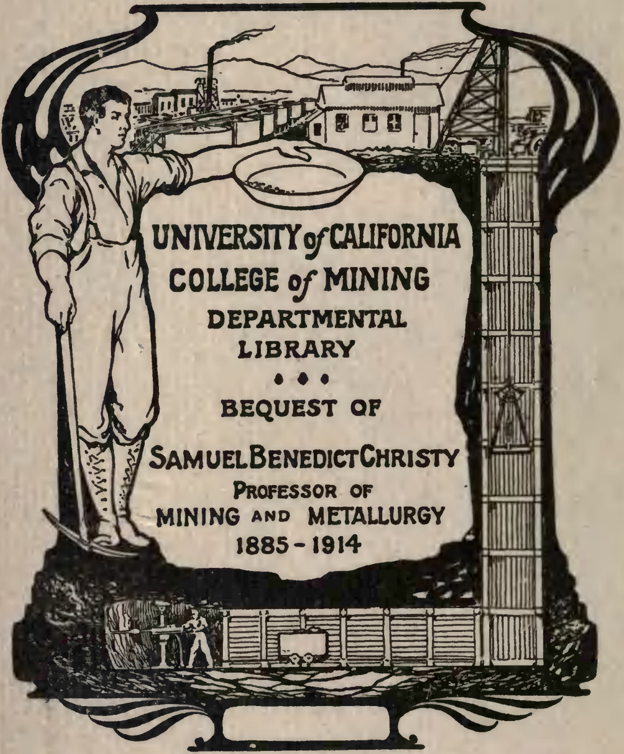


HB Christy

8 2.–

BLOWPIPE ASSAYING

LONDON: PRINTED BY
SPOTTISWOODE AND CO., NEW-STREET SQUARE
AND PARLIAMENT STREET

PRACTICAL
BLOWPIPE ASSAYING

BY

GEORGE ATTWOOD

F.G.S., ASSOC. INST. C.E., F.C.S., MEM. AM. INST. M.E., ETC.

With Seventy-four Woodcuts

NEW YORK
D. VAN NOSTRAND
23 MURRAY STREET
1881

PREFACE.

In publishing this small volume of Practical Blowpipe Assaying it is the wish of the Author to record the methods of assaying adopted by himself during eighteen years of foreign travel, in hopes that they will assist others who have to make examinations where complete assay offices and laboratories are not to be found.

Plattner's instruments and apparatus have been used as much as possible; but, as the methods here adopted have in so many instances differed materially from those of Plattner and other authorities on this subject, different apparatus has been devised to suit the requirements.

The general system of assaying adopted is a simple and a direct one. Sixty-four elements are mentioned in this work, and the assayer may be asked to determine the presence of one or all. The system being a direct one, directions are laid down for the separate determination of each. Practice will, however, soon enable the assayer to determine from one assay piece or sample the presence of several elements instead of one, and thereby save time and labour. For assaying, the Author has always adopted the system of checking his assays by synthetic assays, or, in other words, preparing an assay with a weighed quantity of the chemically pure metal or element to be determined, and mixing it with materials resembling as nearly as possible those of the ore, alloy, or compound to be assayed, and then, after the completion of the assay, adding to the direct assay the loss found to have been incurred in the synthetic.

In the assay of gold and silver alloys a check assay is necessary. In silver assays it is absolutely necessary, and by using the same most accurate results can be obtained. Silver and gold coins, bars, and ingots can be valued or stamped for market, and found to be correctly assayed, by following the methods hereafter described.

Whilst this little book has been going through the press, my old friend, Professor John Morris, has, with his usual kindness to all friends of science, assisted most materially in the correction of the proof sheets and in the revision of the work, and to him the Author now returns his best thanks.

The following list of books has been used in the preparation of this work, and in some cases material has been drawn from them.

4, Upper Gloucester Place, N.W.

BOOKS CONSULTED IN THE PREPARATION OF THIS WORK.

'A Manual of Practical Assaying.' By John Mitchell, F.C.S. Edited by William Crookes, F.R.S. London, 1873.

'Plattner's Manual of Qualitative and Quantitative Analysis with the Blowpipe.' By Professor Th. Richter. Translated by H. B. Cornwall, A.M., E.M. New York, 1873.

'A Manual of Metallurgy.' By George Hogarth Makins, M.R.C.S., F.C.S. London, 1873.

'Chemical and Pharmaceutical Manipulations.' By Professor Campbell Morfit and Clarence Morfit. Philadelphia, 1857.

'A Text-Book of Mineralogy.' By Edward Salisbury Dana. New York, 1877.

'Manual of Determinative Mineralogy.' With an Introduction on 'Blowpipe Analysis.' By Professor George J. Brush. New York, 1878.

'Elements of Metallurgy.' By J. Arthur Phillips, M. Inst. C.E., F.G.S., F.C.S., &c. London, 1874.

'Determination of Minerals by the Blowpipe.' By Dr. C. W. C. Fuchs. Translated and edited by F. W. Danby, M.A., F.G.S. London.

'The Metallurgy of Silver and Lead.' By Robert H. Lamborn, Ph.D. London, 1878.

'The Blowpipe: a Guide to its Use in the Determination of Salts and Minerals.' By Professor George W. Plympton, C.E., &c. New York, 1874.

'A System of Instruction in Quantitative Chemical Analysis.' By Dr. C. Remigius Fresenius. London, 1860.

'Manual of Qualitative Chemical Analysis.' By Dr. C. Remigius Fresenius. New York, 1864.

'Handbook of Chemistry.' By Professors F. A. Abel and C. L. Bloxam.

'Chemical News.' David Forbes. Nos. 380, 384, 392, 396, 398, and 412.

'Journal Chemical Society.' May 1879. Geo. Attwood on the Assay of the Ores and Compounds of Mercury by the Blowpipe.

CONTENTS.

PART I.

DESCRIPTION OF THE MOUTH BLOWPIPE AND APPARATUS.

PART II.

QUALITATIVE DETERMINATION.

PART III.

PART IV.

INTRODUCTION.

In searching for and determining the different elements mentioned in the following tables, the method adopted is a direct examination for each separate element. The beginner will find, by following the methods here described, that his task will be simplified, and when practice has made him proficient he can then look for several elements out of one sample.

Table of 'Metallic' Elements of Commercial Value.

Names of the Elements	Symbols	Atomic Weight	Names of the Elements	Symbols	Atomic Weight
Potassium	K	39·1	Chromium	Cr	26·7
Sodium	Na	23	Iron	Fe	28
Cæsium	Cs	133	Cobalt	Co	29·5
Rubidium	Rb	85·4	Nickel	Ni	29·5
Barium	Ba	68·5	Zinc	Zn	32·6
Strontium	Sr	43·8	Cadmium	Cd	56
Calcium	Ca	20	Copper	Cu	31·7
Magnesium	Mg	12	Lead	Pb	103·5
Aluminium	Al	13·5	Indium	In	—
Manganese	Mn	27·5	Bismuth	Bi	210
Tin	Sn	59	Titanium	Ti	25
Antimony	Sb	122	Mercury	Hg	100
Silver	Ag	108	Platinum	Pt	98·7
Gold	Au	197	Lithium	Li	7

Table of 'Non-Metallic' Elements of Commercial Value.

Names of the Elements	Symbols	Atomic Weight	Names of the Elements	Symbols	Atomic Weight
Oxygen	O	8	Sulphur	S	16
Hydrogen	H	1	Phosphorus	P	31
Nitrogen	N	14	Arsenic	As	75
Fluorine	Fl	19	Carbon	C	6
Chlorine	Cl	35·5	Boron	B	11
Bromine	Br	80	Silicium	Si	14
Iodine	I	127			

Table of 'Metallic' Elements of No Commercial Value.

Names of the Elements	Symbols	Atomic Weight	Names of the Elements	Symbols	Atomic Weight
Glucinum	Be	4·7	Cerium	Ce	46
Lanthanum	La	46	Didymium	Di	48
Yttrium	Y	—	Erbium	Er	—
Terbium	Tr	—	Niobium	Nb	—
Tantalum	Ta	37·6	Thorium	Th	59·5
Uranium	U	60	Thallium	Tl	203
Tungsten	W	92	Molybdenum	Mo	48
Vanadium	V	68·6	Rhodium	Rh	52·2
Palladium	Pd	53·3	Iridium	Ir	99
Ruthenium	Ru	52·2	Osmium	Os	99·6

Table of 'Non-Metallic' Elements of No Commercial Value.

Names of the Elements	Symbols	Atomic Weight	Names of the Elements	Symbols	Atomic Weight
Selenium	Se	39·7	Zirconium	Zi	44·8
Tellurium	Te	64·5			

EXPLANATION OF THE TERMS USED IN THE TABLE OF THE ELEMENTS.

Element.—One of the ultimate indecomposable constituents of any kind of matter, as oxygen and hydrogen, which are the elements of water.

Atomic Weight is the weight of the atom of an element as compounded with that of the atom of another element, ascertained from the proportions by weight in which they combine; or, leaving out of view the hypothetical idea of an atom, it is the number expressing the proportions by weight in which the elements combine, one of the elements, either hydrogen or oxygen, being assumed as the unit for comparison with the others. Oxygen and hydrogen combine to form water in the ratio of 1 of hydrogen to 8 of oxygen; and 1 and 8 are therefore the combining proportions of hydrogen and oxygen—also called, to avoid hypothesis, their 'combining equivalents.'

Symbol.—An abbreviation of the name of one of the elements. Some of the abbreviations are taken from the Latin meaning of one of the words, such as silver, Ag, from *argentum.*

The following elements are nearly always found combined with oxygen, and they are spoken of as oxides in the qualitative determination. For instance, in the case of Potassium (page 45) the expression, 'The presence of potash is detected by the blowpipe in two ways,' is used.

Potassium	Potash.
Sodium	Soda.
Calcium	Lime.
Magnesium	Magnesia.
Aluminium	Alumina.
Titanium	Titanic acid.
Lithium	Lithia.
Phosphorus	Phosphoric acid.
Silicium	Silicic acid.
Glucinum	Glucina.
Tantalum	Tantalic acid.
Tungsten	Tungstic acid.
Vanadium	Vanadic acid.
Niobium	Niobic acid.
Thorium	Thoria.
Molybdenum	Molybdic acid.
Zirconium	Zirconia.

The new earths announced as occurring in gadolinite and samarskite—as mosandrin, philippin, decipin, scandin, holmin, thulin, samarin, ytterbin—are not alluded to in this work, as the characters of some of them are still a subject of enquiry. (See Delafontaine Compt Rend. 1880. x. c. 221).

PART I.

DESCRIPTION OF THE MOUTH BLOWPIPE AND APPARATUS.

BLOWPIPE.
HOW TO USE THE BLOWPIPE.
BLOWPIPE FUEL.
,, LAMPS.
,, FLAMES.
,, SUPPORTS.
,, WEIGHING INSTRUMENTS.
,, TOOLS, SMALL IMPLEMENTS, AND APPARATUS.
,, REAGENTS, WET AND DRY.
,, TEST OR PROOF METALS.

BLOWPIPE.

The mouth blowpipe is a small and convenient instrument by which a blast of air may be forced through the flame produced by the combustion of a candle or lamp fed with oil or alcohol, so as to intensify the heat of the blast to such an extent as to render it a substitute on a small scale for the furnaces used in smelting ores as well as in assaying.

It furnishes what may be termed a miniature blast furnace, which is so perfectly under control that the temperature can be made intense or mild at the will of the operator; therefore the many advantages it affords the mining explorer, the chemist, and metallurgist are great. It is so portable that the little instrument with all the necessary apparatus and reagents, both wet and dry, required for qualitative determinations as well as for assays, can be packed up in a box twelve inches square. For a rapid determination of ores and minerals it has no equal and it possesses in careful hands most accurate means of estimating the actual percentage of metals in most of the commercial ores.

In the assay of gold and silver alloys the blowpipe affords the operator very correct results, and also in the examination of mineral coals it is invaluable. Makins states that he has seen a skilful operator fuse a farthing (a considerable weight of copper) by the blast afforded by the lungs alone. and without fatigue.

Blowpipes are made in many forms, but that devised by Gahn and recommended by Berzelius may be considered to best fulfil all the requirements for general use.

FIG. 1. (Half size.)

FIG. 2.
(Full size.)

It consists of a slightly tapering tube, fitting into a cylindrical chamber one inch long and half an inch in diameter. The chamber serves to collect any moisture which may form in the tube during blowing. Into the side of this chamber a much smaller tube in diameter, about one inch in length, is inserted at a right angle. The end of this tube is covered with a platinum tip (fig. 2) having a fine aperture. Although silver and brass tips answer very well it is always best, when they can be procured, to employ platinum tips, as they are easily cleaned from soot, &c., by heating over the spirit lamp. The assayer should be provided with three or four tips, the finest being used for qualitative work, having an aperture of 0·4 millimetre in diameter.

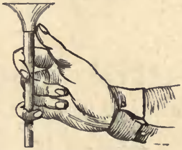
Those required for reductions should have a larger aperture. The blowpipe should be provided with a trumpet-shaped mouthpiece, which is best made of horn or ivory turned in the lathe.

The use of this mouthpiece very much diminishes the fatigue of the muscles of the lips in long-continued blowing, and the difficulty at first felt in preventing the escape of air at the corners of the mouth is easily overcome by practice. The mouthpiece is shown in the drawing (fig. 1). The length of the blowpipe must be adjusted to the sight of the operator, so that the test object may be held at such a distance as to be distinctly visible.

HOW TO USE THE BLOWPIPE.

The blowpipe is held firmly in the right hand (see fig. 3), and in such a manner as to facilitate a direction of the flame upon the substance under process. The assay is held upon a support by the left hand, care being taken to retain the arms in their fixed position, for unsteadiness will prevent an uninterrupted action of the blast on the assay. The mouth furnishes the blast, which derives its force from the muscles of the cheek. To prevent fatigue of the respiratory organs, communication between the mouth and chest must be closed during the blowing, and breathing maintained through the nostrils. A few days' practice removes all the difficulty at first experienced in producing a continuous steady current, and it is by this means only that proficiency can be acquired. The operation is commenced by filling the mouth with air, expanding the cheeks, and then keeping up a steady forcible pressure with the muscles, respiration being allowed to go on as usual through the nose.

FIG. 3.



The blowing is not unhealthy, and with a little perseverance is soon acquired, and assays made for several hours in succession without fatiguing even the muscles of the cheeks.

Beginners are apt to imagine that they must blow with considerable force, and also if they stop blowing for a moment, that the assay will be spoiled. In both these cases a little practice convinces them of their error, and they soon find that although the operator appears to be trying to burst his cheeks in his efforts to fuse an assay, he is quietly using his cheeks as a miniature air-bellows, and not tiring himself in the least. A practised operator, *directly* he lays down his blowpipe, even after a continuous blow of fifteen minutes or more, will speak to a companion with ease, without a single gasp, proving that the blowing has not exhausted his breath.

BLOWPIPE FUEL.

Pure olive oil is the best fuel for reductions and quantitative fusions.

Alcohol makes a good fuel for qualitative work, and is especially useful for the scorification and cupellation of silver and gold alloys, as well as for heating glass tubes and matrasses, and is employed in the assay for mercury. By adding about one-seventh part of turpentine to alcohol the reducing strength is increased.

Refined rapeseed oil answers very well as a blowpipe fuel. The ordinary illuminating gas makes a good fuel, but it is much better for oxidation than for reduction.

The flame of a wax candle, or even the flame of an ordinary candle, answers the purpose when nothing better can be found. Although assays can be made from the flame supplied by candles, yet such assays are generally attended with considerable difficulty, owing to the small volume of the flame.

Paraffin melted and poured into a lamp having an open top and a broad wick attached to one end answers nearly all the purposes required for blowpipe fuel. The great objection is that soot accumulates on the glass tubes or porcelain vessels when heated over the flame.

In some countries—the interior of South America, for instance—alcohol cannot be procured except at a great cost; but as crude spirits made from sugar-cane, &c., are generally plentiful in such places, they afford the explorer a good substitute for alcohol as well as oil, owing to the presence of more carbon than pure alcohol contains. The spirits, however, contain some water; and after the fuel is about one-half consumed it is best to empty the lamp and fill again with fresh spirits.

BLOWPIPE LAMPS.

The form of blowpipe lamp generally used is the one proposed by Berzelius and used by Plattner (see fig. 4). The cistern is made either of sheet brass or tinned sheet iron, about 4½ inches long, and slightly tapering from 1¼ inch in width to 1 inch at the end nearest the operator, and it is usually coated with a dark lacquer.

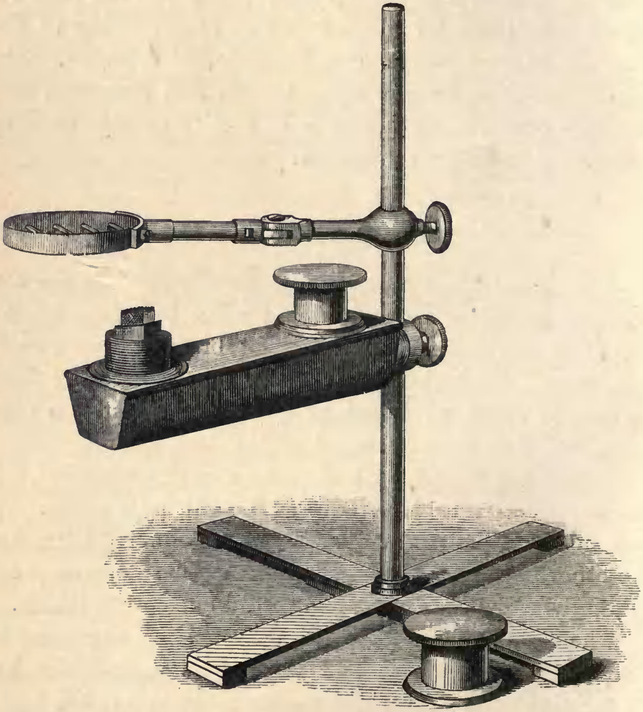
It is made to slide on a German silver or brass rod, and can be adjusted to the required height by a screw. At one end of the lamp is an opening for introducing oil, and at the other is the wick-holder. Both of these openings are closed by screw caps, with the thread cut on the inside.

The escape of oil is prevented by washers cemented to the caps with shell-lac and wax. The wick-holder has its greatest breadth at right angles to the axis of the lamp, and must be cut off obliquely, to allow the flame to be directed downwards. Cylindrical woven wicks, such as are made for the Argand burners, are best adapted for this lamp, and they are pressed flat and folded lengthwise, so as to be introduced fourfold.

The wicks must not fit too tightly, and should be free from lime, which is sometimes used in the bleaching of them.

On the blowpipe stand an arm is attached, which has a metal ring on the top, about $1\frac{3}{4}$ inch in diameter.

FIG. 4.



The arm is movable, and, like the cistern, it can be moved up and down, and it is kept in position by a small thumb screw. The ring is covered with either a network of iron or platinum wire, and is used for holding substances which require to be heated.

The lamp just described is best adapted for burning oils, but alcohol can be used if required.

A small glass lamp for burning alcohol is used in the mercury assay also for heating substances in the glass matrasses, &c. (fig. 5). Fletcher (of Warrington) has invented a most useful blowpipe lamp, which possesses the great advantage of being clean and portable, and it can be easily refilled by melting solid paraffin and pouring it into the reservoir. The lamp is constructed of either tin or German silver (fig. 6). The paraffin reservoir is about $1\frac{3}{4}$ inch in length, and $1\frac{1}{4}$ inch in width at its widest part, and tapers to $\frac{1}{2}$ inch at the wick end, the depth being about 1 inch. The wick is about $\frac{1}{2}$ inch in width and about $\frac{3}{16}$ of an inch thick, and is held in its place by being run through a wick-holder attached to the narrow end of the reservoir.

FIG. 5.
(Half size.)

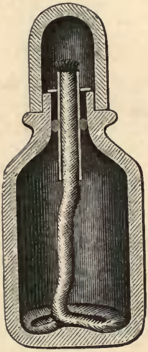


FIG. 6.
(Half size.)

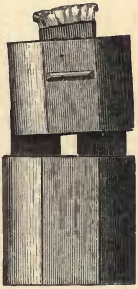


FIG. 7.

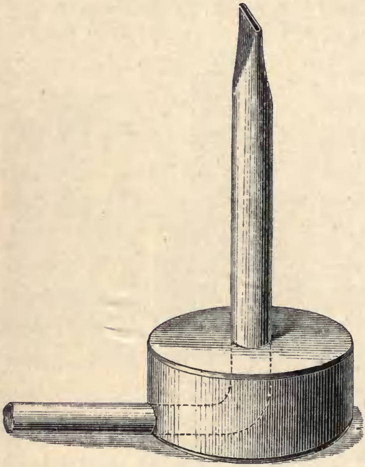
Top View of Lamp. (Half size.)

The reservoir is held by a flat-bottomed hollow cup of a similar form, but made larger, so that when the lamp has been used the reservoir can be reversed and packed away without injuring the wick (fig. 7).

The reservoir is made to slide up and down on a strip of metal soldered to the cup, and by means of a thumb screw it can be inclined to any angle necessary.

For all ordinary blowpipe work this lamp answers every purpose, and it is one of the most convenient and cleanly lamps that are in use at the present time. The lamp required for using the ordinary illumination gas is of the simplest description. Brush recommends the following:—

FIG. 8. (Half size.)



'A blowpipe gas lamp may be readily made by selecting an iron or brass tube, 8 inches in length and $\frac{3}{8}$ of an inch in bore, bending it at a right angle at the middle, and passing it through a block properly cut, or placing it in a mould, which is then filled with melted lead. The top of the tube is then flattened, and the proper inclination given to the orifice by filing' (see fig. 8).

FLAMES OBTAINED BY MEANS OF THE BLOWPIPE BLAST.

The assayer produces, when using the blowpipe, two distinct flames. They are called the oxidising and reducing flames. Practical knowledge of the way to create and use these flames is essential, and until such knowledge has been acquired the operator cannot proceed in his manipulations with safety.

The production of the flames can be acquired in one hour's lesson, or from studying and carrying out the following instructions. Dr. Lamborn describes the blowpipe flames as follows:—

'When we examine the flame of a common candle, we discover that it is composed of four parts.

‘At the base a small crescent (fig. 9) *a b*, with a clear blue colour; higher up, and in the centre of the flame, the dark conical portion *c*; surrounding this is the luminous portion *d*; and exterior to the last is the scarcely perceptible mantle *f e*. The student has to remark the nature of two of these divisions: the exterior non-luminous part *f e*, which is composed of gases already saturated with oxygen, that under certain circumstances goes over to bodies with which the flame is brought in contact, and hence constitutes the oxidising flame; and secondly, the luminous portion *d*, which consists of gases not yet saturated with oxygen, and therefore capable of extracting that element from easily reducible oxides, and hence called the reducing flame.

Fig. 9. (Half size.)

‘When the point of the blowpipe is held one-third of the breadth of the wick in the lamp flame, as in figure 10, a flame is produced by blowing that is long, slender, and blue, which is hottest at the outermost point *a*, and is an oxidising flame. This action, however, is strongest slightly beyond *a*, about *d*, in the stream of heated gas.

Fig. 10. (Half size.)

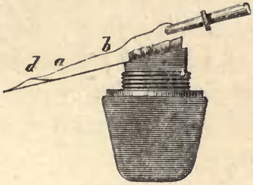
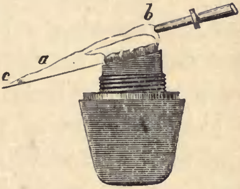


Fig. 11. (Half size.)



‘If now the point of the blowpipe be held as in fig. 11, somewhat higher than before, and not quite within the flame, a larger and more luminous cone of burning gases may be driven in the direction *b c*; within the bright portion of the flame at *a* the above-mentioned chemical action on oxides takes place, which causes this to be called the *reducing flame.*'

The most important matter is to produce optionally oxidation or reduction.

Oxidation is very easily performed, whilst reduction requires more practice. Berzelius recommends the operator to take a small grain of tin, place it on charcoal, then direct the blowpipe upon it; it will soon fuse, and if the operator has not produced a good reducing flame it will become covered with a coat of oxide. The nature of the flame must be altered until, by observation, the proper kind is produced at will.

The longer the button of tin is kept bright the better and more expert the operator.

BLOWPIPE SUPPORTS.

When a substance has to be examined by the blowpipe it must be held by some means firmly. The article used is called a support. A suitable support should be one that will not fuse at a high heat, combine chemically with the fused body, or prevent its complete heating by rapid conduction. The best supports are charcoal and platinum wire or foil.

Charcoal makes an excellent support, as it is infusible; it has great reducing power, and it is also porous, allowing alkalies and fluxes to pass into it, whilst metals and substances that are less fusible remain behind.

Soft pine wood makes the best charcoal for blowpipe work. It should be well charred, and that which snaps or smokes in the fire should be rejected. 'Hard woods' generally contain a large percentage of ash, which contains traces of iron and manganese, and in some qualitative determinations the results are liable to be incorrect by these metals being absorbed by the fluxes.

Straight pieces free from knots should be selected, and sawed in the direction of the fibre into oblong supports, about 6 inches in length and 2 inches broad.

For qualitative determinations small pieces of charcoal answer every purpose; and if the pieces used are too small to be held by the hand, they can be supported on a strip of tin or thin sheet iron and the assay proceeded with.

The saw for cutting the charcoal should be a 'cross-cut' saw with fine teeth, and a blade of 5 inches in length, $\frac{3}{8}$ of an inch in breadth, and $\frac{1}{16}$ of an inch in thickness. Cavities, deep or shallow, according to the substance to be examined, are made by a borer, or by the point of a knife in the charcoal, and the assay placed in the same for treatment.

Oxidation, reduction, and fusion are sometimes so rapidly performed on charcoal that the operator is not certain of the result obtained. In such cases platinum in the form of foil or wire is used.

Platinum foil is best used in a narrow strip about 3 inches long and 1 inch broad, and it is useful for oxidation.

The substance which is to be oxidised is placed on it, near one end, and heat is applied by the blowpipe flame upon its under side. The conducting power of platinum is so inconsiderable that the other end may be held between the fingers without inconvenience.

For reduction platinum cannot be generally used, as it forms fusible alloys with some of the metals; nor should sulphides, arsenides, or chlorides be heated in contact with it.

Platinum wire should be about $2\frac{1}{2}$ inches long, moderately thin, and bent into a hook at one end, which serves as the assay support. The wire may be held in the hand, either with or without a holder, but the latter is more convenient. It is best made out of a piece of hard wood or iron turned; and, to prevent injury to the wires,

FIG. 12. (Half size.)

holders are used, in which the wire is inserted into the middle of two slits crossing each other at right angles; the latter are then shut tight by a band which is thrust over them and arranged to screw up and thus hold the wire (see fig. 12). The large end of the holder unscrews, and five or six of the wires can be kept in a small hole bored in the handle. The form used resembles a crotchet-holder in nearly every respect.

