	...	...	...	...	...	1·285	1·282	1·279	1·276	1·273
...	...	...	...	...	...	1·274	1·271	1·267	1·265	1·262
...	...	...	...	...	...	1·263	1·260	1·257	1·254	1·251
..	...	..	...	...	...	1·252	1·250	1·247	1·244	1·240
...	..	...	...	...	...	1·241	1·239	1·236	1·233	1·230
...	...	...	1·210	1·238	1·236	1·234	1·232	1·230	1·227	1·224
...	...	...	1·230	1·228	1·225	1·223	1·221	1·219	1·216	1·213
...	...	...	1·220	1·218	1·215	1·213	1·210	1·208	1·205	1·201
...	...	...	1·210	1·208	1·206	1·204	1·201	1·199	1·196	1·192
...	...	...	1·200	1·198	1·196	1·194	1·192	1·189	1·186	1·183
1·198	1·195	1·193	1·190	1·188	1·186	1·184	1·182	1·179	1·176	1·173
1·188	1·185	1·183	1·180	1·178	1·176	1·174	1·172	1·169	1·166	1·163
1·177	1·174	1·172	1·170	1·168	1·166	1·164	1·162	1·160	1·157	1·154
1·166	1·164	1·162	1·160	1·158	1·156	1·154	1·152	1·150	1·148	1·145
1·156	1·154	1·152	1·150	1·148	1·146	1·144	1·142	1·139	1·136	1·134
1·146	1·144	1·142	1·140	1·138	1·136	1·134	1·132	1·129	1·126	1·123
1·136	1·134	1·132	1·130	1·128	1·126	1·124	1·122	1·120	1·117	1·114
1·126	1·124	1·122	1·120	1·118	1·116	1·114	1·112	1·110	1·107	1·104
1·116	1·114	1·112	1·110	1·108	1·106	1·104	1·102	1·100	1·098	1·095
1·106	1·104	1·102	1·100	1·098	1·096	1·094	1·092	1·090	1·088	1·085
1·096	1·094	1·092	1·090	1·088	1·086	1·084	1·082	1·080	1·078	1·075
1·086	1·084	1·082	1·080	1·078	1·076	1·074	1·072	1·070	1·068	1·065
1·075	1·073	1·071	1·070	1·069	1·067	1·065	1·063	1·061	1·059	1·056
1·064	1·063	1·061	1·060	1·059	1·057	1·056	1·054	1·052	1·050	1·047
1·053	1·052	1·051	1·050	1·049	1·048	1·046	1·044	1·042	1·040	1·037
1·043	1·042	1·041	1·040	1·039	1·038	1·036	1·034	1·032	1·030	1·027
1·033	1·032	1·031	1·030	1·029	1·028	1·026	1·024	1·022	1·020	1·017
1·023	1·022	1·021	1·020	1·019	1·018	1·016	1·014	1·012	1·010	1·007
1·013	1·012	1·011	1·010	1·009	1·008	1·006	1·004	1·002	1·000	0·997

GRAVITIES OF SOLUTIONS OF SODIUM CARBONATE.

55°.	60°.	65°.	70°.	75°.	80°	85°.	90°.	95°.	100°.
1·270	1·267	1·264	1·260	1·256	1·252	1·247	1·243	1·238	1·234
1·259	1·256	1·253	1·249	1·244	1·240	1·236	1·232	1·228	1·224
1·248	1·245	1·241	1·237	1·233	1·229	1·226	1·222	1·218	1·215
1·237	1·234	1·230	1·227	1·224	1·220	1·217	1·213	1·210	1·206
1·226	1·223	1·220	1·216	1·213	1·210	1·207	1·204	1·200	1·197
1·220	1·217	1·213	1·210	1·206	1·203	1·199	1·195	1·191	1·188
1·209	1·206	1·202	1·199	1·195	1·192	1·188	1·184	1·181	1·178
1·198	1·194	1·191	1·188	1·184	1·181	1·178	1·174	1·171	1·168
1·189	1·185	1·182	1·178	1·175	1·172	1·168	1·165	1·162	1·159
1·179	1·176	1·172	1·168	1·165	1·162	1·158	1·155	1·152	1·149
1·169	1·166	1·163	1·159	1·156	1·153	1·149	1·146	1·143	1·140
1·160	1·156	1·153	1·150	1·147	1·144	1·140	1·137	1·134	1·131
1·151	1·147	1·144	1·141	1·138	1·135	1·131	1·128	1·125	1·122
1·142	1·139	1·136	1·133	1·130	1·126	1·123	1·120	1·117	1·114
1·131	1·128	1·125	1·122	1·119	1·116	1·113	1·110	1·107	1·104
1·120	1·118	1·115	1·112	1·109	1·106	1·103	1·100	1·097	1·094
1·111	1·108	1·105	1·102	1·099	1·096	1·093	1·090	1·087	1·084
1·101	1·098	1·095	1·092	1·089	1·086	1·083	1·080	1·077	1·074
1·092	1·089	1·086	1·083	1·080	1·077	1·074	1·071	1·068	1·065
1·082	1·079	1·076	1·073	1·070	1·067	1·064	1·061	1·058	1·055
1·072	1·070	1·067	1·064	1·061	1·058	1·055	1·052	1·049	1·046
1·062	1·060	1·057	1·054	1·052	1·049	1·046	1·043	1·040	1·038
1·053	1·051	1·048	1·045	1·043	1·040	1·037	1·034	1·032	1·029
1·044	1·041	1·038	1·036	1·032	1·030	1·028	1·025	1·023	1·020
1·034	1·032	1·029	1·027	1·024	1·021	1·019	1·016	1·014	1·011
1·024	1·022	1·019	1·017	1·015	1·012	1·010	1·007	1·005	1·003
1·014	1·012	1·009	1·007	1·005	1·002	1·000	0·997	0·995	0·993
1·004	1·002	0·999	0·997	0·995	0·992	0·990	0·987	0·985	0·983
0·994	0·992	0·989	0·987	0·985	0·982	0·980	0·977	0·975	0·973

Sulphur Recovery (Chance Process).

1. *Estimation of Sulphur as Sulphide in Vat Waste.*—The apparatus consists of a small flask fitted with a stopcock funnel and outlet tube connected with two Mohr's potash bulbs, the first one being empty, the second containing a strong solution of caustic potash. (In lieu of Mohr's bulbs a tube of the shape shown in Fig. 10, p. 144, can be employed with great advantage.) It is preferable to connect the last potash bulb to an aspirator or Bunsen pump, to produce a slight vacuum. About 2 g. of vat waste is put into the flask, and a sufficient quantity of water is added. Then hydrochloric acid, diluted with its volume of water, is run in from the funnel gradually. After the decomposition has ceased, the solution is boiled, until the whole of the gases are displaced by steam, most of the steam condensing in the first empty potash bulbs. When enough steam has been produced to bring the first bulb of the second set, filled with potash solution, up to boiling, the tap of the funnel is opened, and the apparatus allowed to cool down. The potash solution is then transferred to a ¼ or ½ litre flask, made up to the mark, an aliquot part taken, diluted with a large quantity of previously boiled water (free from air), neutralised with acetic acid, and titrated with decinormal iodine, each c.c. of which indicates 0·001604 g. S.

2. *Sulphur as Sulphide in Carbonated Mud.*—About 6 g. is taken for analysis; otherwise the test is conducted just like the preceding one.

3. *Sulphide-sulphur + Carbonic Acid in Vat Waste.*—This test (which is only exceptionally made) is carried out in a small flask, fitted with stopcock funnel, connected with a U-tube containing sodium sulphate to absorb any traces of HCl passing over, and a sufficient number of chloride of calcium tubes to thoroughly dry the gases. To the last of these are connected two weighed potash bulbs containing a strong solution of caustic potash, followed by weighed $CaCl_2$ tubes. The whole apparatus being connected, 2 g. of vat waste is put into the flask, and some water added. A current of nitrogen is then passed through the apparatus to displace the air. [Nitrogen from a cylinder may be passed through a solution of potassium hydroxide to remove any trace of carbon dioxide.] The vat waste is then decomposed by hydrochloric acid, and the contents of the flask are boiled. Afterwards a current of nitrogen is passed through the apparatus for a considerable time to displace the H_2S and CO_2 in the flask and drying tubes. The potash bulbs and the last drying tubes are reweighed, the increase showing the amount of $H_2S + CO_2$ in the vat waste employed. The potash solution is then transferred to a

measuring flask, and the H_2S estimated as described in 1. Deducting the amount from the increase of weight of the absorbing apparatus, we find the amount of CO_2 present.

4. *Sulphur as Sulphide in Solutions of Calcium or Sodium Sulphydrates and Sulphides.*—10 c.c. is diluted to 250, and of this liquid a convenient portion is taken out, largely diluted with air-free water, acidulated with acetic acid, and titrated with iodine, as in test 1. If thiosulphates are present, they are estimated as in 5, and deducted. If polysulphides are present, the sulphur which would be precipitated by an acid is not estimated by this method, but only that which would be liberated as H_2S by an acid.

5. *Soda, Lime, and Thiosulphate in Sulphur Liquors.*—In one sample of the liquor, say 5 c.c., estimate the total alkalinity, *i.e.* $Na_2O + CaO$, by standard hydrochloric acid and methyl orange. Take another sample, say 50 c.c., pass pure CO_2 in till lead paper shows the absence of all sulphides, boil to decompose calcium bicarbonate, dilute with water to 500 c.c., allow the precipitate to settle, take 50 c.c. of the clear liquor and titrate again, the alkalinity this time being due to Na_2O only. CaO is found from the difference between the two titrations.

Another sample of the carbonated liquor is titrated with decinormal iodine for thiosulphate. Each c.c. of iodine solution indicates 0·006414 g. S. as thiosulphate.

6. *Lime-kiln Gases.*—CO_2 is estimated by an Orsat apparatus, or a Honigmann burette, or any other similar apparatus. When using an Orsat apparatus, the test for oxygen can be made as on p. 119.

7. *Gas from Gas-holder.*

(a) *Hydrogen Sulphide + Carbon Dioxide* are estimated by an Orsat apparatus or a Honigmann burette, etc.

(b) *Hydrogen Sulphide only.*—A wide-mouthed bottle of known capacity, holding about 500 c.c., is fitted with a rubber cork and two tubes, one nearly reaching to the bottom, the other ending just below the cork, both of them with stopcocks outside. Gas is passed through for some time, till it has entirely displaced the air in the bottle. Then 20 or 25 c.c. of standard potash solution is run in from a pipette, through one of the stopcocks, the bottle is well shaken until the whole of the H_2S and CO_2 are absorbed, the contents of the bottle are poured into a measuring flask, the bottle is rinsed out completely, and the total liquid made up to the mark.

An aliquot portion is taken out, largely diluted with previously boiled water, acidified with acetic acid, and the H_2S

estimated by iodine. In this case a solution of iodine is employed containing 11·463 g. I per litre, each c.c. of which indicates 1 c.c. of gaseous H_2S at 0° C. and 760 mm. pressure. For somewhat exact estimations, the temperature, pressure, and vapour tension have to be taken into account; but it is unnecessary to observe the thermometer and barometer, and to make any complicated calculations, if a Lunge's gas-volumeter be used (p. 167). In this case the level-tube, C, of the instrument is placed so that the mercury stands at the same height in C as in the reduction tube B; the height of mercury in the latter is read off, which gives the volume occupied by 100 c.c. of dry air of 0° and 760 mm. under the prevailing atmospheric conditions; the number of c.c. of iodine solution, multiplied by 100, is divided by this figure, and thus the correction of the normal volume effected.

8. *Exit Gases from the Claus Kilns.*—These contain SO_2 and H_2S. Both these gases, on being passed through iodine solution, produce 2HI for each atom of S; but whilst H_2S does not further increase the acidity of the solution, SO_2 produces its equivalent of H_2SO_4. Hence SO_2 and H_2S are measured together by the amount of iodine converted into HI, and SO_2 by the acidity present after the HI has been saturated with caustic soda. Since the current of gases carries away some iodine from the decinormal solution, the gases must be passed through caustic soda, or, better, through sodium thiosulphate, to intercept this iodine. The manipulation is hence as follows: Aspirate one or more litres of the gases through 50 c.c. of decinormal iodine solution, contained in a bulb apparatus (Fig. 10, p. 144), or other efficient absorbing-tubes, followed by another apparatus containing 50 c.c. of decinormal thiosulphate solution. Empty the contents of both apparatus into a beaker, and titrate with decinormal iodine and starch solution, till a blue colour appears. The number of c.c. of iodine solution used, if multiplied by 0·001604 g. indicates the total sulphur present as SO_2 and H_2S. Now add a drop of thiosulphate solution to discharge the blue colour, then a drop of methyl orange, and decinormal caustic soda from a burette, till the pink colour of the liquid is discharged. The number of c.c. of caustic soda used, less those of iodine used in the preceding test, multiplied by 0·001604, indicates the sulphur present as SO_2.

VIII. MANUFACTURE OF SODA BY THE AMMONIA PROCESS.

A.—Raw Materials.

1. *Rock Salt*, compare p. 174.
2. *Brine*.—The following determinations are made:—

(a) *Specific Gravity*, by the hydrometer.

(b) *Chlorine*, expressed as NaCl. Dilute 10 c.c. to 1 litre, and titrate 10 c.c. of the diluted solution as on p. 174.

(c) *Sulphates*.—Dilute 50 c.c. brine to 150 or 200 c.c., add a little hydrochloric acid, and precipitate with barium chloride as on p. 134.

(d) *Ferric Oxide and Alumina*.—To 500 c.c. brine add a little nitric acid, heat to 80°, precipitate by an excess of ammonia, digest for half an hour at 80°, filter, and wash well. As a check, redissolve the precipitate in hydrochloric acid and reprecipitate it by ammonia.

In the filtrate *lime* and *magnesia* may be estimated as on pp. 174 and 175.

(e) *Bicarbonates of Iron, Lime, and Magnesia*.—Destroy the bicarbonates as such by prolonged boiling of 500 c.c., replace the water driven off, filter the precipitate formed, wash it, dissolve it in hydrochloric acid, and in the solution estimate the iron by precipitation with NH_3, and lime and magnesia in the ordinary way.

3. *Concentrated Gas-Liquor or Sulphate of Ammonia*, cf. Chapter XIII., pp. 233 and 234.
4. *Limestone*, cf. p. 183.
5. *Quicklime*, cf. p. 184.
6. *Coals or Coke*, cf. p. 117.

B.—Tests made during the Process of Manufacture.

1. *Ammoniacal Brine* from the receivers.

(a) *Sodium Chloride*.—Acidulate with nitric acid and estimate the NaCl by $AgNO_3$ gravimetrically, or volumetrically in the neutral or faintly alkaline solution as on p. 174.

(b) *Ammonia, free and combined*.—Dilute 10 c.c. to 100 c.c. and boil in a distilling flask until all the free ammonia and ammonium carbonate has been expelled; absorb this in a measured volume of normal sulphuric acid, and titrate back. To the solution remaining in the flask add caustic soda solution, distil again, and absorb this "combined" ammonia also in sulphuric acid. *Cf.* Chapter XIII., p. 233.

2. *Carbonators.*—Free and combined NH_3 are estimated as in No. 1 (b).

3. *Mother Liquor.*—Estimate :—

(a) NH_3, free and combined, as above.
(b) Undecomposed NaCl, by evaporating 10 c.c. in a platinum dish, heating until all NH_4Cl is expelled, and weighing.

4. *Crude Bicarbonate.*—Estimate :—

(a) *The Alkalimetrical Degree*, as on p. 190.
(b) CO_2 as on p. 209.
(c) Moisture, by igniting and allowing for the CO_2 present as bicarbonate and found in (b).

5. *Distillation of Ammonia* :—

(a) NH_3, free and combined, in the mother liquor, as in No. 1 (b).
(b) Milk of lime, as on p. 184.
(c) Excess of lime in the stills. Boil 100 c.c. until all NH_3 has been expelled, add a little ammonium sulphate, and boil again. The NH_3 now set free, which corresponds to the excess of lime, is absorbed in standard sulphuric acid and titrated.

6. *Lime-kiln Gases.*—Estimate the CO_2 as on p. 119.

C.—Commercial Products.

1. *Soda Ash*, as on p. 190.

2. *Commercial Bicarbonate* is tested like the crude, No. 1, or very accurately by heating in an air-bath to 270° and receiving the gas in a Lunge's gas-volumeter, p. 167 (compare Lunge, *Z. angew. Chem.*, 1897, p. 522).

IX. CAUSTIC SODA.

A.—Caustic Liquor.

(*a*) Test for total alkali by titration with standard acid, using methyl orange as indicator. If carbonate is present, it can be determined as described on p. 209.

(b) SPECIFIC GRAVITIES OF SOLUTIONS OF SODIUM HYDROXIDE AT 15° C.

Specific Gravity.	Degrees Twaddell.	Degrees Baumé.	Per cent. Na_2O.	Per cent. NaOH.	1 cb.m. contains kg.	
					Na_2O.	NaOH.
1·000	0	0	0	0·00	0	0
1·005	1	0·7	0·33	0·43	3·31	4·32
1·010	2	1·4	0·67	0·86	6·77	8·69
1·015	3	2·1	0·99	1·28	10·05	12·99
1·020	4	2·7	1·31	1·69	13·36	17·24
1·025	5	3·4	1·65	2·13	16·91	21·83
1·030	6	4·1	2·02	2·60	20·81	26·78
1·035	7	4·7	2·37	3·06	24·53	31·67
1·040	8	5·4	2·71	3·50	28·18	36·40
1·045	9	6·0	3·02	3·90	31·56	40·76
1·050	10	6·7	3·36	4·34	35·28	45·57
1·055	11	7·4	3·69	4·76	38·93	50·22
1·060	12	8·0	4·03	5·20	42·72	55·12
1·065	13	8·7	4·39	5·67	46·75	60·39
1·070	14	9·4	4·75	6·13	50·83	65·59
1·075	15	10·0	5·10	6·58	54·83	70·74
1·080	16	10·6	5·46	7·05	58·97	76·14
1·085	17	11·2	5·81	7·50	63·04	81·38
1·090	18	11·9	6·16	7·95	67·14	86·66
1·095	19	12·4	6·50	8·39	71·18	91·87
1·100	20	13·0	6·81	8·78	74·91	96·58
1·105	21	13·6	7·15	9·23	79·01	101·99
1·110	22	14·2	7·50	9·67	83·25	107·34
1·115	23	14·9	7·84	10·12	87·42	112·84
1·120	24	15·4	8·18	10·56	91·62	118·27
1·125	25	16·0	8·57	11·06	96·41	124·43
1·130	26	16·5	8·95	11·55	101·14	130·52
1·135	27	17·0	9·32	12·02	105·78	136·43
1·140	28	17·7	9·68	12·49	110·35	142·39
1·145	29	18·3	10·03	12·94	114·84	148·16
1·150	30	18·8	10·34	13·34	118·91	153·41
1·155	31	19·3	10·67	13·76	123·24	158·93
1·160	32	19·8	11·00	14·19	127·60	164·60
1·165	33	20·3	11·33	14·62	131·99	170·32
1·170	34	20·9	11·67	15·06	136·54	176·20
1·175	35	21·4	12·04	15·53	141·47	182·48
1·180	36	22·0	12·40	16·00	146·32	188·80
1·185	37	22·5	12·75	16·45	151·09	194·93
1·190	38	23·0	13·11	16·91	156·01	201·23
1·195	39	23·5	13·46	17·36	160·85	207·45
1·200	40	24·0	13·80	17·81	165·60	213·72
1·205	41	24·5	14·15	18·26	170·51	220·03

(b) SPECIFIC GRAVITIES OF SOLUTIONS OF SODIUM HYDROXIDE AT 15° C.—*Continued.*

Specific Gravity.	Degrees Twaddell.	Degrees Baumé.	Per cent. Na_2O.	Per cent. NaOH.	1 cb.m. contains kg.	
					Na_2O.	NaOH.
1·210	42	25·0	14·50	18·71	175·45	226·39
1·215	43	25·5	14·87	19·18	180·67	233·04
1·220	44	26·0	15·23	19·65	185·81	239·73
1·225	45	26·4	15·59	20·12	190·98	246·47
1·230	46	26·9	15·97	20·60	196·43	253·38
1·235	47	27·4	16·30	21·03	201·31	259·72
1·240	48	27·9	16·64	21·47	206·34	266·23
1·245	49	28·4	16·97	21·90	211·28	272·66
1·250	50	28·8	17·31	22·33	216·38	279·13
1·255	51	29·3	17·65	22·77	221·51	285·76
1·260	52	29·7	18·01	23·23	226·93	292·70
1·265	53	30·2	18·35	23·68	232·13	299·55
1·270	54	30·6	18·70	24·13	237·62	306·45
1·275	55	31·1	19·05	24·58	242·89	313·40
1·280	56	31·5	19·41	25·04	248·45	320·51
1·285	57	32·0	19·77	25·50	254·04	327·68
1·290	58	32·4	20·12	25·96	259·55	334·88
1·295	59	32·8	20·47	26·41	265·09	342·01
1·300	60	33·3	20·81	26·85	270·53	349·05
1·305	61	33·7	21·20	27·35	276·66	356·92
1·310	62	34·2	21·59	27·85	282·83	364·83
1·315	63	34·6	21·97	28·34	288·91	372·67
1·320	64	35·0	22·35	28·83	295·02	380·56
1·325	65	35·4	22·73	29·32	301·17	388·40
1·330	66	35·8	23·10	29·80	307·23	396·34
1·335	67	36·2	23·47	30·28	313·32	404·24
1·340	68	36·6	23·83	30·74	319·32	411·92
1·345	69	37·0	24·18	31·20	325·22	419·64
1·350	70	37·4	24·61	31·75	332·24	428·63
1·355	71	37·8	25·02	32·28	339·02	437·39
1·360	72	38·2	25·42	32·79	345·71	445·94
1·365	73	38·6	25·78	33·26	351·90	454·00
1·370	74	39·0	26·14	33·73	358·12	462·10
1·375	75	39·4	26·52	34·22	364·65	470·53
1·380	76	39·8	26·90	34·71	371·22	479·00
1·385	77	40·1	27·28	35·20	377·83	487·52
1·390	78	40·5	27·66	35·68	384·47	495·95
1·395	79	40·8	28·02	36·15	390·88	504·29
1·400	80	41·2	28·42	36·67	397·88	513·38
1·405	81	41·6	28·81	37·17	404·78	522·24
1·410	82	42·0	29·18	37·65	411·44	530·87
1·415	83	42·3	29·58	38·16	418·56	539·96

(*b*) **SPECIFIC GRAVITIES OF SOLUTIONS OF SODIUM HYDROXIDE AT 15° C.**—*Continued.*

Specific Gravity.	Degrees Twaddell.	Degrees Baumé.	Per cent. Na_2O.	Per cent. NaOH.	1 cb.m. contains kg.	
					Na_2O.	NaOH.
1·420	84	42·7	29·97	38·67	425·57	549·11
1·425	85	43·1	30·36	39·17	432·63	558·17
1·430	86	43·4	30·75	39·67	439·72	567·28
1·435	87	43·8	31·14	40·18	446·86	576·58
1·440	88	44·1	31·53	40·68	454·03	585·79
1·445	89	44·4	31·93	41·20	461·39	595·34
1·450	90	44·8	32·32	41·70	468·64	604·65
1·455	91	45·1	32·72	42·22	476·07	614·30
1·460	92	45·4	33·14	42·75	483·84	624·15
1·465	93	45·8	33·54	43·27	491·36	633·91
1·470	94	46·1	33·95	43·80	499·07	643·86
1·475	95	46·4	34·36	44·33	506·81	653·87
1·480	96	46·8	34·76	44·85	514·45	663·78
1·485	97	47·1	35·17	45·37	522·27	673·74
1·490	98	47·4	35·57	45·89	529·99	683·76
1·495	99	47·8	35·98	46·42	537·90	693·98
1·500	100	48·1	36·38	46·94	545·70	704·10
1·505	101	48·4	36·79	47·47	553·69	714·42
1·510	102	48·7	37·20	48·00	561·72	724·80
1·515	103	49·0	37·61	48·53	569·79	735·23
1·520	104	49·4	38·02	49·05	577·90	745·56
1·525	105	49·7	38·42	49·58	585·91	756·10
1·530	106	50·0	38·83	50·10	594·10	766·53

[(*c*) INFLUENCE OF TEMPERATURE.

(c) INFLUENCE OF TEMPERATURE ON THE SPECIFIC

0° C.	5°.	10°.	15°.	20°.	25°.	30°.	35°.	40°.	45°.	50°.
1·367	1·364	1·362	1·360	1·357	1·355	1·353	1·350	1·348	1·345	1·342
1·357	1·354	1·352	1·350	1·347	1·345	1·343	1·340	1·337	1·335	1·332
1·347	1·344	1·342	1·340	1·338	1·335	1·333	1·330	1·327	1·325	1·322
1·338	1·335	1·332	1·330	1·328	1·325	1·323	1·320	1·317	1·315	1·312
1·328	1·325	1·322	1·320	1·318	1·315	1·313	1·310	1·307	1·305	1·302
1·318	1·315	1·313	1·310	1·308	1·305	1·303	1·300	1·297	1·294	1·292
1·308	1·305	1·303	1·300	1·297	1·294	1·292	1·289	1·287	1·284	1·282
1·298	1·295	1·293	1·290	1·287	1·284	1·282	1·279	1·277	1·274	1·272
1·288	1·285	1·283	1·280	1·277	1·274	1·272	1·269	1·267	1·264	1·262
1·278	1·275	1·273	1·270	1·267	1·265	1·262	1·260	1·258	1·255	1·252
1·268	1·265	1·263	1·260	1·257	1·255	1·252	1·250	1·248	1·245	1·242
1·257	1·255	1·252	1·250	1·247	1·245	1·242	1·240	1·238	1·235	1·233
1·247	1·245	1·242	1·240	1·237	1·235	1·232	1·230	1·228	1·225	1·223
1·237	1·235	1·232	1·230	1·227	1·224	1·222	1·220	1·218	1·215	1·212
1·227	1·225	1·222	1·220	1·217	1·214	1·212	1·210	1·208	1·205	1·202
1·217	1·215	1·212	1·210	1·207	1·204	1·203	1·200	1·198	1·196	1·192
1·207	1·205	1·202	1·200	1·197	1·195	1·193	1·190	1·188	1·186	1·184
1·197	1·195	1·192	1·190	1·187	1·185	1·183	1·180	1·178	1·176	1·174
1·187	1·185	1·182	1·180	1·177	1·175	1·173	1·170	1·168	1·166	1·164
1·176	1·174	1·172	1·170	1·167	1·165	1·163	1·161	1·158	1·156	1·154
1·166	1·164	1·162	1·160	1·157	1·155	1·153	1·151	1·148	1·146	1·144
1·156	1·154	1·152	1·150	1·148	1·146	1·144	1·142	1·140	1·137	1·135
1·146	1·144	1·142	1·140	1·138	1·136	1·134	1·132	1·130	1·127	1·125
1·136	1·134	1·132	1·130	1·128	1·126	1·124	1·122	1·120	1·118	1·116
1·126	1·124	1·122	1·120	1·118	1·116	1·114	1·112	1·110	1·108	1·106
1·115	1·113	1·112	1·110	1·108	1·106	1·104	1·102	1·100	1·099	1·097
1·105	1·103	1·102	1·100	1·098	1·096	1·095	1·093	1·092	1·090	1·087
1·094	1·093	1·091	1·090	1·088	1·087	1·086	1·084	1·082	1·080	1·078
1·084	1·083	1·081	1·080	1·078	1·077	1·076	1·074	1·072	1·070	1·068
1·074	1·073	1·071	1·070	1·068	1·067	1·066	1·064	1·062	1·060	1·058
1·064	1·063	1·061	1·060	1·058	1·057	1·056	1·054	1·052	1·050	1·048
1·054	1·053	1·051	1·050	1·048	1·047	1·046	1·044	1·042	1·040	1·038
1·044	1·043	1·041	1·040	1·038	1·037	1·036	1·034	1·032	1·030	1·028
1·034	1·033	1·031	1·030	1·028	1·027	1·026	1·024	1·022	1·020	1·018
1·024	1·023	1·021	1·020	1·018	1·017	1·016	1·014	1·012	1·010	1·008
1·014	1·013	1·011	1·010	1·008	1·007	1·006	1·004	1·002	1·000	0·998

GRAVITIES OF SOLUTIONS OF CAUSTIC SODA.

55°.	60°.	65°.	70°.	75°.	80°.	85°.	90°.	95°.	100°.
1·339	1·336	1·333	1·331	1·328	1·326	1·323	1·321	1·318	1·316
1·330	1·327	1·324	1·322	1·319	1·316	1·314	1·311	1·308	1·306
1·320	1·317	1·314	1·312	1·309	1·306	1·304	1·301	1·298	1·296
1·310	1·307	1·304	1·302	1·299	1·296	1·294	1·291	1·288	1·286
1·300	1·297	1·294	1·292	1·289	1·286	1·283	1·280	1·277	1·274
1·289	1·286	1·284	1·281	1·278	1·275	1·272	1·269	1·266	1·263
1·279	1·276	1·274	1·271	1·268	1·265	1·262	1·259	1·256	1·253
1·269	1·266	1·264	1·261	1·258	1·255	1·252	1·249	1·245	1·242
1·259	1·256	1·254	1·251	1·248	1·245	1·242	1·239	1·235	1·232
1·250	1·247	1·245	1·242	1·239	1·236	1·233	1·231	1·228	1·225
1·240	1·237	1·235	1·232	1·229	1·226	1·223	1·221	1·218	1·215
1·231	1·228	1·226	1·223	1·220	1·218	1·215	1·213	1·209	1·207
1·221	1·218	1·216	1·213	1·210	1·208	1·205	1·203	1·200	1·197
1·210	1·208	1·205	1·202	1·200	1·198	1·195	1·192	1·190	1·187
1·200	1·198	1·195	1·192	1·190	1·188	1·185	1·182	1·180	1·177
1·191	1·189	1·186	1·184	1·181	1·179	1·176	1·173	1·171	1·168
1·182	1·180	1·177	1·175	1·172	1·169	1·166	1·163	1·161	1·158
1·172	1·169	1·166	1·164	1·161	1·158	1·155	1·153	1·150	1·147
1·162	1·159	1·156	1·153	1·151	1·148	1·145	1·143	1·140	1·137
1·152	1·149	1·146	1·143	1·140	1·138	1·135	1·132	1·130	1·127
1·142	1·139	1·136	1·133	1·130	1·128	1·125	1·122	1·120	1·117
1·132	1·130	1·127	1·124	1·121	1·118	1·116	1·113	1·110	1·107
1·122	1·120	1·117	1·114	1·111	1·108	1·106	1·103	1·100	1·097
1·113	1·110	1·107	1·104	1·101	1·099	1·096	1·093	1·090	1·087
1·103	1·100	1·097	1·094	1·092	1·089	1·086	1·083	1·080	1·077
1·094	1·091	1·089	1·086	1·083	1·080	1·077	1·074	1·071	1·068
1·084	1·082	1·079	1·076	1·073	1·070	1·067	1·064	1·061	1·058
1·075	1·073	1·070	1·067	1·064	1·061	1·058	1·056	1·052	1·048
1·066	1·063	1·060	1·057	1·054	1·051	1·048	1·046	1·043	1·040
1·056	1·053	1·050	1·047	1·044	1·042	1·039	1·036	1·033	1·030
1·046	1·043	1·040	1·037	1·034	1·032	1·029	1·026	1·023	1·020
1·036	1·033	1·030	1·027	1·024	1·021	1·019	1·016	1·013	1·010
1·026	1·023	1·020	1·017	1·014	1·011	1·009	1·006	1·003	1·000
1·016	1·013	1·010	1·007	1·004	1·001	0·999	0·996	0·993	0·990
1·006	1·003	1·000	0·997	0·994	0·991	0·989	0·986	0·983	0·980
0·996	0·993	0·990	0·987	0·984	0·981	0·979	0·976	0·973	0·970

B.—Lime Mud.

(a) *Sodium as Carbonate and Hydroxide.*—Evaporate to dryness with addition of ammonium carbonate (in order to decompose the insoluble sodium compounds), repeat this, digest with hot water, filter, wash, and test the filtrate for alkali. The soda may have been originally present as NaOH or as Na_2CO_3. It is expressed in terms of Na_2O (0·03100 g. per cubic centimetre of normal acid).

(b) *Caustic Lime.*—Titrate as described (p. 184) with normal hydrochloric acid and phenolphthalein. This indicates NaOH as well, for which half of the amount found in test (a) may be assumed without any serious error.

(c) *Calcium Carbonate.*—Titrate with normal hydrochloric acid and methyl orange, deduct from the cubic centimetres required those required in tests (a) and (b).

C.—Fished Salts.

Dissolve 50 g. in 1 litre of water, and take 50 c.c. of the solution for every test.

(a) *Available Alkali* is tested for with normal hydrochloric acid.

(b) *Sodium Chloride.*—Neutralise with nitric acid, preferably running normal acid out of a burette, and proceed in other respects as described on p. 174.

(c) *Sodium Sulphate.*—Add a slight excess of hydrochloric acid, precipitate with barium chloride, and weigh the $BaSO_4$ (p. 134).

(d) *Sodium Sulphite, Thiosulphate, etc.*—Add an excess of bleaching-powder solution, then hydrochloric acid, till the reaction is acid, and a smell of chlorine is produced; precipitate with $BaCl_2$, weigh the $BaSO_4$, and deduct the amount found in test (c). The remainder is calculated as "Na_2SO_4 from oxidisable sulphur compounds."

D.—Caustic Bottoms.

Dissolve 10 g. in water, and filter. The washed residue is dried and ignited, and yields :—

(a) *Insoluble Matter.*—If necessary, the contained iron is estimated by dissolving in concentrated hydrochloric acid, reducing with zinc, adding manganous sulphate, and titrating with permanganate as on p. 137.

(b) *Available Alkali* is estimated in the aqueous solutions by normal hydrochloric acid, using litmus or lacmoid as indicator. (Methyl orange is not available in this case, owing to the presence of alumina.)

(c) *Sodium Carbonate* is estimated as in commercial soda ash (p. 190).

E.—Commercial Caustic Soda.

The sample must be very carefully taken. The single pieces must be freed from the outer crust by scraping it off, before weighing.

Dissolve 50 g. of the prepared sample in 1 litre of water, and take aliquot portions for each of the following tests with a pipette.

(a) *Available Alkali* is tested in at least 20 c.c. (equal to 1 g.) by normal HCl. If the caustic soda contains more than traces of alumina, methyl orange cannot be used as indicator, but litmus or lacmoid should be employed. In the case of strong caustic this is unnecessary.

(b) *Sodium Carbonate* is estimated by expelling the CO_2 with dilute sulphuric acid, and absorbing it in soda-lime (the pumice saturated with cupric sulphate is left out here). The quantity of CO_2 being so small, any estimation by difference yields unsatisfactory results. Very approximate results can, however, be obtained by titrating first with phenolphthalein till the pink colour is discharged (when all Na_2CO_3 will have been changed into $NaHCO_3$), noting the amount of standard acid used, adding methyl orange and more standard acid till the pink colour appears. The acid used in the second test × 2 indicates Na_2CO_3.

For more exact methods of determining carbonates, see Cumming and Kay's *Quantitative Analysis* (5th Edition), pp. 215 and 219.

(c) *The Table for comparing English, French, and German Degrees* is given on pp. 192 and 193.

X. ELECTROLYTIC ALKALI LIQUORS.

These are analysed just like bleach liquor, p. 189.

1. *Hypochlorites* are titrated as on p. 185.

2. *Free Hypochlorous Acid.*—Estimate the bleaching chlorine as in No. 1, then chloride, chlorate, and other acids on the one hand, and all bases on the other; the acidity in excess represents free HOCl.

3. *Chlorate* may be estimated as on p. 189, but since there is but little chlorate in presence of much hypochlorite, it is prefer-

able to use the direct method of Fresenius, as follows :—To the solution add an excess of neutral lead acetate solution; this produces a precipitate which gradually turns brown, and which contains a quantity of PbO_2 corresponding to the chlorate. Allow to stand for eight or ten hours, until there is no more smell of chlorine, filter, wash, evaporate the filtrate to a small volume, precipitate lead and lime by means of a little sodium carbonate, and estimate the chlorate in the filtrate according to p. 189.

In mixtures of chlorate and hypochlorite, containing large quantities of the latter, Ditz and Knöpfelmacher estimate the chlorate iodometrically, by decomposing it at the ordinary temperature with concentrated hydrochloric acid and potassium bromide. Put the substance, together with a sufficient excess of KBr, into a small flask provided with a hollow glass stopper with dropping funnel and lateral absorbing vessel for the retention of bromine vapours. The latter is charged with 10 c.c. of a 5 per cent. solution of KI. Pour 50 c.c. concentrated hydrochloric acid through the dropping funnel into the flask, allow it to act for an hour, pour in 300 c.c. water, then 20 c.c. of the solution of KI, shake well, transfer the contents of the absorbing vessel to the flask, and titrate the iodine which has been set free by thiosulphate. The quantity of chlorate + hypochlorite is thus ascertained. If there is very much of the latter present, it should be removed beforehand.

4. *Chloride.*—Employ the solution from No. 1, in which all hypochlorite has been converted into chloride, with formation of sodium arsenate, which is an excellent indicator for the titration of the total chlorides by silver nitrate, p. 175, making *no* deduction for any excess of silver nitrate required to produce the colour. From the quantity of chloride thus found, deduct that which corresponds to the hypochlorite.

5. *Carbon Dioxide.*—Destroy the hypochlorite by boiling with ammonia, expel the CO_2 by a strong acid, and estimate it as on p. 209. The ammonia used must itself be free from carbonate.

6. *Bases.*—Convert these into sulphates, by evaporation with sulphuric acid, and estimate them in the residue by the ordinary methods.

7. *Free Alkali.*—Add to the solution a little of Merck's chemically pure hydrogen peroxide, which reacts as follows with the hypochlorite :—

$$NaOCl + H_2O_2 = NaCl + H_2O + O_2.$$

$NaOH$ and Na_2CO_3 remain unchanged in solution, and are titrated as on p. 202.

In regard to the estimation of carbon dioxide in electrolytic *chlorine gas*, see p. 187.

XI. NITRIC ACID MANUFACTURE.

A.—Commercial Nitrate of Soda.

According to the custom of the trade, which has held for many years, no direct estimation of the nitrate is made in the commercial nitrate of soda exported from Chili. The rule is, to estimate moisture, sodium chloride, sodium sulphate, and insoluble substances. The sum of these impurities is called the "refraction," and everything else is assumed to be real nitrate of soda. But as Chili saltpetre sometimes contains potassium nitrate (in which the percentage of NO_3 is less than in $NaNO_3$), errors up to 1 per cent. $NaNO_3$ or even more may be caused by this indirect method of testing. Therefore, besides the above estimations, it ought to be insisted upon to estimate the potassium present and to calculate the results accordingly, or even better, to estimate the nitric-nitrogen directly.

The *sampling* ought to be done very carefully, since especially the amount of moisture may vary considerably in different parts of a cargo, and the reduction of the large sample to a smaller bulk ought to yield a really representative average sample.