After the wires have been in use they can be cleaned by warming the ends in a test tube with hydrochloric acid, or by fusing a bead of soda upon it, and then dissolving it in water.

To use platinum wire, either heat the hook for a moment over the lamp and then dip it into the flux to be used, or moisten it and dip in the flux. Melt the flux over the lamp, and when a good transparent bead has been obtained add the portion to be assayed to it whilst it is still hot; or if that is not practicable moisten the flux bead slightly and let the assay adhere to it.

Fuse the assay over the lamp, and the appearance of the bead in reference to opacity, colour, and other characteristics can be distinctly seen from all sides, and in this way are colorations of the bead by metallic oxides particularly to be distinguished. Some fluxes are so thin that they fall through the loop or hook, but by turning the assay a few times the flux will generally remain on the wire.

Platinum wire cannot be used when reduction to the metallic state is required.

All oxidation and reduction experiments in which the results are to be known by the colour of the fluxes should be effected upon platinum wire.

FIG. 13. (Half size.)

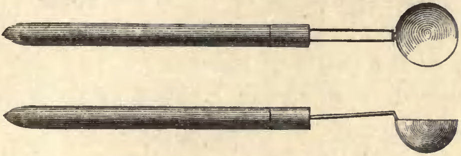


FIG. 14. (Half size.)

Platinum spoons are useful for heating substances with bisulphate of potash and saltpetre. Two sizes are convenient, made similar to figs. 13 and 14.

Crucibles and capsules of fire clay are made by kneading into a thick paste some fine elutriated fire clay and moulding them as follows :—

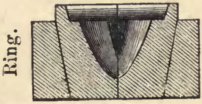
FIG. 15. (Half size.)

Plug.

The crucible mould is made of brass, and consists of three parts—a plug, a box divided into two parts, and a stout ring to keep the box together (figs. 15 and 16).

Knead with the fingers some of the elutriated fire clay and make it into small balls, each one a little larger than is necessary to form the crucible required; oil the inside of the box and the end of the plug; place the clay ball in the box, and after pressing the plug on the clay give the plug a couple of sharp blows with a mallet.

FIG. 16.



Box.

The box in the meantime must rest on a piece of hard wood, or upon an anvil (upon which has been previously placed a piece of old cloth or flannel). The plug is then removed, and after that the ring; the box is then separated easily, and the crucible is ready to be dried. They should be dried very slowly at first, and then baked in an oven, muffle, or crucible.

Capsules, or roasting dishes, or cups, are made in a hard-wood mould (boxwood being generally used) by pressing the clay with a pestle of the same. The clay is prepared in a similar manner as it is for moulding the crucibles (fig. 17).

FIG. 17.
(Half size.)

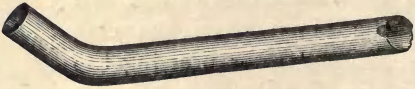
Oil both the mould and the end of the pestle, place over the mould a thin piece of paper, take a small ball of the elutriated clay, place it on the paper, and then press and turn the pestle round until the capsule is of an equal thickness.

Remove the pestle, take the paper by two ends, and lift the capsule out and place it to dry, the paper soon falls off, then bake as in the case of the crucibles.

Open glass tubes, closed tubes, and bulb tubes, made of hard glass free from lead, are used for the ignition of bodies and minerals which become volatile at a high temperature and deposit a sublimate on the glass tube.

Open glass tubes are useful when a substance has to be ignited in an excess of air. They are made from 4 to 6 inches in length, and from $\frac{1}{8}$ to $\frac{1}{4}$ of an inch in

FIG. 18. (Half size.)



diameter (fig. 18), of hard glass, and are easily bent to the required angle by heating them over the spirit or oil lamp.

Closed and bulb tubes (fig. 19) are employed when substances require heating to the exclusion of air as much as possible. The bulb tube is especially serviceable when ores and rocks have to be examined to see if they contain water.

FIG. 19.
(Half size.)

WEIGHING INSTRUMENTS.

A fine, delicate, as well as portable assay balance is required for blowpipe assays. Mr. L. Oertling has constructed a balance under the author's directions which fulfils all the requirements.

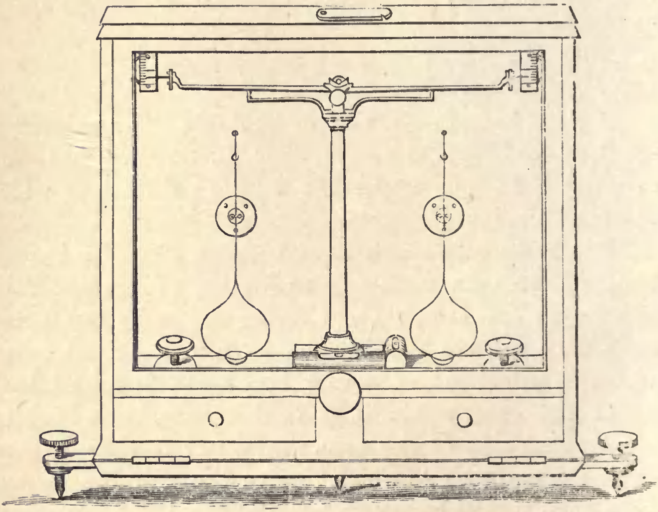
The balance is constructed to carry 30 grains in each pan, and to turn distinctly with $\frac{1}{1000}$ of a grain. The size of the case is only eight inches square by two inches deep. To prepare the balance for use, the front cover, which is attached to the case by hinges, is folded back under the case, where it is held by two brass buckles, one on each side of the case. A stand is thus formed. After the two sockets which receive the adjusting screws have been turned outwards, place in them the two screws (which will be found in the drawers), also the third screw, which fits in the back of the lid. By means of the three screws, assisted by the two levels attached to the stand inside, the balance can be placed in a horizontal position. Now hang to the ends of the beam the two stirrup pans, which will be found fixed against the back of the case in notches, from which they can be removed by turning on one side a small latch which moves on a pin.

2 grms.
= ~~15~~/~~1000~~ gm
0.00006g
= 0.6 mg

The small milled head button at the top of the stand may be removed, and the fork piece which holds the beam firmly to the stand (without allowing the steel knife-edge to come into contact with the agate planes) taken away. The handle may now be put in its place, and the balance is ready for use.

A glass sliding front is included in the balance, which prevents dust and currents of air gaining admission; also two small drawers, in which are carried the adjusting screws, the handle, the set of weights and riders; also a small pair of brass tweezers to handle the latter. The weights are as follows:—

FIG. 20.



10 grains	1·0 grain	0·10 grain
5 ,,	0·5 ,,	0·05 ,,
3 ,,	0·3 ,,	0·03 ,,
2 ,,	0·2 ,,	0·02 ,,
1 grain	0·1 ,,	0·01 ,,

The riders are made of fine gold wire, and weigh 0·10 grain. They are used to increase the fine weighing capacity of the balance by placing them on the top of the beam (which is graduated) and sliding them from one division to another.

At each end of the beam a small steel pointer is fixed, at the back of which are ivory graduated scales. These steel pointers help to indicate the weight of a substance much finer than the weights can be conveniently made. A pair of small metal pans and another pair made of horn complete the balance.

The horn pans are used in weighing ores and minerals, also in weighing the globules obtained in the mercury assay.

The metal pans are used for weighing alloys and beads of gold, silver, copper, &c.

For blowpipe assay purposes another balance is required, which will weigh upwards of 30 ounces, and at the same time must be sensitive and portable.

The author, after experimenting for several years, has at last succeeded in constructing an instrument that answers the purpose in all respects. This balance (fig. 21) resembles in some of its features a steelyard.

A brass bar *a*, $10\frac{3}{4}$ inches in length, $\frac{5}{8}$ of an inch in depth, and $\frac{3}{16}$ of an inch in thickness, represents the beam. The beam is finely polished and graduated. On the right-hand side the graduations represent pounds (lbs.) and ounces; on the left-hand side the graduations represent fractions of ounces and grains.

On the right-hand side there is a large movable weight *b*, which can be clamped at will by means of a small set screw *c* at the top. On the left-hand side there is a light weight *d*, which slides smoothly along the beam. By sliding the large weight to $\frac{1}{2}$, 1, $1\frac{1}{2}$, and 2 lbs. respect-

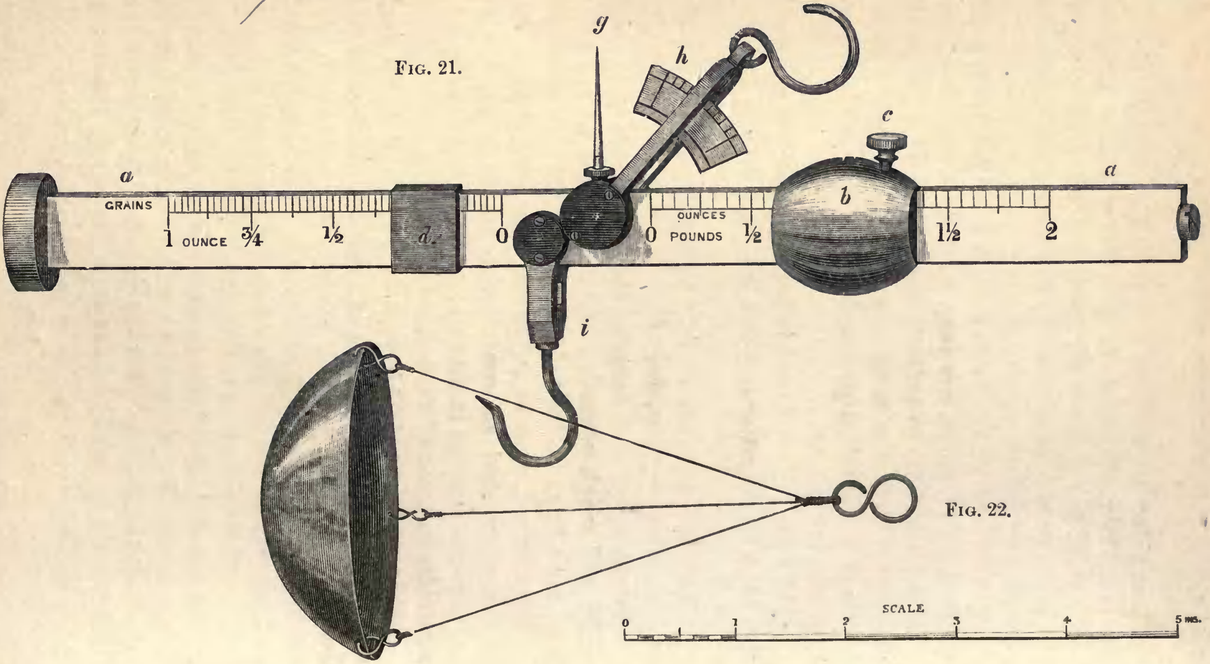


FIG. 21.

g
h
c
a
GRAINS
1 OUNCE
¾
½
d.
0
0
OUNCES
POUNDS
½
b
a
1½
2
i

FIG. 22.

SCALE
0
1
2
3
4
5 INS.

ively, it shows the pounds as marked on the side of the beam, whilst each mark represents 1 ounce.

The minor scale to the left represents 1 ounce in its whole graduated length, whilst its subdivisions represent each 10 grains, and by sliding the weight to one-half or one-quarter of these divisions, 5 or 2½ grains may be weighed by estimation. On the left-hand end of the beam there is a weight attached (*e*) by means of a screw; it serves as a counterpoise, also as a stop to the light weight. On the right-hand end of the beam there is also a stop (*f*) to prevent the heavy weight sliding off.

The beam is provided with an indicating steel needle *g* and with a fixed steel knife-edge, which works in rings of hardened steel which are let into the brass part *h*, called the beam support. The part *h* has fixed to it a small arc, graduated into ten divisions, by means of which the balance can be made to weigh much closer by using the sliding weights.

It has also a steel hook, which enables the assayer to suspend the instrument by means of a string or wire when he wishes to weigh any substance with great care.

The pan (fig. 22) is made of brass or copper, and it is about 3 inches in diameter and 1 inch deep at the centre. The pan is sustained by a steel hook (fig. 21, *i*), which is connected with the short end of the beam.

At the upper end of the hook attachment two hard steel rings are let in, upon which a knife-edge (which is fixed to the beam) works. The hook is sharpened at the point, so that the assayer can weigh small sample bags of ore or minerals without using the pan.

The balance weighs 13½ ounces, and with the pan 14½ ounces; it is very portable, and not liable to get out of repair.

To show the capabilities of the balance, the author has recorded the following experiments which he has made with it:—

Loaded with 32 ounces = 15,360 grains in the pan, it turns distinctly on the addition of 10 grains.

Loaded with 8 ounces = 3,840 grains in the pan, it turns distinctly on the addition of 3 grains.

Loaded with 4 ounces = 1,920 grains in the pan, it turns distinctly on the addition of 1 grain.

Loaded with 1 ounce = 480 grains in the pan, it turns distinctly on the addition of 0·5 grain.

Loaded with ½ ounce = 240 grains in the pan, it turns distinctly on the addition of 0·2 grain.

Loaded with ¼ ounce = 120 grains in the pan, it turns distinctly on the addition of 0·1 grain.

When the large and small sliding weights both point to *zero* the instrument is balanced. The readings are always taken from the inner ends of the sliding weights.[1]

TOOLS, SMALL IMPLEMENTS, AND APPARATUS.

One hammer for chipping and breaking rocks and minerals, for making cupels, and for striking the pestle in the steel mortar.

Total length of the hammer, about 10 inches; length of hammer head, 2½ inches, having a face about ⅝ of an inch square at one end and coming to a sharp point at the other. It must be made of hard steel (fig. 23).

FIG. 23. (One-quarter size.)

---

[1] This balance is made only by L. Casella, 147 Holborn Bars, E.C.

A small hammer (fig. 24) is required for flattening metallic buttons, and it should be made of highly tempered steel and brightly polished.

FIG. 24. (One-quarter size.)

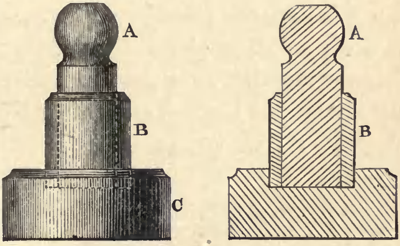
A small steel anvil, highly polished, about 1½ by 1¼ inch and ½ inch thick, is useful to flatten metallic beads upon, and to remove slags from buttons obtained in fusing assays.

To prevent the buttons flying off and being lost, always wrap them up in a piece of paper before using the hammer.

One of the most necessary implements used in preparing ores and minerals for assay is a steel mortar.

The mortar consists of three separate pieces, each of which is smoothly turned and made of hard steel (fig. 25). A is the pestle, B is a cylinder in which the pestle fits tightly, and C is the mortar into which both A and B fit.

FIG. 25. (Half size.)

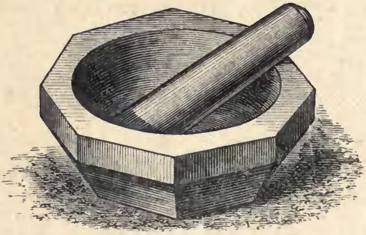


In using, place the cylinder in the mortar, then add the mineral or rock, place the pestle in the cylinder, and with the hammer strike a few hard blows. (It is best to place the mortar on some firm base before using the hammer.) The mineral will soon be reduced fine enough to be removed to an agate mortar for its final grinding.

An agate mortar and pestle are used to grind to the finest powder the ores for assay, also to crush up slags for further examination (fig. 26).

A mortar about 2 inches in diameter in the clear on the top, and $2\frac{1}{2}$ inches on the outside, and $\frac{1}{2}$ of an inch in depth at the bottom, answers the purpose.

Fig. 26.



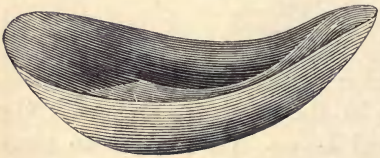
A small selection of files is most useful. Flat, round, triangular shapes are best, and they should not be more than 6 inches long.

A small knife and a pair of scissors are constantly needed, and should be included with the other tools.

A steel magnet, 4 inches long, sharp at the end, like a chisel, is used in the detection of iron, nickel, &c.

A horn spoon, made from a bullock's horn, cut, and finely scraped in the inside, so that it is perfectly smooth, is a most useful addenda to the assayer's outfit. The horn is generally hardened by soaking it for some hours in a weak solution of sulphate of iron or copper, after it has been scraped. It is used for vanning or washing ores of all kinds, also to wash slags after they have been powdered, to see if the operation has been carried on successfully (see fig. 27).

Fig. 27. (Quarter size.)



Charcoal borers are made of different sizes and shapes.

Fig. 28 represents a borer used for boring holes large enough to make the charcoal furnace, which holds crucibles, mercury retorts, and roasting cups.

Fig. 28. (Half size.)

Fig. 29 represents the borer mostly used in making assays of silver and gold ores.

FIG. 29. (Half size.)

Fig. 30 is a long bore, the small end of which is used for boring holes through the coal cover and sides of the charcoal furnace. The flat end is used for boring holes on charcoal for qualitative determinations.

FIG. 30. (Half size.)

Forceps with platinum tips are used to hold substances directly in the blowpipe flame when testing for fusibility (fig. 31).

FIG. 31. (⅔ nat. size.)

Brass forceps with very fine points are used to hold small objects, such as the small silver beads obtained in cupellation (fig. 32).

FIG. 32. (Half size.)

Iron forceps, very strong, are useful in rough work, such as holding a button of metal whilst it is hammered on the anvil, or raising and cleaning the lamp wick (fig. 33).

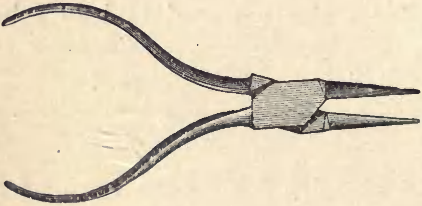
FIG. 33. (Half size.)

Cutting shears are used to clip pieces of assay silver, gold, and all kinds of metals after they have been beaten or rolled out. They should be made of good steel, and the blades kept sharp (fig. 34).

FIG. 34. (Half size.)

Steel pliers having fine points, with jaws slightly roughed on the inside, are used to remove buttons and beads from slags and cupels, also in separating a button from slag by gently pressing the substance after placing it near the inner part of the jaw, or to clean a cupel bead the same way. Good pliers are often strained by placing the substance to be pressed too near the point of the pliers (fig. 35).

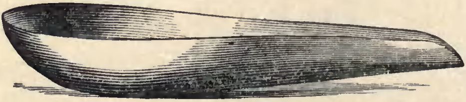
FIG. 35. (Half size.)



A magnifying glass composed of two convex lenses is the best, and it answers all the purposes required in blowpipe work.

Two small mixing capsules, one of polished brass, the other of horn, are used to mix the powdered mineral with the flux, and then to pour the charge conveniently into the assay crucible, roasting cup, or paper cornet in the assays (fig. 36).

FIG. 36. (Full size.)



A small ivory spoon is used to remove fluxes from the bottles, and minerals from the mortar. After a little practice it is not necessary to weigh many of the fluxes, as, the weight once ascertained, the operator can judge by measure (fig. 37).

FIG. 37. (Full size.)

Two small wire sieves, one having 1,400 holes to the square inch (wire sieving), the other 2,000 holes to the square inch.

Punched screens will do, but it is difficult to get them as fine as the sieving.

A stand is necessary to hold cupels and cupel moulds for the cupellation of gold and silver.

Fig. 38 represents a useful form. The top is made of iron, and is set in a wooden stand to prevent the heat affecting the fingers during the operation. (For cupels, see p. 29; for moulds, see p. 29.)

FIG. 38. (Half size.)

A small cylinder of hard wood, turned, is used to prepare the soda paper cornets for assays (fig. 39).

FIG. 39. (Half size.)

A small quantity of fine iron and platinum wire is used for holding the small crucibles in the furnace, and the pieces can be cut and bent to suit (fig. 40).

The charcoal-holder and furnace is described fully in the mercury assay.

Evaporating dishes and small cups, also watch-glasses, are necessary when acids are used. It is best to have half a dozen different sizes. Figs. 41 and 42 are convenient sizes.

FIG. 40. (Full size.)

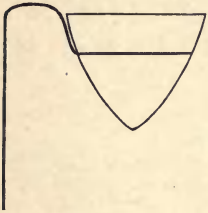


FIG. 41. (Half size.)

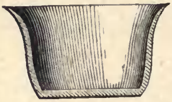
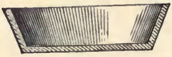


FIG. 42. (Half size.)



Test tubes for separating gold from silver are useful (fig. 43).

A few small pipe-clay annealing cups to collect the finely-powdered gold that has been separated in the test tube from silver by means of acids are useful, as the gold can be dried and annealed in them, and afterwards removed for weighing in one lump.

FIG. 43. (Half size.)

Beaker glasses, a few small funnels, and a stand to match are required (fig. 44).

FIG. 44.

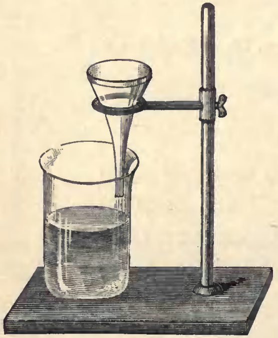
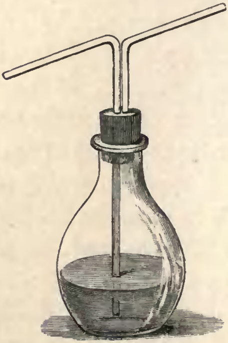


FIG. 45.



A small glass wash bottle is used for washing precipitates, &c. (fig. 45).

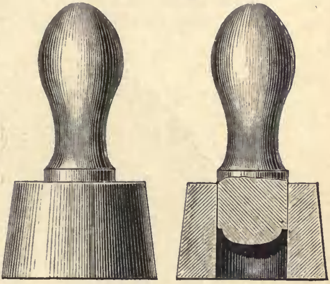
A small drop bottle to hold acids is useful (fig. 46).

FIG. 46.

A small cupel mould is used to make cupels for the assay of gold and silver alloys, which are called the 'previously prepared cupels' (fig. 47).

To make the above cupels, finely crushed bone ashes that have been previously burnt, so that they contain no animal matter, are moistened, and the mould filled to the top, the mould resting on a solid substance, such as a piece of hard wood. The pestle is placed on the top, and a few sharp blows are struck with a mallet or heavy piece of wood.

FIG. 47. (Half size.)



The cupel is removed and carefully dried. When perfectly dry, it should be smooth at the top and show no flaws or cracks.

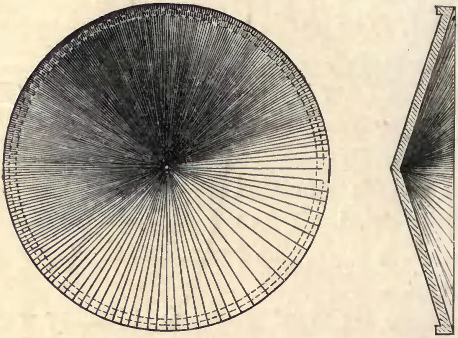
A package of best Swedish filtering paper is required in some of the assays. Blotting or some soft paper, soaked in a strong solution of carbonate of soda, then dried and cut into slips about 1½ inch long by 1 inch wide, is used in the assay of silver and gold ores, and a supply should always be kept on hand.

The batéa is one of the most useful parts of the mining explorer and assayer's outfit, and it enables the operator to make preliminary examinations of gold, silver, copper, mercury, lead, tin, ores, &c. It is also used in the assay of gold and tin ores.

Melville Attwood describes it as follows: 'Batéa is the name given to the gold-washer's bowl or vanning dish, used in the *placers* and gold mines of Brazil—a small implement which affords the most simple method of separating on a limited scale the grains of gold from the dirt, sand, pyritic matter, magnetic iron, &c. The form of the batéa in common use in Brazil is a circular shallow wooden dish or bowl, rudely fashioned with an adze and chisel, varying considerably in depth and size, but nevertheless in practical hands giving remarkable results.'

The best form of batéa is represented in fig. 48, and John Roach, of San Francisco, describes it as 'a disk of 17 inches diameter, being turned conical 12 degrees, will have a depth of 1⅞ inch from centre to surface. The thickness may be ⅝ of an inch. The outer edge, perpendicular to axis, will require wood 2½ inches thick for its construction—the best wood, Honduras mahogany.'

FIG. 48. ($\frac{1}{10}$ size.)



The author has used them for more than twenty years, and finds that by taking a hot iron and blackening the wood from the centre about 1½ inch all round the peculiarities of the separated gold, or material, are shown more distinctly than with the batéa in its normal condition as it comes from the lathe.

To use the batéa requires practice, and to describe the modus operandi is difficult.

Prof. Warington Smyth states as follows: ‘A quantity of the material to be operated on having been mingled and well stirred by hand with water in the bowl, it is shaken from side to side and circularly with a variety of movements suited to the form and the nature of the ore, only to be acquired by long practice. The separation of the gold is partly assisted by striking one side of the bowl occasionally, so as to arrest the course of the particles for the moment; and, finally, several different layers or lines of mineral matter may be distinguished from one another, the gold occupying the lower position, then the magnetic iron, then the pyrites, and lastly other wastes.’

Henry Hanks also gives a very good description of the way to use a batéa. He states—

‘The manner of using the batéa may be described as follows:—

‘A quantity of water will be required. This may be contained in a tank or large tub, or at a convenient place near the bank of a stream or lake.

‘The pulverised ore—several pounds at a time—is placed in the batéa, which is gradually sunk in the water. Several times it is broken down with the fingers, while the batéa floats on the water. When the ore is thoroughly wet and formed into mud, the batéa is taken by-the-bye with both hands and again sunk in the water. A circular motion is then imparted to it (soon learned by practice). The lighter particles will continuously flow over the edge and sink, while the heavier ones collect at the centre.

‘When only a small portion remains the batéa may be lifted, and the water held in the depression caused to sweep round the centre, while one edge is slightly depressed.

'This motion will gradually remove the heavier particles toward the depressed part. If there is any gold, platinum, galena, cinnabar, or other unusually heavy substance, its gravity will resist the power of the water, while comparatively light particles move slowly forward.

'The form of the vessel is such that the heaviest matter forms a point, and can be closely observed. If there is a particle of cinnabar present it will be found at the point of the prospect, clearly distinct from all other substances. The value of the batéa to the prospector cannot be too highly estimated, and it should come into more general use.'

Batéas can be made over two feet in diameter, or only a few inches. A portable and useful size is about 17 to 18 inches in diameter.

By seeing the batéa once used, and then taking time to wash the first few samples, the operator very soon becomes an expert at the management of the batéa; and when he has once learned its use he will seldom examine strange ores without it.

REAGENTS REQUIRED FOR BLOWPIPE ASSAYING.

All reagents which are employed in blowpipe investigations should be chemically pure.

Dry.

1. Carbonate of soda.
2. Neutral oxalate of potassa.
3. Cyanide of potassium.
4. Borax (biborate of soda).
5. Salt of phosphorus, or microcosmic salt (phosphate of soda and ammonia).

6. Nitre (nitrate of potash or saltpetre).
7. Bisulphate of potassa.
8. Vitrified boracic acid.
9. Protosulphate of iron.
10. Arsenic (metallic).
11. Argol (bitartrate of potash).
12. Red and blue litmus paper.
13. Common salt (chloride of sodium).
14. Fluor spar.
15. Quartz (silicic acid).
16. Graphite (soft lead-pencil scrapings answer every purpose).
17. Sulphate of copper.
18. Magnesium wire (in testing for phosphorus).
19. Caustic potash.
20. Oxide of copper.
21. Oxychloride of lead.
22. Litharge (absolutely free from silver).
23. Finely crushed burnt-bone ash.
24. A small stick of roll sulphur.
25. Carbonate of ammonia.
26. Carbonate of potash.
27. Oxalate of nickel.
28. Chloride of ammonia.

Wet.

1. Nitric acid.
2. Nitrous acid.
3. Sulphuric acid.
4. Hydrochloric acid.
5. Ammonia.
6. Nitrate of cobalt.
7. Sulphide of ammonium.

The assayer can purchase all the above reagents from the chemist; therefore it is not necessary to give any instructions in regard to their preparation.

To obtain pure metals for test or proof purposes to prove the assays is frequently a difficult matter; therefore the author has added the methods adopted by himself to obtain pure silver, gold, lead, copper, tin, bismuth, mercury, and iron.

TEST OR PROOF METALS.

Silver.

The silver used for both qualitative and quantitative examinations by the blowpipe *must be* chemically pure to enable the operator to make accurate and reliable assays of either gold or silver.

For convenience it is best to have the silver in two forms, one in the shape of an ingot—say, about 1½ inch long and ¼ inch square—the other should be in thin foil, which latter will be found most useful in the gold assay.

If chemically pure silver cannot be procured from a reliable source, such as a mint, a first-class laboratory, or assay office, it can be prepared as follows:—Dissolve the purest silver that can be obtained in weak nitric acid, dilute with water, allow the solution to settle for several hours, after which decant carefully and reserve for use only the portions that are perfectly clear, to which add a solution of chloride of sodium (common salt) until the white flocculent clouds of chloride of silver cease to appear. The precipitation is then complete. Filter and wash the precipitate repeatedly in warm distilled water, then dry and fuse (in a new and perfectly clean crucible) with its own weight of crystallised carbonate of soda and about ⅛ of its weight of pure nitre. The heat should be applied gently at first, and finally raised to the fusing point of silver, and when cold the crucible should be broken and the button of silver carefully washed. The silver must be again dissolved in nitric acid, water added, the solution allowed to settle, and great care taken in decanting as before. The silver is precipitated as before, and the precipitate repeatedly washed for twenty-four hours with *warm distilled water.* Dry, and again fuse with carbonate of soda. If this process is carefully carried out the silver obtained will be found to be chemically pure.

Gold.

Gold for blowpipe examinations should be pure, especially for assays of nickel and copper. The most convenient form will be found to be that of a thin foil.

If not procurable it can be prepared as follows:—Take a piece of gold coin and fuse it with three times its weight of silver, and when in the state of fusion pour into a vessel containing cold water. Collect the granulations thus formed, and dissolve in a flask or beaker glass with dilute nitric acid. After boiling for fifteen or twenty minutes decant carefully, and wash the gold residue with distilled water; then attack the gold with strong nitric acid (of 1·30 specific gravity) for twenty to thirty minutes. Decant and wash repeatedly with warm water, then add nitro-hydrochloric acid and boil until the gold is completely dissolved. Dilute with water, warm slightly, allow the solution to settle for about twenty-four hours, then decant and add oxalic acid slightly in excess. The mixture of trichloride and acid to be heated gently. The precipitation is slow, but is greatly assisted by heat. When finished, decant and wash on a filter; afterwards heat over a gas or lamp flame in an evaporating dish or capsule. The gold is easily reduced by this means to a metallic state. Then fuse with an addition of bisulphate of potash and cast into an ingot or any other desirable shape. The gold can be beaten or rolled into thin foil, and it is then ready for use.

The author recommends the addition of bisulphate of potash as an extra precaution in case that a slight trace of silver should still remain with the gold before the fusion.

Lead.

Lead is difficult to procure entirely free from silver, and has generally to be prepared by the operator.

It can easily be done by dissolving acetate of lead in distilled water and then precipitating the lead by pieces of metallic zinc, always rejecting the first portions of lead thrown down. The second portion should be washed repeatedly in warm distilled water, to remove any acid still remaining, and afterwards dried carefully between pieces of thick filter paper. The lead thus obtained should be melted on charcoal (in a hole bored for the purpose) by the blowpipe, and for convenience in use some of it should be rolled or beaten out into thin foil and the rest fused into the form of a small ingot. The foil is used to wrap up the pieces of gold or silver alloys preparatory to cupellation. The ingot shape will be found most suitable for the following plan, which the author has found very successful in the assays of silver and gold ores: i.e. instead of using granulations, as generally recommended, take the ingot, and by means of a small fine flat file reduce the lead to the finest possible powder.

By care and rejecting any large filings that may have been formed, a 'lead powder,' nearly as fine as ground litharge, will be obtained, which can be intimately mixed with the ore about to be assayed.

The lead filings so prepared can then be kept in a small glass bottle, well corked, and will be ready for immediate use.

The files must be kept in a small case by themselves, and never used on any other metal but the pure lead, else inaccurate results are likely to be obtained.

Copper.

The copper of commerce is seldom sufficiently pure for proof purposes.

The following is the most convenient mode of preparing pure copper :—Dissolve crystallised sulphate of copper in distilled water, and precipitate the metal by a *clean* iron plate ; free the precipitated copper from the iron by boiling with hydrochloric acid, dilute with water, allow to settle, then decant and remove the precipitate to a filter, wash repeatedly with warm water, then dry and fuse in a *clean crucible.*

When cold, break the crucible, wash, then dry and beat or roll into a thin sheet or foil.

N.B. Pure copper rolls easily, but it must be repeatedly annealed to obtain thin sheets.

Pure copper, especially when in the form of a thin sheet, should be cut into narrow strips and *kept free from the atmosphere* in a tightly corked bottle.

Tin.

The best qualities of commercial tin generally contain 3 per cent. of impurities. Pure tin can be prepared as follows :—Dissolve good commercial tin in hydrochloric acid : thus hydrogen will be evolved and the metals all converted into chlorides, with the exception of antimony and arsenic. If either of these be present, it will combine with hydrogen and be evolved as a gas, viz. as antimoniuretted or arsensiuretted hydrogen, and some of the antimony may also remain as an insoluble black residue. Any residue having been separated by filtration, the liquid is to be evaporated to a small bulk and then treated with nitric acid. This will convert the tin into insoluble metastannic acid, a crystalline white body. The whole is now evaporated to dryness, and then washed with a little hydrochloric acid, after which it is to be thrown upon a filter, thoroughly washed and dried, and subsequently reduced by mixing it with charcoal, and heated strongly in a crucible, when a button of pure tin will be the result.

The button of tin can now be rolled or beaten out into sheets or foil, and is ready for use.

Bismuth.

The chief impurities of commercial bismuth are sulphur, traces of arsenic, lead, and iron.

The best method of purification is the following:—Dissolve the crude metal in nitric acid, and then concentrate the solution by evaporation. Next pour the clear solution into a large bulk of distilled water. It will be thus decomposed, and a white sparkling soluble powder falls, which is a basic nitrate. This is to be removed and digested for a time in a little caustic potash, whereby any arsenious or arsenic acids present will be dissolved. Next the basic nitrate is to be well washed, dried, and heated with about one-tenth its weight of charcoal in an earthen crucible; thus the salt is reduced, and the bismuth subsides in the pot in a state of purity.

The bismuth thus obtained can be broken into small pieces and placed in a bottle for use.

Mercury.

The mercury of commerce is often adulterated with lead, tin, zinc, bismuth, gold, &c.

Pure mercury can be obtained by the following method :—Take about half a pound of mercury, place it in a bottle of one-quarter of its capacity, and add about one ounce of powdered white sugar; shake vigorously for a few moments, then pour the portion of mercury that is still in moderate-sized globules into another bottle, add more finely powdered sugar, and again shake for several minutes; then filter the mercury by pouring it into a small cone of *blotting paper* having its apex pierced with a small pin. The filter retains the oxides of foreign metals, also a portion of the mercury that is in a very fine state of division. The mercury filters slowly; but when complete remove it to a small glass retort, distil at a *low temperature very slowly, and only allow about two-thirds of the whole to go over in vapour.* Collect the condensed mercury and keep it for use in a bottle with a glass stopper.

N.B. Mercury that has been used in amalgamation works, even after having been distilled, invariably contains traces of gold and silver, besides lead, &c. (often owing to the rapid manner in which it is volatilised during the distillation of amalgams); and in selecting mercury for purification it is always advisable to procure some that has not been employed for such purposes.

Proof mercury should be tested for gold by dissolving it in nitric acid, and if any insoluble residue remains the mercury is impure and must be again distilled until found to be pure.

Iron.

Chemically pure iron is very difficult to prepare. The method used by Berzelius gives iron of sufficient purity for blowpipe investigations, and is the one generally adopted.

Clean ordinary iron filings are taken and mixed with about one-fifth their weight of fine oxide of iron. The mixture is placed into a refractory crucible and covered with a layer of green bottle glass, such being used that is free from oxide of lead. The whole is luted up, and heated for an hour to whiteness. In this way traces of carbon and silicon are oxidised by the oxygen of the iron scale, and, such foreign matters being removed by the glass flux, a button of pure iron subsides in the pot.

The button thus obtained, after being cleaned carefully, can be used as a proof, but it must be kept sealed up from the air to prevent oxidation.

Piano wire of different sizes will be found not only of sufficient purity, but also a most convenient form to use in the assay of lead.

PART II.

QUALITATIVE DETERMINATION.

COLOUR OF SUBLIMATES ON CHARCOAL.

THE colour of the sublimates found on the surface of a piece of charcoal after a mineral has been heated in either the O.F. or R.F. frequently affords the assayer a very good idea of the nature of the mineral to be assayed.

Charcoal ashes vary in colour, and care must be taken not to confound the colour of the ash with that of the sublimate. For instance, the ash which is formed on some of the hard-wood charcoal by the blowpipe blast is generally of a bluish white colour, whilst the ash obtained from burning soft-wood or pine charcoal shows a dullish or darkish white colour, and after cooling scarcely any colour can be observed. The colour of the hard-wood ash, however, remains unaltered when cold.

Before heating a mineral on charcoal apply a strong R.F. to a piece of the charcoal about to be used. Note the colour of the ash, and then heat the mineral on it. The sublimate derived from the mineral is generally found some distance from the charcoal ash, and it can then be examined with comparative certainty.

The following table on the colours of sublimates on charcoal, prepared by D. Forbes, will be found of use:—

Colours of Sublimates or Coatings on Charcoal before the Blowpipe in

		Oxidising Flame.	Reducing Flame.
White	White	Te, As, Sb, Zn, Sn, PbS, BiS, NaCl, NH_4Cl, KCl, CdCl, PbCl, BiCl, NaBr, KBr, NaI, KI, Il	Pb, Sn, Zn, Mo_3, Te, As, Sb, NaS, PbS, BiS, KCl, NaCl, NH_4Cl, HgCl, SbCl, ZnCl, CdCl, PbCl, BiCl, SnCl, KBr, NaBr, KI, NaI
	Greyish white	LiCl, As	LiS, LiCl, As
	Bluish white	Sb, Bi, Pb, CuCl	CuCl, Sb, Bi, Pb
	Reddish white	(Ag + Sb)	
	Yellowish white	Sn	Sn
Yellow	Faint yellow	Sn, Mo	Sn, Mo_3
	Yellow	Zn, $PbOSO_3$	Zn
	Sulphur yellow	Pb	Pb
	Lemon yellow	Bi	Bi
	Dark lemon yellow	Pb	Pb
	Dark yellow	Te, CuCl, Cd, In	Te, Cd, CuCl
	Orange yellow	Bi, Cd	Cd
	Dark orange yellow	Pb, Bi	Bi
	Brown yellow	CuCl	CuCl
Brown	Brown	CuCl	CuCl
	Reddish brown	Cd	Cd
Red	Red	Te	
	Dark red	Ag	
	Copper red	Mo	
	Carmine red	(Sb + Ag + Pb)	
	Whitish red	(Ag + Sb)	
Violet	Faint violet	Se	Se
Blue	Blue	Mo_3	
	Iridescent	Cd	Cd
Grey	Dark grey	Se, As, CuCl	Se, As, CuCl
	Steel grey	Se, As	Se, As

The following give no sublimate or incrustation in either flame.

BaO, SrO, MgO, Al_2O_3, Zr_2O_3, YO, ThO, EO, SiO_2, Ce_2O_3, Cr_2O_3, Di, Fe, Au Ir, Co, Cu, Zn, Mn, Ni, Os, Pd, Co, Pt, Ru, Ta, Ti, Ur, Vd, Wo.

The abbreviation of O.F. for the oxidising flame and of R.F. for the reducing flame will in future be used.

POTASSIUM.

The presence of potash is detected by the blowpipe in two ways.

1st. By the more or less intense violet colour imparted to the outer flame when a substance containing it is heated in the point of the blue flame.

2nd. By the property which potash has of producing a blue glass when fused into a borax bead containing protoxide of nickel.

In the first instance it is simply necessary to expose a small quantity of the substance (held in the loop of a platinum wire) to the point of the blue flame, when, upon fusion, the outer flame immediately beyond the substance should show the characteristic violet colour.

This reaction, however characteristic in the case of tolerably pure potash salts, as the carbonate, nitrate, sulphate, chloride, bromide, iodide, and cyanide, is very easily interfered with.

Phosphates and borates of potash do not give it, and even a small percentage of soda renders it invisible in the overpowering yellow reaction.

When lithia is present it is easily obscured by the more intense red flame due to that alkali. In very few silicates is this reaction of value, as most of them contain more or less soda; and even when they are quite free from soda the reaction is generally too indistinct, and particularly so in the more infusible ones.

In employing the second method the loop of a platinum wire is filled up with a fused globule of borax glass, to which a small quantity of boracic acid has been added. Sufficient protoxide of nickel (oxalate of nickel is the best salt to use) is now dissolved in it, so as to make the glass bead, when cold, appear of a brownish colour. This globule is now melted in the oxidising flame along with the substance supposed to contain potash, and when perfectly cold is examined to see if it has changed its original brown colour to a more or less blue tint. If no potash is present, or too little of the substance has been dissolved in the glass, the colour will be unchanged; but if sufficient of the substance has been employed, and it was not too poor in potash, then the glass bead will be found to possess a blue tint, not unlike that of a weak solution of oxide of nickel in ammonia.

As the colour of the glass is unchanged when smaller quantities of potash are present, this method is of little use in the examination of most silicates, and the determination must be left to spectroscopic examination or to a chemical analysis.

SODIUM.

When soda is fused in the point of the blue flame, the outer flame is coloured strongly yellow, or rather reddish yellow.

This property affords an excellent test for detecting the presence of soda in its compounds, as it is only necessary to heat a splinter (in the platinum forceps, or in the loop of a perfectly clean platinum wire) in the point of the blue flame, when, if soda is present, the outer flame will be seen to enlarge itself and be coloured reddish yellow.

This test is extremely sensitive. It is applicable to silicates and the more infusible compounds, and it is not interfered with by the presence of considerable quantities of potash or lithia.

When potash is present in much greater quantity than the soda, provided no phosphoric or boracic acid is present, the outer flame nearest the assay is tinged more or less violet, but farther off shows only the soda yellow. If lithia is present the flame will be of a more or less reddish yellow, or yellowish red colour, in proportion to the greater or less amount of lithia contained in the substance under examination.

CÆSIUM.

Cæsia is a rare alkali; and although its volatile salts communicate a violet colour to the flame, its determination cannot be effected with certainty by the blowpipe, and it must be examined by the spectroscope. The spectrum of cæsium characterises the element with certainty, its pale blue lines being very brilliant as well as distinct.

RUBIDIUM.

Rubidia, like cæsia, is a rare alkali, found generally in mineral waters. It gives a violet colour to the flame, but the definite determination must be referred to the spectroscope. Its splendid indigo blue lines, as shown by the above instrument, are most prominent as well as characteristic.

BARIUM.

Baryta and its compounds, when fused in the point of the blue flame, communicate more or less an intense yellowish green colour to the outer flame. When moistened with a very weak solution of nitrate of cobalt and fused in the O.F., it gives a light brown bead. With a strong solution it gives a brown or brick red bead, which loses its colour on cooling, and on exposure to air breaks up to a faint grey-coloured powder.

On charcoal alone the hydrate fuses, boils, swells up, and is absorbed by the charcoal.

With soda on charcoal baryta fuses and is absorbed. On charcoal alone the carbonate of baryta fuses easily to a clear glass, which becomes enamel white on cooling, and if longer heated become caustic, boils up, and is absorbed. With borax on platinum wire baryta dissolves to a clear glass, which, if sufficiently saturated, can be flamed to a white enamel. If supersaturated the glass becomes of itself enamel white on cooling. With salt of phosphorus the reactions are the same as with borax. In silicates, either natural or artificial, the blowpipe is altogether inefficient to detect the presence of baryta without the assistance of humid analysis.

STRONTIUM.

The compounds of strontium, when heated in the point of the blue flame, colour the outer flame purple red. When much baryta is present this coloration is obscured by the yellow green due to baryta. When a soluble strontia salt is dissolved in strong alcohol and the solution burnt alone, or on a small piece of cotton wool attached to a platinum wire, the purple red coloration of the flame is seen. In some cases a few drops of hydrochloric acid are previously added, which forms a chloride and colours the flame more intensely. But if it is a sulphate of strontia subject it to a R.F. on charcoal (forming a sulphide); then treat it with acid and alcohol, which will give an intense red flame.

The hydrate, when heated on charcoal, boils up in its water of crystallisation, solidifies, and again fuses with violence, and is absorbed by the charcoal. The carbonate only fuses at its edges and effloresces at the same, and it is reduced to strontia, giving a strong light and colouring the reducing flame red, and on cooling reacts alkaline for test papers.

The red coloration of strontia is so much stronger than that produced by lime, that a small quantity of strontia can be detected in aragonite (carbon dioxide 44 and lime $56 = 100$). The mineral must be previously decrepitated, then heated in the blue flame (it does not fuse). It will soon be observed that the flame is coloured more red than it would be by an equally large piece of calc spar.

When testing the carbonate or sulphate, the flame is often noted to be first yellowish, but afterwards purple red is seen.

CALCIUM.

Lime, when heated in the point of the blue flame, communicates to the outer flame a weak red colour, much fainter than that produced by strontia. In its compounds this colour is more or less mixed with yellow. In the case of carbonates it is at first yellow, and later on, as the carbonic acid is driven off, it becomes red. The sulphate, chloride, and fluoride all give this reaction.

The presence of barytes or soda in any quantity obscures this test, which is also not visible in the compounds of lime with phosphoric, arsenic, boracic, titanic, and tungstic acids; and amongst silicates (wollastonite, silica 51·7, lime $48{\cdot}3 = 100$) stands alone in producing a faint reddish flame before the blowpipe, due to the presence of lime.

Before the blowpipe lime is unchanged; the carbonate becomes caustic, and at the same time it appears strongly illuminated by the flame, and, if in pieces, slacks and falls to powder when moistened, and reacts alkaline. With borax it dissolves easily to a clear glass, which becomes opaque on flaming. When the glass is saturated it crystallises on cooling, and loses its round form, but in no case does it become as white as the glass from baryta or strontia.

With soda on charcoal it is not affected ; the soda, being absorbed by the charcoal, leaves the lime behind.

With nitrate of cobalt it is infusible and acquires a greyish colour.

When lime is associated with baryta or strontia, as sometimes in heavy spar, strontianite, baryta, &c., the powdered substance, when treated with soda on charcoal, leaves the lime and oxides of iron on the charcoal surface, whilst the other substances sink into the charcoal.

In silicates little dependence can be placed on reactions for lime, but in general the presence of lime may be suspected by the following tests :—

1st. The swelling or frothing up in testing for fusibility.

2nd. Reactions with borax and salt of phosphorus prove that silicates containing lime dissolve easily, and with salt of phosphorus alone the silica is separated, and the glass on cooling is in most cases opalescent.

3rd. With a small quantity of soda it fuses to a globule, but with more soda it gives a slaggy mass.

It is best, however, to employ the humid process.

MAGNESIUM.

Before the blowpipe magnesia does not give any sensible colorations to the flame, and it remains unchanged. The carbonate is decomposed by the heat and becomes more luminous and reacts alkaline to test papers.

With borax magnesia is easily soluble to a clear bead, which can be flamed opaque, and after saturation gives on cooling a crystalline glass, but less so than lime.

It is easily soluble in salt of phosphorus, forming a clear glass, rendered opaque by flaming, and if fully saturated the glass becomes milk white on cooling.

With soda on charcoal the soda sinks into the charcoal, leaving the magnesia unchanged.

With nitrate of cobalt it acquires a flesh-red colour, which is best seen when entirely cold. The phosphates of magnesia melt and give a violet red colour on similar treatment.

Native magnesia (periclase or magnesium oxide), the hydrate (brucite, magnesia 69, water 31 = 100), the carbonate (magnesite, carbon dioxide 52·4, magnesia 47·6 = 100), and hydromagnesite (carbon dioxide 36·3, magnesia 43·9, water 19·8 = 100), and in Epsom salts (epsomite, sulphur trioxide 32·5, magnesia 16·3, water 51·2 = 100), the above reactions are sufficiently characteristic to decide the presence of magnesia if the minerals in question are free from other colouring metallic oxides; but in nearly all the other metallic compounds the wet way must be resorted to, except in cases where the physical properties or chemical reactions of the other constituent of the mineral in question give a clue to its identity.

Zehmen gives the following method for distinguishing ordinary limestones from dolomite or magnesian limestone (which is often a question of interest). A quantity of the finest possible powder is placed in a small depression on platinum foil, or a platinum spoon, and heated several minutes strongly to a thorough red heat. Ordinary limestone on cooling sinters together slightly, and can be turned out of the platinum without breaking up if handled carefully, and it often shows a tendency to adhere to the platinum, and therefore it requires a little assistance to detach it.

Dolomite (calcium carbonate 54·35, magnesium carbonate 45·65 = 100), on the contrary, does not sinter after heating, but falls to pieces, forming a still more porous and light powder, and many dolomites even on heating swell up from the fact that the gas frequently carries off traces of the powder with the flame.

ALUMINIUM.

Alumina in both the oxidising and reducing flames remains unchanged. With borax it dissolves slowly, forming a clear glass, which is not rendered turbid on flaming, nor does it become so on cooling. If a large quantity is added to the glass in the state of the finest powder it is rendered opaque, and on cooling the surface becomes crystalline and is almost infusible. With phosphate salt it is dissolved to a clear glass, which remains so. A very large quantity renders the glass semitransparent.

With soda on charcoal it swells up a little and gives an infusible product, whilst the excess of soda is absorbed by the charcoal. With nitrate of cobalt and a high temperature it gives a fine blue compound, the colour of which is most intense when cold.

In minerals which contain no colouring metallic oxide the blue furnished by the action of nitrate of cobalt gives a very good test for alumina.

MANGANESE.

The oxides are infusible both in the O.F. and R.F., and they leave on the charcoal the red oxide, which has a reddish brown colour.

With borax the oxide is dissolved in the O.F., forming a glass which is of an amethyst violet colour when hot, and when cold a reddish violet. If too much mineral is treated the glass may appear quite black, as the above colour is very intense, and even opaque, unless pressed flat or drawn out by the forceps. In the R.F. this coloured glass becomes colourless, and if very dark it is best reduced on charcoal by the addition of a little tin.

With phosphate glass in the O.F., if much manganese is dissolved, the glass, when hot, is brownish violet, and when cold it is reddish violet, but it never becomes opaque. If the glass contains but little oxide and is nearly colourless, the addition of a little nitre will bring out the colour.

On charcoal with soda in R.F. the oxide is not reduced, and remains behind whilst the soda is absorbed by the charcoal. In O.F. on platinum wire or foil with soda, when too much oxide is not used, a transparent green mass is formed (manganite of soda), which on cooling becomes bluish green and opaque.

In substances which do not contain metals giving coloured beads with borate and phosphate salts in O.F. and R.F. manganese is very easily detected by its behaviour with the above reagents, the former of which gives a much more intense colour. If other colouring metals are present in small quantities they do not have much influence on the amethyst colour seen in the O.F. bead, but in the reduction bead show their colours (for example, iron oxides) distinctly, as the manganese colour has disappeared. If much iron oxide is present the bead will appear in the O.F. blood red, and after the R.F. action yellow.

In case the manganese present is so small that it does not colour the phosphate beads, a small crystal of nitre is placed in a porcelain capsule, and the phosphate bead, having been made to take up as much as possible of the substance under examination in the O.F., is, whilst fused, quickly brought into contact with the crystal of nitre, which causes the glass to swell up, and it is seen at the point of contact to tint the froth an amethyst or rose-red colour the instant after cooling, an effect due to the formation of manganite of potash at the point.

If a substance is mixed with other volatile oxides, but contains above 0·1 per cent. of oxide of manganese, it should be brought to the finest powder and mixed with two or three times its bulk of soda, then melted in O.F. on platinum foil; the soda forms manganate of soda, having a transparent green colour, more so when hot, but a bluish green on cooling. Even with less than 0·1 per cent., by using two parts soda and one part nitre instead of soda alone, the manganese is more completely oxidised and tints the mass bluish green when cold.

If chrome was present the yellow chromate of soda would give a yellow tint; this, however, would not destroy the test, which may even be used for finding a trace of manganese in oxide of chromium; the colour is, however, when cold, yellowish green instead of bluish green.

To employ these tests with metallic alloys they must first be oxidised by roasting, action of acids, or deflagration with nitre. In case of sulphides and arseniates they must first be roasted on charcoal.

If the ore contains at the same time both silica and oxide of cobalt, this test would give a blue colour on treating it in this way, from the cobalt present; therefore the test for manganese is destroyed and the mineral must be determined by the humid way.

TIN.

Heat any compound supposed to contain tin with a flux made of equal parts of borax and cyanide of potassium. A malleable globule of tin will be obtained.