1. *Moisture.*—Heat 10 g. or more of a good average sample in a small glass or porcelain dish to 130° for four or five hours, till the weight is constant; or, about 0·5 g. is accurately weighed in a small silica crucible and heated gently over a Bunsen flame until the nitrate just fuses. The crucible is then cooled in a desiccator and re-weighed.

2. *Insoluble.*—Dissolve 10 g. in water, filter, wash, and ignite. If there is a very appreciable quantity of organic matter present, first dry at 100° C. and weigh the filter with the precipitate before igniting it. The solution is used for the tests Nos. 4 to 6.

3. *Sodium Nitrate.*—In order to obtain a really representative sample, take about 20 g. of the carefully taken, large, average sample, dry this at 110°, grind it very finely, mix it thoroughly, and use it for the estimation of nitrate, etc. For the nitrate test, weigh out about 0·35 g. (that is, a quantity which will yield between 100 and 120 c.c. NO at the ordinary temperature and barometric pressure) in a narrow weighing-tube. Pour its contents as completely as possible into the decomposition vessel D of the gas-volumeter, Fig. 12, p. 167, so that the substance gets as much as possible to the bottom of the beaker of D. Weigh the weighing-tube again, with the small quantity of nitrate still adhering to it, so as to ascertain the weight of nitrate taken $= a$, in D. The three-way tap must be closed. Now run in 0·5 c.c. water, wait until the nitrate has been entirely or nearly all dis-

solved, draw the solution with any small crystals into the inside of D, by lowering the level-tube E and cautiously opening the tap, rinse the beaker with ½ or at most 1 c.c. water, and then allow 15 c.c. of pure concentrated sulphuric acid to enter in the same way. (It is important not to employ more than 1·5 c.c. water altogether to 15 c.c. of strong acid, for if the acid is too much diluted, a froth of basic mercuric sulphate is formed which prevents an exact reading of the volume. On the other hand, the addition of a little water to the strong acid prevents the solution of an appreciable quantity of NO in the liquid.)

The reaction is finished by vigorous shaking of the acid solution with the mercury (as in the ordinary nitrometer). During this period the level-tube should be roughly put into position, to avoid any considerable differences of pressure and possible leakages through the tap. When the agitating has been finished wait half an hour for cooling. Then connect tube *c* of vessel D (Fig. 12, p. 167) with tube *e* of the measuring tube A, so that glass touches glass, as described p. 168, and transfer all the gas to A, by raising E and lowering C, but not allowing any acid to get into A. Then shut both taps, and by adjusting the tubes A, B, C, in the manner described, p. 168, compress the gas volume to that corresponding to 0° and 760 mm. pressure.

Of course it is also possible to employ, in lieu of the gas-volumeter, an ordinary nitrometer, that is, to leave out the "reduction-tube" B. In this case the volume NO is read off under the prevailing atmospheric pressure, by adjusting the level-tube accordingly; the volume of NO is then reduced to 0° and 760 mm. by reading the thermometer and barometer, and employing the Tables 12, I. and II., pp. 20 *et seq.* The reduced volume of NO we call x. Each c.c. of it corresponds to 0·0037963 g. $NaNO_3$ (compare the table, p. 20); the whole divided by the weight of the nitrate employed a and multiplied by 100, indicates the percentage of real nitrate; that is:—

$$\frac{0{\cdot}37963x}{a}.$$

A plus correction of 0·4 per cent. of the $NaNO_3$ found is necessary to allow for the solubility of NO.

(*N.B.*—The nitrometer should be tested whether it really contains exactly 100 c.c. to the mark 100, by inverting it, filling in mercury to the mark 100, running it off, and weighing. It should weigh 1360 g. reduced to 0°, or 1355 g. at 15° C. If there is an error, this must be allowed for in each reading.)

4. *Sodium Sulphate* is estimated in the solution No. 2 by precipitation with $BaCl_2$ and weighing the $BaSO_4$. (*Cf.* pp. 134 and 176.)

5. *Sodium Chloride* is titrated with silver nitrate. (*Cf.* p. 174.)

6. *Iodine* is detected by reducing the iodic acid with zinc, heating the solution with concentrated sulphuric acid, which liberates the iodine, diluting and agitating with carbon disulphide, which takes up the iodine, and is thereby coloured pink. The faintest traces of iodate are found by dissolving 5 g. in 100 c.c. of boiled water, adding a little nitric acid, a few drops of a solution of potassium iodide in boiled water, and a drop of starch solution. In the presence of as little as 0·01 mg. I in 1 g. of nitre, a blue colour will appear. A check test must, however, be made with the potassium iodide employed for this test, as this often contains some iodate.

7. *Potassium.*—Evaporate a special sample several times, with strong hydrochloric acid until all the nitrate is decomposed, and estimate the K as in the analysis of potassium chloride, p. 221. Calculate it as KNO_3, 100 parts of which is equivalent to 84·08 of $NaNO_3$.

8. *Perchlorate* (Gilbert).—Treat 20 g. of the dried substance with 2 or 3 c.c. concentrated hydrochloric acid in a flat platinum dish; add about 1 g. manganese dioxide, free from chlorine, dry by heating over a small flame; bring to fusion, put on the lid and keep the dish at a red heat during one-quarter hour. Dissolve the melt in hot water and dilute the solution to 250 c.c. Take out 50 c.c. (= 4 g. nitre), acidulate with nitric acid and add a 1 per cent. solution of $KMnO_4$, until the red colour persists for a full minute. Then add ferric potassium sulphate (iron alum), and titrate the chloride by means of silver nitrate (Volhard's method). From the Cl thus found, deduct that which was originally present (No. 5), and calculate the remainder as perchlorate. 1 part NaCl corresponds to 2·095 $NaClO_3$.

B.—Nitre-Cake.

1. *Free Acid* is titrated with standard alkali (p. 175). If considerable quantities of ferric oxide or alumina are present, no indicator is employed, but normal alkali is added till the first flakes of a precipitate indicate the end of the reaction.

2. *Nitric Acid* should be estimated in a nitrometer with a narrow measuring-tube (p. 165); the method employed is exactly the same as described there, viz., dissolving in the beaker in very little water, and decomposing with a large excess of sulphuric acid.

3. *Ferric Oxide and Alumina* (as pp. 170 and 175).

C.—Nitric Acid.

1. SPECIFIC GRAVITY OF NITRIC ACID AT 15° C., COMPARED WITH WATER OF 4° C. (IN VACUO).

(Lunge and Rey.)

Degrees Twaddell.	Specific gravity.	Percentage by weight.		Grams per litre.	
		N_2O_5.	HNO_3.	N_2O_5.	HNO_3.
0	1·000	0·08	0·10	1	1
1	1·005	0·85	1·00	8	10
2	1·010	1·62	1·90	16	19
3	1·015	2·39	2·80	24	28
4	1·020	3·17	3·70	33	38
5	1·025	3·94	4·60	40	47
6	1·030	4·71	5·50	49	57
7	1·035	5·47	6·38	57	66
8	1·040	6·22	7·26	64	75
9	1·045	6·97	8·13	73	85
10	1·050	7·71	8·99	81	94
11	1·055	8·43	9·84	89	104
12	1·060	9·15	10·68	97	113
13	1·065	9·87	11·51	105	123
14	1·070	10·57	12·33	113	132
15	1·075	11·27	13·15	121	141
16	1·080	11·96	13·95	129	151
17	1·085	12·64	14·74	137	160
18	1·090	13·31	15·53	145	169
19	1·095	13·99	16·32	153	179
20	1·100	14·67	17·11	161	188
21	1·105	15·34	17·89	170	198
22	1·110	16·00	18·67	177	207
23	1·115	16·67	19·45	186	217
24	1·120	17·34	20·23	195	227
25	1·125	18·00	21·00	202	236
26	1·130	18·66	21·77	211	246
27	1·135	19·32	22·54	219	256
28	1·140	19·98	23·31	228	266
29	1·145	20·64	24·08	237	276
30	1·150	21·29	24·84	245	286
31	1·155	21·94	25·60	254	296
32	1·160	22·60	26·36	262	306
33	1·165	23·25	27·12	271	316
34	1·170	23·90	27·88	279	326

SPECIFIC GRAVITY OF NITRIC ACID AT 15° C., COMPARED WITH WATER OF 4° C. (IN VACUO)—*Continued.*

Degrees Twaddell.	Specific gravity.	Percentage by weight.		Grams per litre.	
		N_2O_5.	HNO_3.	N_2O_5.	HNO_3.
35	1·175	24·54	28·63	288	336
36	1·180	25·18	29·38	297	347
37	1·185	25·83	30·13	306	357
38	1·190	26·47	30·88	315	367
39	1·195	27·10	31·62	324	378
40	1·200	27·74	32·36	333	388
41	1·205	28·36	33·09	342	399
42	1·210	28·99	33·82	351	409
43	1·215	29·61	34·55	360	420
44	1·220	30·24	35·28	369	430
45	1·225	30·88	36·03	378	441
46	1·230	31·53	36·78	387	452
47	1·235	32·17	37·53	397	463
48	1·240	32·82	38·29	407	475
49	1·245	33·47	39·05	417	486
50	1·250	34·13	39·82	427	498
51	1·255	34·78	40·58	437	509
52	1·260	35·44	41·34	447	521
53	1·265	36·09	42·10	457	533
54	1·270	36·75	42·87	467	544
55	1·275	37·41	43·64	477	556
56	1·280	38·07	44·41	487	568
57	1·285	38·73	45·18	498	581
58	1·290	39·39	45·95	508	593
59	1·295	40·05	46·72	519	605
60	1·300	40·71	47·49	529	617
61	1·305	41·37	48·26	540	630
62	1·310	42·06	49·07	551	643
63	1·315	42·76	49·89	562	656
64	1·320	43·47	50·71	573	669
65	1·325	44·17	51·53	585	683
66	1·330	44·89	52·37	597	697
67	1·335	45·62	53·22	609	710
68	1·340	46·35	54·07	621	725
69	1·345	47·08	54·93	633	739

SPECIFIC GRAVITY OF NITRIC ACID AT 15° C., COMPARED WITH WATER OF 4° C. (IN VACUO)—*Continued.*

Degrees Twaddell.	Specific gravity.	Percentage by weight.		Grams per litre.	
		N_2O_5.	HNO_3.	N_2O_5.	HNO_3.
70	1·350	47·82	55·79	645	753
71	1·355	48·57	56·66	658	768
72	1·360	49·35	57·57	671	783
73	1·365	50·13	58·48	684	798
74	1·370	50·91	59·39	698	814
75	1·375	51·69	60·30	711	829
76	1·380	52·52	61·27	725	846
77	1·385	53·35	62·24	739	862
78	1·390	54·20	63·23	753	879
79	1·395	55·07	64·25	768	896
80	1·400	55·97	65·30	783	914
81	1·405	56·92	66·40	800	933
82	1·410	57·86	67·50	816	952
83	1·415	58·83	68·63	832	971
84	1·420	59·83	69·80	849	991
85	1·425	60·84	70·98	867	1011
86	1·430	61·86	72·17	885	1032
87	1·435	62·91	73·39	903	1053
88	1·440	64·01	74·68	921	1075
89	1·445	65·13	75·98	941	1098
90	1·450	66·24	77·28	961	1121
91	1·455	67·38	78·60	981	1144
92	1·460	68·56	79·98	1001	1168
93	1·465	69·79	81·42	1023	1193
94	1·470	71·06	82·90	1045	1219
95	1·475	72·39	84·45	1068	1246
96	1·480	73·76	86·05	1092	1274
97	1·485	75·18	87·70	1116	1302
98	1·490	76·80	89·60	1144	1335
99	1·495	78·52	91·60	1174	1369
100	1·500	80·65	94·09	1210	1411
101	1·505	82·63	96·39	1244	1451
102	1·510	84·09	98·10	1270	1481
103	1·515	84·92	99·07	1287	1501
104	1·520	85·44	99·67	1299	1515

2. INFLUENCE OF TEMPERATURE ON THE SPECIFIC GRAVITY OF NITRIC ACID.

0° C.	5°	10°	15°	20°	25°	30°	35°	40°	45°	50°
1·424	1·414	1·407	1·400	1·392	1·385	1·378	1·371	1·363	1·356	1·349
1·413	1·404	1·397	1·390	1·382	1·375	1·367	1·361	1·354	1·347	1·340
1·402	1·394	1·387	1·380	1·372	1·365	1·357	1·351	1·344	1·339	1·332
1·391	1·383	1·377	1·370	1·363	1·356	1·349	1·342	1·335	1·330	1·323
1·380	1·373	1·367	1·360	1·353	1·346	1·340	1·333	1·326	1·320	1·314
1·369	1·362	1·356	1·350	1·343	1·337	1·330	1·323	1·317	1·312	1·305
1·359	1·352	1·346	1·340	1·333	1·327	1·320	1·314	1·308	1·303	1·297
1·348	1·342	1·336	1·330	1·324	1·318	1·311	1·305	1·299	1·294	1·288
1·338	1·332	1·326	1·320	1·314	1·308	1·302	1·296	1·290	1·285	1·280
1·327	1·321	1·316	1·310	1·304	1·299	1·293	1·287	1·281	1·276	1·271
1·317	1·311	1·306	1·300	1·294	1·289	1·283	1·278	1·273	1·268	1·263
1·307	1·301	1·296	1·290	1·284	1·279	1·273	1·268	1·263	1·258	1·253
1·297	1·291	1·286	1·280	1·274	1·269	1·263	1·258	1·253	1·248	1·243
1·287	1·281	1·276	1·270	1·265	1·259	1·254	1·248	1·243	1·238	1·234
1·277	1·271	1·266	1·260	1·255	1·249	1·244	1·238	1·233	1·228	1·224
1·266	1·260	1·255	1·250	1·245	1·240	1·235	1·229	1·224	1·219	1·215
1·256	1·250	1·245	1·240	1·235	1·230	1·225	1·220	1·215	1·210	1·205
1·245	1·240	1·235	1·230	1·225	1·220	1·215	1·210	1·206	1·201	1·196
1·235	1·230	1·225	1·220	1·215	1·210	1·205	1·200	1·196	1·191	1·186
1·224	1·219	1·214	1·210	1·205	1·200	1·196	1·191	1·187	1·182	1·177
1·213	1·208	1·204	1·200	1·195	1·190	1·186	1·181	1·177	1·172	1·167
1·202	1·198	1·194	1·190	1·185	1·181	1·177	1·172	1·168	1·163	1·158
1·192	1·188	1·184	1·180	1·177	1·171	1·167	1·163	1·158	1·154	1·150
1·182	1·178	1·174	1·170	1·166	1·162	1·158	1·154	1·149	1·145	1·141
1·172	1·168	1·164	1·160	1·156	1·152	1·148	1·144	1·140	1·136	1·132
1·161	1·158	1·154	1·150	1·146	1·142	1·139	1·135	1·130	1·127	1·123
1·151	1·147	1·144	1·140	1·136	1·132	1·129	1·125	1·121	1·118	1·114
1·139	1·136	1·133	1·130	1·126	1·123	1·119	1·116	1·112	1·109	1·105
1·129	1·126	1·123	1·120	1·116	1·113	1·110	1·106	1·103	1·100	1·096
1·118	1·115	1·112	1·110	1·107	1·104	1·101	1·097	1·094	1·091	1·087
1·108	1·105	1·102	1·100	1·097	1·094	1·091	1·088	1·085	1·082	1·079
1·098	1·095	1·092	1·090	1·087	1·084	1·081	1·078	1·075	1·073	1·070
1·088	1·085	1·082	1·080	1·077	1·074	1·071	1·068	1·065	1·063	1·060
1·077	1·075	1·072	1·070	1·067	1·064	1·061	1·058	1·056	1·054	1·051
1·067	1·064	1·062	1·060	1·057	1·055	1·052	1·050	1·048	1·045	1·043
1·057	1·054	1·052	1·050	1·047	1·045	1·043	1·040	1·038	1·035	1·033
1·047	1·044	1·042	1·040	1·037	1·035	1·033	1·030	1·028	1·025	1·023
1·037	1·034	1·032	1·030	1·027	1·025	1·023	1·020	1·018	1·015	1·013
1·027	1·024	1·022	1·020	1·017	1·015	1·013	1·010	1·008	1·005	1·003
1·017	1·014	1·012	1·010	1·007	1·005	1·003	1·000	0·998	0·995	0·993

INFLUENCE OF TEMPERATURE ON THE SPECIFIC GRAVITY OF NITRIC ACID—*Continued.*

55°	60°	65°	70°	75°	80°	85°	90°	95°	100°
1·342	1·335	1·329	1·323	1·316	1·310	1·303	1·296	1·290	1·283
1·333	1·327	1·320	1·314	1·308	1·302	1·294	1·288	1·282	1·276
1·325	1·319	1·312	1·305	1·300	1·293	1·286	1·280	1·274	1·267
1·316	1·310	1·304	1·298	1·292	1·286	1·279	1·274	1·267	1·260
1·308	1·302	1·296	1·290	1·284	1·278	1·272	1·266	1·260	1·254
1·300	1·294	1·288	1·282	1·276	1·270	1·265	1·259	1·253	1·247
1·291	1·286	1·280	1·274	1·268	1·263	1·257	1·252	1·246	1·240
1·282	1·278	1·272	1·266	1·261	1·255	1·250	1·245	1·240	1·234
1·274	1·269	1·264	1·258	1·253	1·248	1·243	1·238	1·233	1·228
1·266	1·261	1·256	1·251	1·246	1·240	1·235	1·230	1·225	1·220
1·258	1·253	1·248	1·243	1·238	1·232	1·227	1·222	1·217	1·212
1·248	1·244	1·239	1·234	1·229	1·223	1·218	1·213	1·208	1·203
1·238	1·234	1·229	1·224	1·219	1·214	1·209	1·204	1·199	1·194
1·229	1·225	1·220	1·215	1·210	1·205	1·199	1·195	1·190	1·185
1·219	1·215	1·210	1·205	1·200	1·195	1·190	1·185	1·180	1·175
1·210	1·206	1·201	1·196	1·191	1·186	1·181	1·176	1·171	1·167
1·200	1·196	1·191	1·186	1·181	1·177	1·172	1·167	1·162	1·158
1·191	1·187	1·182	1·177	1·172	·1·168	1·163	1·158	1·153	1·149
1·182	1·177	1·172	1·167	1·163	1·158	1·153	1·148	1·144	1·139
1·173	1·168	1·163	1·160	1·154	1·149	1·144	1·140	1·135	1·130
1·163	1·158	1·154	1·150	1·145	1·140	1·136	1·131	1·126	1·122
1·154	1·150	1·146	1·141	1·136	1·132	1·128	1·123	1·119	1·115
1·145	1·141	1·137	1·133	1·128	1·124	1·120	1·116	1·112	1·107
1·137	1·132	1·128	1·124	1·120	1·116	1·113	1·108	1·105	1·100
1·128	1·124	1·120	1·116	1·112	1·108	1·105	1·101	1·097	1·094
1·119	1·115	1·112	1·108	1·104	1·100	1·097	1·095	1·090	1·086
1·110	1·107	1·103	1·100	1·096	1·093	1·090	1·086	1·082	1·079
1·102	1·099	1·094	1·091	1·088	1·084	1·081	1·078	1·075	1·071
1·093	1·090	1·086	1·083	1·080	1·076	1·073	1·070	1·067	1·064
1·084	1·081	1·078	1·075	1·072	1·068	1·065	1·063	1·060	1·056
1·076	1·073	1·070	1·067	1·064	1·061	1·058	1·055	1·052	1·049
1·067	1·064	1·061	1·058	1·055	1·052	1·050	1·048	1·045	1·042
1·058	1·055	1·052	1·050	1 047	1·044	1·042	1·040	1·038	1·036
1·049	1·046	1·044	1·042	1·039	1·037	1·034	1·031	1·029	1·027
1·040	1·038	1·036	1·034	1·031	1·029	1·026	1·023	1·021	1·018
1·030	1·028	1·026	1·024	1·021	1·019	1·015	1·014	1·012	1·009
1·020	1·018	1·016	1·014	1·011	1·009	1·007	1·004	1·002	1·000
1·010	1·008	1·006	1·004	1·001	0·999	0·997	0·994	0·993	0·990
1·001	0·990	0·997	0·995	0·992	0·990	0·988	0·985	0·983	0·981
0·991	0·989	0·987	0·985	0·982	0·980	0·978	0·975	0·973	0·971

3. *Total Acidity.*—Titrate a diluted sample by standard caustic soda solution. Methyl orange can be quite well used as indicator, if the titration is performed as described, p. 162, although it would be destroyed by prolonged contact with nitrous acid. Strong fuming acid is weighed in a bulb-tap pipette, Fig. 13, p. 171; from this the acid is slowly run on to the bottom of a flask, containing ice-cold water, and the titration is performed quickly, to prevent a decomposition of the nitrous acid. Less concentrated nitric acids may be measured by pipettes or burettes, in lieu of weighing.