Sulphides of tin must be first roasted on charcoal, then treated in R.F. with soda and borax. A metallic button of tin will be obtained, which can always be detected by removing the slag from it, and again placing it on charcoal and applying the R.F. The globule cannot be kept bright, and becomes covered with a crust of oxide, which can only be removed with difficulty by adding borax. For further particulars on tin, see Tin Assay.

ANTIMONY.

Antimony fuses easily on charcoal, and coats the charcoal in R.F. or O.F. with oxide of antimony (nearer the assay than the oxide of arsenic) in a thin layer of bluish white, and it can be driven about the charcoal by a gentle O.F. without colouring the flame, but if a R.F. be used the flame will be coloured a faint greenish blue. As the sublimate of antimony is less volatile than that of arsenic it may be easily distinguished from the last.

When metallic antimony is fused on charcoal and heated to redness, and the blowing stopped, the fused metal keeps itself a long time liquid and evolves a dense white smoke, which deposits on the charcoal and at last coats the globule itself with white pearly crystals of oxide of antimony. This phenomenon is due to the absorption of oxygen by the metal and the heat eliminated in the combination.

Antimony with lead and bismuth may be detected by dissolving the above metals in boracic acid, provided the fused mass is kept covered with the blue flame. A coating of fine oxide of antimony is formed, if the heat is not applied too strong.

Antimony and zinc both give a white sublimate on charcoal near the assay. The zinc oxide is not volatilised in the outer flame, whilst the oxide of antimony can be driven from place to place or almost entirely volatilised. If antimony is combined with tin or copper, the assay is treated on charcoal in R.F. with soda and borax; by this means small metallic globules are formed. The globules are separated by triturating and washing in the horn spoon. The globules are then fused on charcoal in the R.F. with 3 to 5 times their volume of lead and a little boracic acid. If the *glass only* is exposed to the R.F. the antimony is volatilised, and it coats the coal distinctly with its oxide.

In alloys of copper, silver, lead, and iron, a small piece of the alloy should be dissolved in nitric acid, and the antimony will be found in an insoluble white powder (antimonic acid), and it should be then dried and treated on charcoal for the antimonial sublimate.

SILVER.

Silver can be detected with the greatest accuracy, and the percentage estimated by following the instructions in Silver Assay.

GOLD.

Gold can be detected with great certainty, and the percentage estimated, by following the rules laid out in the Gold Assay.

CHROMIUM.

The oxides of chromium afford a distinct reaction before the blowpipe when they are tested in the O.F. with borax or salt of phosphorus, the beads appearing yellowish green when quite cool; and the bead (if free from the oxides of lead or copper) in the R.F. becomes a beautiful emerald green. If the above metals are present the beads become when cool opaque, red, or grey.

IRON.

The sesquioxide of iron is unchanged by the O.F., but in the R.F. it loses part of its oxygen, and then becomes black and is attracted by the magnet.

In O.F. it dissolves in borax, and if a small quantity is present the glass is, whilst hot, yellow, and, when cold, colourless. If in a larger amount it is, when hot, red, and, when cold, yellow; and if fully saturated is, when hot, dark red, and, on cooling, dark yellow.

In R.F. the glass formed as above becomes bottle green, and if treated on charcoal with a little metallic tin it becomes first a bottle-green colour, and on continued reducing copperas green.

With phosphate salt in O.F. the glass formed is, when hot, yellowish red, and, in the course of cooling, it loses colour, becoming yellow, then greenish, and lastly colourless when cold. When saturated it is, when hot, dark red, and, in cooling, successively brown red, dirty green, and then brownish red when cold. The latter colours show themselves much quicker during cooling than when borax is used.

In the R.F. the phosphate glass, if it does not contain much iron, is unchanged, but if more saturated with iron it becomes, when red hot, and, in cooling, successively yellow, greenish, and at last reddish when cold. Treated with glass on charcoal, this glass becomes, on cooling, green, and when cold colourless.

In detecting the presence of iron in its numerous compounds the reactions of borax and salt of phosphorus will in most cases be sufficiently characteristic.

In metallic alloys which are not easily fusible it is only necessary to treat them with borax on charcoal in an O.F. until the glass has taken up sufficient of the oxide formed to give it a distinct colour. If the alloy is very fusible, from containing lead, tin, bismuth, antimony, or zinc, the R.F. should be used by directing it on the glass, which causes it to absorb as little as possible of these metals. In either case the glass is, whilst still fused, separated by the forceps and treated on clean charcoal with the R.F., which separates the readily reducible metals, especially copper, nickel, arsenic, bismuth, antimony, and zinc (which are to a great part volatilised and sublimed on the charcoal around), and leaves the glass coloured bottle green, due to iron. If the alloy contained tin the assay may be of a copperas green colour; if not it becomes so by treating with R.F. on charcoal with metallic tin (should, however cobalt have been present the glass will turn out blue). The bead (free from any adherent reduced metallic matter) should now be treated on platinum wire in a good O.F. until all iron is fully oxidised (if the colour is too intense for inspection a part of it only need to be taken and fused with fresh borax, so as to dilute it), when, according to the proportion of iron present, the colour will be more or less yellow, or even brown red. If a little cobalt is present the glass, while warm, is a dark green, and when cold green forms the admixture of colours. When, on the contrary, but little iron is present along with much cobalt it will appear, when hot, green, but on cooling pure blue.

Compounds of iron with arsenic and sulphur may be examined by several methods.

(*a*) In most cases it is best to fuse the substance with borax on charcoal, using the R.F., and when the whole is in fusion the flame should be directed on the glass alone, so that the air may have access to the metallic globules. As soon as the glass begins to be coloured by the absorbed metallic oxide it is removed by the forceps, and can be examined for iron in both flames and with tin.

(*b*) The sulphide or arsenide may be calcined on charcoal, and a little of the oxide thus produced is taken up by a borate globule upon platinum wire in O.F., until the glass is coloured. Frequently when no metals having strong colouring properties are present this test suffices at once to determine the presence or absence of iron. If not, the glass can be treated on charcoal in R.F., which separates copper, nickel, or any other easily reducible metals (sometimes to effect the separation of such metals a small piece of gold or silver may be added to them, as it enables the metals to separate much quicker by so alloying); then the bead is left with the iron reactions visible and it can be examined as before.

(*c*) According to Plattner the powdered substance can be fused with borax and some lead on charcoal, covering the whole with a good R.F. When the borax has united and formed a pearl the flame is directed on to this alone, so that air has access to the fluid metallic globule.

When the borate is coloured by the absorbed metallic oxides it should be removed quickly with the forceps, and treated on fresh charcoal in R.F. to reduce any oxide of lead in the glass, after which it may be examined for iron reactions as usual.

In oxides, when no copper, nickel, chromium, or uranium is present, the iron is recognised without difficulty. In case of uranium a humid analysis is necessary, as this metal gives the same coloration as iron.

With nickel the colour is more or less brownish yellow or yellowish brown.

In case of both nickel and copper they may (as before mentioned) be reduced out of the glass, when the colour of iron is then distinctly seen. With cobalt the colour of the glass has already been noted, but if very little iron is present the wet way must be used. If manganese is present the colour in O.F. will be violet red, or if very much is present dark red when hot, and, on cooling, red with a violet tinge. On treating such a glass in R.F. on charcoal with tin the manganese colour disappears and the copperas green is at once seen. If very little manganese is present merely treat it in R.F., which will be sufficient to reduce the manganese and bring forward the bottle-green colour due to iron.

When a great deal of manganese is present the phosphate test shows the iron at once, as the manganese colour of this glass is not very intense in the O.F., and in R.F. it becomes colourless, whilst the iron colour after treatment with R.F. remains generally reddish.

When iron is in combination with chromium the blowpipe test does not give a sufficiently decided result, owing to the colours produced by the chromium.

If, however, the substance be melted in the platinum spoon with 3 parts nitre and 1 part soda, and the result washed well with water, the residual oxide will at once react for iron as usual.

If tungsten or titanium is present the O.F. will, with borax or phosphorus salt, give the iron reaction, as the above metals give too feeble a yellow colour to interfere with it, also with borax in R.F., but with phosphate in R.F. both of these become darkened to brown red. The compounds of iron with carbonic acid, sulphuric acid, phosphoric acid, arsenic acid, tantalic acid, silicic acid, and alumina are in general easily shown to contain iron by the reactions with borate and phosphate salts. It is also the case with most slags and other products of the arts.

In such metallurgical products as pig iron, steel, brass, black copper, copper, tin, or lead (containing iron), speiss, regulus, &c., the iron can easily be shown by the treatment given for alloys or compounds of sulphur and arsenic.

COBALT.

Before the blowpipe in O.F. the oxide is unchanged. In R.F. it does not fuse, shrinks a little, and is reduced to a metallic powder, which receives lustre by friction and is attracted by the magnet. In both O.F. and R.F. the oxide is dissolved by borax, and gives, both when hot and cold, a pure blue glass, which is seen, especially on cooling, to be less intense than with borax glass, from equal saturation.

On platinum in O.F. with soda the oxide, if in very small quantity, dissolves to a clear bright red mass, which becomes grey on cooling. The examination for cobalt is generally easy, and especially so when no other strongly colouring metal is present. This being the case, the substance, when treated with borax in O.F., will indicate the presence of cobalt by the blue colour of the glass. If iron is present the glass, when warm, may appear green, from the admixture of colours, but on cooling (if the iron be not in very large amount) the blue is seen above the peculiar colour arising from the mixture of bottle green and blue. When the glass is treated in the R.F. it is not easily mistaken for any other reaction; also the action of the R.F.

renders a manganese glass colourless. This substance if present. is no obstacle in the way of recognising the blue of the cobalt, as it is when using the O.F. with iron and cobalt.

Plattner detects cobalt in metallic alloys of nickel by converting the metal into an arsenide before testing it for cobalt by mixing it in thin scales or filings with a little metallic arsenic, fusing them together in a small cavity on charcoal with the R.F., and treating the fused button a short time with borax directly with the tip of the blue flame; if any cobalt is present the glass becomes blue, and if the amount is not too small the cleansed button will impart a blue colour to a fresh portion of borax also.

NICKEL.

The protoxide in the O.F. is unchanged. In the R.F. it is reduced to an infusible metallic powder, which is magnetic.

With borax in the O.F. on platinum wire a little of the oxide colours the hot glass violet, but when cold a pale reddish brown; with more oxide the colours are darker. In R.F. with borax the glass becomes grey and cloudy or quite opaque, owing to finely divided metallic nickel. On continuing the blast the reduced metallic particles collect together without fusing, and the glass becomes colourless.

With phosphate salt on platinum wire in O.F. it dissolves to a reddish glass, yellow on cooling. In R.F. on platinum wire it is unchanged. On charcoal with tin it becomes at first opaque and grey, but after long blowing all the nickel is reduced and the glass becomes colourless.

With soda it is insoluble in O.F., but in R.F. on charcoal it is easily reduced to white metallic particles, which, after washing, follow the magnet.

Plattner detects a small quantity of nickel in oxides of cobalt, manganese, and iron by dissolving a small quantity in borax on platinum wire in O.F.—the dark or opaque bead is shaken off, and two or three such beads prepared. These are treated in a cavity on coal, or in a coal crucible, with a small pure gold button in a strong, active R.F. until it is certain that all the nickel is reduced from the bead and collected in the gold button, which has been brought into contact with every portion of the fluid glass by carefully turning the coal. When the button has solidified, it is lifted from the glass and freed from any adherent glass between paper on the anvil. If the borax glass was not supersaturated with oxides, so that none of the cobalt could be reduced, the gold button treated for some time in the O.F. on coal with phosphate will impart to this only the nickel colour, reddish to brownish red whilst hot, and yellow to reddish yellow after cooling, according to the amount dissolved. If, however, cobalt has been reduced it will oxidise sooner than the nickel, and either produce a blue cobalt bead or a bead which will be dark violet when hot and dirty green on cooling, if some nickel had been oxidised.

In either case the button, freed from glass, is treated with fresh phosphate in O.F. until the hot glass seems coloured, when, if the original borax beads had not been too highly supersaturated, the glass will show only the nickel coloration; if the metallic oxides were, however, free from nickel the glass will be colourless (Plattner's 'Manual,' p. 245).

ZINC.

If the substance contains much zinc, or when it is free from other metals which form a sublimate on charcoal, the presence of this metal is easily detected. When a small amount of zinc is combined with much lead, bismuth, or antimony it is quite impossible to prove its presence with certainty, and frequently the presence of tin prevents its detection.

The examination for zinc is in all cases based upon the reduction of the metal or the formation of sublimate (white when cold and yellow when hot) on the charcoal. This sublimate, being further tested by reheating with a solution of nitrate of cobalt, produces the characteristic yellowish green colour.

Large quantities of oxide of lead or bismuth in the sublimate may obscure this reaction; but in some cases the lead and bismuth oxides may be driven farther off, so as to leave the zinc reaction tolerably clear.

If the quantity of zinc present is extremely small, and only produces a very faint coating of sublimate, which might be easily lost mechanically, it is in such cases better to moisten the charcoal first with a drop of nitrate of cobalt before blowing. It must, however, be observed, if much antimony or tin is present, a greenish colour is also produced with nitrate of cobalt from combinations with the oxide of cobalt which are not volatile in the O.F. (the colour with tin a bluish green), and in such cases dependence cannot be placed on this reaction.

When much zinc is present a zinc flame is observed in R.F., and the charcoal is covered with a strong sublimate, closer to the assay than that of lead oxide. Substances containing zinc in combination with sulphur can be treated alone on charcoal in R.F.

Those containing zinc as oxide with but little sulphur are treated with soda on charcoal in the R.F.

Those containing other metallic oxides and earths require borax in addition. A mixture of 2 parts soda with 1 to 1½ borax glass on charcoal in R.F. (especially when in combination with alumina) soon frees the zinc, and the usual sublimate is readily formed.

CADMIUM.

Metallic cadmium fuses readily and volatilises, covering the charcoal with a reddish brown (in thin films), dark yellow, or orange-coloured sublimate of the oxide, which still farther off on the charcoal gives an iridescent play of colours.

The oxide treated on platinum is unchanged in O.F. On charcoal in R.F. it is reduced, and covers the charcoal with a red brown to dark yellow sublimate (colour best seen when cold), as in the case of metallic cadmium.

In borax glass in O.F. the oxide readily dissolves, and gives a transparent yellow glass when hot; on cooling it is almost colourless; on larger saturation the glass can be flamed to a milky enamel, and when still more saturated it becomes enamel white on cooling.

On charcoal in R.F. the phosphatic glass is slowly and but partially reduced, giving but a very faint sublimate of a dark yellow colour; the true colour is only seen well on cooling. An addition of tin hastens the reduction.

With soda in O.F. the oxide remains unchanged, but in R.F. it is reduced, with the production of the characteristic sublimates before described.

It does not give any characteristic reaction with nitrate of cobalt.

In searching for this mineral the means of detecting the cadmium depends entirely upon the reduction and the subsequent volatilisation of the metal, giving rise to the characteristic sublimate of the metal.

Substances containing much cadmium give the above reaction if powdered finely and heated quickly in the R.F.

If the mineral contains as little as 1 per cent. of cadmium it is better to mix the powder with soda and heat for a very short time in a R.F., when the sublimate will be seen.

As zinc is frequently present with cadmium, the heat, if continued too long, will also drive off the less volatile zinc, the white sublimate of which may more or less obscure the cadmium reaction.

COPPER.

The oxides of copper, when heated on charcoal in R.F. with soda, yield a metallic button of copper.

When heated in the O.F. on platinum wire with borax, they colour the glass strongly ; a little oxide causes a green glass when hot and a blue when cold, and with more it is dark green to opaque when hot, but greenish blue on cooling.

With borax in the R.F. on platinum wire, if saturated to a certain degree, the glass soon becomes colourless, but on cooling it becomes red and opaque. On charcoal the copper is reduced to metal, and the cold glass is quite colourless.

The sulphides of copper are roasted on charcoal with the O.F. and R.F. alternately, and on the completion of the roasting soda is added, a R.F. applied, and a globule of metallic copper produced.

Silicates and other salts of copper dissolve in O.F. in the glass fluxes to green beads, which should be blue on cooling.

For full details of copper assay see p. 146.

LEAD.

Metallic lead fuses easily, tinging the flame light blue, and in both R.F. and O.F. volatilises, covering the charcoal around it with a sublimate of pure oxide of lead, dark orange yellow when hot and sulphur yellow when cold, on the outskirts of which is generally seen a thin bluish-white sublimate of carbonate of lead. The flame of the blowpipe chases these sublimates from place to place on the charcoal, which, when red hot, reduces the oxides, volatilising the metal to a greater distance when it is redeposited as a sublimate of oxide, at the same time colouring the flame light blue.

The protoxide of lead heated in O.F. on platinum alone becomes darker in colour and fuses to a yellow glass. The red oxide becomes almost black, and at a low red heat is converted into protoxide, and it behaves as before stated under similar circumstances.

On charcoal in both O.F. and R.F. all the oxides are reduced to metallic lead with effervescence, which on continued blowing is volatile and is deposited as a sublimate of oxide, which can be reduced again to metallic lead by the R.F., which is thus tinged light blue.

With borax glass in O.F. the oxides dissolve readily, forming a clear yellow glass, colourless on cooling. With greater saturation this glass can be flamed opaque, and upon full saturation on cooling it becomes of itself a yellow opaque enamel.

In R.F. this borax globule upon charcoal spreads out with effervescence, and the lead may be reduced to its metallic state by continued blowing, leaving a clear borax globule.

With phosphate salt in O.F. the oxide (the same as with the borate) requires more saturation before the globule shows any yellow colour when hot.

In R.F. the phosphate salt globule on charcoal becomes greyish and opaque, and when the globule is saturated the charcoal around is covered by a yellow sublimate of oxide. The addition of tin to the globule makes it more opaque and darker grey in colour, but it never becomes quite opaque.

With soda on platinum wire it dissolves in O.F. to a clear glass, becoming yellowish and opaque on cooling.

With soda on charcoal it is reduced to metallic lead in R.F., which on continued blowing covers the charcoal with oxide.

INDIUM.

In O.F. the oxide becomes of a dark yellow colour, does not fuse, and on cooling recovers its lighter colour.

On charcoal in R.F. it is slowly reduced and volatilised, and the oxide sublimed on to the charcoal. During the reduction the outer flame is coloured very distinctly violet. With borax in O.F. it dissolves to a clear glass, feebly yellowish whilst hot, but colourless on cooling. A more saturated globule becomes opaque.

With borax in R.F. the glass does not change, but on charcoal it commences to reduce and to give a sublimate on the charcoal; at the same time the violet colouring of the outer flame is seen, and is not concealed by the soda coloration.

With phosphate salt the reactions are the same as with borate, but if tin be added to the glass in the R.F. the glass on cooling becomes grey and opaque.

With soda in O.F. it is not dissolved, but on charcoal in R.F. is reduced, and part of the metal volatilises and forms a sublimate of oxide on the charcoal, whilst some nearly silver white globules of indium are seen in the soda.

BISMUTH.

Bismuth fuses very easily, and gives a coat of oxide, which is dark orange yellow when hot, and lemon yellow when cold, being yellowish white in thin layers.

The yellow coat is pure oxide, and the yellowish white one (which is at the greatest distance) is carbonate with some oxide of bismuth. It can be driven about on the glowing coal like lead, but does not colour the R.F. during the operation.

Bismuth combined with sulphur gives on charcoal a white coat of sulphate of bismuth beyond the yellow coat, but it is prevented by a small addition of soda.

When much lead or antimony is present, roast carefully on charcoal, then fuse with 3 times its volume of bisulphate of potash in the platinum spoon, then treat the mass with water in a small porcelain dish until everything is detached from the spoon. Sulphate of potash and other soluble sulphates are dissolved, leaving neutral sulphate of lead and basic sulphate of bismuth. Antimony, if present, remains behind as acid.

After decanting the clear solution the residue is boiled in distilled water, to which a few drops of sulphuric acid and some nitric acid are added, when the sulphate of bismuth dissolves, leaving a residue of sulphate of lead with any oxide of antimony present. After filtration the bismuth is thrown down from the warm filtrate by means of salt of phosphorus as a white precipitate, which is collected on a filter and tested with phosphate salt.

The phosphate bead on platinum wire is colourless, or faintly yellow, but on coal with tin in R.F. becomes dark grey on cooling, behaving there like oxide of bismuth.

Oxides of bismuth, if treated either alone or with soda on charcoal, give the usual bismuth coating.

TITANIUM.

Titanic acid both in R.F. and O.F. on charcoal assumes a yellow colour, but it is white again on cooling.

With borax on platinum wire in O.F. it dissolves easily to a clear glass; if much is present it appears yellow whilst hot and colourless on cooling, and becomes opaque by flaming. In R.F. a small addition yields a yellow glass; more oxide yields a dark yellow to brown glass. A saturated glass becomes emanel blue by flaming.

With phosphate salt on platinum wire in O.F. it dissolves easily to a clear glass, yellow while hot. In R.F. the glass becomes yellow while hot, but reddens on cooling and assumes a fine violet colour. If the acid contains iron the glass becomes brownish yellow to brownish red on cooling.

With soda in O.F. on charcoal it dissolves with effervescence to a dark yellow glass, which crystallises on cooling and thereby evolves so much heat that the globule glows strongly again. When perfectly cold the glass is greyish white to white.

With cobalt solution in the O.F. it assumes a yellowish green colour, similar to oxide of zinc, but not so fine.

Plattner recommends the following plan to detect small amounts of titanium:—In complex substances which give no decisive reaction for titanium with the fluxes the finely powdered substance is fused in a platinum spoon at a moderate red heat with 6 to 8 times its weight of bisulphate of potash, the mixture being melted in small portions at a time. The mass is then dissolved in just sufficient water in a porcelain dish over the lamp, and the insoluble parts allowed to settle.

The solution, if concentrated, may be heated to boiling. The clear solution is then poured into a larger dish, mixed with a few drops of nitric acid diluted with at least 6 times as much water, and then boiled.

If the substance contains titanium the latter is dissolved by the fusion with bisulphate of potash and treatment with water, and it is precipitated from the acid solution by continued boiling as white titanic acid.

If the solution is not acidified with nitric acid before boiling, a yellow ferruginous titanic acid is obtained when the substance contains iron. The precipitated titanic acid is collected upon a small filter, washed with water containing nitric acid, and tested with phosphate salt either on platinum wire or charcoal.

If the amount of titanic acid is so small that in R.F. it does not impart to the phosphate salt the violet colour of the sesquioxide of titanium, add a little sesquioxide of iron when the assay is upon a wire, or a small piece of iron wire when on charcoal, and fuse the glass a short time with the R.F.; it then appears yellowish while hot and brownish red when cool ('Manual,' 1873, p. 323).

MERCURY.

The assay for mercury is treated fully on p. 135.

PLATINUM.

Platinum, when treated with borax or phosphate salt, does not fuse, and is neither oxidised nor dissolved.

Platinum is found native, and forms alloys with other metals—iron, copper, rhodium, iridium, ruthenium, osmium, gold, and silver. To examine an alloy for platinum dissolve a small piece in aqua regia (3 parts hydrochloric acid and 1 part nitric acid). If there is any black, fine, metallic insoluble powder in the bottom of the flask it is iridium. Separate it by decanting carefully, then evaporate the blood-red solution almost to dryness; the acid fluid is then diluted with water; a few drops of a solution of potassa is added. A yellow precipitate is formed, which consists chiefly of platinchloride of potassium.

LITHIUM.

Lithia, when heated in the point of the blue flame, communicates a fine purple-red colour to the outer flame. According to Plattner, when lithia is fused upon platinum foil it causes the platinum in contact with it to acquire a yellow tarnish, which is removed by water, but upon drying or heating leaves the platinum surface without lustre, as if acted upon.

To detect lithia in its compounds it is only necessary to heat them on a platinum wire or in the platinum forceps and in the point of the blue flame. Observe the purple-red colour communicated to the outer flame. This reaction serves also for silicates. Those which contain very little lithia require to be tested according to Turner's method, by mixing 1 part of the impalpable powder with 2 parts fluor spar and three parts bisulphate of potash, and by addition of a little water rendering the mixture plastic enough to stick to the loop of a platinum wire. This is now subjected to the blue flame. If no lithia is present, only the violet colour due to the potash employed will be seen, but if the contrary is the case the lithia red will be seen even more or less overpowering the violet. The presence of soda in the mineral may render this reaction indistinct; but if boracic acid is contained in the substance the green colour due to this body will be first seen, but it subsequently gives place to the lithia reaction. In testing for lithia it must be remembered that strontia and lime also produce a red coloration of the flame. When soda is present along with lithia the red coloration may be overpowered by the intense soda yellow, especially if the heat employed be high. By employing the outer flame and less heat the lithia reaction is frequently seen when otherwise invisible. Stein states that 1 part lithia in 2,580 parts soda gives a red coloration, if the substance be heated so as to soften and render it porous by quenching it in tallow and then heating it in the flame of a candle.

Potash interferes less with the lithia reaction, but communicates a stronger or weaker violet tinge in proportion to the amount present. When both potash and soda are associated with an excess of lithia the outer flame will be reddish violet nearest and reddish yellow farther away from the assay. If soda is present in excess both potash and lithia reactions disappear, but sometimes the lithia can be observed by using less heat, as before mentioned.

If a lithia mineral containing phosphoric acid (but no soda) be treated in the blue flame, two distinct colours are seen in the outer flame, which do not mix with one another, being the lithia red and a bluish green due to phosphoric acid.

OXYGEN.

According to Fuchs, this element is only detected in substances which can readily be made to part with it in a free state. In substances that give up their oxygen when heated in a glass tube, the gas is recognised by its rekindling a glowing match. This reaction is often inconclusive, owing to the small size of the fragment under examination. However, another test presents itself at once for these small quantities. The assay is heated in a test tube with a fragment of chloride of sodium and a few drops of sulphuric acid. Chlorine is now evolved in place of oxygen, and it may be recognised by its characteristic odour, or by its bleaching effect on a piece of moist litmus paper.

HYDROGEN.

To detect hydrogen in water, place a small piece of metallic zinc in a small porcelain cup, and add a few drops of sulphuric acid. Hydrogen gas is given off, which is easily recognised by its sickly odour.

The examination for hydrogen does not come within the scope of a blowpipe investigation, and it must be determined by chemical analysis.

NITROGEN.