4. *Chlorine.*—Saturate with sodium carbonate, free from choride, till the reaction is neutral or faintly alkaline, and titrate with silver nitrate according to p. 174.

5. *Sulphuric Acid.*—Saturate almost completely with sodium carbonate and precipitate with barium chloride as on p. 134. If the acid on evaporating leaves any appreciable fixed residue, this usually consists of sodium sulphate.

6. *Nitrous Acid* or *Nitrogen Tetroxide* are estimated by running the acid from a burette into a measured volume of warm, dilute potassium permanganate (*cf.* p. 162). The result may be expressed in terms of nitrogen peroxide, N_2O_4. Each c.c. $\frac{1}{5}$ normal permanganate = 0·023005 g. N_2O_4. Hence, if m c.c. acid have been used and n c.c. permanganate required, the amount of N_2O_4 is :—

$$\frac{0{\cdot}023005\,n}{m}\text{ g.}$$

The result may also be expressed as nitrous acid calculated to HNO_3. Each c.c. $\frac{1}{5}$ normal permanganate = 0·011755 g. HNO_2 and the factor for conversion to HNO_3 = 1·34.

The quantity of N_2O_4 is often so considerable that the specific gravity tables give a very deceptive result as to the real percentage of HNO_3, and an actual determination should be made.

7. *Fixed Residue*, consisting chiefly of sodium sulphate, with a little ferric oxide, etc., is estimated by evaporating to dryness in a place protected from dust, igniting, and weighing.

8. *Iron.*—Precipitate with excess of ammonia, filter, weigh, and ignite the Fe_2O_3.

9. *Iodine* is detected by digesting for a short time with pure zinc, which reduces iodic acid and generates some nitrous acid; the latter sets the iodine of the HI free, and this can then be recognised by shaking up with carbon disulphide, which thereby assumes a pink colour.

N.B.—Tests Nos. 8 and 9 are only made with nitric acid sold as chemically pure.

D.—Mixtures of Sulphuric Acid and Nitric Acid.

Such mixtures are sold for the manufacture of explosives and other nitrating purposes. They are analysed by the methods described by Lunge and Berl, *Z. angew. Chem.*, 1905, p. 1681; *Chem. Zeit.*, 1907, p. 485.

1. *Total Acidity.*—Weigh about 1 g. in a bulb-tap pipette, Fig. 13, p. 171, and titrate with normal caustic soda solution. When employing methyl orange as indicator, either add it only towards the end of the titration (or else renew it as destroyed), or else add an excess of soda, then the indicator, and titrate back with normal hydrochloric acid.

2. *Nitrous Acid* is estimated as on p. 162, by running the mixed acid into a measured quantity of seminormal permanganate. It may be calculated as HNO_2, or N_2O_3, or even as N_2O_4. In the latter case each c.c. of the $\frac{1}{2}$ normal permanganate indicates 0·023005 g. N_2O_4. If we call the c.c. of permanganate used x, the c.c. of mixed acid required for decolorising it y, and s the specific gravity of the latter, the N_2O_4 is $= \frac{23x}{y}$ g. per litre, or $\frac{2 \cdot 3x}{ys}$ per cent. by weight of N_2O_4 in the mixed acid.

3. Total nitrogen acids are estimated by the nitrometer, p. 165. A quantity of acid, varying with the nature of the mixed acid being analysed, is weighed by difference into the cup of a calibrated nitrometer to which 2 c.c. of pure nitrogen-free 94·5 per cent. sulphuric acid has previously been added. A Lunge-Rey pipette is used for this purpose. The sample is then run into the nitrometer and the cup thoroughly washed by five successive washings of 2 c.c. of sulphuric acid, followed by a sixth washing of 5 c.c. The decomposition is effected in the usual way. The observed volume of gas is reduced to N.T.P. and the result calculated as percentage of nitric acid (HNO_3). Each c.c. NO at N.T.P. corresponds to 0·0028144 g. HNO_3, so that the percentage total nitrogen acids expressed as nitric acid is given by the formula

$$\frac{v \times 0 \cdot 0028144 \times 100}{w}$$

where v = volume of NO and w = weight of mixed acid taken.

A plus correction of 1 per cent. of the total nitrogen acids found is necessary to allow for the solubility of NO.

4. Nitric acid is obtained by subtracting the nitrous acid (as HNO_3) from the total nitrogen acids (as HNO_3).

5. Sulphuric acid is found by subtracting the value for the total nitrogen acids expressed as H_2SO_4 from the total acidity also expressed as H_2SO_4. For this purpose the percentage of total nitrogen acids expressed as HNO_3 is multiplied by 0·778 which represents the ratio between equivalent weights of sulphuric acid and nitric acid, $\frac{1}{2}H_2SO_4 : HNO_3$.

XII.—POTASSIUM SALTS.

A.—Crude Salts (Carnallite, Kainite, etc.).

1. *Moisture.*—Heat 10 g. to 150° for some time, and allow to cool in a desiccator.

2. *Percentage of Potassium* :*—

(a) *In the Absence of more than* 0·5 *per cent. Potassium Sulphate.*—Obtain a well-mixed sample; dissolve 7·640 g. in a half-litre flask, fill up to the mark, and filter. Place 20 c.c. of the filtrate (=0·3056 of the crude salt) in a porcelain dish; add 5 c.c. of a solution of platinum chloride containing 10 g. Pt. in 100 c.c. Evaporate on the water-bath to a syrupy condition, with frequent agitation, so that most of the HCl is driven off and the mass appears dry after cooling. When cool, crush it with a flattened glass rod, add 20 c.c. strong alcohol (at least 94 per cent.), mix well through and pour the liquid portion through a filter which has been previously dried at 120° to 130° till the weight is constant, then weighed and moistened with alcohol. The filter should not be filled up to the top. Pour fresh alcohol on the residue, and heat it on the water-bath nearly to boiling. Wash the solid portion on to the filter, remove most of the liquid by suction, press it between layers of filter paper and dry it till the weight is constant at 120° to 130° (this will usually require only twenty minutes). Each milligram of the potassium-platinum chloride corresponds to 0·1 per cent. KCl in the quantity of substance employed.

(b) *In the Presence of more than* 0·5 *per cent. Potassium Sulphate.*—Dissolve 30·56 g. of the crude salt in a $\frac{1}{2}$-litre flask in 300 c.c. water + 15 c.c. strong hydrochloric acid by boiling, allow to cool, and fill the flask up to the mark. Put 50 c.c. of the clear

* These are the methods given by Tietjens in *Tech. Meth.*, vol. i., p. 520, as worked out and practised at all the Stassfurt works. This applies also to the figures employed for the calculation of the results which are not based on the real atomic weight of platinum (=194·80) and on the formula K_2PtCl_6, but are empirical data, based on many years' experience. The difference is mainly caused by the fact that the precipitate is not pure K_2PtCl_6, but contains some chemically combined water which is not given up even after prolonged drying.

solution into a 200 c.c. flask, heat to boiling, and precipitate the sulphate with the exactly necessary quantity of barium chloride, adding the principal portion of the reagent quickly, the remainder in single drops, always waiting till the liquid shows a clear layer and throwing into this a minute crystal of barium chloride, until this ceases to produce a cloud. If too much $BaCl_2$ should have been accidentally added, it must be removed by a drop or two of dilute sulphuric acid. After cooling, fill up to the mark and take 20 c.c. of the clear solution = 0·3056 g. salt, which is then treated with platinum chloride as described in No. 1. One mg. of the precipitate corresponds to 0·1 per cent. KCl, if the K is to be calculated as such.

For the analysis of salts consisting essentially of K_2SO_4, like kainite, dissolve 35·71 g., in which case each mg. of the platinum precipitate indicates 0·1 per cent. K_2SO_4. When testing rich sulphate (90 to 97 per cent. K_2SO_4) it is necessary to add to the percentage thus found a correction of +0·3 per cent., but this should not be made in the case of potasso-magnesium sulphates.

3. *Percentage of Sodium Chloride*:—

(a) *In High-Grade Salts.*—If there is little or no sulphate present, the NaCl is calculated from the difference between the KCl found directly by gravimetric analysis and the total chlorides as found by titration with silver solution, p. 174. If there is an appreciable proportion of sulphate present, the percentage of (combined) SO_3 must be estimated, as well as that of potassium and chlorine. The barium sulphate obtained is calculated to KCl (1 part $BaSO_4$ = 0·7465 K_2SO_4 = 0·6388 KCl); this amount is deducted from the total quantity of K, calculated as KCl; the remaining KCl, which was present as such and must be quoted as such in the analysis, is deducted from that which is found when calculating all the Cl as KCl. The now remaining nominal amount of KCl is calculated as NaCl, 100 parts KCl being equivalent to 78·41 NaCl. The SO_3 found is calculated as K_2SO_4.

(b) *In Low-Grade Salts* it is not usual to estimate the NaCl. If it is to be done, a complete analysis is required. KCl is estimated as above, in addition: Ca (p. 174), Mg (pp. 170 and 223), SO_3 (p. 133), insoluble matter, and moisture. SO_3 is calculated as $CaSO_4$; if there is not enough Ca present for all the SO_3, the remainder is calculated as $MgSO_4$, and after that as K_2SO_4. If more Mg is present than is required to saturate the SO_3 at disposal, the remaining Mg is calculated as $MgCl_2$. Any excess of Cl over that required to form KCl and $MgCl_2$ is calculated as NaCl.

4. *Magnesium Chloride.*—**In order to distinguish the carnallite salts (which give up the $MgCl_2$ to alcohol) from the non-carnallitic**

salts (which do not do this), shake 10 g. of the crude salt for ten minutes in a $\frac{1}{2}$-litre flask with 100 c.c. 96 per cent. alcohol and titrate 10 c.c. of the filtrate with $\frac{1}{10}$ normal silver solution. Such salts as contain upwards of 6 per cent. Cl soluble in alcohol are regarded as belonging to the carnallite group.

5. *Total Magnesium.*—Boil 10 g. of finely ground, crude salt with 300 c.c. of water in a $\frac{1}{2}$-litre flask for an hour; after cooling add 50 c.c. twice-normal sodium hydroxide solution, in the case of much lime being present also 20 c.c. of a 10 per cent. solution of neutral potassium oxalate, fill the flask up to the mark, filter after a quarter of an hour, and titrate 50 c.c. of the filtrate by normal hydrochloric acid. Each c.c. of the twice-normal alkali used up is = 0·04032 g. $MgCl_2$. To the percentage of MgO 0·2 per cent. should be added (Precht, *Z. anal. Chem.*, 1879, p. 438).

B.—Commercial Potassium Chloride.

Weigh out 7·640 g. and proceed exactly as described under A, 2 (a), p. 221. The calculation is also made in the same manner.

Potassium chloride made from vinasses contains much sulphate and a little carbonate, which is estimated alkalimetrically.

Cyanide is sometimes present in commercial potassium chloride, occasionally in appreciable quantity.

C.—Potassium Sulphate.

Proceed just as in the case of sodium sulphate, p 176. The potassium must sometimes be estimated, which is done as on p. 221 for A, 2 (b).

D.—Beet Ashes.

For this material special methods have been worked out by Heyer (*Chemiker-Zeitung*, 1891, pp. 1489 *et seq.*), and by Alberti and Hempel (*ibid.*, p. 1623).

E.—Commercial Carbonate of Potash.

1. *Available Alkali* is titrated with normal hydrochloric acid, as on p. 190.

2. *Total Potassium* is estimated according to p. 221, A (b), so that all sulphate is converted into chloride. Of course, initially, more hydrochloric acid must be employed in order to decompose the carbonate.

3. *Chloride* is estimated by decinormal silver solution, p. 174. 1 c.c. of this = 0·007456 g. KCl.

4. *Sulphate* is estimated as $BaSO_4$, p. 134. 1 g. $BaSO_4$ = 0·7465 K_2SO_4.

5. *Insoluble matter*, as on p. 190.

6. *Silicate.*—Saturate the salt with hydrochloric acid, evaporate to dryness, moisten with HCl, evaporate again, dissolve in dilute HCl, filter, wash, and strongly ignite the SiO_2. This test is only made exceptionally, and the potassium silicate is calculated together with the carbonate.

7. *Phosphate* is estimated by the magnesia method, and is treated like the silicate.

8. *Calculation of the Analyses.*—Calculate :—

(*a*) K_2CO_3 from the difference between the total potassium and that corresponding to the Cl and SO_3 found.

(*b*) Na_2CO_3 from the difference between the total available alkali and the K_2CO_3 as calculated in (*a*).

(*c*) KCl and

(*d*) K_2SO_4 as above.

(*e*) Water and

(*f*) Insoluble matter, if necessary also iron, by a special test.

1. SPECIFIC GRAVITIES OF SOLUTIONS OF POTASSIUM CARBONATE AT 15°.

Specific Gravity.	Degrees Twaddell.	Degrees Baumé.	Per cent. K_2CO_3.	1 cb.m. contains kg. K_2CO_3.
1·000	0	0	0	0
1·005	1	0·7	0·50	5·0
1·010	2	1·4	1·04	10·50
1·015	3	2·1	1·60	16·24
1·020	4	2·7	2·10	21·42
1·025	5	3·4	2·64	27·06
1·030	6	4·1	3·21	33·06
1·035	7	4·7	3·77	39·02
1·040	8	5·4	4·34	45·14
1·045	9	6·0	4·90	51·21
1·050	10	6·7	5·47	57·44
1·055	11	7·4	6·00	63·30
1·060	12	8·0	6·50	68·90
1·065	13	8·7	7·07	75·30
1·070	14	9·4	7·60	81·32
1·075	15	10·0	8·10	87·08
1·080	16	10·6	8·67	93·64
1·085	17	11·2	9·20	99·82
1·090	18	11·9	9·70	105·73
1·095	19	12·4	10·20	111·69
1·100	20	13·0	10·70	117·70
1·105	21	13·6	11·26	124·42
1·110	22	14·2	11·80	130·98
1·115	23	14·9	12·30	137·15
1·120	24	15·4	12·80	143·36
1·125	25	16·0	13·30	149·63
1·130	26	16·5	13·80	155·94
1·135	27	17·0	14·30	162·31
1·140	28	17·7	14·80	168·72
1·145	29	18·3	15·30	175·19
1·150	30	18·8	15·80	181·70
1·155	31	19·3	16·30	188·27
1·160	32	19·8	16·80	194·88
1·165	33	20·3	17·30	201·55
1·170	34	20·9	17·80	208·26
1·175	35	21·4	18·30	215·03
1·180	36	22·0	18·80	221·84
1·185	37	22·5	19·26	228·23

SPECIFIC GRAVITIES OF SOLUTIONS OF POTASSIUM CARBONATE AT 15°—*Continued.*

Specific Gravity.	Degrees Twaddell.	Degrees Baumé.	Per cent. K_2CO_3.	1 cb.m. contains kg. K_2CO_3.
1·190	38	23·0	19·70	234·43
1·195	39	23·5	20·20	241·39
1·200	40	24·0	20·70	248·40
1·205	41	24·5	21·15	254·86
1·210	42	25·0	21·60	261·36
1·215	43	25·5	22·05	267·91
1·220	44	26·0	22·50	274·50
1·225	45	26·4	22·96	281·26
1·230	46	26·9	23·41	287·94
1·235	47	27·4	23·90	295·17
1·240	48	27·9	24·40	302·56
1·245	49	28·4	24·86	309·51
1·250	50	28·8	25·32	316·50
1·255	51	29·3	25·80	323·79
1·260	52	29·7	26·30	331·38
1·265	53	30·2	26·77	338·64
1·270	54	30·6	27·17	345·06
1·275	55	31·1	27·60	351·90
1·280	56	31·5	28·05	359·04
1·285	57	32·0	28·50	366·23
1·290	58	32·4	28·96	373·58
1·295	59	32·8	29·42	380·99
1·300	60	33·3	29·97	389·61
1·305	61	33·7	30·43	397·11
1·310	62	34·2	30·86	404·27
1·315	63	34·6	31·24	410·81
1·320	64	35·0	31·60	417·12
1·325	65	35·4	32·06	424·80
1·330	66	35·8	32·52	432·52
1·335	67	36·2	32·96	440·02
1·340	68	36·6	33·38	447·29
1·345	69	37·0	33·80	454·61
1·350	70	37·4	34·22	461·97
1·355	71	37·8	34·64	469·37
1·360	72	38·2	35·06	476·82
1·365	73	38·6	35·48	484·30
1·370	74	39·0	35·90	491·83

SPECIFIC GRAVITIES OF SOLUTIONS OF POTASSIUM CARBONATE AT 15°—*Continued.*

Specific Gravity.	Degrees Twaddell.	Degrees Baumé.	Per cent. K_2CO_3.	1 cb.m. contains kg. K_2CO_3.
1·375	75	39·4	36·32	499·40
1·380	76	39·8	36·74	507·01
1·385	77	40·1	37·17	514·80
1·390	78	40·5	37·60	522·64
1·395	79	40·8	38·02	530·38
1·400	80	41·2	38·45	538·30
1·405	81	41·6	38·88	546·26
1·410	82	42·0	39·30	554·13
1·415	83	42·3	39·73	562·19
1·420	84	42·7	40·16	570·27
1·425	85	43·1	40·59	578·41
1·430	86	43·4	41·02	586·59
1·435	87	43·8	41·45	594·81
1·440	88	44·1	41·85	602·64
1·445	89	44·4	42·22	610·08
1·450	90	44·8	42·58	617·41
1·455	91	45·1	42·97	625·21
1·460	92	45·4	43·37	633·20
1·465	93	45·8	43·77	641·23
1·470	94	46·1	44·17	649·30
1·475	95	46·4	44·57	657·41
1·480	96	46·8	44·96	665·41
1·485	97	47·1	45·38	673·89
1·490	98	47·4	45·81	682·57
1·495	99	47·8	46·24	691·29
1·500	100	48·1	46·66	699·90
1·505	101	48·4	47·03	707·80
1·510	102	48·7	47·40	715·74
1·515	103	49·0	47·78	723·87
1·520	104	49·4	48·15	731·88
1·525	105	49·7	48·53	740·08
1·530	106	50·0	48·90	748·17
1·535	107	50·3	49·26	756·14
1·540	108	50·6	49·61	763·99
1·545	109	50·9	49·96	771·88
1·550	110	51·2	50·33	780·12
1·555	111	51·5	50·70	788·39
1·560	112	51·8	51·07	796·69
1·565	113	52·1	51·45	805·19