Substances containing nitrates detonate when heated on charcoal. Heated in a tube with a little sulphuric acid, they give off red fumes of nitric peroxide. A small amount of a nitrate present in another salt or substance can be readily detected by heating it with rather more than its volume of bisulphate of potassa in a closed tube or matrass. The tube becomes filled with gaseous nitrous acid, the yellow colour of which may be seen by looking down through the tube. Should there be so little nitrate present that this colour cannot be plainly seen, the minutest quantities may, according to Stein, be detected by heating the assay with litharge, which at first absorbs the nitric acid, but yields it up at a higher temperature. A slip of paper which has been immersed in a solution of protosulphate of iron, free from sesquioxide and acidulated with some sulphuric acid, is inserted into the neck of the tube, and if nitrous acid is present it will assume a yellowish to brown colour. In this way the nitric acid in a mixture of 1 part of nitre with 1,000 parts of sulphate of soda containing only 0·0005 nitric acid can be distinctly shown. The paper quickly loses its colour if too strongly heated, and therefore the tube or matrass should be rather long. Nitre, soda nitre, and nitrocalcite are immediately recognised as nitrates by the above tests, and their bases may be distinguished by the colour they impart to the flame.

FLUORINE.

Fluorides, when treated in a closed tube, give off fumes of hydrofluoric acid, which react acid with test papers and sometimes etch the glass. If no acid reaction has taken place, first heat with a little sulphuric acid in the closed tube, and if that still does not evolve fumes of hydrofluoric acid heat in a closed tube with a small quantity of bisulphate of potash. In case no characteristic reaction has taken place Berzelius recommends the following test:—

The finely powdered substance is mixed with phosphate salt (previously fused on charcoal), and the mixture heated in the open tube, so that the flame can be carried inside the tube by the current of air. Under the solvent action of the phosphate upon minerals free from silica, hydrofluoric acid is formed, which passes through the tube; and it can be recognised both by its peculiar pungent odour and by its effects on the glass, which it attacks and renders dull, especially where any moisture has collected. The escaping air will also turn Brazil-wood paper yellow.

CHLORINE.

According to Berzelius, 'chlorine may be detected in its compounds by dissolving oxide of copper in salt of phosphorus or platinum wire in O.F. until the glass is opaque, and then causing the substance under examination to adhere to the soft bead, which is then treated with the tip of the blue flame.'

'If chlorine is present the bead will be surrounded with an intense azure blue flame of chloride of copper, which volatilises as long as chlorine remains. A fresh addition of the substance will reproduce this reaction. Bromine is the only other body occuring in minerals which produces a similar flame.' As the above frequently occur together the result is not satisfactory without a still further investigation. When a substance gives the azure blue reaction in salt of phosphorus, fuse another portion of the compound in phosphate glass with copper oxide. As soon as the fusion is complete stop blowing, let the glass cool, then crush into the finest powder on the agate mortar and attack it in a tube or matrass with a small quantity of nitric acid. Add water, allow the assay to settle for a few moments, then add a solution of nitrate of silver. If chlorine alone is present the precipitate will be a milky white. If the compound contains as much as ½ per cent. of bromine the precipitate will have a beautiful light lemon yellow tinge. If the compound contains a large percentage of chlorine to a very small percentage of bromine the colour will only be observed at the moment of precipitation; but if a large amount of bromine is in the compound the yellow colour is permanent, and will often be seen entirely separate from the pure milky white precipitate which is thrown down by chlorine. The colours, however, cannot be correctly discerned after the test tube has been shaken up. In mineral waters and aqueous salts the slightest traces of chlorine can be detected (if very dilute, evaporate down) by adding a few drops of nitrate of silver. A milky cloud will be observed immediately after the above addition if any chlorine is present.

BROMINE.

Bromides behave in a similar manner to chlorine, and with phosphorus salt and oxide of copper the same reaction takes place as with silver. The flame, however, has not a pure azure blue colour, but inclines to green, especially at the edges.

When all the bromine has been eliminated the green flame of the oxide of copper alone remains.

To distinguish bromides from chlorides Berzelius has proposed to fuse them in a matrass with bisulphate of potash, when bromine and sulphurous acid are liberated, and the matrass is filled with reddish yellow vapours of bromine, which can be recognised by their similarity to that of chlorine notwithstanding the sulphurous acid. Bromide of silver forms an exception, as it yields very little bromine, but it may be distinguished from chloride of silver by the asparagus green colour which it assumes when exposed to the sunlight after fusion with the bisulphate of potash.

IODINE.

Iodides, if fused with oxide of copper in a phosphate bead, produce an intense green flame.

When iodides are fused in the matrass with bisulphate of potash, the iodine is sublimed and partly fills the matrass with violet vapours, while sulphurous acid is simultaneously evolved.

The test is so delicate that small quantities of iodine may be detected in salts, &c.

SULPHUR.

Sulphur fuses in the matrass; sublimes, leaving a fine yellow sublimate when cool. If ignited on charcoal it burns with a bluish flame, evolving sulphurous acid, which is easily recognised by its characteristic pungent odour.

By roasting a finely powdered mineral in an open tube sulphurous acid will be evolved, and if the odour is not perceptible the presence of sulphur will be ascertained by inserting a small strip of moistened litmus paper.

According to Plattner, in some cases even a very little sulphur may be detected by fusing the powdered substance with 2 parts of soda and 1 part of borax on charcoal in R.F., provided no selenium is present. In the case of easily fusible metals which contain only finely disseminated sulphides and cannot be pulverised—e.g. raw lead, black copper, &c.—a fragment of the size of the mustard seed or small peppercorn is used. In case of metals that fuse with difficulty, as raw iron, the amount may be obtained by filing.

When the powdered substance is fused with soda and borax in R.F. on charcoal, sulphide of sodium is formed, which leaves a sulphur reaction when the fused mass is removed from the charcoal, pulverised, and placed on a bright sheet of silver (a silver coin will do), and moistened with water. Sulphuretted hydrogen is evolved, which colours the silver black with sulphide of silver if a notable amount of sulphur is present, but if less is present only dark brown or yellow.

A minute trace of sulphur can be detected in water made acid (by a small addition of nitric acid) and then adding a little nitrate of baryta in a test tube. If sulphur is present a fine white precipitate of baryta is thrown down. The precipitation is greatly facilitated by slightly warming over the spirit lamp.

PHOSPHORUS.

Phosphoric acid imparts a green colour to the flame, especially after having been moistened with sulphuric acid. This test is, however, not always conclusive.

Crush up and then ignite the assay to expel any moisture; place in a tube with a little magnesium wire, close the tube entirely, heat strongly. Magnesium phosphide is the result.

When the fused mass is treated with water and broken up the characteristic odour of phosphoretted hydrogen is evolved.

Pig iron may be examined for phosphorus by dissolving a fragment in nitric acid; then evaporating to dryness in a porcelain dish, heat it strongly, and then test for phosphoric acid as directed above.

Substances consisting of earths, metallic oxides, iron ore, &c., are tested by intimately mixing (after they have been ground to a fine powder) with 5 parts by volume of a previously prepared mixture (4 parts by weight of soda and 1 of silica) in the agate mortar, and transferring it to a soda-paper cornet and fusing it in O.F. to a clear bead. (In case of iron ores it is best to take 4 assays of about 0·5 grain each and afterwards treat as one globule.)

The bead is pulverised in the steel mortar, and the powder boiled in a small porcelain dish with water. Phosphate of soda, also the excess of soda, are dissolved. The clear liquid is either filtered or carefully decanted from the insoluble matter and removed into a small porcelain dish. If much silica has been dissolved and remains in the clear liquid, add a little carbonate of ammonia, boil, and the silica will be separated in a gelatinous form.

Filter, and to the filtrate add an excess of acetic acid, then some acetate of lead, stir, and if the phosphoric acid amounts to several per cent. a white precipitate of phosphate of lead is at once formed, which is collected on a filter, dried, and fused in a shallow cavity on charcoal.

If the precipitate has been well washed a white or yellowish globule with a crystalline surface is obtained.

When the precipitate formed by acetate of lead is so trifling that it cannot be removed without partially destroying the filter, a drop of dilute sulphuric acid must be added, which produces a mixture of sulphate and phosphate of lead in such quantity that it may readily be transferred from the filter to charcoal.

When this is fused by the blowpipe the sulphate is reduced partly to sulphide of lead, which soon volatilises, and partly to metallic lead, which gradually volatilises, leaving small globules of phosphate of lead that can be recognised with the aid of the magnifying glass by reason of its characteristic qualities.

ARSENIC.

Arsenic on charcoal evolves an unmistakable smell of garlic. A slight grey incrustation is formed some distance from the assay, which in R.F. disappears, assuming a faint blue tinge.

Metallic arsenides, if heated on charcoal with R.F., yield part of their arsenic, which volatilises, forming a coat of arsenious acid. If a large amount of arsenic is present greyish white fumes are evolved, and the odour of garlic is recognised without stopping the blast. If the latter is not recognised the glowing assay must be held directly under the nose, so that the smallest quantity of escaping arsenic may be recognised.

In cases of nickel and cobalt ores when arsenic is separated with difficulty, fuse the compound with lead in O.F. on charcoal, and the presence of the volatilising arsenic will be ascertained by its odour.

Provided the quantity of arsenic is very small in a metallic compound the following process must be resorted to: brittle metals are pulverised to powder ; malleable ones are reduced by filing:—

Mix 1 grain with 6 volumes of nitre and ignite in the platinum spoon with the blowpipe flame until no metallic particles are visible. Arsenic acid is formed, which combines with the potassa. The other metals are oxidised and nitrous acid is liberated. The mass in the spoon is now digested with water in a beaker glass over the spirit lamp, until everything is removed from the spoon.

The clear solution is poured off from the oxides into a small porcelain vessel, acidified with hydrochloric acid, about 0·7 grain sulphate of magnesia dissolved in it by heating slightly, an excess of ammonia added, and the whole heated to boiling.

Arseniate of ammonia and magnesia separate and settle quickly when the vessel is removed from the flame. The clear fluid is decanted from the precipitate, which is washed in strong water of ammonia, again allowed to settle, and freed by decantation from the fluid, after which it is dried in the vessel. The dry salt is mixed with 6 volumes of a mixture of cyanide of potassium and soda in equal parts, then treated (1) on charcoal or (2) in a matrass with a narrow neck. In the former case it is fused in R.F., and the volatilised arsenic detected by the odour. In the latter case it is first warmed over the spirit lamp in the matrass, to expel any traces of moisture (which are collected by an inserted roll of blotting paper), after which the mixture is heated to fusion.

The arsenic acid is reduced, and forms a sublimate of metallic arsenic in the neck of the matrass *a* (fig. 49). If the amount of the arsenic is too small to produce a distinct mirror, cut off the neck above the sublimate with a file, then hold the portion of the matrass containing the sublimate in the flame. If the sublimate consists of arsenic it will volatilise and yield the arsenic odour.

Fig. 49.

Oxide of antimony (antimonious acid), containing less than $\frac{1}{1000}$ part of arsenic when heated to redness in a narrow-necked matrass with 3 volumes of neutral oxalate of potash and 1 volume of charcoal dust, will afford a very distinct mirror, which on further treatment in the spirit flame is volatilised with an unmistakable odour.

CARBON.

Pure carbon (diamond) in a fine state of division glows like coal and burns slowly if placed on a piece of platinum foil and the flame directed down on it. It is consumed, the product of combustion being carbonic acid.

Coal, anthracite, graphite, asphaltum, amber, &c., and all such compounds of carbon volatilise when heated in the platinum spoon, first with a mild O.F. and then with a strong R.F., leaving nothing but silica, lime, and other non-volatile elements. Minerals containing carbonic acid are easily tested, and with great certainty, by crushing them up finely and adding a little dilute nitric acid to them in a glass vessel and observing whether any effervescence ensues. The glass should be slightly heated if no gas is evolved. If carbonic acid exists in a large amount the effervescence is most violent.

In raw iron, steel, and brass, the carbon (no matter how combined) is easily found by digesting a small fragment in a porcelain dish with about 6 times its weight of fused chloride of silver and some water acidulated with a few drops of hydrochloric acid, leaving the whole covered with a watch glass until all the iron is dissolved. The iron is converted into protochloride, the carbon remains behind, and a corresponding amount of silver is reduced.

As the carbon compounds may contain earthy matter, they must be dried, mixed with 3 parts of antimoniate of potash, then heated to redness in a matrass over the spirit lamp. The carbon is oxidised at the expense of the antimonic acid, forming carbonic acid, which combines with the liberated potassa. When cold, fill the matrass nearly to the neck with water, which is gradually heated to boiling. The carbonate and sulphate of potash dissolve with part of the undecomposed antimoniate of potash, whilst most of the latter remains with the earths and metallic oxides.

To the warm solution a few drops of nitric acid are added, which causes effervescence, more or less lively, according to the amount of carbonic acid present. Not a bubble ascends if the substance contains no carbonic acid, but several will be seen when the most trifling amount is present.

BORON

Is a substance found in nature combined with water, soda, ammonia, and metallic oxides, and never native.

Turner has proposed a test for boracic acid in salts and minerals as follows:—The fine powder is mixed to a paste with a little water and 1 part of a flux (it is better to employ 3 parts to obtain a reliable test), consisting of 4½ parts bisulphate of potash and 1 part of finely powdered fluor spar perfectly free from boracic acid. It is then fused on a platinum wire within the blue flame, and as soon as the water is expelled fluoboracic acid is found, which is volatilised and imparts a yellowish green tinge to the flame. This colour is very transient, however, and must be looked for with great attention if little boracic acid is present.

SILICIUM.

Silicic acid, in the forms commonly known as quartz, flint, &c., is infusible before the blowpipe. It dissolves (when powdered finely) slowly in borax to a clear, difficultly fusible glass, which while hot is frequently coloured by the metallic oxides present. It is scarcely attacked by phosphate salt; with soda it fuses to a clear glass with effervescence.

Both natural and artificial silicates can be tested by fusing a bead of phosphate salt on a platinum wire, then adding a splinter of the silicate and treating it in O F. The bases dissolve, leaving a silica skeleton, which floats in the hot, clear bead.

Quartz rocks and all such directly infusible and insoluble compounds of silica should be treated in the following manner:—

One part, very finely powdered, is fused with four times its weight of carbonate of soda in the platinum spoon. When fused, remove to a small beaker glass and add about 20 times its volume of water, then add hydrochloric acid, enough to make the solution a weak one. Warm the beaker over the spirit lamp until the solution has been effected and the carbonic acid gas expelled; remove to a porcelain dish and evaporate to dryness. When cold, moisten with hydrochloric acid, allow it to stand a short time, then dilute with hot water, stir, allow to deposit, then decant the fluid, and again treat the residue with warm water, after which filter and dry. Remove the fine white precipitate, which is pure silicic acid.

The silicium in raw iron, steel, brass, &c., is easily separated by dissolving a fragment in nitric acid, which holds in solution the metallic oxides formed and leaves the silica in a fine white powder, which should be tested by fusing with soda on coal. If the powder contains silica, it will be dissolved in the soda with effervescence.

GLUCINIUM.

Glucina alone is unchanged before the blowpipe. In borax it dissolves in considerable quantity, forming a clear glass, which by flaming becomes milk white, as it does on cooling when fully saturated. In phosphate salt it dissolves with the same reactions as borax. With soda on charcoal it is unchanged. With nitrate of cobalt it shows a faint bluish grey colour.

The blowpipe characters of glucina are not sufficiently prominent to admit of its being recognised in such minerals as contain it; therefore it must be detected by the humid analysis. To detect glucina the finely powdered mineral must be dissolved in hydrochloric acid, then evaporated to dryness, the residue moistened with hydrochloric acid, dissolved in boiling water, and the silica filtered out. The acid solution is made slightly anmoniacal, when glucina and any traces of sesquioxide of iron are thrown down. They are collected on a filter, washed thoroughly, and heated while moist with a solution of potassa, until the glucina is redissolved and the iron remains behind. After diluting the solution with water, filtering it, and making it slightly acid with hydrochloric acid the glucina can be again thrown down with ammonia, and may then be tested for alumina. Filter, thoroughly wash, and shake in a test tube with an excess of carbonate of ammonia solution, which dissolves the glucina, leaving the alumina. On boiling the ammoniacal solution the glucina goes down as a carbonate, and this can be converted into pure glucina by ignition in the platinum capsule.

LANTHANUM.

The oxide alone on charcoal is not changed.

With borax in O.F. it dissolves to a transparent colourless glass, which, if dissolved in a sufficient quantity, can be flamed enamel white. If saturated, the glass of itself, on cooling, becomes enamel white.

In R.F. with borax it reacts the same as in O.F.

With phosphate it acts the same as with borax. With soda on charcoal the soda is absorbed, and the oxide remains with a greyish colour behind. As lanthanum is generally found combined with cerium and didymium the exact determination of it must be referred to the laboratory.

For humid assay see Cerium, p. 89.

YTTRIUM

Before the blowpipe is unchanged.

On borax it dissolves to a clear glass bead, which by flaming becomes milk white as well as on cooling if fully saturated.

With phosphate salt it presents the same reactions as with borax.

With soda on charcoal it is unchanged.

Yttrium is but rarely met with, and then nearly always in common with erbium in various combinations. The wet way must be employed to correctly distinguish this element.

TERBIUM.

The oxide is unchanged before the blowpipe. In borax it dissolves to a transparent glass, rendered milk white on flaming or on cooling, when sufficiently saturated.

In phosphate glass it presents the same reactions as in borax.

With soda on charcoal it does not change. It must be determined by the wet way.

TANTALUM.

Tantalic acid in O.F. alone on charcoal becomes slightly yellow, but is white again when cold. In R.F. the same.

With borax on platinum wire it dissolves easily to a clear glass, which with a certain amount appears yellowish while hot, colourless on cooling, and can be made opaque by flaming. With still more the glass becomes enamel white on cooling. In R.F. the same as in O.F.

With phosphate salt in O.F. it dissolves largely to a clear glass, which with a very large amount is yellowish while hot, but colourless on cooling. In R.F. the above glass undergoes no alteration.

With soda in O.F. with a little more than its volume of soda it fuses on charcoal with effervescence and soon spreads out, and with more soda it sinks into the coal. In the R.F. the same reaction takes place and it cannot be reduced to metal.

The wet way must be employed for its compounds.

URANIUM.

The sesquioxide of uranium, when heated in O.F. with phosphate salt, yields a yellow glass, which becomes yellowish green on cooling and pure green in R.F.

This test is a very good one ; but when oxides of iron, and probably titanic acid, are present the phosphate bead becomes red on cooling, and the uranium colour can only be perceived by treating the glass in O.F., when it assumes, on cooling, a green colour mixed with much yellow.

Any further examination must be made by the wet way.

TUNGSTEN.

Tungstite, according to Von Kobell, acts before the blowpipe as follows :—

On charcoal in R.F. it becomes black.

In phosphate salt in O.F. it dissolves to a colourless or yellowish glass, which in R.F. becomes fine blue when cold.

Tungstic acid can be easily recognised by its examination with phosphate salt. The bead in R.F. becomes blue when cold, or in the presence of iron more or less red.

The presence of tungstic acid in tin slags may be recognised by the deep indigo blue solution which is formed when the pulverised slag is warmed in a test tube with hydrochloric acid.

VANADIUM.

Vanadic acid alone on charcoal fuses, is reduced, and goes partly into the coal; the remainder assumes the colour and lustre of graphite and is protoxide of vanadium.

With borax on platinum wire in O.F. it dissolves to a clear, colourless glass, but with more it gives a yellow glass, yellowish green on cooling. In R.F. the above glass changes, appearing brownish when hot and fine chrome green on cooling.

With phosphate salt on platinum wire in O.F. it dissolves to a clear glass; if not in too small a quantity, dark yellow while hot, and light yellow on cooling. In R.F. the same as with borax.

Vanadium is a very rare metal, and has only been found as an acid in a very few minerals. The further examination must be made by means of a humid analysis.

PALLADIUM.

Protoxide of palladium is reduced at a red heat, but the metallic particles are infusible.

In O.F. and R.F. on charcoal with borax the metallic oxides are reduced without dissolving, and a metallic button cannot be obtained.

With phosphate salt the same as with borax.

With soda on charcoal the soda sinks into the coal, leaving the palladium as an infusible powder.

Palladium reduced from its oxides behaves, according to Berzelius, as follows:—

'Carefully heated on platinum foil to low redness, it acquires upon the surface a blue colour, which, however, disappears at full redness.

'On charcoal alone it is infusible and unchangeable. With sulphur in R.F. it fuses, but in O.F. the sulphur burns off, leaving the palladium behind. When fused with bisulphate of potash in a sufficiently large matrass it is dissolved with evolution of sulphurous acid. The salt appears yellow when cool.'

RUTHENIUM.

This metal is only found in small quantities in native platinum, and is grey white, brittle, and very infusible. It is not attacked by fusing with bisulphate of potash, and is scarcely acted upon by aqua regia. No characteristic blowpipe reactions can be obtained from this metal.

CERIUM.

Before the blowpipe on charcoal the protoxide is changed by O.F. into the sesquioxide, which remains unchanged even in R.F.

In borax with O.F. it is soluble to a dark yellow or red glass (similar to the sesquioxide of iron glass), but in cooling it is yellow. If sufficiently saturated the glass can be flamed opalescent, and if fully saturated it becomes so of itself on cooling.

In R.F. the yellow glass becomes colourless, and a strongly saturated glass on cooling becomes enamel white and crystalline.

In O.F. with phosphate glass it reacts the same as with borax, but the colour disappears entirely on cooling. In R.F. no saturation prevents the glass being transparent. It is colourless both whilst hot and cold (which distinguishes oxide of cerium from oxide of iron).

With soda on charcoal the soda is absorbed, and the oxide is reduced to protoxide, which remains behind, of a light grey colour.

As cerium, lanthanum, and didymium are generally combined together, the following simple method is given to enable the assayer to determine all three:—The mixed oxides, after having been ignited, are first treated with weak, then with concentrated nitric acid, which extracts the lanthanum and didymium. Upon evaporating this solution, igniting the salt, and again treating the oxides with very dilute nitric acid, any oxide of cerium which has been dissolved now remains undissolved.

From the solution of lanthanum and didymium the oxides are thrown down with ammonia and dissolved in sulphuric acid. The dry salt being then dissolved to saturation in water at 43° to 45° Fahr., and the solution then warmed to 100°, sulphate of lanthanum separates, leaving the didymium salt in the solution, from which it can be precipitated by potassa. The oxides may be obtained still purer by repeating the process.

DIDYMIUM.

The oxide on charcoal in O.F. is unchanged, but in R.F. with a strong heat it loses its brown colour and becomes grey. In borax with O.F. it dissolves to a clear glass of a dark amethyst colour.

In phosphate salt it behaves the same as with borax.

With soda on charcoal it is insoluble; the soda is absorbed and the oxide remains of a grey colour.

For a minute examination see assay of cerium, p. 90.

ERBIUM.

The yellow oxide in R.F. becomes lighter in colour and translucent in appearance.

In borax it dissolves with difficulty to a colourless glass, which by flaming, and also when saturated, is milk white.

With phosphate salt the same reactions as with borax.

With soda on charcoal it is unaltered.

The humid method must be employed for any further examinations of erbium.

NIOBIUM, or COLUMBIUM.

Niobic acid, before the blowpipe on charcoal in O.F., becomes yellowish, but is white again on cooling. In R.F. the same.

With borax in O.F. on platinum wire it dissolves easily to a clear, colourless glass, becoming opaque by flaming with a moderate addition, and with more becomes opaque when cool. In R.F. yields a glass which, after treatment in O.F., becomes opaque of itself, and on cooling remains unaltered.

With phosphate salt on platinum wire in O.F. it dissolves largely to a clear glass, yellow while hot, but colourless on cooling.

In R.F. with a very large addition the glass becomes brown. The addition of sulphate of iron causes a blood red bead.

With soda in O.F. fuses with an equal volume of soda, with effervescence, but with more soda goes into the coal. In R.F. the same, and it cannot be reduced to metal.

The wet way must be employed for an accurate determination.

THORIUM.

Thoria alone before the blowpipe remains unaltered. With borax on platinum wire it dissolves in small quantity to a clear glass, milk white on cooling, if saturated, but if it appears clear on cooling it cannot be made opaque by flaming.

With phosphate salt, same as with borax. With soda on charcoal it is insoluble.

Thorium is a rare element, seldom met with, and as it gives no characteristic blowpipe reaction the humid analysis must be employed.

THALLIUM.

Thallium melts very easily on charcoal, and when touched with the point of the blue flame the metal is surrounded by a green flame.

When being fused on charcoal a moderate amount of white coat of oxide is formed at some distance from the assay, which is driven off when R.F. is applied.

Its salts also give an intense green flame.

With the spectroscope it can be readily determined.

MOLYBDENUM.

When molybdic acid is heated on charcoal in O.F. it volatilises; at the same time the support acquires a yellow coating, often crystalline, which becomes white on cooling. In R.F. metallic molybdenum is formed, which may be obtained as a grey powder by washing the pulverised charcoal. Sulphide of molybdenum, when heated in O.F., yields sulphurous acid gas and a sublimate of molybdic acid.

In order to find a small amount of molybdenum in its compounds it is necessary to have recourse to the wet way.

RHODIUM.

Rhodium gives no characteristic reactions with the blowpipe.

IRIDIUM.

Iridium before the blowpipe cannot be determined. It can be separated from platinum, gold, silver, copper, &c., by following the method laid out in the gold assay (Class *B*, *f*), and the percentage estimated.

OSMIUM.

Osmium generally occurs with platinum and iridium, &c., and forms, with iridium, iridosmine.

The metal as well as the protoxide and binoxide change easily, when heated in the air, to osmic acid, which is volatile and recognisable by its highly characteristic, penetrating, and disagreeable odour, resembling that of chlorine and bromine. If osmium be placed on a strip of platinum and brought into the outer flame at half its height, the flame becomes intensely luminous.

For minute portions the wet method must be employed.

SELENIUM.

Selenium, even when combined with other elements, is easily determined by heating on charcoal, when it evolves a strong odour of bad horse-radish. When heated in a glass tube selenium forms a red sublimate.

Selenium, when fused within the blue flame on coal, volatilises with an intense azure blue flame.

The salts of selenium (selenates and selenites) are reduced in R.F. on coal, either alone or with addition of soda, to selenides, which emit a distinct horse-radish odour.

TELLURIUM.

Tellurium is very rare, and is found alloyed with other elements and as tellurous acid in tellurite. It is a white, brittle, and easily fusible metal. It sublimes in a glass tube over the lamp. Heated on charcoal, it burns with a greenish blue flame, with production of dense white vapours of tellurous acid.

ZIRCONIUM.

Zirconia is infusible and unchanged by either R.F. or O.F.

If prepared from the sulphate and heated by a blowpipe it becomes so brilliant that it dazzles the eye, and in this property it exceeds any other substance.

In borax it dissolves to a transparent glass, which becomes on flaming, or if saturated on cooling, milk white.

In phosphate glass it dissolves slower than in borax, and gives quickly an opaque glass.

With soda on charcoal it is unchanged.

With nitrate of cobalt in O.F. it receives a dirty violet colour.