2. INFLUENCE OF TEMPERATURE ON THE SPECIFIC

0° C.	5°.	10°.	15°.	20°.	25°.	30°.	35°.	40°.	45°.	50°.
1·588	1·586	1·583	1·580	1·577	1·574	1·571	1·568	1·566	1·563	1·559
1·577	1·575	1·573	1·570	1·568	1·565	1·563	1·560	1·557	1·554	1·551
1·567	1·565	1·563	1·560	1·558	1·555	1·553	1·550	1·548	1·545	1·543
1·557	1·554	1·552	1·550	1·548	1·546	1·544	1·541	1·538	1·536	1·533
1·547	1·544	1·542	1·540	1·538	1·536	1·534	1·531	1·528	1·526	1·523
1·536	1·534	1·532	1·530	1·528	1·526	1·524	1·521	1·518	1·515	1·512
1·526	1·524	1·522	1·520	1·518	1·516	1·514	1·511	1·508	1·505	1·502
1·516	1·514	1·512	1·510	1·508	1·506	1·503	1·500	1·498	1·495	1·492
1·506	1·504	1·502	1·500	1·498	1·496	1·493	1·490	1·488	1·485	1·482
1·496	1·494	1·492	1·490	1·488	1·486	1·484	1·481	1·478	1·475	1·472
1·486	1·484	1·482	1·480	1·478	1·476	1·474	1·471	1·468	1·465	1·462
1·476	1·474	1·472	1·470	1·468	1·466	1·464	1·461	1·458	1·455	1·452
1·466	1·464	1·462	1·460	1·458	1·456	1·454	1·451	1·448	1·445	1·442
1·456	1·454	1·452	1·450	1·448	1·446	1·444	1·441	1·438	1·435	1·432
1·446	1·444	1·442	1·440	1·438	1·436	1·434	1·431	1·428	1·425	1·422
1·436	1·434	1·432	1·430	1·428	1·426	1·424	1·420	1·418	1·414	1·411
1·426	1·424	1·422	1·420	1·418	1·416	1·414	1·410	1·408	1·404	1·401
1·416	1·414	1·412	1·410	1·408	1·406	1·404	1·401	1·398	1·395	1·392
1·406	1·404	1·402	1·400	1·398	1·396	1·394	1·391	1·388	1·385	1·382
1·396	1·394	1·392	1·390	1·388	1·386	1·384	1·381	1·378	1·376	1·373
1·386	1·384	1·382	1·380	1·378	1·376	1·374	1·371	1·368	1·366	1·363
1·376	1·374	1·372	1·370	1·368	1·366	1·364	1·361	1·358	1·356	1·353
1·366	1·364	1·362	1·360	1·358	1·356	1·354	1·351	1·348	1·346	1·343
1·356	1·354	1·352	1·350	1·348	1·346	1·344	1·341	1·338	1·336	1·333
1·346	1·344	1·342	1·340	1·338	1·336	1·334	1·331	1·328	1·326	1·323
1·336	1·334	1·332	1·330	1·328	1·326	1·324	1·321	1·318	1·316	1·313
1·326	1·324	1·322	1·320	1·318	1·316	1·314	1·311	1·308	1·306	1·303
1·316	1·314	1·312	1·310	1·308	1·306	1·303	1·300	1·298	1·295	1·292
1·306	1·304	1·302	1·300	1·298	1·296	1·293	1·290	1·288	1·285	1·282
1·296	1·294	1·292	1·290	1·288	1·286	1·283	1·280	1·278	1·275	1·273
1·286	1·284	1·282	1·280	1·278	1·276	1·273	1·270	1·268	1·265	1·263
1·276	1·274	1·272	1·270	1·268	1·265	1·263	1·260	1·257	1·255	1·252
1·266	1·264	1·262	1·260	1·258	1·255	1·253	1·250	1·247	1·245	1·242
1·256	1·254	1·252	1·250	1·248	1·246	1·243	1·240	1·238	1·235	1·232
1·246	1·244	1·242	1·240	1·238	1·236	1·233	1·230	1·228	1·225	1·222
1·236	1·234	1·232	1·230	1·228	1·226	1·224	1·222	1·219	1·217	1·214
1·226	1·224	1·222	1·220	1·218	1·216	1·214	1·212	1·209	1·207	1·204
1·216	1·214	1·212	1·210	1·208	1·206	1·204	1·202	1·199	1·197	1·194
1·206	1·204	1·202	1·200	1·198	1·196	1·194	1·192	1·189	1·187	1·184
1·196	1·194	1·192	1·190	1·188	1·186	1·184	1·182	1·179	1·177	1·174
1·186	1·184	1·182	1·180	1·178	1·176	1·174	1·172	1·170	1·167	1·164
1·175	1·173	1·171	1·170	1·168	1·166	1·164	1·162	1·160	1·157	1·155
1·165	1·163	1·161	1·160	1·158	1·156	1·154	1·152	1·150	1·147	1·145
1·155	1·153	1·151	1·150	1·148	1·146	1·144	1·142	1·140	1·137	1·135
1·144	1·143	1·141	1·140	1·138	1·136	1·134	1·132	1·130	1·127	1·125
1·133	1·132	1·131	1·130	1·128	1·126	1·124	1·122	1·120	1·117	1·114
1·123	1·122	1·121	1·120	1·118	1·116	1·114	1·112	1·110	1·107	1·104
1·113	1·112	1·111	1·110	1·108	1·106	1·104	1·102	1·100	1·097	1·094
1·103	1·102	1·101	1·100	1·098	1·096	1·094	1·092	1·090	1·087	1·084
1·093	1·092	1·091	1·090	1·089	1·087	1·086	1·083	1·081	1·079	1·077
1·083	1·082	1·081	1·080	1·079	1·077	1·076	1·073	1·071	1·069	1·067
1·073	1·072	1·071	1·070	1·069	1·067	1·066	1·064	1·062	1·060	1·058
1·063	1·062	1·061	1·060	1·059	1·057	1·056	1·054	1·052	1·050	1·048
1·053	1·052	1·051	1·050	1·049	1·047	1·046	1·044	1·042	1·040	1·038
1·043	1·042	1·041	1·040	1·039	1·037	1·036	1·034	1·032	1·030	1·028
1·033	1·032	1·031	1·030	1·028	1·027	1·025	1·024	1·022	1·020	1·018
1·023	1·022	1·021	1·020	1·018	1·017	1·015	1·014	1·012	1·010	1·008
1·013	1·012	1·011	1·010	1·008	1·007	1·005	1·004	1·002	1·000	0·998

GRAVITIES OF SOLUTIONS OF POTASSIUM CARBONATE.

55°.	60°.	65°.	70°.	75°.	80°.	85°.	90°.	95°.	100°.
1·556	1·553	1·550	1·546	1·542	1·538	1·534	1·530	1·526	1·521
1·548	1·545	1·541	1·537	1·533	1·530	1·526	1·522	1·518	1·513
1·539	1·536	1·532	1·528	1·525	1·522	1·517	1·513	1·509	1·505
1·530	1·527	1·524	1·521	1·517	1·513	1·509	1·504	1·501	1·498
1·520	1·517	1·514	1·511	1·508	1·504	1·500	1·497	1·494	1·490
1·509	1·507	1·504	1·500	1·497	1·494	1·491	1·488	1·485	1·481
1·499	1·497	1·494	1·490	1·487	1·484	1·481	1·478	1·475	1·471
1·489	1·487	1·484	1·480	1·477	1·474	1·471	1·468	1·465	1·461
1·479	1·476	1·474	1·470	1·467	1·464	1·461	1·458	1·455	1·451
1·469	1·466	1·464	1·460	1·457	1·454	1·450	1·447	1·444	1·441
1·459	1·456	1·454	1·450	1·447	1·444	1·440	1·437	1·434	1·431
1·449	1·446	1·444	1·440	1·437	1·434	1·431	1·428	1·424	1·421
1·439	1·436	1·434	1·430	1·427	1·424	1·421	1·418	1·414	1·411
1·429	1·426	1·423	1·420	1·417	1·414	1·410	1·408	1·405	1·402
1·419	1·416	1·413	1·410	1·407	1·404	1·400	1·398	1·396	1·392
1·409	1·406	1·404	1·401	1·398	1·395	1·391	1·388	1·385	1·382
1·399	1·396	1·394	1·391	1·388	1·385	1·381	1·378	1·375	1·372
1·390	1·387	1·384	1·380	1·377	1·374	1·371	1·368	1·365	1·362
1·380	1·377	1·374	1·370	1·367	1·364	1·361	1·358	1·355	1·352
1·370	1·367	1·364	1·361	1·358	1·355	1·351	1·348	1·345	1·342
1·360	1·357	1·354	1·351	1·348	1·345	1·341	1·338	1·335	1·332
1·350	1·347	1·344	1·341	1·338	1·335	1·332	1·329	1·326	1·323
1·340	1·337	1·334	1·331	1·328	1·325	1·322	1·319	1·316	1·313
1·330	1·327	1·324	1·321	1·318	1·315	1·312	1·309	1·306	1·303
1·320	1·317	1·314	1·311	1·308	1·305	1·302	1·299	1·296	1·293
1·310	1·307	1·304	1·301	1·298	1·295	1·292	1·289	1·286	1·284
1·300	1·297	1·294	1·291	1·288	1·285	1·282	1·279	1·276	1·274
1·290	1·287	1·284	1·281	1·278	1·276	1·273	1·270	1·267	1·264
1·280	1·277	1·274	1·271	1·268	1·266	1·263	1·260	1·257	1·254
1·270	1·267	1·264	1·261	1·258	1·256	1·253	1·250	1·247	1·244
1·260	1·257	1·254	1·251	1·248	1·246	1·243	1·240	1·237	1·234
1·250	1·247	1·244	1·242	1·239	1·236	1·234	1·231	1·228	1·225
1·240	1·237	1·234	1·232	1·229	1·226	1·224	1·221	1·218	1·215
1·230	1·227	1·224	1·221	1·218	1·216	1·213	1·210	1·208	1·205
1·220	1·217	1·214	1·211	1·208	1·206	1·203	1·200	1·198	1·195
1·212	1·209	1·205	1·202	1·198	1·196	1·194	1·192	1·188	1·186
1·202	1·199	1·196	1·193	1·190	1·187	1·184	1·182	1·178	1·176
1·192	1·189	1·186	1·183	1·180	1·178	1·175	1·172	1·169	1·167
1·182	1·179	1·176	1·173	1·171	1·168	1·165	1·162	1·159	1·157
1·172	1·169	1·166	1·164	1·161	1·158	1·155	1·152	1·149	1·146
1·162	1·159	1·156	1·154	1·151	1·148	1·145	1·142	1·139	1·136
1·152	1·150	1·147	1·144	1·141	1·138	1·135	1·132	1·129	1·126
1·142	1·140	1·137	1·134	1·131	1·128	1·125	1·122	1·119	1·116
1·132	1·130	1·128	1·125	1·122	1·118	1·115	1·112	1·109	1·106
1·122	1·120	1·118	1·115	1·112	1·108	1·105	1·102	1·099	1·096
1·112	1·110	1·108	1·105	1·102	1·098	1·095	1·092	1·089	1·086
1·102	1·100	1·098	1·095	1·092	1·088	1·085	1·082	1·078	1·076
1·092	1·090	1·087	1·084	1·082	1·079	1·075	1·072	1·069	1·067
1·082	1·080	1·077	1·074	1·072	1·069	1·065	1·062	1·059	1·057
1·074	1·071	1·068	1·065	1·063	1·060	1·057	1·054	1·050	1·048
1·066	1·062	1·059	1·056	1·054	1·051	1·048	1·045	1·041	1·038
1·056	1·053	1·050	1·047	1·045	1·042	1·039	1·036	1·032	1·029
1·046	1·044	1·041	1·038	1·036	1·033	1·030	1·026	1·023	1·020
1·036	1·033	1·031	1·028	1·025	1·022	1·019	1·016	1·013	1·010
1·026	1·023	1·021	1·018	1·015	1·012	1·009	1·006	1·003	1·000
1·016	1·014	1·012	1·009	1·006	1·002	0·999	0·996	0·993	0·990
1·007	1·004	1·002	0·999	0·996	0·993	0·990	0·987	0·984	0·981
0·996	0·994	0·992	0·989	0·986	0·983	0·980	0·977	0·974	0·971

8. SPECIFIC GRAVITY OF SOLUTIONS OF POTASSIUM HYDROXIDE AT $\frac{15^\circ}{4^\circ}$. Calculated from the results obtained by Pickering (*Journ. Chem. Soc.*, lxiii., 890).

Specific Gravity.	Degrees Twaddell.	Degrees Baumé.	100 parts by weight contain		1 cb.m. contains kg.	
			K_2O.	KOH.	K_2O.	KOH.
1·000	0	0	0·00	0·00	0·00	0·00
1·005	1	0·7	0·50	0·60	5·03	6·03
1·010	2	1·4	0·99	1·18	10·00	11·92
1·015	3	2·1	1·45	1·73	14·72	17·56
1·020	4	2·7	1·91	2·28	19·48	23·26
1·025	5	3·4	2·37	2·82	24·29	28·91
1·030	6	4·1	2·82	3·36	29·05	34·61
1·035	7	4·7	3·27	3·90	33·84	40·37
1·040	8	5·4	3·73	4·44	38·79	46·18
1·045	9	6·0	4·19	4·99	43·79	52·15
1·050	10	6·7	4·64	5·53	48·72	58·07
1·055	11	7·4	5·10	6·08	53·81	64·14
1·060	12	8·0	5·54	6·60	58·72	69·96
1·065	13	8·7	6·00	7·15	63·90	76·15
1·070	14	9·4	6·45	7·68	69·02	82·18
1·075	15	10·0	6·90	8·22	74·18	88·37
1·080	16	10·6	7·35	8·76	79·38	94·61
1·085	17	11·2	7·79	9·28	84·52	100·69
1·090	18	11·9	8·24	9·82	89·82	107·04
1·095	19	12·4	8·68	10·37	95·05	113·22
1·100	20	13·0	9·13	10·87	100·43	119·57
1·105	21	13·6	9·62	11·46	106·30	126·63
1·110	22	14·2	10·00	11·92	110·00	132·31
1·115	23	14·9	10·44	12·44	116·41	138·71
1·120	24	15·4	10·88	12·96	121·86	145·15
1·125	25	16·0	11·32	13·48	127·35	151·65
1·130	26	16·5	11·76	14·01	132·89	158·31
1·135	27	17·0	12·21	14·53	138·58	164·92
1·140	28	17·7	12·63	15·04	143·98	171·46
1·145	29	18·3	13·06	15·56	149·53	178·16
1·150	30	18·8	13·50	16·08	155·25	184·92
1·155	31	19·3	13·92	16·58	160·78	191·50
1·160	32	19·8	14·36	17·10	166·58	198·36
1·165	33	20·3	14·79	17·62	172·30	205·27
1·170	34	20·9	15·22	18·13	178·07	212·12
1·175	35	21·4	15·65	18·64	183·89	219·02

SPECIFIC GRAVITY OF SOLUTIONS OF POTASSIUM HYDROXIDE AT $\frac{15^\circ}{4^\circ}$—*Continued.*

Specific Gravity.	Degrees Twaddell.	Degrees Baumé.	100 parts by weight contain		1 cb.m. contains kg.	
			K_2O.	KOH.	K_2O.	KOH.
1·180	36	22·0	16·08	19·15	189·74	225·97
1·185	37	22·5	16·51	19·66	195·64	232·97
1·190	38	23·0	16·93	20·17	201·47	240·02
1·195	39	23·5	17·35	20·66	207·33	246·89
1·200	40	24·0	17·77	21·17	213·24	254·04
1·205	41	24·5	18·18	21·66	219·07	261·00
1·210	42	25·0	18·60	22·16	225·06	268·14
1·215	43	25·5	19·03	22·67	231·21	275·44
1·220	44	26·0	19·45	23·17	237·29	282·67
1·225	45	26·4	19·86	23·66	243·29	289·84
1·230	46	26·9	20·27	24·14	249·32	296·92
1·235	47	27·4	20·69	24·64	255·52	304·30
1·240	48	27·9	21·10	25·13	261·64	311·61
1·245	49	28·4	21·51	25·62	267·80	318·97
1·250	50	28·8	21·91	26·10	273·88	326·25
1·255	51	29·3	22·32	26·59	280·12	333·70
1·260	52	29·7	22·73	27·07	286·40	341·08
1·265	53	30·2	23·14	27·56	292·72	348·63
1·270	54	30·6	23·54	28·04	298·96	356·11
1·275	55	31·1	23·94	28·52	305·24	363·63
1·280	56	31·5	24·35	29·00	311·68	371·20
1·285	57	32·0	24·75	29·48	318·04	378·82
1·290	58	32·4	25·15	29·96	324·44	386·48
1·295	59	32·8	25·55	30·43	330·87	394·07
1·300	60	33·3	25·95	30·91	337·35	401·83
1·305	61	33·7	26·34	31·37	343·74	409·38
1·310	62	34·2	26·73	31·84	350·16	417·10
1·315	63	34·6	27·13	32·31	356·76	424·88
1·320	64	35·0	27·52	32·78	363·26	432·70
1·325	65	35·4	27·91	33·24	369·81	440·43
1·330	66	35·8	28·29	33·70	376·26	448·21
1·335	67	36·2	28·68	34·16	382·88	456·04
1·240	68	36·6	29·07	34·63	389·54	464·04
1·345	69	37·0	29·46	35·09	396·24	471·96
1·350	70	37·4	29·85	35·55	402·98	479·93
1·355	71	37·8	30·23	36·01	409·62	487·94
1·360	72	38·2	30·61	36·46	416·30	495·86

SPECIFIC GRAVITY OF SOLUTIONS OF POTASSIUM HYDROXIDE AT $\frac{15°}{4°}$—*Continued.*

Specific Gravity.	Degrees Twaddell.	Degrees Baumé.	100 parts by weight contain		1 cb.m. contains kg.	
			K_2O.	KOH.	K_2O.	KOH.
1·365	73	38·6	30·99	36·92	423·01	503·96
1·370	74	39·0	31·37	37·37	429·77	511·97
1·375	75	39·4	31·76	37·83	436·70	520·16
1·380	76	39·8	32·14	38·28	443·53	528·26
1·385	77	40·1	32·52	38·73	450·40	536·41
1·390	78	40·5	32·89	39·18	457·17	544·60
1·395	79	40·8	33·27	39·63	464·12	552·84
1·400	80	41·2	33·66	40·09	471·24	561·26
1·405	81	41·6	34·03	40·53	478·12	569·45
1·410	82	42·0	34·40	40·98	485·04	577·82
1·415	83	42·3	34·77	41·42	492·00	586·09
1·420	84	42·7	35·15	41·87	499·13	594·55
1·425	85	43·1	35·53	42·32	506·30	603·06
1·430	86	43·4	35·90	42·76	513·37	611·47
1·435	87	43·8	36·27	43·20	520·47	619·92
1·440	88	44·1	36·63	43·63	527·47	628·27
1·445	89	44·4	36·99	44·06	534·51	636·67
1·450	90	44·8	37·36	44·50	541·72	645·25
1·455	91	45·1	37·72	44·93	548·83	653·73
1·460	92	45·4	38·09	45·37	556·11	662·40
1·465	93	45·8	38·45	45·80	563·29	670·97
1·470	94	46·1	38·81	46·23	570·51	679·58
1·475	95	46·4	39·17	46·66	577·76	688·24
1·480	96	46·8	39·54	47·09	585·19	696·93
1·485	97	47·1	39·89	47·51	592·37	705·52
1·490	98	47·4	40·24	47·93	599·58	714·16
1·495	99	47·8	40·60	48·36	606·97	722·98
1·500	100	48·1	40·95	48·78	614·25	731·70
1·505	101	48·4	41·31	49·20	621·72	740·46
1·510	102	48·7	41·68	49·64	629·37	749·56
1·515	103	49·0	42·03	50·06	636·75	758·41
1·520	104	49·4	42·38	50·48	644·18	767·30
1·525	105	49·7	42·73	50·90	651·63	776·23
1·530	106	50·0	43·09	51·32	659·28	785·20
1·535	107	50·3	43·44	51·74	666·80	794·21
1·540	108	50·6	43·78	52·15	674·21	803·11

XIII. AMMONIA MANUFACTURE.

A.—Gas-Liquor.