PART III.

ASSAY OF SILVER.
„ GOLD.
„ MERCURY.
„ COPPER.
„ LEAD.
„ BISMUTH.
„ TIN.
„ IRON.
„ NICKEL.
„ COBALT.
„ NICKEL AND COBALT.
„ COAL.

SILVER.

Only a small proportion of the large amount of silver which is at the present time produced for commercial purposes is found native, and then not pure, as it is generally alloyed with a little copper, gold, platinum, mercury, arsenic, iron, lead, bismuth, or antimony.

Native silver occurs in masses or in arborescent and filiform shapes in veins traversing gneiss, schists, porphyry, and other rocks; it also occurs disseminated in native copper and galena, but usually invisible to the naked eye, therefore requiring the aid of a good microscope to determine its presence.

Silver, when pure, has a metallic lustre. Colour and streak, silver white. Ductile. Hardness, 2·5- 3. Specific gravity when pure, 10·5. Minerals containing silver are found in veins of nearly all descriptions, and even in sea water minute traces have been found by a careful analysis.

The principal minerals containing silver are as follows:—

Argentite: silver glance, containing 87 per cent. silver, with sulphur.

Stephanite: brittle silver ore, containing 68 per cent. silver, with sulphur and antimony.

Proustite: light red silver ore, containing 65·4 per cent. silver, with sulphur and arsenic.

Pyrargyrite: dark red silver ore, containing 59 per cent. silver, with sulphur and antimony.

Argentiferous grey copper ore (fahlerz), containing from 5·7 to 18–31·8 per cent. silver, with antimony and sulphur.

Argentiferous sulphide of copper, containing 53 per cent. silver, with sulphur and copper.

Polybasite, containing 72–94 per cent. silver, with copper, sulphur, arsenic, and antimony.

Chilenite, containing 86·2 per cent. silver, with bismuth 13·8 per cent.

Bromyrite, containing 57·4 per cent. silver, with bromine 42·6 per cent.

Cerargyrite (horn or chloride), containing 75·3 per cent. silver, with chlorine 24·7 per cent.

Embolite, containing 60–72 per cent. silver, with bromine and chlorine.

Sternbergite, containing 33·2 per cent. silver, with iron 36 per cent. and sulphur 30 per cent.

Iodyrite, containing 46 per cent. silver, with iodine 54 per cent.

Selenic silver, containing 11·6–42·8–65·5 per cent. silver, with selenium, copper, and lead.

Hessite, containing 62·8 per cent. silver, with tellurium 37·2 per cent.

Silver is a metal extensively used in the arts and manufactories, and many of their products contain it in more or less proportions.

Silver will be found in the products as well as in the refuse from nearly all lead and copper smelting works, if carefully looked for, and a very small amount can be determined with great accuracy. Any mineral, alloy, or product containing what is termed 'a trace of silver,' about ½ ounce to the ton of 2,000 pounds, can be assayed, and the metal extracted and determined with accuracy by the following methods.

Assay of Silver.

In order to separate silver from its ores and compounds by the blowpipe the previous metal must be formed into an alloy with lead; then the silver lead concentrated by a process known as scorification, by which the bulk of the lead, copper, &c., is oxidised; then the concentrated silver lead is subjected to the process of cupellation, whereby *all* the lead and other base metals are oxidised and the silver left in the form of a metallic button.

Commercial ores, especially very rich ones, frequently differ in richness; it is therefore advisable in all cases of importance to make two or three assays of each sample, and if the results do not agree to make one or two more, and then to take the mean or average of the whole, and to that add the loss of silver proved by the synthetical assay. In assays of alloys, proof and synthetical assays are absolutely necessary to prove the work.

Silver Assay.

The assay of silver is divided into three classes, *A*, *B*, and *C*.

A. When the silver is principally in combination with non-metallic bodies.

(*a*) Containing volatile matters, as sulphur and arsenic, and so combined as to be decomposed by fusion with borax and lead on charcoal.

(*b*) Containing sulphides not decomposed by borax and lead alone (argentiferous sulphides of molybdenum).

(*c*) Containing chlorine, bromine, and iodine, with little or no other volatile matters.

(*d*) Consisting of metallic oxides, easily reduced on charcoal (litharge, &c.)

(*e*) *General method adapted to the assay of a, b, c; either to one or all.*

B. Metallic alloys ready for cupellation after the necessary addition of lead.

(*a*) Bar and ingot silver, standard silver, coins, native silver, alloys of silver, gold, and copper.

C. Metallic alloys requiring either distillation, or fusion with fluxes before they are ready for cupellation.

(*a*) Containing mercury in the form of amalgam.

(*b*) Test and precipitated silver. Retorted silver amalgam.

(*c*) Containing copper or nickel with more or less sulphur, arsenic, zinc, black copper, brass, and German silver.

(*d*) Containing tin — argentiferous tin, bronze, bell metal, gun metal, and bronze coinage.

(*e*) Containing antimony, tellurium, or zinc.

(*f*) Iron bears from smelting furnaces and silver-steel, &c.

(*g*) Containing alloys of lead or bismuth with silver, in which the proportions of the former predominate.

(*h*) Containing copper in the form of coins, ingot, sheet, or wire; cement and copper *nickel alloys* containing silver.

A. (*a*) Consists of most commercial ores which contain iron, copper, and arsenical pyrites, antimonial glance, blende, selenides, silver glance, sulphide of silver, ruby silver, sulphide of silver and copper, miargyrite, &c.; also copper ores, as copper glance, purple copper, fahlerz, &c.; also lead ores, as galena, selenide of lead, &c.; also copper and lead mattes, lead sublimate, and cobalt speiss.

Reduction to Silver Lead.

The ore is reduced to powder and passed through a sieve of 2,000 holes to the linear inch; it is then thoroughly mixed and 1·5 grain weighed out. The ore is fluxed with borax and lead. The amount of borax required is dependent on the fusibility and amount of matter to be slagged. Ores containing much gangue, iron, cobalt, or tin require 1½ grain borax glass. When ores contain little gangue and much metallic sulphides 0·8 to 1·2 grain borax glass is quite sufficient. Should the assay during the fusion show itself refractory, a little more borax may be added to it.

The amount of lead required depends on the other metals present in the ore. A substance containing 7 per cent. copper or 10 per cent. nickel requires five times its weight of lead (7·5 grains), but when it contains more than this amount the proportion must be dependent on the amount of copper, &c., present. When this is not known it is in all cases better to use too much than too little lead, as in the last case the separation of the silver from the copper is not effected, and a lead alloy rich in nickel cannot be cupelled.

The following table will show the relative proportions to be employed :—

Copper glance, containing about 80 per cent. copper, requires 15 times its weight of lead.

Covellite, containing about 65–66 per cent. copper, requires 12 times its weight of lead.

Purple copper, containing about 55-60 per cent. copper, requires 11 times its weight of lead.

Tennantite, containing about 48–50 per cent. copper, requires 10 times its weight of lead.

Kupferblende, containing about 41–40 per cent. copper, requires 10 times its weight of lead.

Fahlerz, containing about 30–40 per cent. copper, requires 10 times its weight of lead.

Cupreous bismuth ore, containing about 34–35 per cent. copper, requires 10 times its weight of lead.

Copper pyrites, containing about 30–34 per cent. copper, requires 10 times its weight of lead.

Sulphide of copper and silver, containing about 30–31 per cent. copper, requires 10 times its weight of lead.

Tin pyrites, containing about 29–30 per cent. copper, requires 7 times its weight of lead.

Eukairite, containing about 23–25 per cent. copper, requires 7 times its weight of lead.

Bournonite, containing about 12–13 per cent. copper, requires 7 times its weight of lead.

Copper regulus, containing up to 45 per cent. copper, requires 10 times its weight of lead.

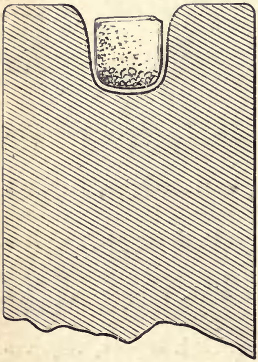
Copper regulus, containing up to 50–60 per cent. copper, requires 10 times its weight of lead.

Lead speiss, containing up to 10–40 per cent. copper, requires 10 times its weight of lead.

Cobalt speiss, containing up to 40–50 per cent. copper, requires 10 times its weight of lead.

The assay having been prepared, is poured with care into a soda-paper cornet, placed in a charcoal bore of about $\frac{4}{10}$ of an inch in diameter at the bottom, and from $\frac{5}{10}$ to $\frac{6}{10}$ at the top. The cavity is bored wider at the top, to allow the flame to reach down to the bottom of the bore. The top of the cornet is then closed up with a pair of pliers and pressed firmly down (see fig. 50). The assay is now inclined towards the flame, and *a reduction flame*, at first moderately strong, is employed to cover nearly all the top of the assay. The paper, is not consumed until the particles below it have entered into fusion and prevented mechanical loss. The whole assay is now submitted to a strong but pure R.F. at an angle of 30° to 35° degrees. By the action of this flame a part of the sulphur, arsenic, antimony, zinc, &c., is volatilised, but the greater

FIG. 50. (Full size.)

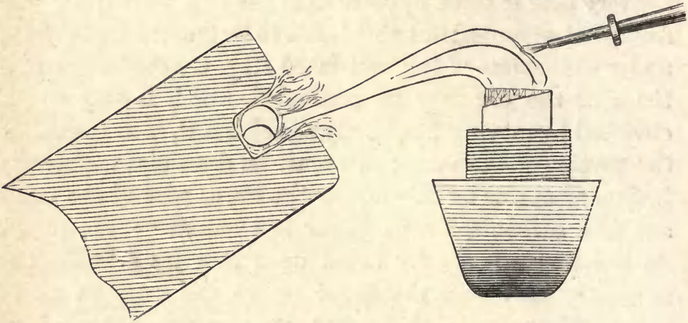


part, along with the metallic bases, unite with the lead to a globule, whilst the gangue, the difficultly reducible metals, and a smaller part of the easily oxidisable but non-volatile metals (which have been oxidised by the first action of the heat) combine with the borax to form the slag. With refractory ores it often appears as if the slag were quite free from lead globules; but this is not to be trusted to, as often, under the surface of the well-fused slag, unacted-upon particles of the ore may be concealed, which is only to be obviated by moving frequently the charcoal, so as to change the portion of the assay; this must be done also with easily fusible assays, as by this means the lower part of the assay and the carbonised soda paper is exposed to the flame. As the paper is hardly acted upon in a good R.F., it is necessary to direct the flame on to the slag, so as to cover it but leave the paper on one side with access to the air, by which it is consumed, while the slag is not affected. When consumed, the whole slag is again covered by the R.F., to reduce any litharge that may have been formed, and which by this means is united to the main globule.

If the slag, after being treated thus in the R.F. and moved about several times, forms a globule itself, and shows no lead globules, and is perfectly fluid, it may be considered free from silver. Whilst the slag is covered with the R.F. the metallic globule is only touched by the side of the flame, to keep it perfectly fluid and ready to take up any straggling lead globule (fig. 51). The assay is allowed to cool, and then removed with the pliers and placed between two thick pieces of paper on the steel anvil and broken up with the hammer; the lead button carefully picked up with the pliers and brushed, is then ready for the next process.

The finely crushed slag is washed in water and then examined with the magnifying glass, to see if any small globules of lead, &c., remain, and if such are found the safest plan to secure a perfect assay is to repeat the operation. In assays of no commercial importance the fine globules can be separated from the slag by vanning in water and then adding them to the main globule.

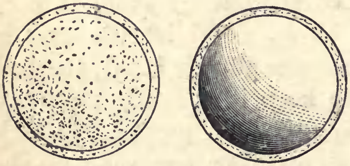
FIG. 51. ($\frac{3}{4}$ nat. size.)



Scorification and Concentration of the Silver Lead.

If the lead button is malleable the scorification can be proceeded with direct; but if, on the contrary, it is brittle, from one to three grains of proof lead and 0·3 grain borax glass is added to it on the scorifier, and the operation carried on as before. The scorification is best carried on in a small scorifier made of good fine clay, about $\frac{8}{10}$ of an inch in diameter, $\frac{1}{8}$ of an inch thick in its deepest place, and $\frac{1}{5}$ of an inch deep in the centre (see fig. 52). It is used in a holder made of fire clay, which is partially covered with thick, smooth paper about 2$\frac{3}{4}$ inches long and with a hollow place in

FIG. 52. (Full size.)



the top, in which the scorifier fits (see fig. 53). A piece of charcoal will also make a good holder, and can be readily cut to the required shape.

FIG. 53. (Full size.)

The scorifier is warmed, and when at a red heat the globule of silver lead is added and brought into a state of fusion by the use of the R.F. Then the O.F. is used and the heat applied gently. The fluid litharge soon forms, and portions of which adhere and glaze the sides of the cup. The formation of the litharge is greatly assisted by slowly turning the assay round and round and from side to side at a gentle inclination, and at the same time keeping the flame at the edge of the bead.

When the litharge has once formed, it accumulates rapidly, and from five to ten minutes completes the operation. If the ore is poor in silver the scorification can be carried on until what is termed the 'eye' appears, i.e. the small button of lead is nearly covered with litharge and only just visible. The operator can, after a few experiments, decide when the operation should be discontinued. When the lead is rich in silver it oxidises very slowly and assumes a spherical form.

The assay is allowed to cool, and then the scorifier is broken on the steel anvil and the button carefully brushed. It is then ready for cupellation.

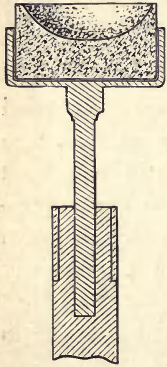
N.B. Plattner and David Forbes advise scorification to be partially carried on, on charcoal, after the reduction of the assay, and then finished on a cupel of coarse bone ash. The author has found a loss of silver, as well as an occasional spirting, &c., by the prolongation of the assay *on* *charcoal after the complete reduction of the assay has been effected*, and for accuracy and despatch he recommends the above method, as it has been used for some years with success by himself.

Cupellation.

When an alloy of lead, silver, gold, copper, &c., is fused in a cupel in a current of air, the lead is readily oxidised and forms a very fusible oxide. The lead parts with portions of its oxygen to the copper and other base metals. The oxides thus produced are dissolved and carried down into the porous cupel in a liquid state by the vitrified oxide of lead, leaving the silver and gold in the form of a small globule on the surface of the cupel.

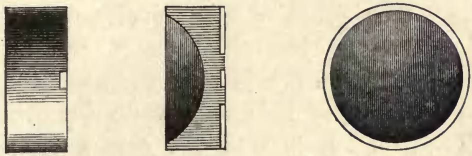
The cupellation is conducted as follows:—Any lead alloy over 5 grains in weight is best cupelled in one of the previously prepared cupels placed in the cupel-holder (see fig. 54). If the weight is under 5 grains a small cupel is sufficient, which can be rapidly prepared by moistening some of the finely powdered bone ash with enough water to form a dryish paste. The paste is placed *in* the steel cupel mould (see fig. 55), the bottom of which must either rest on the steel anvil or some hard solid substance, and a cupel formed by placing the bolt (fig. 56) on the top of the mould and applying a few light strokes. The mould (fig. 57) containing the cupel is now dried slowly over the lamp, and finally heated to redness, and if no cracks or flaws appear, and the cupel presents a smooth and regular surface, the alloy can now be added (it is never advisable to proceed with the cupellation unless the cupel is found to be perfect), and a mild R.F. applied until the assay is

FIG. 54. (Full size.)



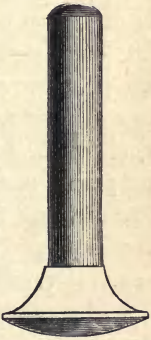
in a state of fusion; directly it is so the O.F. must be applied, and the same continued at the outer edge of the globule, and without touching the assay. A strong enough heat must be imparted to the bone ash, to keep the assay in oxidation without allowing it to become chilled or quiet. The cupel can also be moved slightly from side to side, which gives the lead a fresh surface of clean bone ash to act upon and facilitate the completion of the operation. It is best to finish the assay about the centre of the cupel, but at the same time it is not absolutely necessary for the accuracy of the assay.

FIG. 55. (Full size.)



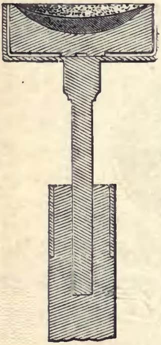
With a little practice the operator can tell when the oxidation is nearly finished by the surfaces of the bead being covered with iridescent colours (resembling rainbow colours), which only last but a moment, when the globule rotates and brightens. Directly the colours disappear the heat should be slightly raised, to free the bead from the last traces of lead, and then the assay is cooled down slowly. In assays very poor in silver the latter precaution is scarcely necessary. In the case of rich ores, alloys, &c., much care must be exercised in cooling the bead gradually, else a violent spurting takes place and small particles of the silver are thrown out from the bead, and the assay cannot be relied upon, and it should be repeated. When cool the bead is removed with the steel pliers from the cupel and

FIG. 56. (Full size.)



cleaned from any adherent bone ash, and if too small to be weighed it must be very carefully detached by a needle or some other sharp instrument, and so as not to injure its form. It is then measured or weighed, according to its size, but when the bead weighs more than 0·01 grain it is more correctly estimated by the balance than if measured. In case the ore is very poor, and the button found to be very minute (on scale below No. 16, or 0·11 per cent.), it is best to make a duplicate assay and add the first button to the silver lead on the cupel of the second assay, and when finished measure or weigh both together.

FIG. 57.
(Full size.)



The loss of silver by reduction, scorification, and cupellation can be corrected by comparing the results obtained from the ore or alloy with those obtained by operating on a carefully weighed piece of *proof silver*, which is added to an artificial compound, prepared by the operator to resemble as nearly as possible the composition of the ore or alloy which has been assayed. The synthetical assay, so prepared, must be free from silver, with the exception of the amount weighed and added; and it should be fused, scorified, and cupelled in a similar manner to the native ore or alloy, and with the same quantity of lead and fluxes.

The difference in weight of the proof silver before assaying, and what is found afterwards, will represent the loss of silver, and it should be added to the assay weight of the ore or alloy which has been assayed, and it may be considered as the correct loss which has taken place.

Ores and alloys very poor in silver, and so poor that their weight cannot be readily ascertained by the balance, do not require any compensation to be made for the loss of silver in cupellation, &c., as the loss on very small beads is so minute that it can scarcely be estimated with accuracy, and even if it could it would be too little to be of any commercial importance.

Most accurate results will be obtained by making synthetical assays and following the methods here described, *and the student will find that by adopting the same he can easily make his assays, check them himself, and have perfect confidence in the results he obtains.*

Synthetical assays entail more labour and time than that of using tables which have been compiled by authorities on the subject; but it ensures great accuracy, owing in a great measure to the different ways in which different operators use the blowpipe, also to the degrees of heat, apparatus, quality of material, and the fuel, &c., employed.

The following tables, with full instructions for their use, have been compiled by David Forbes, and will be found of great service to the assayer.[1]

'*Determination of the Weight of the Silver Globule obtained on Cupellation.*—As the amount of lead which can, by the method before described, be conveniently cupelled before the blowpipe is necessarily limited, the silver globule which remains upon the bone-ash surface of the cupel at the end of the operation is, when substances poor in silver have been examined, frequently so very minute that its weight could not be determined with correctness by the most delicate balances in general use.'

The blowpipe balance employed by the author turns readily with $\frac{1}{1000}$ of a grain, but could not be used for determining weights below that amount.

Globules of silver of far less weight than $\frac{1}{1000}$ are distinctly visible to the naked eye—a circumstance which induced Harkort to invent a volumetrical scale based upon the measurement of the diameters of the glo-

---

[1] See Mitchell's *Manual of Practical Assaying*, pp. 676–681; also D. Forbes, *Chemical News*, Nos. 380, 384, 392, 396, 398, and 412.

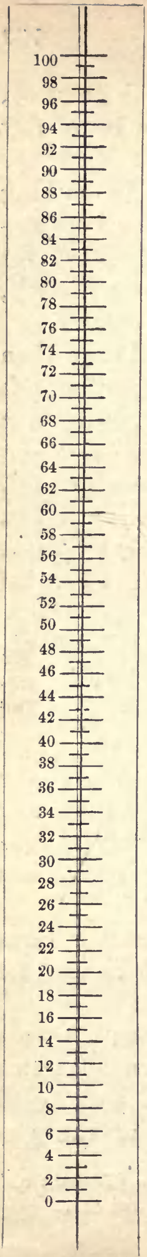


Fig. 58.

bules, which scale in practice has been found of very great utility in the blowpipe assay of silver.

The scale for this purpose which is employed by the author is shown in full size in the annexed woodcut.

This figure (58) represents a small strip of highly polished ivory about $6\frac{1}{2}$ inches long, $\frac{2}{3}$ inch broad, and $\frac{1}{8}$ inch in thickness, on which are drawn, by an extremely fine point, two very fine and distinct lines emanating from the lower or zero point, and diverging upwards until, at the distance of exactly 6 English standard inches, they are precisely $\frac{4}{100}$ parts of an inch apart. This distance (6 inches) is, as shown in woodcut, divided into 100 equal parts by cross lines numbered in accordance from zero upwards. It is now evident, if a small globule of silver be placed in the space between these two lines, using a magnifying glass to assist the eye in moving it up or down until the diameter of globule is exactly contained within the lines themselves, that we have at once a means of estimating the diameter of the globule itself, and therefrom are enabled to calculate its weight.

As the silver globules which cool upon the surface of the bone-ash cupel are not true spheres, but are considerably flattened on the lower surface, where they touch and rest upon the cupel, it follows that the weight of globules corresponding in diameter to the extent of divergence at the different degrees of the scale cannot be calculated directly from their diameters as spheres, but require to have their actual weight experimentally determined in the same manner as employed by Plattner.

The table appended on next page has been calculated by the author, and in one column shows the diameter in English inches corresponding to each number or degree of the scale itself, and in the two next columns the respective weights of the flattened spheres which correspond to each degree or diameter; for convenience these weights are given in the different columns in decimals, both of English grains and of French grammes.

These weights are calculated from the following data, found as the average result of several very careful and closely approximating assays, which showed that globules of silver exactly corresponding to No. 95 on this scale, or 0·038 inch in diameter, possessed a weight of 0·0475573 grain, or 0·003079 gramme. From this the respective weights of all the other numbers or degrees on this scale were calculated, on the principle that solids were to one another in the ratio of the cubes of their diameters. This mode of calculation is not, however, absolutely correct in principle, for the amount of flattening of the under surface of the globule diminishes in reality with the decreasing volume of the globule. In actual practice, however, this difference may be assumed to be so small that it may be neglected without injury to the correctness of the results.

The smaller the diameter of the globule, the less will be the difference or variation in weight in descending the degrees of this scale, since the globules themselves vary in weight with the cubes of their diameters; for this reason, also, all such globules as come within the scope of the balance employed should be weighed in preference to being measured, and this scale should be regarded as more specially applicable to the smaller globules beyond the reach of the balance.

No. on Scale	Greatest Diameter in Inches	Weight of Globule in Grains	Weight of Globule in Grammes
1	0·0004	0·00000005	0·000000003
2	0·0008	0·00000044	0·000000028
3	0·0012	0·00000149	0·000000096
4	0·0016	0·00000355	0·000000229
5	0·0020	0·0000069	0·00000044
6	0·0024	0·0000119	0·00000077
7	0·0028	0·0000190	0·00000120
8	0·0032	0·0000284	0·00000184
9	0·0036	0·0000403	0·00000262
10	0·0040	0·0000554	0·00000359
11	0·0044	0·0000736	0·00000478
12	0·0048	0·0000958	0·00000620
13	0·0052	0·0001218	0·00000789
14	0·0056	0·0001522	0·00000985
15	0·0060	0·0001872	0·00001203
16	0·0064	0·0002272	0·00001471
17	0·0068	0·0002725	0·00001764
18	0·0072	0·0003234	0·00002094
19	0·0076	0·0003804	0·00002463
20	0·0080	0·0004437	0·00002872
21	0·0084	0·0005137	0·00003327
22	0·0088	0·0005906	0·00003823
23	0·0092	0·0006748	0·00004367
24	0·0096	0·0007668	0·00004964
25	0·0100	0·0008667	0·00005611
26	0·0104	0·0009749	0·00006311
27	0·0108	0·0010918	0·00007068
28	0·0112	0·0012176	0·00007883
29	0·0116	0·0013528	0·00008758
30	0·0120	0·0014976	0·00009696
31	0·0124	0·0016524	0·00010698
32	0·0128	0·0018176	0·00011677
33	0·0132	0·0019934	0·00012817
34	0·0136	0·0021801	0·00014114
35	0·0140	0·0023786	0·00015397
36	0·0144	0·0025879	0·00016755
37	0·0148	0·0028097	0·00018190
38	0·0152	0·0030437	0·00019705
39	0·0156	0·0032903	0·00021302
40	0·0160	0·0035550	0·00022983
41	0·0164	0·0038230	0·00024751
42	0·0168	0·0041096	0·00026606
43	0·0172	0·0044111	0·00028553
44	0·0176	0·0047250	0·00030589

No. on Scale	Greatest Diameter in Inches	Weight of Globule in Grains	Weight of Globule in Grammes
45	0·0180	0·0050546	0·00032725
46	0·0184	0·0053991	0·00034955
47	0·0188	0·0057590	0·00037285
48	0·0192	0·0061344	0·00039716
49	0·0196	0·0065258	0·00042250
50	0·0200	0·0069335	0·00044890
51	0·0204	0·0073581	0·00047638
52	0·0208	0·0077799	0·00050495
53	0·0212	0·0082580	0·00053464
54	0·0216	0·00873438	0·00056549
55	0·0220	0·00922854	0·00059748
56	0·0224	0·0097412	0·00063067
57	0·0228	0·0102725	0·00066506
58	0·0232	0·0108228	0·00070021
59	0·0236	0·0113922	0·00073753
60	0·0240	0·0119815	0·00077570
61	0·0244	0·0125901	0·00081513
62	0·0248	0·0132119	0·00085588
63	0·0252	0·0138901	0·00089797
64	0·0256	0·0145440	0·00094141
65	0·0260	0·0152311	0·00098623
66	0·0264	0·0159472	0·00103245
67	0·0268	0·0166828	0·00108010
68	0·0272	0·0174414	0·00112918
69	0·0276	0·0182220	0·00117974
70	0·0280	0·0190256	0·00123177
71	0·0284	0·0198529	0·00128535
72	0·0288	0·0207035	0·00134041
73	0·0292	0·0215782	0·00139704
74	0·0296	0·0224469	0·00145525
75	0·0300	0·0234010	0·00151504
76	0·0304	0·0243496	0·00157645
77	0·0308	0·0253224	0·00163950
78	0·0312	0·0263228	0·00170422
79	0·0316	0·0273484	0·00177060
80	0·0320	0·0284000	0·00183869
81	0·0324	0·0294789	0·00190852
82	0·0328	0·0305838	0·00198008
83	0·0332	0·0317162	0·00205340
84	0·0336	0·0328768	0·00212851
85	0·0340	0·0340649	0·00220549
86	0·0344	0·0349739	0·00228400
87	0·0348	0·0364422	0·00235938
88	0·0352	0·0378008	0·00244730

No. on Scale	Greatest Diameter in Inches	Weight of Globule in Grains	Weight of Globule in Grammes
89	0·0356	0·0390138	0·00253168
90	0·0360	0·0404368	0·00261797
91	0·0364	0·0417943	0·00270790
92	0·0368	0·0431930	0·00279642
93	0·0372	0·0446162	0·00288860
94	0·0376	0·0460718	0·00298279
95	0·0380	0·0475573	0·00307900
96	0·0384	0·0465239	0·00317728
97	0·0388	0·0506249	0·00327759
98	0·0392	0·0522069	0·00338020
99	0·0396	0·0538215	0·00348452
100	0·0400	0·0554688	0·00359138

Silver Assay. Cupellation Loss.—This term is applied to indicate a minute loss of silver, unavoidably sustained in the process of cupellation, which arises from a small portion of that metal being mechanically carried along with the litharge into the body of the cupel. The amount of this loss increases with the quantity of lead present in the assay (whether contained originally in the assay or added subsequently for the purpose of slagging off the copper, &c.); it is relatively greater, as the silver globule is larger, but represents a larger percentage of the silver actually contained in the assay, in proportion as the silver globule obtained diminishes in size. It has, however, been experimentally proved that in assays of like richness in silver, this loss remains constant when the same temperature has been employed, and similar weights of lead been oxidised in the operation.