This liquor generally contains the ammonia principally in the state of carbonate and sulphide, which can be driven off by boiling, without employing lime or alkali, and which are indicated by alkalimetrical testing (*volatile ammonia*). There is, however, always a certain quantity of ammonia present in the state of salts which are not appreciably volatilised by mere boiling, and not indicated by simple testing with standard acid. These are the chloride, thiocyanate, sulphite, thiosulphate, sulphate, ferrocyanide (*fixed ammonia*). No other salts need be enumerated.

For technical purposes, it is sufficient to make the following tests:—

1. *Volatile Ammonia.*—Direct titration of the liquor gives inaccurate results.

Dilute 25 c.c. of the liquor to 350 c.c. and distil from a round-bottom flask through a Leibig condenser into a tube containing excess of $\frac{N}{2}$ H_2SO_4. The tube should be packed with fragments of hard glass (not beads as these often yield alkali). Distil until 200 c.c. has passed over and titrate back the acid with standard alkali.

2. *Fixed Ammonia.*—The residue in the flask is then made up to about the original volume, excess of sodium hydroxide added and the ammonia distilled again as above into a measured amount of standard acid. The ammonia is determined as before by finding the amount of acid used by back titration with standard alkali.

3. *Carbonic Acid.*—Fifty c.c. of the liquor are added to an excess of an ammoniacal solution of calcium chloride and heated for two hours on the water-bath. After cooling, the precipitate is filtered through a Gooch crucible, washed three or four times with warm water, dissolved in standard hydrochloric acid and back titrated with standard alkali.

4. *Total Sulphur.*—Run 50 c.c. of gas-liquor, drop by drop, into bromine, covered by hydrochloric acid, evaporate to dryness on the water-bath, and precipitate the sulphuric acid formed by barium chloride, as described, p. 134.

Sometimes it may be desirable to deduct from the total sulphur that originally present in the gas-liquor as sulphate, which is estimated by boiling the unoxidised gas-liquor with HCl and proceeding as above.

5. *Thiocyanate.*—Evaporate 50 c.c. of gas-liquor to dryness, heat the residue at 100° C., for three or four hours, digest it with strong alcohol, filter, wash on the filter with alcohol, evaporate all the alcoholic solutions to dryness, dissolve in water, filter from any residue, add a mixed solution of sulphurous acid and cupric sulphate, and heat gently, when cuprous thiocyanate will be precipitated. Wash the precipitate of CuCNS into a flask, dissolve it in nitric acid, boil for some time, and precipitate the Cu as CuO by NaOH. The weight of CuO × 0·9561 = the equivalent amount of (NH_4) CNS (Dyson, *S.C.I.*, 1883, p. 231). Or else proceed by titration, employing a solution containing

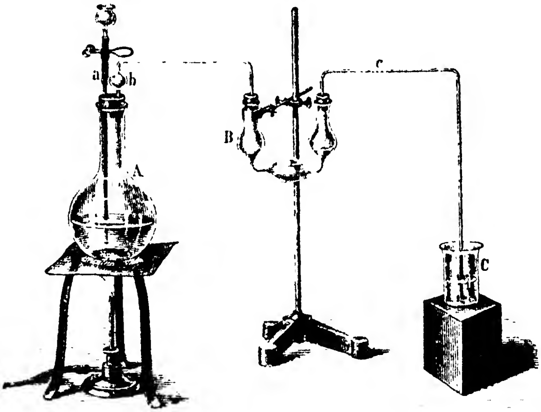

FIG. 18.

6·236 g. $CuSO_4$, $5H_2O$ per litre, 1 c.c. of which is equivalent to 0·00145 g. SCN = 0·00190 g. (NH_4) SCN, which is added to a boiling solution, to which some sodium bisulphite has been added, till a drop of the mixture, brought into contact with a drop of a solution of potassium ferrocyanide in 20 parts of water, produces *immediately* a brown coloration (Barnes and Liddell, *S.C.I.*, 1883, p. 122).

B.—Sulphate of Ammonia.

1. *Estimation of Ammonia.*—The average sample, carefully drawn, is well ground up, passed completely through a sieve with 10 holes to the linear inch, and a smaller sample is taken from this. Weigh 17·03 g. of the latter sample in a stoppered tube, dissolve and dilute to 500 c.c., and place 50 c.c. of the solution

without filtration into the apparatus, Fig. 18 (p. 234). The test is carried out exactly as in A, No. 2. As absorbent, use 60 c.c. of $\frac{N}{2}$ H_2SO_4 and when the distillation is complete, find the number of c.c. of $\frac{N}{2}$ NaOH = a c.c. required to complete the neutralisation of the sulphuric acid. Each c.c. of the quantity

$$\frac{60 - a}{2} \text{ is } = 0{\cdot}01703 \text{ g. } NH_3 \text{ or } = 1{\cdot}0 \text{ per cent.}$$

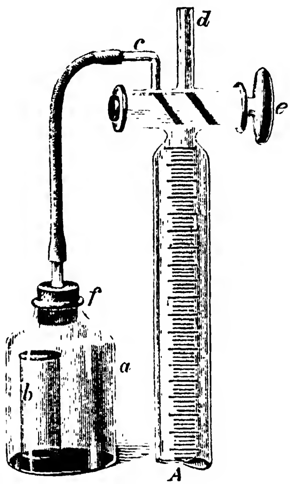

FIG. 19.

The analysis of sulphate of ammonia is, however, best, and much more quickly performed by the bromine method, in which the NH_3 is converted into nitrogen. This method can be carried out in the "Azotometer." The necessary "brominated soda" is prepared by dissolving 100 g. 70 per cent. caustic soda in 1250 g. water, and cautiously adding 25 g. bromine. The reagent must be kept in a dark, cool place, but even then does not keep more than a few days. The ammonium salt, preferably dissolved in water, is introduced into the outer space of the decomposing flask a, Fig. 19, and 25 or 30 c.c. brominated soda poured into the inner vessel b. The cork f, having been already attached to the volumeter-tube by means of a short rubber tube, is pressed tightly down into the flask a, taking hold of this only by the neck; the pressure thus produced is relieved by momentarily pulling out the stopper of the volumeter-tap *e*. If thereby the mercury in A should sink a little, it is brought back to the zero point by raising the "level-tube," while A communicates through *d* with the outer air. When the temperatures are equalised and the mercury is up to the tap, this is put in such a position that *a* communicates through *c* with A; then the flask *a* is tilted so that the contents of *b* run into the outer space; the flask is then shaken till no more gas is evolved. The mercury levels in A and the level-tube are made to coincide, after waiting a quarter of an hour, or, better, half an hour, in order to cool down the flask. (This may be expedited by placing *a* both before and after the operation, in a large vessel filled with water of the temperature of the room.) When the levels have been exactly adjusted, as described p. 168, so as to bring the gas to the volume it would occupy at 0° and 760 mm. in the dry state, read off the number of c.c. of gas in A; each c.c. = 0·0012818 g. N = 0·0015582 g. NH_3 (this includes the necessary correction for absorption or incomplete evolution of N). In order to save all calculations, dissolve 1·558 g. sulphate of ammonia in 100 c.c. of water, and employ 10 c.c. = 0·1558 g. for each test; in this case each c.c. of gas contained in A = 1 per cent. NH_3.

2. *Thiocyanate.*—*Cf.* p. 143, A, No. 4.

3. *Free Acid* is found by titration with decinormal soda solution and methyl orange.

4. *Moisture* is estimated by drying 50 g. in a stove at 100° up to constancy of weight.

C.—Ammonia (Liquor Ammoniæ).

This is mostly sold by specific gravity, the relation of which to the percentage of NH_3 is shown in the subjoined table No. 1.

The *empyreumatic* substances in liquor ammoniæ are detected qualitatively by the smell on exact neutralisation with sulphuric acid. The *pyridine bases* (which do not redden phenolphthalein) can be tested for by the method of Pennock and Morton (*Journ. Amer. Chem. Soc.*, vol. xxiv., p. 377). Neutralise 100 c.c. of the liquor exactly by sulphuric acid, employing methyl orange as indicator and cooling the vessel used from the outside; distil into a flask charged with 30 c.c. water until this volume has increased to about 100 c.c., add phenolphthalein and a solution of mercuric chloride until the liquid is decolorised, then a few more drops of the mercury solution (thereby precipitating the NH_3), filter, and titrate with decinormal acid and methyl orange, each c.c. of which = 0·0079 g. pyridine.

The testing of *liquid ammonia*, as sent out in iron bottles, is described in *Tech. Meth.*

1. SPECIFIC GRAVITIES OF SOLUTIONS OF AMMONIA AT 60° F. (Price and Hawkins, *J.S.C.I. Trans.*, 1924, 43, 113.)

Specific gravity.	Per cent. NH_3.	Specific gravity.	Per cent. NH_3.
0·875	36·90	0·938	16·25
0·876	36·56	0·940	15·65
0·877	36·22	0·942	15·06
0·878	35·88	0·944	14·47
0·880	35·20	0·946	13·89
0·882	34·53	0·948	13·31
0·884	33·86	0·950	12·74
0·886	33·19	0·952	12·17
0·888	32·52	0·954	11·61
0·890	31·85	0·956	11·05
0·892	31·18	0·958	10·50
0·894	30·51	0·960	9·95
0·896	29·84	0·962	9·40
0·898	29·17	0·964	8·86
0·900	28·50	0·966	8·32
0·902	27·83	0·968	7·79
0·904	27·16	0·970	7·27
0·906	26·49	0·972	6·75
0·908	25·82	0·974	6·24
0·910	25·15	0·976	5·73
0·912	24·48	0·978	5·23
0·914	23·82	0·980	4·73
0 916	23·16	0·982	4·24
0·918	22·50	0·984	3·75
0·920	21·85	0·986	3·27
0·922	21·21	0·988	2·79
0·924	20·57	0·990	2·31
0.926	19·94	0·992	1·84
0·928	19·31	0·994	1·37
0·930	18·69	0·996	0·91
0·932	18·07	0·998	0·45
0·934	17·46	1·000	0·00
0·936	16·85	...	...

See also Ferguson, *J. Soc. Chem. Ind.*, 1905, 781, for table adopted by the Manufacturing Chemists' Association of the United States.

2. SPECIFIC GRAVITIES OF SOLUTIONS OF COMMERCIAL AMMONIUM CARBONATE, AT 15° C. (Lunge and Smith.)

Degrees Twaddell.	Degrees Baumé.	Specific Gravity at 15°.	Per cent. Commercial Ammonium Carbonate.	Change of Specific Gravity for ± 1° C.
1	0·6	1·005	1·66	0·0002
2	1·4	1·010	3·18	0·0002
3	2·1	1·015	4·60	0·0003
4	2·7	1·020	6·04	0·0003
5	3·4	1·025	7·49	0·0003
6	4·1	1·030	8·93	0·0004
7	4·7	1·035	10·35	0·0004
8	5·4	1·040	11·86	0·0004
9	6·0	1·045	13·36	0·0005
10	6·7	1·050	14·83	0·0005
11	7·4	1·055	16·16	0·0005
12	8·0	1·060	17·70	0·0005
13	8·7	1·065	19·18	0·0005
14	9·4	1·070	20·70	0·0005
15	10·0	1·075	22·25	0·0006
16	10·6	1·080	23·78	0·0006
17	11·2	1·085	25·31	0·0007
18	11·9	1·090	26·82	0·0007
19	12·4	1·095	28·33	0·0007
20	13·0	1·100	29·93	0·0007
21	13·6	1·105	31·77	0·0007
22	14·2	1·110	33·45	0·0007
23	14·9	1·115	35·08	0·0007
24	15·4	1·120	36·88	0·0007
25	16·0	1·125	38·71	0·0007
26	16·5	1·130	40·34	0·0007
27	17·1	1·135	42·20	0·0007
28	17·8	1·140	44·29	0·0007
29	17·9	1·1414	44·90	0·0007

XIV. MANUFACTURE OF COAL-GAS (ILLUMINATING GAS).

A.—Coal-Gas.

For a satisfactory analysis of coal-gas the Orsat apparatus (p. 120) is not sufficiently accurate, and the gas-burettes of Bunte, Hempel, Drehschmidt, or Pfeiffer should be used. The following rules are taken from the private notes, printed for Professor Bunte's students, with his permission.

The analysis is performed by means of Bunte burettes, which must satisfy the following conditions :—The capillary tube below the bottom tap must not allow any water to come out, even on shaking. The upper (three-way) tap must be made so as to shut off communication with any one of the three outlets. (The Greiner-Friedrichs patent tap, with two oblique bores, as shown in Fig. 19, p. 235, admits of doing this without any difficulty.) The taps should be greased with a mixture of 2 parts para-gum, 2 parts bees-wax, and 10 parts tallow, and they must be tight even in a strong vacuum. The confining water must have the temperature of the room, and this must remain unchanged during the whole time occupied by the work. The burette must be held only at the top funnel or at the capillary tubes. The correctness of its graduation must be controlled by running out its contents of water in portions of 10 c.c., and weighing these. When one of the components of the gas has been absorbed, first allow the water to rise from below and then adjust the pressure by allowing water to run in from the top funnel. To do this, fill it to the mark, open the tap and wait a minute, until the surface of the water inside the burette remains constant.

To take a sample of the gas to be tested, employ either an empty burette, or one filled with water. In the former case, connect the top tap (the funnel being charged with water) side-ways with the gasholder or pipe, the bottom tap being open, and allow the gas to pass through, until it has driven out all the air ; then shut first the bottom tap and immediately afterwards the top tap. In the second case fill the burette with water, connect the top tap with the gasholder or pipe, open the bottom tap, until the water has sunk a little below the zero mark, then shut first the top tap and afterwards the bottom tap.

If the gas is at a lower pressure than the atmospheric pressure, take the sample by means of a rubber bellows, or a water aspirat-ing bottle, or a water-pump, and connect then with the bottom capillary.

Measuring the gas in the burette.—Adjust the three-way tap so that all its bores are closed, fill the funnel with water up to the mark, connect the rubber tube of the pressure bottle (levelling bottle), previously entirely filled with water, with the bottom tap, and allow the water to rise up to about 0·2 c.c. above the zero mark. Now open the three-way tap, whereupon a little gas escapes and the pressures are equalised. The water then usually stands at the zero mark ; if not, read the actual volume and calculate from this. Then turn the three-way tap, after having put a short rubber tube on its lateral outlet, so as to run a little water into this, and close the tube by a small piece of glass rod. As long as the tap is not used, it remains in this position.

Introduction of the absorbing liquids.—Draw off the confining liquid by means of the aspirating bottle, holding the bottom tap fast in its position, and shutting it at once when the water has got down to the capillary. Take the rubber tube off and draw the liquid back into the aspirating bottle, lest it should siphon itself off. Then pour the absorbing liquid into a small porcelain capsule, and allow it to rise in the burette.

The various gases are estimated, *seriatim*, as follows :—

1. *Carbon Dioxide*, CO_2, by absorption with a solution of caustic potash, 1 in 3 water—that is, specific gravity 1·23. Of this 1 c.c. takes up 90-100 c.c. CO_2. It is sufficient, if the inside of the burette is once wetted with the solution. Afterwards water is allowed to enter from below and to run in from the top, to wash the glass; then the normal pressure is re-established and the volume read off. In the case of crude gas the H_2S must be first removed by a tube containing pumice soaked with cupric sulphate.

2. *Heavy hydrocarbons*, C_mH_n.—Draw out the confining water as completely as possible, rinse off the potash solution with a little water (which is also drawn off), allow about 10 c.c. of water, saturated with bromine, to enter, and shake the burette. When the space above the liquid ceases to show the brown colour of the bromine, draw off the liquid and replace it by fresh bromine water. Finally, in order to absorb the bromine vapour, draw about 1 c.c. of caustic potash solution into the burette, shake this up in the burette, allow a little water to run in at the top, establish the normal pressure, and read off the volume. Thus all the illuminants are absorbed—*i.e.*, ethylene and the other unsaturated hydrocarbons, also benzene vapour.

3. *Oxygen* is absorbed by drawing in about 2·5 c.c. of a solution of pyrogallol (1 to 5 water) and after this 7·5 c.c. caustic potash solution (1 : 3). Shake well for five minutes, run in water through the funnel until the pressure is equalised, shake again, and continue this until no more water will enter the burette. Run off the dark liquid at the bottom, allowing water to run in at the top, so that a layer of clear water remains at the top, which allows a correct reading after re-establishing the pressure.

Accurate estimations of oxygen are made by titration with potassium iodide, manganous chloride, and thiosulphate, as described in *Tech. Meth.*, vol. i, pp. 209 and 334.

4. *Carbon Monoxide*.—Draw off the confining water, wash with more water, draw in 10 c.c. ammoniacal solution of cuprous chloride (made by dissolving 200 g. commercial cuprous chloride and 250 g. ammonium chloride in 750 c.c. water, placing a copper spiral in the bottle, and before use mixing 3 vols. of this solution with 1 vol. ammonia, specific gravity 0·905), shake for one minute, draw off the solution, replace it by a fresh quantity, shake again, and repeat this procedure at least twice. After the last removal of the absorbent, run through the funnel 3 or 4 c.c. concentrated

hydrochloric acid, and then a little water, which forms a layer at the top. Draw off the liquid, wash with water, draw in 1 or 2 c.c. concentrated potash solution, shake up, allow some water to enter, re-establish the normal pressure, and take the reading.

5. *Hydrogen.*—The gas now contains nothing but H, CH_4, and N. The hydrogen is estimated by fractional combustion, for which purpose a second burette (B) is needed. Measure in the first burette (A) 22 to 25 c.c. of the residual gas under normal pressure, and mix with air for burning the hydrogen. For this purpose open first the bottom tap, then the top tap, so as to communicate outwards, whereupon water will run out and air enter. When the level of the water has gone down to about 5 c.c. below 0, quickly shut the top tap and after this the bottom tap, mix the gases by shaking, regulate the pressure to that of the atmosphere plus that of the column of water in the funnel, and read the volume. Now fill burette B up to the capillary and connect both three-way taps, interposing a *palladium tube* C, between them. C is a tube of glass of high melting point, 10 cm. long, 3 mm. bore, and 5 mm. thick. It contains a 100 mm. of palladium wire, 0·3 mm. thick, folded into four and introduced into the central part of tube C. By heating this part of the tube, it is made to collapse and to hold the wire fast; the remaining portion of C is loosely filled with long fibrous asbestos. The connection between C and the capillaries of A and B is made by short, thick-walled rubber tubing.

Now turn both three-way taps so that both are closed, fill the funnel of burette A with water, lower the pressure by opening the bottom tap for a moment, turn both three-way taps at the same time and quickly, so that C communicates with the interior of both burettes, and heat C. The air in C thus increases its volume, and forces the water in the capillaries back into both burettes. Now connect the rubber tube of the pressure bottle with the lower tap of A, open this tap, heat C at its narrowed part until the small flame turns yellow, and open the lower tap of B, so that the gas passes from A through C into B in a moderately quick current. The water should issue from B in a continuous jet, not in single drops, and the palladium wire should not become red-hot on the side where the gas enters; otherwise some methane would be burnt together with the hydrogen. As soon as the water has got to the top of the burette A, quickly shut first the bottom tap of A and then that of B, and syphon the gas back from B to A as described above. After cooling, the pressure in A is made equal to the normal; the volume is then read, and the contraction ascertained.

Example: 100 c.c. coal-gas, taken for analysis, after absorbing CO_2, heavy hydrocarbons, O and CO, left 85 c.c. Of this 22·2 c.c. were transferred to burette A, and diluted with air to 105·3. After the combustion the volume was 86·3, showing a contraction of 19·0. Calculating this upon a 100 c.c. of the original gas, we find $\frac{19·0 \times 85·0}{22·2} = 72·8$.