In the blowpipe assay this loss is not confined to the ultimate operation of cupellation, but occurs, though in a less degree, in the concentration of the silver lead, and in the previous scorification of the assay, had such operation preceded the concentration. The total loss in the blowpipe assay is found, however, to be less than in the ordinary muffle assay, since in the latter case the whole of the oxidised lead is directly absorbed by the cupel.

In mercantile assays of ore it is not customary to pay attention to the cupellation loss, and the results are usually stated in the weight of silver actually obtained. Where, however, great accuracy is required, especially when the substances are very rich in silver, the cupellation loss is added to the weight of the silver globule obtained, in order to arrive at the true percentage.

The amount to be added for this purpose is shown in the annexed table, which is slightly modified from Plattner's:—

Actual Percentage of Silver found by Assay	Cupellation Loss, or Percentage of Silver to be added to the actual percentage found by assay in order to show the true percentage of silver contained in same, the entire amount of lead in or added to the assay being the following multiples of the original weight of assay:—									
	1	2	3	4	5	6	8	11	13	16
99·75 99·5	0·25	0·32	0·39	0·45	0·50	—	—	—	—	—
90	0·22	0·29	0·36	0·42	0·47	0·69	0·83	—	—	—
80	0·20	0·26	0·33	0·39	0·44	0·64	0·75	—	—	—
70	0·18	0·23	0·29	0·35	0·40	0·58	0·68	0·82	—	—
60	0·16	0·20	0·26	0·30	0·36	0·52	0·61	0·74	—	—
50	0·14	0·17	0·23	0·26	0·32	0·46	0·54	0·65	—	—
40	0·12	0·15	0·20	0·22	0·27	0·39	0·46	0·55	0·62	—
35	0·11	0·13	0·18	0·18	0·25	0·36	0·42	0·50	0·57	—
30	0·10	0·12	0·16	0·16	0·22	0·32	0·38	0·45	0·51	—
25	0·09	0·10	0·14	0·14	0·20	0·29	0·34	0·40	0·45	—
20	0·08	0·09	0·12	0·12	0·17	0·25	0·29	0·35	0·39	0·45
15	0·07	0·08	0·10	0·11	0·15	0·20	0·23	0·28	0·32	0·37
12	0·06	0·07	0·09	0·10	0·13	0·17	0·19	0·23	0·26	0·32
10	0·05	0·06	0·08	0·09	0·11	0·15	0·17	0·20	0·23	0·27
9	0·04	0·05	0·07	0·08	0·10	0·14	0·16	0·18	0·21	0·25
8	0·03	0·04	0·06	0·07	0·09	0·13	0·15	0·16	0·18	0·22
7	0·02	0·03	0·05	0·06	0·08	0·12	0·13	0·14	0·16	0·20
6	0·01	0·02	0·04	0·05	0·07	0·10	0·11	0·12	0·14	0·17
5	—	0·01	0·03	0·04	0·06	0·09	0·10	0·11	0·12	0·14
4	—	—	0·02	0·03	0·05	0·07	0·08	0·09	0·10	0·11
3	—	—	0·01	0·02	0·04	0·05	0·06	0·07	0·08	0·09
2	—	—	—	0·01	0·03	0·04	0·04	0·05	0·06	0·07
1	—	—	—	—	0·01	0·03	0·03	0·04	0·04	0·05

The use of the above table is best explained by an example, as the following:—An assay to which there had been added, in all, five times its weight of assay lead, gave a globule of silver equivalent to 6 per cent. Upon referring to the table, it will be seen that the cupellation loss for this would be 0·07; consequently the true percentage of silver contained in the assay would be 6·07. This table is only extended to whole numbers, but fractional parts can easily be calculated from the same.

To enable the operator to sum up the result of his assays the author has compiled the following tables for estimating the amount of gold or silver in one ton of ore, also the percentage found in the 'assay sample' of 1½ grain.

They are arranged for both the 'long' and 'short' ton, and have been calculated from the following data:—

Avoirdupois.

'Long ton' . = 20 cwt. = 2,240 lbs. = 1015·649 kilogrammes.
'Short ton' . . . = 2,000 ,, = 906·8296 ,,
Hundredweight . . = 112 ,, = 50·78245 . ,,
Quarter . . . . . = 28 ,, = 12·6956144 kilogrms.
Pound . . = 16 oz. = 7,000 grains = 433·4148 grammes.
Ounce . . = 16 drams = 437·5 ,, = 28·3375 ,,
Dram . . . . . = 27·344 = 1·77108 gramme.

Troy (Precious Metals).

Pound . . = 12 oz. = 5,760 grains = 373·096 grammes.
Ounce . . = 20 dwt. = 480 ,, = 31·0913 ,,
Pennyweight . . . = 24 ,, = 1·55457 gramme.
Grain . . . . = 0·064773 ,,

Owing to the great fluctuation which has of late years taken place in the value of silver no permanent standard can be made for its value per ounce, and the assayer should report only the ounces or percentage found, and give the market value to date of same.

After the weight of the silver has been determined the button must always be examined to see if it contains any gold (by dissolving it in nitric acid), and if such is found the weight of same must be ascertained and deducted from that of the button, and the percentage of silver estimated accordingly.

Gold and Silver Tables for calculating the amount of gold or silver in 1 *ton of* 2,240 *lbs., or* 35,840 *ounces, or* 15,680,000 *grains, using* 1½ *grain for the assay sample.*

Weight of Ore or Alloy. Grains	Gave Fine Metal. Grains	Equivalent per Ton to Ounces Dec.	Equivalent to per Cent.
1·5	1·000000	23893·33	66·666
1·5	0·900000	21503·99	59·999
1·5	0·800000	19114·66	53·333
1·5	0·700000	16725·33	46·666
1·5	0·600000	14335·99	39·999
1·5	0·500000	11946·66	33·333
1·5	0·400000	9557·33	26·666
1·5	0·300000	7167·99	19·999
1·5	0·200000	4778·66	13·333
1·5	0·100000	2389·33	06·666
1·5	0·090000	2150·39	05·999
1·5	0·080000	1911·46	05·333
1·5	0·070000	1672·53	04·666
1·5	0·060000	1433·59	03·999
1·5	0·050000	1194·66	03·333
1·5	0·040000	955·73	02·666
1·5	0·030000	716·79	01·999
1·5	0·020000	477·86	01·333
1·5	0·010000	238·93	00·6666
1·5	0·009000	215·03	00·5999
1·5	0·008000	191·14	00·5333
1·5	0·007000	167·25	00·4666
1·5	0·006000	143·35	00·3999
1·5	0·005000	119·46	00·3333
1·5	0·004000	95·57	00·2666
1·5	0·003000	71·67	00·1999
1·5	0·002000	47·78	00·1333
1·5	0·001000	23·89	00·06666
1·5	0·000900	21·50	00·05999
1·5	0·000800	19·11	00·05333
1·5	0·000700	16·72	00·04666
1·5	0·000600	14·33	00·03999
1·5	0·000500	11·94	00·03333
1·5	0·000400	9·55	00·02666
1·5	0·000300	7·16	00·01999
1·5	0·000200	4·77	00·01333
1·5	0·000100	2·38	00·006666
1·5	0·000090	2·15	00·005999
1·5	0·000080	1·91	00·005333

Gold and Silver Tables—continued.

Weight of Ore or Alloy. Grains	Gave Fine Metal. Grains	Equivalent per Ton to Ounces Dec.	Equivalent to per Cent.
1·5	0·000070	1·67	00·004666
1·5	0·000060	1·43	00·003999
1·5	0·000050	1·19	00·003333
1·5	0·000040	0·95	00·002666
1·5	0·000030	0·71	00·001999
1·5	0·000020	0·47	00·001333
1·5	0·000010	0·23	00·0006666
1·5	0·000009	0·215	00·0005999
1·5	0·000008	0·191	00·0005333
1·5	0·000007	0·167	00·0004666
1·5	0·000006	0·143	00·0003999
1·5	0·000005	0·119	00·0003333
1·5	0·000004	0·095	00·0002666
1·5	0·000003	0·071	00·0001999
1·5	0·000002	0·047	00·0001333
1·5	0·000001	0·023	00·00006666

Gold and Silver Tables for calculating the amount of gold or silver in 1 *ton of* 2,000 *lbs., or* 32,000 *ounces, or* 14,000,000 *grains, using* 1½ *grain for the assay sample.*

Weight of Ore or Alloy. Grains	Gave Fine Metal. Grains	Equivalent per Ton to Ounces Dec.	Equivalent to per Cent.
1.5	1·000000	21333·33	66·666
1·5	0·900000	19200·00	59·999
1·5	0·800000	17066·66	53·333
1·5	0·700000	14933·22	46·666
1·5	0·600000	12799·99	39·999
1·5	0·500000	10666·66	33·333
1·5	0·400000	8533·33	26·666
1·5	0·300000	6399·99	19·999
1·5	0·200000	4266·66	13·333
1·5	0·100000	2133·33	06·666
1·5	0·090000	1920·00	05·999
1·5	0·080000	1706·66	05·333
1·5	0·070000	1493·32	04·666
1·5	0·060000	1279·99	03·999
1·5	0·050000	1066·66	03·333
1·5	0·040000	853·33	02·666

Gold and Silver Tables—continued.

Weight of Ore or Alloy. Grains	Gave Fine Metal. Grains	Equivalent per Ton to Ounces Dec.	Equivalent to per Cent.
1·5	0·030000	639·99	01·999
1·5	0·020000	426·66	01·333
1·5	0·010000	213·33	00·6666
1·5	0·009000	192·00	00·5999
1·5	0·008000	170·66	00·5333
1·5	0·007000	149·33	00·4666
1·5	0·006000	127·99	00·3999
1·5	0·005000	106·66	00·3333
1·5	0·004000	85·33	00·2666
1·5	0·003000	63·99	00·1999
1·5	0·002000	42·66	00·1333
1·5	0·001000	21·33	00·06666
1·5	0·000900	19·20	00·05999
1·5	0·000800	17·06	00·05333
1·5	0·000700	14·93	00·04666
1·5	0·000600	12·79	00·03999
1·5	0·000500	10·66	00·03333
1·5	0·000400	8·53	00·02666
1·5	0·000300	6·39	00·01999
1·5	0·000200	4·26	00·01333
1·5	0·000100	2·13	00·006666
1·5	0·000090	1·92	00·005999
1·5	0·000080	1·70	00·005333
1·5	0·000070	1·49	00·004666
1·5	0·000060	1·27	00·003999
1·5	0·000050	1·06	00·003333
1·5	0·000040	0·85	00·002666
1·5	0·000030	0·63	00·001999
1·5	0·000020	0·42	00·001333
1·5	0·000010	0·21	00·0006666
1·5	0·000009	0·192	00·0005999
1·5	0·000008	0·170	00·0005333
1·5	0·000007	0·149	00·0004666
1·5	0·000006	0·127	00·0003999
1·5	0·000005	0·106	00·0003333
1·5	0·000004	0·085	00·0002666
1·5	0·000003	0·063	00·0001999
1·5	0·000002	0·042	00·0001333
1·5	0·000001	0·021	00·00006666

Class A (*b*).—This class consists only of argentiferous molybdenite, and decomposes very readily when soda is used.

The ore is finely powdered, and 1·5 grain is fluxed with 7·5 grains proof lead, 2·3 soda, and 2·3 borax glass in a soda-paper cornet (which has been previously placed in a charcoal bore), and is heated with a strong R.F. When the assay is thoroughly fused incline it gently and allow the lead globules to come out from under the slag. Treat it with the O.F. for several minutes, until all the molybdenum is volatilised; then allow it to cool, and scorify and cupel as before.

Class A (*c*).—To this class belong bromyrite, cerargyrite, embolite, iodyrite, all ores and furnace products calcined with salt, amalgamation residues, old test and cupels, all argentiferous slags, and silver sweeps and polishings.

Finely powdered ore . . .	1·5 grain.
Borax glass	1·0 ,,
Proof lead	7·5 grains.

The above, after being mixed, is placed in a soda-paper cornet on charcoal, and fused by a R.F. until all the silver is combined with the lead, and the slag shows itself as a perfectly fluid globule. If copper is present in the ore the quantity of assay lead must be added in proportion to the percentage of copper, as stated under *A* (*a*).

Taking all the precautions noted under reduction of Class *A* (*a*), the assay is soon finished, as the chlorine, bromine, and iodine unite and form chlorides, bromides, and iodides of lead, which volatilise, whilst the silver unites with the lead.

The reduced lead is scorified and cupelled, as described in Class *A* (*a*).

Class A (*d*).—The most important substance of this class is litharge (lead oxide), which is readily reduced on charcoal, but generally very poor in silver; so it is necessary to take a larger amount for assay than is ordinarily used.

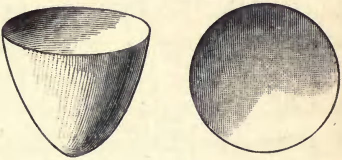
Five times the weight of the usual assay sample—7·5 grains—is mixed with 1 grain borax glass and 1 grain soda in a soda-paper cornet, and treated with R.F. until all the oxide is reduced and the fluid slag shows no lead globules. Towards the end of the operation the flame is directed principally on to the slag; otherwise the metal may become too much agitated and cause a loss. The silver lead thus obtained is then ready for scorification and cupellation, and it can be proceeded with as described in Class *A* (*a*).

N.B. It is often found necessary to make several assays of substances of the above class, on account of the very small amount of silver they contain.

Class A (*e*).—General method adapted to the assay of *a*, *b*, *c*, either to one or all (*d*, being composed of litharge, does not come under the head of this assay).

Take finely powdered ore 1·5 grain, and add to it from five to ten times its weight in finely powdered litharge (which must be free from silver). *The excess of litharge is necessary only when the ore contains a large amount of metallic sulphides*; for ordinary ores 5 times the weight will be found ample. Add soda 0·7 grain and finely powdered charcoal 0·5 grain.

FIG. 59. (Full size.)

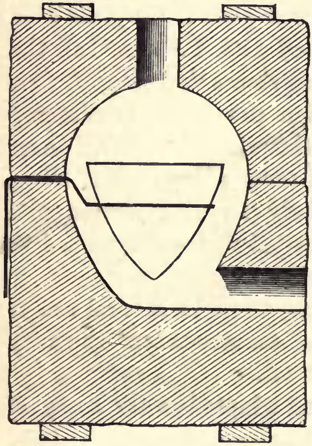


Mix intimately and then remove to a small fire-clay crucible (see fig. 59).

A piece of platinum wire is now bent into the required form to act as a holder and support to the crucible whilst it is in the charcoal furnace (see fig. 60).

The charcoal furnace (fig. 61) is made out of two sound pieces of charcoal, and the inside bored out by the large borer (see fig. 28, apparatus), and the blast hole and escape way made by the small borer (see fig. 30, apparatus). For furnace holder see Mercury Assay.

Fig. 60. (Full size.)



The crucible, already charged, is placed in the furnace and held in its place by the platinum wire. The furnace is then held securely by the holder; the flame is applied through the blast hole—at first a gentle flame, then a strong R.F. Flames will soon be seen to issue from the top hole, and by looking into the same the operator can see whether the assay is fused or not. If it is found to be fused, give it a strong blast for about one minute, and then allow it to cool. The crucible, when cool, is broken and the lead button cleaned. The slag must be examined, and if a perfect fusion has not taken place the assay must be repeated. The assay will be finished as described in *a*.

Class B (*a*) consists of alloys ready for cupellation after an addition of lead. The following table will guide the operator in regard to the quantity of lead required.

The sample to be assayed is either hammered or rolled out, and from 1 to 2 grains weighed for assay.

A preliminary assay should first be made and an excess of lead added. After cupelling and ascertaining the approximate fineness, the assay can be prepared according to the following scale, and the synthetical also.

Table of the Amount of Test Lead to be added to Alloys of Copper and Silver for their Cupellation by the Blowpipe.

Fineness of Silver	Parts of Lead	Fineness of Silver	Parts of Lead
1000	2	750	11
975	4	700	12
950	5	650	13
925	6	600	14
900	7	550	15
875	8	500	16
850	9	100	17
800	10		

Take from 1 to 2 grains of the alloy, and, after adding the amount of lead necessary, place it on a previously prepared cupel and proceed according to method described in p. 106 under the head of 'Cupellation.'

The synthetical assay is conducted in the same manner, and its loss of silver should be added to what is found in the assay of the alloy, which will give the actual loss experienced in the manipulation. The button obtained from the alloy must, after weighing, be always tested for gold by dissolving it in nitric acid, and if gold is present the weight of the same is deducted from that of the silver.

In assaying silver bars that are over 950 fine it is advisable not to take more than 1 grain for assay, and in all cases where the operator has not had much practice it is best to only take 1 grain.

Class C (*a*), consisting of amalgams, is treated first according to assay of mercury and Class *C*, p. 137. The retorted residue is now assayed according to *b*.

(*b*) Two grains of the precipitated, or retorted, silver are fused on charcoal with 0·7 grain of borax, and the button thus cleaned is cupelled as an alloy. See Class *B* (*a*).

(*c*) Consisting of brass, black copper.

Take of alloy 1 grain and mix with 15 times its weight of lead and 1 grain of borax glass; melt with a strong R.F. until a complete fusion has taken place and the silver lead button has a bright appearance. Then scorify and cupel according to Class *A* (*a*).

(*d*) Tin and gun metal.

Fuse 1 grain of the alloy with 12 parts assay lead and 0·5 grain dry carbonate of soda and 0·5 grain borax glass. Place in a soda cornet and fuse in charcoal. First apply a strong R.F. As soon as the assay is melted, change the flame to an oxidising one, and continue until all the tin has become absorbed in the flux.

If any tin is suspected to be still in the alloy, remove the button and again scorify with a little borax on charcoal, as tin cannot be cupelled. The button should now be treated as Class *A* (*a*).

(*e*) Antimony, tellurium, and zinc.

One grain of the alloy is mixed with 5 grains lead and 0·5 grain borax glass, and melted on a soda cornet on charcoal. A strong R.F. is first applied, then an O.F., until the lead button appears clear and white. If the latter does not occur in a few minutes allow the assay to cool, and repeat the fusion with more lead and borax until it does. Then finish as in *A* (*a*).

(*f*) Silver-steel and iron not uniting with lead, the alloy must be first converted into a sulphide of iron by fusion with sulphur.

The alloy must be broken into fragments, the largest not to weigh over 0·5 grain.

Take 1·5 grain alloy fragments.
,, 12·0 grains lead.
,, 1·0 grain borax glass.
,, 0·8 ,, sulphur.

Fuse in a soda-paper cornet on charcoal with the R.F. until a good fluid globule is formed, then add 1·5 grain more borax glass to complete the slagging of the iron. Treat with a strong O.F. until the lead is clear and has a bright surface. Then cool, clean, and treat as in *A* (*a*).

(*g*) Alloys of lead or bismuth.

Take 10 grains and melt with a little borax on charcoal. Then clean the button, and if it is found brittle (from an excess of bismuth) add a small quantity of lead and then scorify and cupel. See *A* (*a*).

(*h*) Copper coins, wire, and cement, containing sometimes nickel.

Take 1·5 grain of the alloy and fuse with 10 grains lead and 0·7 grain of borax glass on charcoal. When the assay has been fused apply the O.F., to slag as much as possible of the copper. Clean the button when the borax and litharge are fully charged with the copper oxide. Then scorify with 20 grains of lead and 0·5 grain of borax, as in *A* (*a*), and finish the assay as usual.

GOLD.

Gold is nearly always found in the metallic state, but '*never pure.*' A good crystal is considered a rarity. The octahedron and dodecahedron are the most common forms. Crystals sometimes acicular, through elongation of octahedral or other forms; also passing into filiform, reticulated, and arborescent shapes, and occasionally spongiform from an aggregation of filaments; edges of crystals often salient. Cleavage none. Twins: twinning plane octahedral. Also massive and in thin laminæ. The above forms usually occur in veins or lodes.

In alluvial soils, streams, rivers, and gravel beds gold is generally found in flattened grains or scales and in rolled masses.

Hardness = 2·5 – 3. Spec. gravity = 15·6 – 19·5; 19·30 – 19·34 when quite pure (G. Rose).

Gold is generally alloyed with silver in various proportions, and pieces from California, Idaho, and Nevada, U.S.A., have been assayed by the author and found to contain as much as 50 per cent. silver; whilst the purest native gold from the same sources that he has examined have assayed 97 per cent. pure gold and nearly 3 per cent. silver.

Gold is also found combined with copper, iron, bismuth, palladium, rhodium, and tellurium.

Gold combines with mercury in what is generally termed gold amalgam.

Gold is also found associated (or as an incidental ingredient) with certain ores containing iron and copper pyrites, mispickel, blende, and galena.

In metallurgical works the proportions of mercury to gold in amalgam vary greatly, owing to the size as well as the purity of the particles of gold which have been brought into contact with the mercury. The author has found in reduction works in California that the percentage of mercury in the gold amalgam there obtained varied from 36 to 85 per cent.

Nearly all metallurgical products from lead, silver, and copper smelting works contain gold, and especially those obtained from the smelting of argentiferous lead ores; but as a general rule the quantity is too small to pay for extraction, as in many instances 'a slight trace' can only be found by the most careful analysis.

Gold Assay.

The assay for gold, although apparently easy, is decidedly the reverse, and accurate results depend greatly upon the judgment of the operator in first selecting the sample and then employing the correct method of assaying the same.

Gold is separated from its matrix by fusion with lead, and the button so obtained is scorified in the same manner as the ores described in the silver assay. Gold alloys are fused with lead; three times the weight of pure silver is added, then the assay is cupelled and the button boiled in nitric acid, which dissolves the silver, leaving the gold in a fine powder, which is heated to redness and weighed.

In assaying gold ores it is necessary to take a large quantity for assay, and as such cannot be fused by the blowpipe the author has adopted the following methods:—

The assay of gold is divided into three classes—*A*, *B*, *C*.

A. *Ores, minerals, furnace slags, mint, and jewellers sweeps.*

B. *Gold alloys.*

C. *Gold amalgams.*

A (*a*). Ordinary gold ores, from which the metal is extracted by raw amalgamation. Wash 5 lbs. (80 oz.) in a batéa; then collect the sulphides, &c. (from which the lighter portions have been separated by the vanning), remove them to a flask, and boil in nitric acid; then filter, and burn the filter paper and insoluble residue in a small evaporating dish, add twice its weight of lead and its own weight of borax. (The filtrate can now be tested for silver, adding a few drops of hydrochloric acid, and if silver be present it will be thrown down in a white flocculent cloud as a chloride of silver. The same should be collected on a filter, and can be weighed after drying carefully and then gently fusing in a small porcelain cup that has been previously weighed, silver, 75·28; chlorine, 24·72.) Place in a soda-paper cornet and then fuse in the deep bore on charcoal as in the Silver Assay. Clean the lead button so obtained, then scorify, and afterwards cupel. Weigh the button found after cupellation and fuse it on charcoal with three times its weight of silver; boil it in a small flask with nitric acid, and after all action has ceased pour off the liquor and wash the fine dark powder with distilled water, add more acid, boil again, wash again, and then remove to a small porcelain cup and allow it to dry slowly over the lamp; when it is quite dry heat the cup to a bright red colour, and then remove the gold (now pure) to the balance and weigh.

(*b*) Gold ores consisting of nearly pure pyrites, also quartz mill concentrations, cannot be washed with safety.

After the mineral has been finely pulverised take from 100 to 1,000 grains, according to the amount of silica in the ore, and roast it on an ordinary piece of sheet iron, turned up at the edges (an old worn-out miner's shovel has often been used by the author), which has been previously coated with a little moist fire clay; heat the sheet iron over a charcoal or coal fire, keeping it at a dull red heat, and stir continually until the smell of sulphurous acid is no longer perceptible; then boil the roasted ore in nitric acid until all soluble matter is dissolved, and proceed as in *a*.

Assays of the above class are generally of great commercial importance, and in such cases make three assays and take the mean for the report.

(*c*) Gold sands, such as are found in the rivers and streams of California and British Columbia, and also on the sea beach in Oregon, U.S.A., contain a large amount of specular and titanic iron, and is called 'black sand' by the miners. The gold is generally very fine and in the form of thin laminæ. Platinum and iridium are often found in the same sand.

The above sand cannot be washed for assay. Take 100 to 1,000 grains, according to the amount of black sand in the ore, and attack with aqua regia in a flask; boil for about 30 minutes or more, dilute with water, and filter. If gold is present it will now be held in solution in the filtrate; remove the filter and evaporate the filtrate to dryness; then add a little hydrochloric acid and redissolve the dry salt in warm water; add to the solution so formed protosulphate of iron, which will throw down the gold in the form of a fine dark precipitate. The precipitate is seldom pure, being mixed with oxides of iron, and must now be dried in the filter paper and both burned over the lamp in a porcelain dish. Then mix the dried precipitate with three times its weight of lead, and its own weight of borax, and one-half its volume of soda; fuse, scorify, and cupel as directed in *a*. In case platinum, iridium, &c., are found associated with the gold an extra amount of pure silver should be added before cupellation, and the gold button will be found pure.