Therefore the hydrogen amounts to $\frac{2 \times 72·8}{3} = 48·5$ per cent.

As a final control, estimate the *oxygen* left after combustion; it must be less than that originally employed by two-thirds of the contraction observed.

6. *Methane* is estimated, together with hydrogen, by burning another portion of the gas remaining after the operations 1 to 4, in the "explosion burette." For this, measure off 12 to 15 c.c. of this gas, draw in an excess of air, shake up, ascertain the volume, draw off the confining water, explode by means of an electric spark (generated by a battery and induction coil), ascertain the contraction, let 1 or 2 c.c. potash solution run down inside the burette, and after this, slowly, some water, adjust the pressure and ascertain the total contraction, which is equal to $H_2O + CO_2$. From this deduct the amount corresponding to the hydrogen found in No. 5; one-third of the remaining contraction corresponds to the methane, for 1 vol. CH_4 + 2 vols. O_2 = 0 vols. CO_2 + 0 vols. H_2O.

Example: Residual gas employed, 12·7 c.c. (forming part of the 86 c.c. remaining after the absorption of CO_2, C_mH_n, O_2, and CO); after addition of air = 104·1; therefore air employed = 91·4. After the explosion remain 78·9 c.c. gas; therefore contraction = 25·2; calculated upon the total gas $\frac{85 \times 25·5}{12·7} = 168·8$. From this deduct the contraction due to hydrogen, according to No. 5, = 72·8; this leaves for the methane a contraction of 168·8 − 72·8 = 96·0, or one-third of it = 32·0 per cent. methane.

7. *Nitrogen* is represented by the deficit from 100 after estimating all the other constituents. Suppose we have found:—

From No. 1,	2·0	per cent. (by volume)	CO
,, ,, 2,	4·0	,,	heavy hydrocarbons
,, ,, 3,	0·4	,,	O_2
,, ,, 4,	8·6	,,	CO
Together	15·0	,,	
From No. 5,	48·0	,,	H_2
,, ,, 6,	32·0	,,	CH_4
	95·0	,,	
Leaving	5·0	,,	for N_2

The estimation of ethylene, benzene, acetylene, naphthalene, hydrogen sulphide, total sulphur, ammonia, cyanogen, etc., is described in Lunge-Keane's *Tech. Meth. of Chem. Anal.*, vol. ii.

The calorific power of coal-gas is best ascertained by means of the Junckers calorimeter, which is always sold with instructions for use.

B.—Purifying Material (Spent Oxide).

1. *Cyanogen* (Bueb).—Boil 20 g. of an average sample of spent oxide (from which the sulphur has been previously extracted as below), or the same quantity of pressed "cyanide mud," with 100 c.c. caustic potash solution (specific gravity 1·26) and 200 c.c. water for half an hour, dilute to 1010 c.c. (reckoning 10 c.c. for the volume of the solid substance), and pass through a dry filter. Take 25 c.c. of the filtrate, add 50 c.c. water and 10 c.c. dilute sulphuric acid (1 : 10), and titrate with *zinc solution*. This solution is made as follows:—Dissolve 10·2 g. of pure crystallised zinc sulphate ($ZnSO_4$, $7H_2O$), together with 10 c.c. sulphuric acid of specific gravity 1·7 in water, make up to 1 litre, and compare this with a freshly made solution of 10 g. pure crystallised potassium ferrocyanide in 1 litre, in the following manner:—To 25 c.c. of the ferrocyanide solution add 50 c.c. water and 10 c.c. dilute sulphuric acid. This mixture is titrated with the zinc solution, testing for the completion of the reaction by drops put on to filter paper soaked with a 1 per cent. solution of ferric chloride. The end of the reaction is reached when no blue coloration is produced on the paper.

Other methods for the estimation of cyanides (described by Knublauch and by Drehschmidt) are given in *Tech. Meth.*, vol. i., pp. 546 *et seq.*, and vol. ii., p. 725.

2. *Sulphur.*—Extract 15 g. of the air-dried mass in a Soxhlet apparatus with 100 c.c. carbon disulphide in a 200 c.c. round-bottomed flask of known weight. Heat on a water-bath, condensing the vapours by a reflux condenser, until twenty extractions have been made. Distil off the CS_2, remove the last portions by hot air, and after cooling again weigh the flask. The difference between the weighings = S.

Sometimes it is desirable to know the amount of S which on burning the oxide forms SO_2, since a certain quantity of S is always retained by lime, etc., on burning the spent mass. For this purpose Pfeiffer burns 1 g. of the sample, by putting a piece of tinder in a litre flask filled with oxygen and previously charged with 25 or 30 c.c. of normal caustic soda solution. Finally he adds 1 c.c. neutral 30 per cent. hydrogen peroxide and titrates back with standard HCl and methyl orange. Each c.c. of the normal soda solution consumed corresponds to 1·6 per cent. of S burnt.

Processes for estimating all the essential constituents of spent oxide are described in *Tech. Meth.*, vol. ii., pp. 723 to 730.

XV. CALCIUM CARBIDE AND ACETYLENE.

A.—Raw Materials.

(a) *Coke*, see p. 117.
(b) *Limestone*, see p. 183.

B.—Commercial Calcium Carbide.

(a) *The sampling* in this case has to be done with special care, since it is anything but easy to obtain a small sample representing the real average quality. The sample is quickly crushed in an iron mortar, provided with a rubber cover, or in a coffee-mill, and the powder must be kept free from contact with air.

(b) *The estimation of the yield of gas* should always be made by actual measurement of the gas, not by loss of weight. Take 50 g. carbide, and put it into a glass tube, 2 or 3 cm. wide inside, which is connected with the gas-generating flask (250 c.c.) by a rubber tube so that the carbide can be dropped in small quantities into the flask. 150 c.c. water, previously saturated with acetylene, are first placed in the flask, the cork of which is also provided with an exit-tube connected with a measuring bottle. This bottle holds 20 litres, and has a division on which $\frac{1}{4}$ litre can be read off. It is connected by means of a lateral neck just over the bottom and by a rubber tube with a level-bottle of the same size, filled with water saturated with acetylene. By raising the level-flask, the water is forced into the measuring flask up to its neck; during the time the gas is given off, the level flask is lowered, so that there is never any notable pressure in the measuring bottle. When all the gas has been collected in the latter, the level-bottle is placed so that the water is exactly at the same level in both bottles, and about two hours are allowed for the temperature to reach that of the surrounding air. Read the thermometer and barometer, and reduce the volume of the gas by the tables, pp. 12 *et seq.*, to the normal state, regarding it as saturated with moisture. If, as usual, the reduction is to be made not to 0°, but to 15° C., this can be done with sufficient accuracy by the formula:—

$$V = \frac{v}{100}(140{\cdot}2 - 0{\cdot}6\,t)\frac{B}{100}$$

where V is the volume at 15°, v the volume at $t°$, and B the (corrected height) of the barometer. (Cf. *Tech. Meth.*)

(c) *Impurities.*—It is best to test for these, not in the carbide, but in the acetylene given off from it. Put 70 or 80 g. carbide, crushed to the size of a pea, into a previously weighed, well-dried, half-litre flask, and weigh it on an ordinary balance which turns to 0·1 g. The cork of this flask is fitted with a dropping funnel, contracted at the outlet, with glass tap, and with a side tube connected with a ten-bulb tube, like that shown in Fig. 10, p. 144. The latter contains 75 c.c. of a 2 to 3 per cent. solution of sodium hypochlorite. Run from the funnel three to seven drops of water on to the carbide, and shake the flask gently from time to time. The gas should all be liberated in three or four hours; it may, if required, be measured, or else allowed to escape. Then the flask is filled up to its neck, so as to drive all the gas into the bulb-tube, and in the contents of the latter the phosphoric acid which has been formed by the hypochlorite from the *hydrogen phosphide* contained in the gas, is estimated by the ordinary magnesia method.

If it is required to estimate the *sulphur* also, which escapes principally as H_2S, divide the contents of the bulb-tube in two portions, estimate in one of these the phosphoric acid as above, and in the other the sulphuric acid, formed from the H_2S, as $BaSO_4$.

XVI. EXAMINATION OF THE RAW MATERIALS AND PRODUCTS OF THE MANUFACTURE OF FERTILISERS.

Note.—This section is based on the resolutions agreed to at the Fifth International Congress of Applied Chemistry at Berlin (1903).

A.—Sampling.

Samples must be taken out of every tenth sack in the case of shipments in bulk, in at least ten places, by means of the sampling-auger described on p. 105; in the case of ship cargoes, from every fiftieth tub; the total weight to be about 300 g. for each of the three normal samples. In the case of unequal composition, the samples must be ground and mixed; in the case of moist fertilisers, this must be done by hand.

B.—Moisture.

Moisture in crude phosphates, bone charcoal, etc., is estimated by drying 10 g. at 100° until weight is constant; in the case of gypsum, during three hours. If the substance alters its percentage of moisture during grinding, the moisture must be determined both in the coarsely crushed and in the finely ground sample, and the result of the analysis calculated on the original coarsely crushed sample.

C.—The Insoluble Matter.

The insoluble matter is determined in 10 g. of the sample. (*a*) When dissolving in mineral acids, after rendering the silica insoluble by heating on the water-bath during several hours, or on the air-bath to 120°, the residue must be ignited. (*b*) When dissolving in water, the residue must be dried at 100° up to constancy of weight.

D.—Phosphoric Acid.

1. Preparation of the Solutions.

(a) *Phosphates soluble in Water.*—Shake 20 g. in a litre flask with about 800 g. water for half an hour, and fill up to the mark. Solutions of so-called double superphosphates must be boiled with addition of nitric acid (10 c.c. concentrated nitric acid to 25 c.c. of the solution) before precipitating the phosphoric acid, in order to convert any pyrophosphoric acid present into orthophosphoric acid.

(b) *Phosphates soluble in Ammonium Citrate* are treated according to Petermann's method. In the case of superphosphates containing upwards of 20 per cent. P_2O_5, take 1 g.; of those containing 12 to 20 per cent. P_2O_5, take 2 g.; if there is less than 10 per cent., P_2O_5, or of a composite fertiliser, take 4 g. for each sample. Grind it first dry, then with 20 to 25 c.c. water, decant on to a filter, and wash with water until the volume of the filtrate is about 200 c.c. If the filtrate is not quite clear, add a drop of nitric acid. Put the filter and residue into a 250 c.c. flask, add 100 c.c. of the ammonium citrate solution (prepared as below), digest about fifteen hours at the ordinary temperature, with frequent shaking, then one hour at 40°, allow to cool, fill up to the mark, take 50 c.c. of the filtrate and 50 c.c. of the above aqueous solution, mix these, boil with 10 c.c. concentrated nitric acid for ten minutes, and estimate the total phosphoric acid soluble in water and in citrate by the molybdenum or the citrate method.

Preparation of the Ammonium Citrate Solution.—Dissolve 500 g. citric acid in water, neutralise with ammonia, allow to cool, reduce the specific gravity to 1·09, and add to a litre of this solution 50 c.c. ammonia, specific gravity 0·92. The specific gravity of the final solution should be from 1·082 to 1·083.

(c) *Total Phosphoric Acid.*—Boil 5 g. with a mixture of three parts hydrochloric acid (specific gravity 1·12) and 1 part nitric acid (specific gravity 1·20), or with 20 c.c. concentrated nitric acid and 50 c.c. concentrated sulphuric acid for half an hour, and make up to 250 c.c.

(d) In *Thomas-Slag Phosphates* the phosphoric acid is estimated in the portion which passes through a 2-millimetre sieve, but the result is calculated upon the whole sample, including the coarser portion. The following estimations are made :—

1. *Phosphoric Acid soluble in Citric Acid.*—Shake 5 g. Thomas phosphate in a half-litre flask, previously charged with 5 c.c. alcohol, with a 2 per cent. solution of pure citric acid during half an hour at 17½°, in a revolving agitator which makes thirty to forty revolutions per minute.

2. *Total Phosphoric Acid.*—Soak 10 g. Thomas phosphate (for the analysis of fine flour passed through sieve No. 100=0·19 mm. mesh) in a half-litre flask with 5 c.c. water, then boil with 50 c.c. concentrated sulphuric acid half an hour, stirring frequently, and fill up to the mark.

2. Examination of the Solutions.

For phosphoric acid, according to one of the following methods :—

(a) *Molybdenum Method*, according to Wagner.—To 25 or 50 c.c. solution, free from silica and containing from 0·1 to 0·2 g. P_2O_5, add so much concentrated solution of ammonium nitrate (750 g. per litre) and so much molybdenum solution (150 g. ammonium molybdate, dissolved in 1 litre water and poured into 1 litre nitric acid of specific gravity 1·2) that the total liquid contains 15 per cent. ammonium nitrate, and for each 0·1 g. P_2O_5 not less than 50 c.c. molybdenum solution. Heat to 80° or 90° for ten minutes, put aside for an hour, filter, wash the precipitate with dilute solution of ammonium nitrate (150 g. $(NH_4)NO_3$+10 c.c. nitric acid in 1 litre) until there is no reaction for calcium, pierce the filter, wash the precipitate into a beaker by means of a 2½ per cent. ammonia, dissolve it by stirring, and add so much ammonia that the total volume is 75 c.c. Then add for each 0·1 g. P_2O_5 10 c.c. of magnesium mixture (55 g. crystallised magnesium chloride +70 g. ammonium chloride, dissolved in 1 litre of 2·5 per cent. ammonia), in single drops, stirring constantly, cover the beaker, allow to stand for two hours, filter the precipitate, wash it with 2·5 per cent. ammonia until the reaction for chlorine ceases, and dry at 100°. Detach the precipitate from the filter, place it in a platinum crucible, add the rolled-up filter, and carbonise it in a covered crucible; then heat the crucible for ten minutes in an upright position over the Bunsen flame and for five minutes on the blowpipe.

(b) *Citrate Method.*—In the case of aqueous solutions of superphosphate, employ 50 c.c. citrate solution for 50 c.c. of the phosphate solution, corresponding to 1 g. substance; in that of acid solutions of bone meal, fish guano, Thomas-slag, flour, etc., take 100 c.c. of the citrate solution for 50 c.c. of the phosphate solution (=½ g. substance). The *citrate solution* is made by dissolving 1100 g. pure citric acid in water, adding 4 litres of 24 per cent.

ammonia, and making up to 10 litres. After adding the citrate solution, add *at once* 25 c.c. magnesium mixture (550 g. magnesium chloride + 1050 ammonium chloride, dissolved in 6½ litres water + 3½ litres 27 per cent. ammonia), and shake or stir for half an hour. Filter the precipitate, preferably by means of a Gooch or Neubauer crucible (see below), rinse the beaker with 5 per cent. ammonia, and wash the precipitate five or six times with the same solution, using a filter pump. Dry the crucible on a hot plate until the mass begins to crack, ignite for three to five minutes (preferably in a Roessler furnace), and allow to cool in a desiccator. After weighing, the crucible may at once be used for a fresh determination, without removing the precipitate, and thus thirty or forty estimations can be made in it without renewing the asbestos filter.

This method involves several errors, which, however, compensate one another, so that when the above details are strictly adhered to, the final result is perfectly correct. According to the resolutions of the Union of the German Agricultural Research Stations in 1903, the citrate method is the only one admissible for all fertilisers, except crude phosphates.

The preparation of a Gooch crucible—that is, a platinum crucible with platinum sieve and asbestos filter—is a little troublesome; it is described in *Tech. Meth.* (second edition), vol. i., p. 18.

The Neubauer crucible (sold by W. C. Heræus, Hanau) is similar to the Gooch crucible, but contains a platinum sponge filter on the sieve. It is ready for use, as obtained from the dealers, and is much more convenient than a Gooch crucible.

E.—Free Acids.

(*a*) The total free acid is estimated by titration with caustic soda solution and methyl orange.

(*b*) Free phosphoric acid is estimated gravimetrically in the alcoholic extract, as described above.

F.—Ferric Oxide and Alumina.

In Germany the accepted method is that of E. Glaser. Dissolve 5 g. phosphate in 25 c.c. nitric acid (specific gravity 1·2) + 12·5 c.c. hydrochloric acid (specific gravity 1·12), and dilute to 500 c.c. Put 100 c.c. (= 1 g. of the phosphate) in a 250 c.c. flask, add 25 c.c. concentrated sulphuric acid (specific gravity 1·84); after five minutes' shaking add 100 c.c. 95 per cent. alcohol, allow to cool, fill up to the mark with alcohol, shake well, and fill up again. After waiting for half an hour, filter, heat 100 c.c. of the filtrate in a platinum dish until the alcohol is driven off, transfer to a beaker, add 50 c.c. water, and heat to boiling. Remove the flame, add NH_3 till the reaction is alkaline, boil off the excess of NH_3, allow to cool, filter, wash with hot water, ignite, and weigh. The weight found is assumed to be aluminium phosphate + ferric phosphate, or 50 per cent. of it $= Fe_2O_3 + Al_2O_3$.

G.—Nitrogen.

1. *Nitric-nitrogen* is estimated gas-volumetrically by the nitrometer (pp. 164 and 165), or by Schloesing-Grandeau's method (*Tech. Meth.*, second edition, vol. i., p. 482), or by one of the methods for reducing it to NH_3. The following method is due to Ulsch. Into a flat-bottomed half-litre flask put 25 c.c. of the aqueous nitrate solution (which ought to contain at most 0·5 g. KNO_3 = 0·4 g. $NaNO_3$) and 10 c.c. dilute sulphuric acid (1 vol. concentrated acid + 2 vols. water), add 5 g. commercial "ferrum hydrogenio reductum" (iron reduced by hydrogen), and close the flask with a pear-shaped glass vessel of 25 c c. capacity filled with water, which at the same time serves as a reflux condenser. Heat first cautiously, then more strongly, at least for half a minute to full boiling (altogether five minutes), dilute with 50 c.c. water, add 20 c.c. caustic soda solution (specific gravity 1·25), and distil the NH_3 formed into titrated hydrochloric or sulphuric acid. The distillation may be finished in five to seven minutes after the commencement of the boiling. By titrating back the excess of acid the quantity of NH_3 is ascertained; each c.c. normal acid saturated = 0·01401 g. N or 0·06302 HNO_3 or 0·10116 KNO_3 or 0 08506 $NaNO_3$.

2. *Ammoniacal nitrogen*, cf. p. 233. Preferably distil with freshly calcined magnesia, 3 g. to 1 g. NH_3. In the case of ammoniacal superphosphates, the solution prepared as on p. 246 should be used.

3. *Total nitrogen* is estimated in presence of nitrates by Kjeldahl-Jodlbauer's method. Place 1 g. substance in a flask of difficultly fusible glass holding about 350 c.c., slowly add 30 c.c. phenolsulphuric acid (made by dissolving 200 g P_2O_5 in 500 c.c. concentrated sulphuric acid, and 40 g. phenol in 500 c.c concentrated sulphuric acid, and uniting the two solutions, after cooling), shaking continuously, and cooling by placing the flask in cold water. When finished agitate for another half-hour or hour, add a drop of mercury (about 1 g.) and then gradually 2 to 3 g. dried zinc dust, with good agitation and cooling. Allow to stand for one or two hours; then boil until the solution has become clear and colourless, allow to cool, wash with water into a distilling flask, add 110 c.c. of caustic soda solution of specific gravity 1·285 (which must be free from nitrogen compounds), distil the NH_3

into normal hydrochloric acid, and estimate it by retitrating. The calculation is made as above, *sub* G, 1.

Damp substances are ground up with a little gypsum before adding the phenolsulphuric acid.

4. *Organic nitrogen*, in the absence of nitrates and ammonium salts, is estimated according to Kjeldahl-Wilfarth's method. Put 1 g. substance in a 150 c.c long-necked flask of Bohemian glass, add a drop of mercury and 25 c.c. of concentrated sulphuric acid, to a litre of which 200 g. P_2O_5 and 15 g. K_2SO_4 have been added. Heat at first slowly, then to violent boiling, putting the flask, or several flasks, on a wire gauze in a slanting position. The whole is best placed on a sheet of lead with turned-up edges, covered with a thick layer of sand and placed under a hood, so that no damage is done if a flask is cracked. In the case of badly frothing liquids put a little paraffin in the flask and close this loosely by a Kreusler's stopper, *i.e.*, a glass tube drawn out below into a long point, and sealed at the bottom. Continue the boiling until the contents of the flask are quite clear, which may take half an hour to three hours. Then wash its contents by the aid of 200 c.c. water into a half-litre flask, add 100 c.c. caustic soda solution of specific gravity 1·285 (free from N) and 1 to 1·5 g zinc dust, and distil into titrated HCl, proceeding just as in No. 1.

In the case of substances which cannot be finely ground, prepare a good average sample by weighing off 3 to 5 g., boil with 50 to 60 c.c. sulphuric acid and 2 to 3 g. mercury, wash, after cooling, into a 300 c.c. flask, filling this up to the mark, mix by shaking, and take 100 c.c. for the distillation with caustic soda and zinc dust.

H.—Potash.

Potash is estimated as in potassium chloride containing sulphate, p. 221, or by the perchloric acid method.

Details for the examination of the various fertilisers are given in *Tech. Meth.*, vol. ii., pp. 418 *et seq.*

XVII. ALUMINA PREPARATIONS.

A.—Raw Materials.

1. *Kaolin* (*china clay*), see p. 254, *sub* "Clay."

2. *Bauxite* (a) —Dry 2·500 g. at 100° for eight hours, boil with 30 c.c. of a mixture of 1 part concentrated sulphuric acid + 1 water, with good agitation, until vapours of SO_3 begin to escape, allow to cool, run the paste slowly into 300 c.c. cold water so as to prevent heating (which would cause a precipitation of TiO_2), add

10 c.c. hydrochloric acid, digest six hours with agitation, filter the solution (a) from the precipitated crude silica and make it, with the washings, up to 500 c.c. Ignite the crude silica, weigh it, evaporate with 2 c.c. hydrofluoric acid and three drops of dilute sulphuric acid, and ignite; the residue is weighed as Al_2O_3, and by deducting it from the crude silica we obtain the pure SiO_2.

(b) Take 200 c.c. of the solution (a) (= 1·000 g. bauxite), neutralise with sodium carbonate until a slight precipitate begins to appear, bring this again into solution by adding a few drops of dilute sulphuric acid, reduce the contained iron to the ferrous state by $NaHSO_3$ or gaseous SO_2, dilute to 400 or 450 c.c., boil for two hours, replacing the evaporated water by an aqueous solution of SO_2. The *titanic acid* is thus precipitated. Allow to cool, make up to 500 c.c., pour through a dry filter and wash the TiO_2 with warm water containing a little ammonium chloride, but keep the washings separate from the first filtrate. Dry, ignite, and weigh the TiO_2.

(c) Boil 125 c.c. of the first filtrate obtained in (b) (=0·250 g. bauxite) till the SO_2 has been removed, add a little zinc, dilute strongly, and estimate the *iron* by titration with permanganate, after having rendered the solution slightly acid by sulphuric acid, as described p. 180.

(d) *Alumina, Ferric Oxide, and Titanic Acid* together are estimated in the first solution (a). Take 25 c.c. of this solution (=0·125 g. bauxite), add a little fuming nitric and hydrochloric acid, dilute considerably, add NH_3 in slight excess, boil up for a moment, filter, dissolve the precipitate again in hydrochloric acid, precipitate again with NH_3 wash, filter, dry and weigh. By adding the alumina found in (a), and deducting the TiO_2 found in (b), and the ferric oxide in (c), we obtain the remainder = *Alumina*.

(e) Ignite a fresh sample of dried bauxite for a quarter of an hour by means of the blowpipe; the loss of weight is = chemically combined water + organic matter.

B.—Control of Working Conditions.

1. The *residue* from decomposing the bauxite is tested by boiling 2 g. with 3 c.c. concentrated sulphuric acid + 3 c.c. water until the red colour is destroyed, diluting a little, filtering, and making the filtrate up to 100 c.c. In this we estimate:

(a) *Iron* in 10 c.c. by reducing it to the ferrous state and titrating with $KMnO_4$, p. 180.

(b) *Ferric oxide + Alumina* by precipitation with NH_3.

(c) *Soluble soda* by boiling 20 c.c. with a solution of ammonium chloride and absorbing the NH_3 set free in titrated hydrochloric acid.

2. *Aluminate solution.*—In this we estimate Na_2O and Al_2O_3 in the same operation, as described below for sodium aluminate.

C.—Commercial Products.

1. *Sulphate of Alumina and Alum* :—

(a) ***Estimation of Alumina***—(α) *Gravimetric* estimation.—Dissolve 10 g. in water, dilute to ½ litre, take 50 c.c. of the clear solution = 1 g. of the substance, add ammonia in slight excess, boil up for a moment, filter, wash, dry the precipitate, ignite, and weigh the Al_2O_3. It is slightly contaminated with traces of iron, silicate, and phosphoric acid, which may be neglected.

(β) *Volumetric Analysis.*—Dissolve 5 g. in water, dilute to ½ litre, take out 50 c.c. = 0·5 g. substance, neutralise the free acid by dilute solution of caustic soda (indicator: methyl orange, till the pink changes to yellow), then add phenolphthalein and titrate with standard caustic soda solution until the red colour appears. Each c.c. of the NaOH solution corresponds to 0·1703 g. Al_2O_3.

N.B.—This method gives only approximate results, unless a number of precautions, detailed in *Tech. Meth.*, vol. i., p. 613, are observed.

(b) *Iron* cannot be estimated either gravimetrically or by titration, on account of its small quantity. Hence it is estimated colorimetrically by Lunge and Keler's method. We require for this a number of small stoppered cylinders of white glass, 13 mm. internal diameter, 17 cm. high, containing 25 c.c. divided in 0·1 c.c., and a free space of 5 c.c. above the 25 c.c. mark. Also the following reagents:—(1) a 10 per cent. solution of potassium thiocyanate; (2) pure ether; (3) a solution of 8·630 g. ammonium-iron-alum and 5 c.c. concentrated sulphuric acid in 1 litre; (4) a solution prepared from (3) by diluting it in the proportion of 1 : 100, so that this solution contains 10 mg. Fe per litre. It should be kept protected from sunlight, but even then keeps only for a few days, whereas solution (3), when protected from air and light, keeps a long time without getting turbid; (5) pure nitric acid. It is hardly possible to obtain nitric acid absolutely free from iron, but this does not matter, if it gives only a slight pink colour with potassium thiocyanate, since very little of it is used, and an equal quantity for the check test as for the actual test.

Dissolve 1 or 2 g. of the aluminium sulphate, weighed exactly, in a little water, add exactly 1 c.c. of the pure nitric acid (5), heat a few minutes, allow to cool, and dilute to 50 c.c. Put 5 c.c. of this solution into one of the colorimeter cylinders, A. (*N.B.*—If this method is applied to estimate traces of iron in sulphuric acid, this is diluted in the same way.) Into a second cylinder, B, put 5 c.c. of dilute nitric acid, obtained by diluting 1 c.c. of (5) to 50 c.c., and a certain accurately measured quantity of the iron-alum solution (3), *e.g.*, 1 c.c. Add as much pure water to cylinder A as you put iron solution in B, so as to always have the same degree of dilution in A and B. Then add to both A and B 5 c.c. of the thiocyanate solution (1) and 10 c.c. of the ether (2), put the stopper in and shake thoroughly, until the aqueous layer has become colourless and the red colour has passed over entirely into the ether. The comparison of the colours in A and B is most accurate after a few hours, since they deepen a little on standing, but marked differences can be observed at once, so that three cylinders will suffice, of which A receives the solution to be tested, B and C the quantities of iron most nearly approaching to A. The comparison is made by holding the cylinders a little distance from a white surface (*not* putting them down upon it!) and looking at them from the top downwards It is then quite easy to estimate differences of $\pm 0{\cdot}1$ c.c. of the iron-alum solution (5), that is of $\pm 0{\cdot}001$ mg. Fe in the 5 c.c. employed for analysis, but only when the total quantity of iron does not exceed 2 c.c. of the solution, that is $= 0{\cdot}02$ mg. Fe. If there should be more than this present, the permanganate method is applicable.

(c) *Free acid* in aluminium sulphate cannot be directly titrated by any of the hitherto known indicators. Beilstein and Grosse proceed as follows:—Dissolve 1 or 2 g. of the sulphate in 5 c.c. water, add 5 c.c. of a cold saturated solution of ammonium sulphate, stir fifteen minutes, and precipitate with 50 c.c. 95 per cent. alcohol. Wash the precipitate with 50 c.c. alcohol, evaporate the alcohol from the mixed filtrate and washings on the water-bath, and titrate the acid in the residue by decinormal soda solution and phenolphthalein.

(d) *Zinc* only occurs occasionally in commercial sulphate of alumina, but is very injurious. Estimate it by adding to the solution of the sulphate a sufficient quantity of barium acetate to precipitate all the sulphuric acid, and precipitating the zinc in the filtrate as ZnS.

2. *Aluminate of Soda* :—

(a) *Soda and Alumina.*—Dissolve 2 g. in water, dilute to 100 c.c. and titrate 10 c.c. ($= 0{\cdot}2$ g. substance) quite hot, with phenolphthalein as indicator, by fifth normal hydrochloric acid until the red colour has vanished. The soda only is saturated at this stage, and each c.c. of the acid corresponds to 0·0062 g. Na_2O. Now add a single drop of methyl orange and continue the titration with the same acid, but at a temperature of 30°, until the alumina first precipitated has been redissolved and the red colour has appeared. Each c.c. of acid used in this second titration corresponds to 0·003407 g. Al_2O_3. The percentage is obtained directly when employing 0·200 g. substance by multiplying the c.c. used in the first titration (a) by $3{\cdot}105 =$ per cent. Na_2O, and those used in the second titration (b) by $1{\cdot}704 =$ per cent. Al_2O_3.

(b) *Insoluble* matter is estimated in 10 to 20 g. substance in the usual manner, but employing "hardened" filtering paper, since ordinary filter paper would not stand the strongly caustic solution.

(c) *Silica* is estimated by evaporating with hydrochloric acid, digesting the residue with dilute HCl, filtering, washing, igniting, and weighing the residue.

3. *Commercial Alumina* is either the hydrate or anhydrous. In this the *silica* occurring as an impurity is estimated as in 2 (c); *total soda* by igniting at a red heat, digesting with water, heating with normal HCl, and titrating back the excess of acid; *soluble soda* by boiling with 100 c.c. water and titration with normal HCl and phenolphthalein; *iron* in the hydrochloric acid solution as in No. 1 (b); *loss of weight on ignition* ($= H_2O + CO_2$) by heating for fifteen minutes over the blowpipe.

XVIII. CEMENT INDUSTRY.

A.—Portland Cement.

1. Raw Materials.

(a) *Limestone.* (α) Estimate *carbon dioxide*, as described p. 184, by titration or by volumetric estimation of CO_2. It is calculated as CO_2. In the presence of considerable quantities of magnesia (which is considered as an injurious constituent of cement), estimate it in the hydrochloric acid solution, as on p. 175, calculate it as $MgCO_3$, and calculate the excess of CO_2 as $CaCO_3$.

(β) *Argillaceous residue* is the difference between 100 and the carbonates found in (a). If there is much present, it may be examined like clay, No. (b).

(b) *Clay.*—The percentage of coarse *sand* (quartz) is found by elutriation. Weigh 50 g. of the *coarsely* ground, dried average sample into a rather large porcelain dish, pour over it 100 c.c. dilute hydrochloric acid (1 concentrated acid+8 water), boil for about three hours, allow to cool, pour off the acid and direct a jet of water on to the mass, carefully rubbing it up with the fingers, so that only clay goes away with the water and pure sand remains behind. This plan is better than the application of mechanical elutriating apparatus.

The sand may be sorted by sieves into different sizes, viz., fine dust (down to 0·025 mm.), dust (0·040 mm.), fine sand (0·20 mm.), coarse sand (above this).

Complete analysis of clay (cf. *Tech. Meth.*, vol. i., p. 569, and pp. 688 *et seq.*).

1. *Decomposition by means of alkaline carbonate, i.e.*, a mixture of equal parts potassium carbonate and sodium carbonate, of which 6 to 10 g. are required for one part of clay. Dry the clay at 120°, grind it very finely, mix it intimately with the alkaline carbonate in the platinum crucible itself by means of a platinum or glass spatula (which is afterwards cleaned with a little car-

bonate), and heat in the covered crucible, first slowly, then up to full, quiet fusion. A good Mecker or Fletcher burner is preferable to the blowpipe for the heating. After cooling, heat the bottom of the crucible by a small flame to a low red heat twice successively, in order to facilitate the separation of the fused mass, allow to cool, add a few c.c of water, and heat gently with a small flame, until the cake detaches itself from the crucible. Wash it into a good-sized platinum dish, cover this with a large watch-glass and heat on the water-bath until the mass has softened and fallen to powder. Then add an excess of hydrochloric acid, remove the watch-glass, wash its under-surface, and evaporate to dryness on the water-bath. During the evaporation the mass is stirred with a glass rod, so as to render the residue powdery. Then heat the dish in an air-bath to 120° for an hour, moisten it, after cooling, with moderately strong hydrochloric acid, allow to stand for an hour, heat up with water, pour the clear portion through a filter, and continue this treatment until the residue ceases to yield a colour with hydrochloric acid. Then transfer it to a filter, wash, dry, and ignite it first over a small flame, then to constancy of weight, and weigh it *as silica*. It may still contain some *titanic acid*. This is separated by evaporating with hydrofluoric acid and concentrated sulphuric acid on the water-bath as a residue which should be tested whether it yields the purple microcosmic salt bead of TiO_2.

The filtrate from the titanic acid is divided in two halves. In one of these estimate *alumina + ferric oxide* by adding pure ammonia (free from carbonate) in slight excess, boiling up for a moment, filtering, washing, and igniting. In the other half estimate the *iron* by reducing with zinc and titrating with permanganate.

In the filtrate from the precipitate of $Al_2O_3 + Fe_2O_3$, estimate *calcium* by precipitation with ammonium oxalate (p. 175), and in the filtrate from this *magnesium* by ammonium phosphate (p. 175).

2. *The Alkalies* can be estimated, if desired, by decomposing about 5 g. clay with hydrofluoric acid ; cf. *Tech. Meth.*, vol. i., p. 694.

3. *Sulphur*, present as sulphates or pyrites, is estimated by oxidation with aqua regia and precipitating the hydrochloric acid solution with barium chloride ; *cf.* p. 134.

4. *Carbon dioxide*, as in the case of limestone, p. 184.

5. *Loss of weight on ignition* over the blowpipe or a powerful gas burner gives water + organic matter + CO_2 + sulphur present as pyrites, etc.

(c) *Separation of Silica present as Quartz, and that present in the Form of Silicates.*—The separation of these two kinds of silica is frequently demanded in so-called "rational analysis of clay." It can be effected by the process of Lunge and Milberg (*Z. angew. Chem.*, 1897, p. 393), on the basis of the observation that extremely finely divided *quartz* is dissolved by concentrated caustic soda solution, but not by a 5 per cent. solution of sodium carbonate, whilst the latter dissolves the silica, separated from *silicates* by strong acids in an *amorphous* state, when heated on the water-bath for half an hour. This is applied to the separation of the two modifications of silica as follows:—Heat 5 g. of clay (dried at 120°) with dilute sulphuric acid (50 c.c. concentrated acid + 100 c.c. water) to boiling in a porcelain or platinum dish, covered with a watch-glass, until the water has been driven off and fumes of SO_3 begin to escape, allow to cool, dilute with water, pour off the liquid, moisten the residue with hydrochloric acid, heat for a quarter of an hour, filter, and wash. Wash the moist residue, which contains a mixture of both modifications of SiO_2, into a porcelain dish, make up the solution to about 250 c.c. add about 12·5 g. pure anhydrous sodium carbonate, and heat on the water-bath for half an hour. Then pour off the clear liquid and repeat the treatment with 5 per cent. solution of Na_2CO_3 three times. Finally, wash the insoluble matter on to a filter and wash it thoroughly with water containing a little alcohol. The dried and ignited residue consists of the SiO_2 present as quartz; the difference between this and the total SiO_2 found in (b) 1 is the SiO_2 present as silicates.

2. Control of the Working Conditions.

The *crude mixture* is tested for its percentage of clay and calcium carbonate like limestone; compare A, 1. Usually the estimation of CO_2 (p. 184) is sufficient.

The *clinker* is analysed like the finished cement, if this is required.

3 Commercial Cement.

Ignite 1 g. cement in a platinum crucible over the blowpipe for fifteen minutes, decompose by hydrochloric acid, filter from the insoluble matter, fuse this with sodium carbonate, dissolve the melt in water, and unite this solution with the filtrate previously obtained. In this solution the following estimations are made:—

(a) *Silica* is determined by boiling down the united solutions and filtering off the precipitated SiO_2. The filtrate is again concentrated by boiling, and any SiO_2 that separates is united with the first portion. Dry the total (crude) silica, heat on the blowpipe for half an hour, and weigh. Then heat with 10 c.c. hydrofluoric acid and four drops concentrated sulphuric acid till fumes cease to be given off, and deduct the residue from the crude SiO_2; the portion thus removed by volatilisation represents the real SiO_2.

(b) Divide the united filtrates into two halves. In one of these estimate the *Sesquioxides*, $Al_2O_3 + Fe_2O_3$, by precipitation with pure ammonia, as on p. 255.

(c) *Ferric oxide* is estimated in the second half of the filtrate from (a), by reducing to the ferrous state by means of zinc or H_2S and titrating with permanganate.

(d) *Calcium* is estimated in the filtrate obtained in (b) by precipitation with ammonium oxalate, p. 175.

(e) *Magnesium* in the filtrate from (d), by precipitation with ammonium phosphate, p. 175.

(f) *Sulphates* are determined in a special sample by dissolving 1 g. in hot hydrochloric acid, filtering, and precipitating with barium chloride, p. 134.

(g) *Total Sulphur*.—Fuse 1 g. cement with sodium carbonate and a little potassium nitrate, dissolve in hot water, filter, acidify, and precipitate with barium chloride.

(h) The estimation of *alkalies* is rather troublesome, and is only carried out in exceptional cases; cf. *Tech. Meth.* i., p. 694.

(i) The *physical tests* for *fineness of grinding*, *time of setting*, *breaking strain*, etc., are described *ibid.*

B.—Hydraulic Lime and Roman Cement.

The raw material for these are *marls*. In these usually only CO_2 and argillaceous residue are estimated, as in the case of limestone, p. 254.

An accurate analysis can be made as described for clay, p. 254, more especially the separation of the silica present as quartz from that of the silicates.

C. Puzzuolanas, Trass, Granulated Blast-Furnace Slag.

1. *Hygroscopic water* is estimated by drying 10 g. at 110°.

2. *Chemically combined Water*.—Ignite 1 g. of the substance dried as in No. 1 in a platinum crucible by means of the blowpipe, a Hempel gas-furnace, or other suitable means The temperature ought to be raised gradually, so as to attain a red heat in about ten minutes, in order to avoid mechanical losses by dust being carried away through a sudden liberation of steam. After this continue the heating for half an hour to a yellow heat, and then transfer at once to the desiccator. The loss of weight is an important criterion for the hydraulicity.

3. *Silica present as silicates* should be estimated as well as that of quartz as an important hydraulic factor, as described p. 255.

4. *Mechanical tests* for fineness of grinding, etc., as for cement, *supra*, p. 254.

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