(*d*) Gold from alluvial deposits, ancient and modern river-beds, and placer washings.

The greater part of the gold obtained from such sources is usually found to consist of coarse grains, nuggets, &c., making it a difficult matter to take a sample for assay.

A large quantity (20 tons or more) should be washed through the ordinary gold sluice-box (which has rifles or stops charged with a small quantity of mercury) and the gold collected; then a careful sample should be taken of the tailings or residues and three to five different assays made. Weigh out 5 lbs. (80 oz.) of the tailings and wash carefully in a batéa. The concentrated mineral must be dried, and fused in small portions (about 2 grains at a time) with twice its weight in lead, and its own weight in borax, and half its volume of soda, and the assay carried on as in *a*.

The coarse gold first obtained should now be weighed and a sample taken for assay. The assay must be conducted as described on p. 130 under the head of 'Gold Alloys.'

The assay of the tailings or residues must be added to that of the gold alloy first obtained, and the value per ton of the whole will be ascertained.

(*e*) Furnace slags generally contain a very small percentage of gold, which at the same time is so minutely distributed through the slag that a direct fusion is the only safe method to employ.

Take 2 grains slag.
,, 6 ,, lead.
,, 1 grain borax.
,, ½ ,, soda.

After a complete fusion in charcoal reduce the lead by scorification and cupel. The assay is now finished as directed in *a*.

(*f*) Mint and jewellers 'sweeps' are composed of such various metals and compounds that it is difficult to select an average sample for blowpipe assay; therefore

Take 100 grains of the sweeps and boil them in a flask with nitric acid until all the soluble matter is held in solution. Dry the insoluble matter and the filter, and burn the latter. After so doing fuse with lead according to directions in *e*, and finish as directed in *a*.

(*g*) Direct and universal method for assaying gold ores and minerals, such as telluride of gold, mixed sulphides with which gold is associated—for instance, sulphides of arsenic, copper, zinc, bismuth, iron, lead, &c.&c.

Take 1·5 grain of ore, mix with 5 to 10 times its weight of pure litharge, and assay in precisely the same way and with the same apparatus as used and described in the Silver Assay, *A* (*e*), and purify the gold as directed in p. 127.

B (*a*). Fine gold, bar and ingot gold, coins and native gold, without any adhering matrix or foreign substances.

All the above are capable of direct cupellation after an addition of lead. The lead must be added in the following proportions:—

Fineness of Gold in Alloy	Parts of Lead necessary to remove the Copper by Cupellation	Fineness of Gold in Alloy	Parts of Lead necessary to remove the Copper by Cupellation
1000	5	700	27
975	7	650	30
950	9	600	33
925	11	550	35
900	13	500	36
875	15	400	36
850	17	300	36
825	19	200	36
800	21	100	36
750	24		

The gold coin of France is 900 gold to 100 copper, and that of the U.S. of America the same. The British standard is gold 916·66 and the remainder copper.

Weigh out 1 grain of alloy and 3 grains of pure silver, and wrap up in a small piece of rolled assay lead which has been weighed, and cupel on a previously prepared cupel (see fig. 54, Silver Assay). The heat required is greater than that which is employed in the Silver Assay, as the alloys of gold, copper, and silver require a high temperature for cupellation. Gold suffers but a slight loss by volatilisation. When the cupellation is complete remove the button with the pliers and clean the lower surface with a small brush; then beat the button on the steel anvil until a thin sheet has been obtained.

The last operation can be facilitated by placing the assay on a piece of charcoal and heating it to redness and then beating it out. When thin enough anneal again and twist the small sheet of alloy into the form of a coil, and boil in a small flask or test tube with about $\frac{1}{2}$ oz. of nitric acid (of 1·3 specific gravity) for 5 to 10 minutes; then add a little pure water and pour off the nitrate of silver; again add $\frac{1}{2}$ oz. of nitric acid (of 1·3 specific gravity) and boil until all action has ceased. Then pour off the acid, add an ounce of pure water, and boil for a minute. Pour off the hot water and fill the tube with cold water, and remove the gold into a small pipe-clay crucible by first placing the crucible on the mouth of the flask or test tube (see fig. 61), then inverting them both (see fig. 62). The gold will (even if in a fine powder) soon settle to the bottom of the cup, and it can be quickly done if the operator will slightly tap the sides of the tube with his finger nail, remove the tube from the crucible, and carefully pour off the water, and then allow to dry slowly, and when dry heat the crucible to a bright redness over the spirit lamp, and then remove the gold to the balance and weigh as pure.

FIG. 61.
(Half size.)

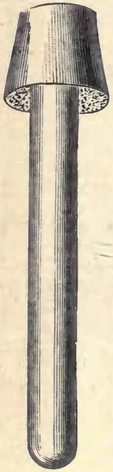


FIG. 62.
(Half size.)

If the alloy is only about 800 (or under) fine take 0·7 gr. for assay, and cupel first with the necessary quantity of lead, and add the charge of silver with 2 grains of lead when the cupellation is nearly complete.

Chemically pure gold, even when boiled 3 times in nitric acid, still retains a trace of silver, and 1,000 parts of pure gold, after being carefully cupelled and parted, will weigh 1000·2. The amount is, however, so small that it is only deducted in the Mint and Gold Assay Office reports.

(*b*) Gold nuggets and fine gold dust.

Take 1 grain, and fuse on charcoal with 1 grain borax and ½ grain nitre, and after the bead is thoroughly cleaned by the fusion proceed as in *B* (*a*). In assaying nuggets cut them in two, and get an average sample if possible.

The outside is generally deceptive, and frequently coated with foreign substances, such as silicates, iron oxides, &c.

(*c*) Worn-out copper plates that have been used in gold amalgamation works, copper coins, wire, and cement.

Weigh out 10 grains, and attack with dilute nitric acid; after a thorough boiling and decantation, dry the fine dark residue, add to it pure silver and lead, cupel, and then finish the assay as in *B* (*a*).

(*d*) Gold containing palladium and not more than 10 per cent. of platinum.

Cupel 1 grain of alloy with 4 grains of silver and the proper quantity of lead (see table, p. 131). Attack with nitric acid three times, and the gold residue will be found pure.

(*e*) Gold containing more than 10 per cent. of platinum.

Dissolve 1 grain of the alloy in nitro-hydrochloric acid (3 parts hydrochloric and 1 part nitric acid). Whilst the solution is still warm add chloride of ammonium to it, and evaporate the whole to dryness at a moderate temperature. The dried salt is then washed on a filter with alcohol of 70° to 80° until a fresh addition of it is no longer coloured yellow. The gold is by this means dissolved out. Add water to the alcoholic solution, remove the alcohol by evaporation, and then precipitate the gold with protosulphate of iron according to the methods described in *A* (*c*).

(*f*) Gold containing iridium. Dissolve 1 grain in aqua regia. The iridium remains behind in the form of a black powder, which can be washed and dried and the percentage of iridium estimated. The gold can be estimated as in *A* (*c*).

If the alloy contains copper it must be first cupelled with about 5 parts of lead, and the last trace of lead removed by fusing it on charcoal with boracic acid.

(*g*) Gold with platinum and silver.

Plattner recommends the following plan:—When the silver has to be determined, it must be extracted by sulphuric acid. To do this with proper accuracy the alloy should contain for 1 part of gold and platinum not less than 1¼ nor more than 2 parts of silver, because some platinum seems to dissolve with more silver. When silver is lacking, an accurate quantity of pure silver must be added, and if gold is lacking the alloy must be melted with pure gold, to secure the necessary proportions of the metals.

One grain of the alloy being weighed out and brought to the proper proportions by fusing it with gold or silver and borax glass on coal, the button is beaten as thin as possible, heated to redness, and rolled up.

After being weighed, to see that no mechanical loss has occurred, it is covered with concentrated sulphuric acid in a porcelain vessel and boiled for 10 minutes. After cooling, the acid solution containing sulphate of silver is decanted, and the porous metallic residue boiled five minutes longer with fresh acid to complete the separation of the silver. The remaining roll is boiled with distilled water, dried, ignited, and weighed; the difference gives the weight of silver. The gold and platinum are then separated according to *B* (*d*).

(*h*) Gold containing rhodium.

Weigh 1 grain of alloy, dissolve in aqua regia, and precipitate the gold with protosulphate of iron, as in *A* (*c*). The rhodium remains in solution.

(*i*) Gold with lead, bismuth, gun metal, antimony, zinc, brass, &c., is assayed according to Class *B* in Silver Assay. If much antimony or zinc is present the alloy should be fused on charcoal with borax before cupellation.

(*j*) A rapid method of making an approximate assay of gold coins, nuggets, gold dust, or bullion.

Take 1 grain of the alloy, melt it with 4 grains of silver, 1 grain borax, 0·5 grain nitre, on charcoal.

After a thorough fusion beat it out and dissolve as usual in nitric acid. The assay can be made in a few minutes, and will be within 5 to 10 thousandth of the true standard.

C (*a*). Gold amalgams are first retorted according to Class *C* in assay of mercury. Then the alloy is fused with a small quantity of borax and nitre on charcoal. One grain of the fused metal is weighed out and treated as in *B* (*a*).

MERCURY.

Mercury occurs in small fluid globules scattered through its gangue.

Specific gravity = 13·56. Lustre metallic. Colour tin white. Becomes solid at 39° Fahr. below zero, and crystallises in octahedrons. Volatilises at 64° Fahr. and entirely so at 662° Fahr.

The rocks affording the metal and its ores are mostly clay shales or schists of different geological ages.

Cinnabar, or sulphide of mercury.

Contains sulphur 13·8 per cent., mercury 86·2 per cent.

Cinnabar is of a bright red or reddish brown colour, and is sometimes impure from clay, oxide of iron, and bitumen.

Tiemannite, or selenide of mercury.

Contains selenium 28·4 per cent., mercury 71·6 per cent.

Calomel, or flour mercury.

Contains chlorine 15·1 per cent., mercury 84·9 per cent.

Mercury is also found combined in various proportions with sulphides of zinc, and also with iodine.

Amalgams.

Mercury with gold, silver, and copper in the form of amalgam has been frequently found in nature, but the proportions vary greatly in different localities, and no correct formula has yet been arrived at.

In metallurgical products mercury is obtained in combination with many metals, the principal of which are gold, silver, copper, lead, bismuth, zinc, iron, tin, &c., and under certain conditions it combines with sodium and potassium.

Amalgams of silver, bismuth, &c., are extensively used by dentists.

In the practice of medicine mercury is largely used, the general forms being metallic, subchloride, chloride, and oxide. Mercury is nearly always determined by distillation, but before making an assay of its ores the operator should examine with great care the ore in question with regard to metallic globules of mercury, and if such are found to exist (which is frequently the case, especially in the ores from Californian mines) several ounces of the ore should be weighed, and then crushed up and vanned carefully in a horn spoon, or porcelain bowl, and the metallic mercury collected on blotting or filter paper, which, when dry, weigh, and add the percentage so found to what is afterwards obtained by assay from the remainder.

The residue both of water and crushed ore must be all carefully saved, the water evaporated, and when dry mix and take a sample for assay.

Assay for Mercury.

The compounds to be examined are divided into three classes, and will be called *A*, *B*, *C*.

Class A.

Consisting of metallic mercury.
,, cinnabar (artificial slate forms what is called vermillion).
,, tiemannite.
,, sub-oxide.
,, protoxide.
,, mixed sulphides, &c.

Class B.

Consisting of calomel (sub-chloride).
,, chloride of mercury (corrosive sublimate).
,, iodide of mercury.

Class C.

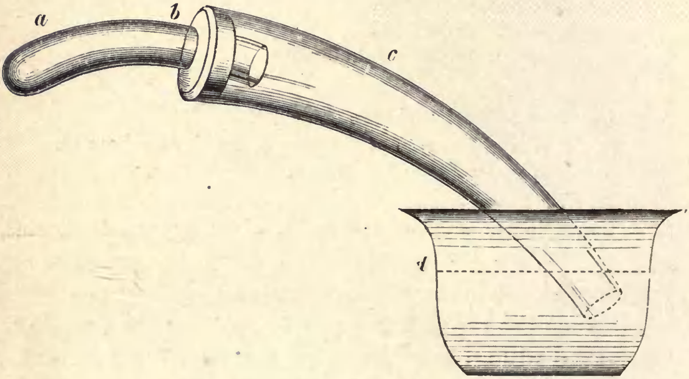
Consisting of amalgams of gold, silver, copper, lead, zinc, tin, &c. &c.

Class A.—The assay is conducted as follows:—

Reduce the ore to a fine powder, so that the sample to be assayed will all pass through a sieve of 2,000 holes to the linear inch. Weigh out from 10 to 20 grains of ore, according to its richness; intimately mix with 5 to 10 times its weight of finely powdered litharge, and distil in a small glass retort over the spirit lamp.

Retorts of the following size and shape (see fig. 63) have been found to give very accurate results, and can be made by the operator from hard flint glass tubing by closing one end over the lamp and then bending it, when heated, to the required angle. The retort *a*, or cup, is made $\frac{3}{4}$ inch in length, and neck *b* of same $\frac{3}{4}$ inch, and $\frac{1}{4}$ inch in diameter. The neck is fitted into a good tight cork, and placed firmly in the top of a glass tube *c* of about $2\frac{1}{2}$ inches in length and $\frac{6}{10}$ of an inch in diameter, tapering at the bottom to $\frac{1}{4}$ of an inch. The tube is also bent slightly, to facilitate the collection of mercurial vapour in the receiver *d*. The end of the tube is kept immersed during the heating of the assay in a small cup or capsule containing water, and, as the operation occupies only a few minutes, the retort and condensing tube can be held with a small pair of wooden tongs without any inconvenience.

FIG. 63. (Full size.)

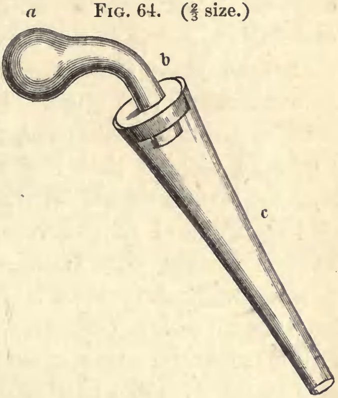


Before the retort is used expel all the moisture by a thorough drying. The above-shaped retorts are easily charged by pouring in the ore and litharge from a small mixing spoon, and then connecting it by means of the cork with the condensing tube.

The retort is heated very gradually at first over the spirit lamp, and finally the heat is raised until the assay is fused, and the glass softens and nearly melts. The greater portion of the mercury will be found in the receiving cup, but small particles will generally be found in the condensing tube. Heat the tube slightly, which has the effect of bringing the minute globules of mercury together; then remove them carefully with a feather and add them to the globules in the cup. The retort and its fused contents should now be broken up in a horn spoon or porcelain dish, in which a small quantity of water has been previously added, and after vanning examine carefully with a magnifying glass, to see if any globules can be found. If they are the assay should be repeated.

Slightly heat the receiving cup over the lamp, taking care to have it half full of water. The fine globules of mercury will then unite into one globule. Pour off the water and dry the mercury with blotting paper, and remove to a small weighing cup and ascertain its weight on the balance. The mercury so obtained can be considered pure.

FIG. 64. ($\frac{2}{3}$ size.)



Class B.—Cannot be reduced by litharge alone, and a different reducing agent as well as shaped retort must be employed. Take of the finely powdered ore or product 10 grains, and mix it with about 3 times its volume of neutral potassium oxalate and 1 volume of potassium cyanide, and distil in a retort of the following description (see fig. 64):—A small bulb-shaped retort *a*, constructed of *thick*, hard flint glass, about $\frac{1}{2}$ inch in diameter at its widest part and $\frac{3}{4}$ inch in depth; length of neck *b* about $\frac{3}{4}$ inch; diameter of the latter about $\frac{3}{4}$ inch. The neck is fitted with a good cork and placed firmly on the top of a glass tube about $2\frac{1}{2}$ inches in length, and $\frac{6}{10}$ of an inch in diameter at the top, tapering at the bottom to $\frac{1}{4}$ of an inch. The mixture having been placed on the retort, the heat is applied very slowly and with great care at first, to avoid the rapid reaction which would otherwise take place. The distillation only occupies a few minutes, and the assay should be completed and the mercury collected and weighed with all the precautions mentioned in Class *A*.

Class C.—Native and artificial amalgams, as well as dentists' products, are often so hard and compact, as well as mixed with lead, bismuth, zinc, copper, &c., that a correct determination cannot be arrived at by direct distillation, owing to the swelling, spitting, and spurting that take place soon after the application of heat. An approximative test should be made on charcoal or in a small crucible or glass tube, and if the spurting is found to be so violent that the amalgam cannot be distilled without loss, it should be crushed up in the agate mortar and then placed in the retort for distillation. In many cases the latter plan is most difficult, and in some impossible without losing a large portion of the sample. In such a case weigh out one equal part of pure mercury, mix it with the assay sample, and then crush it in the agate mortar. The amalgam will then be found to be in a semi-fluid condition, in which state remove it to the iron retort, and the mercury can be evaporated and collected without danger of loss in spitting, and the weight of the mercury added *deducted* from the total found.

In assaying amalgams make two assays.

1st. Distil the amalgam, then condense and collect the mercury, and weigh.

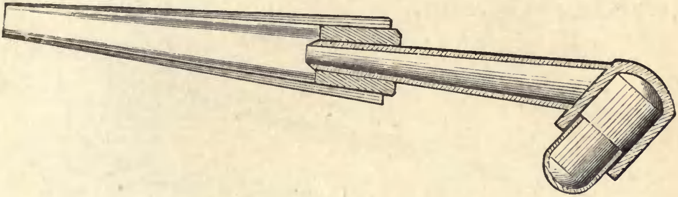
2nd. Subject the amalgam to the blowpipe flame either in an open cup or dish, and take the loss of weight to be mercury. The heat never to be sufficient to fuse the retorted metal, else a loss will arise from the volatilisation of lead, zinc, silver, &c., all of which are frequently found combined with mercury.

The last method will be found to be very accurate when the amalgams consist of nearly pure silver or gold combined with the mercury, but if other metals exist with them the results are very uncertain.

It serves, however, not only as an approximate assay, but as a check on the distillation assay.

The retorts used for the determination of the amount of mercury contained in amalgams must be differently constructed to those which are used for Classes *A* and *B*, and are best made of cast steel, which is afterwards turned in the lathe to the required form.

FIG. 65. (¾ size.)



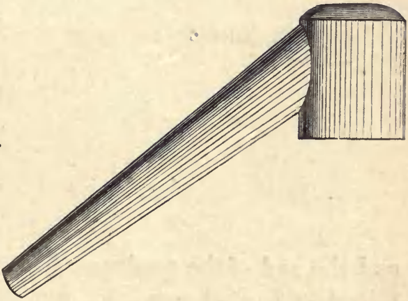
The retort is made 1 inch in height, which includes the cup and cap; the neck about 2 inches in length, having a gentle taper towards the end, which is made to fit into a good cork which has been previously placed in the glass condenser. (See fig. 65, cross section of the steel retort with glass condenser.)

Fig. 66, view of the cup and distillation pipe of the amalgam retort.

Fig. 67, view of the receiving cup of the amalgam retort.

Fig. 68, view of the glass condenser.

FIG. 66. (Full size.)



Ten to 30 grains of the amalgam to be examined is weighed, wrapped up in a small piece of tissue paper, and (the weight of ash, contained in a similar piece of the same paper, must always be determined in a quantitative assay) placed in the receiving cup (fig. 67). The cap is now placed firmly on. The joint being perfectly air-tight, no luting is necessary.

FIG. 67. (Full size.)

The condenser (fig. 68) is attached, and the retort placed in the charcoal furnace, which has now to be held firmly by the holder. See fig. 69, a side view of the holder and charcoal furnace, showing end of retort.

FIG. 68. (Full size.)

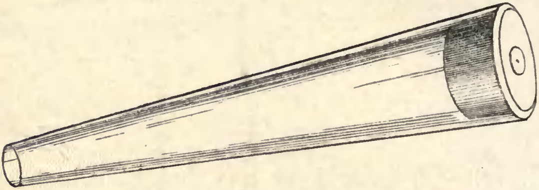
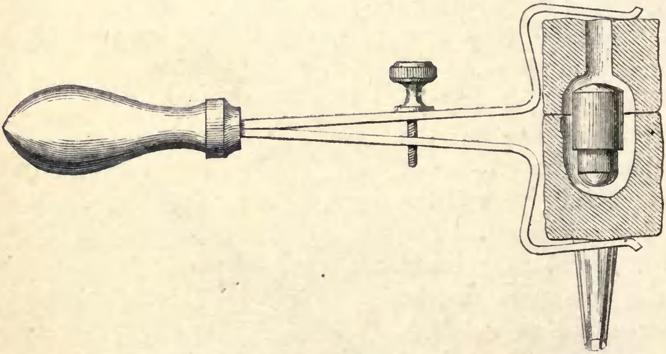


Fig. 70, a top view of the charcoal furnace and holder.

The furnace is now brought near the blowpipe lamp and the end of the condenser kept immersed in water contained in a small porcelain crucible.

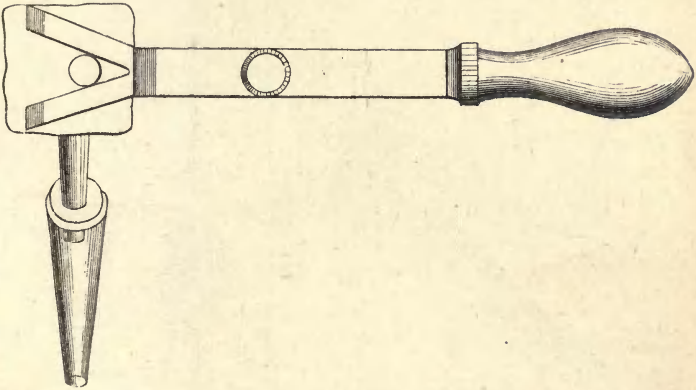
FIG. 69. (Half size.)



The heat is applied very quietly at first, but in a few minutes a strong R.F. may be applied through the hole in the lower part of the furnace. Flames will soon be seen coming out of the top hole of the furnace, and the retort will be found to be red hot. Keep it so for about two minutes, then cease blowing and allow the retort to cool.

See fig. 71, sectional view of blowpipe stand and lamp, with flame playing on the amalgam retort, which has been placed in the charcoal furnace; also a view showing the position of the condenser and receiver of the mercurial vapour.

FIG. 70. (Half size.)



The whole operation does not take ten minutes, and although the retort may appear large, the operator will find no difficulty even in obtaining a white heat if necessary; and in a few minutes the assay is completed.

The mercury is collected and weighed according to the methods laid down in Class *A*.

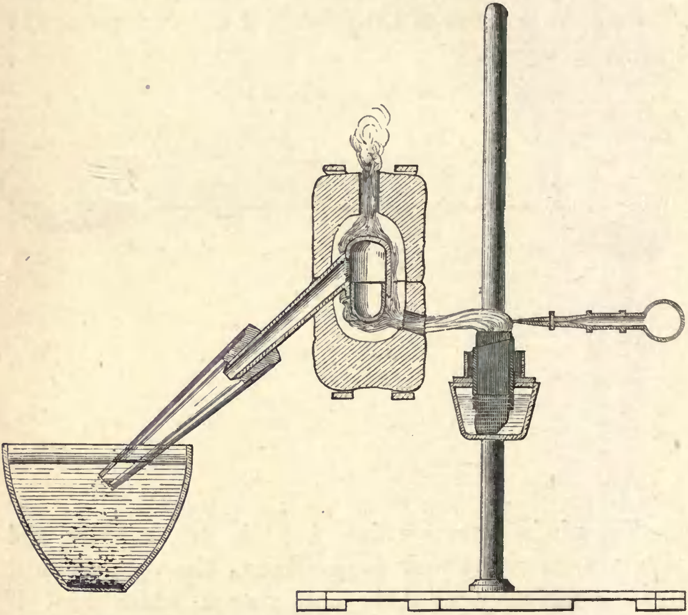
Most accurate results will be obtained by following the above instructions.

In Plattner's 'Manual of Qualitative and Quantitative Analysis with the Blowpipe,' by Prof. T. Richter, and translated by Henry B. Cornwall, and published 1873, on p. 509 will be found the following under the head of 'Assay for Mercury:'—

'This assay, essentially the same as that proposed by Domeyko and described in the "Berg- und Hüttenm.-Zeitung," 1845, No. 20, is very simple and exact.'

A glass tube, about 3 lines in diameter and 7 to 8 inches long, of not too thin glass, is bent as shown in fig. 72, and closed at one end, leaving the shorter arm *a* $1\frac{1}{2}$ to 2 inches long.

FIG. 71.[1] ($\frac{2}{5}$ size.)



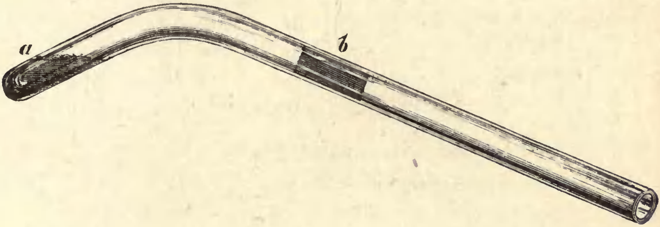
The tube is thoroughly dried, and then from 500 to 3,000 milligrammes of finely powdered ore, according to its richness, intimately mixed with 5 to 10 grammes litharge,

---

[1] The three different retorts, also charcoal holder, all originally designed by the author, were made by L. Cassella, 147 Holborn Bars, E.C., where similar ones can now be procured.

being introduced into it, the lower end is gradually heated over the spirit lamp until the whole mass is fused and the glass begins to soften. The moisture that may be present condenses in the middle of the tube, while the mercury will settle as a thin film, sometimes scarcely perceptible, on the sides of the glass (see fig. 72). When all of the mercury has been sublimed the tube is carefully heated, so as to concentrate the mercury as much as possible to a ring at *b*; the tube is allowed to cool, cut off with a file close to the ring, and the mercury then brushed together to one drop and transferred to a weighed capsule.

FIG. 72. (Half size.)



In this way 0·05 per cent. of mercury can be very readily determined, and the nature of the gangue has no influence upon the result. The excess of litharge serves not only to oxidise the sulphur and selenium, but also to remove the arsenic, antimony, and bitumen so frequently found in ores of mercury, and the resulting metal is so pure that it can be very easily and perfectly united in one drop.

COPPER.

Copper is a metal having a metallic lustre and of a copper-red colour. It has a streak, metallic shining, and is ductile and malleable with a hackly fracture.

Hardness, 2·5 to 3. Specific gravity, 8·838 when native.

The principal ores of copper are—

Copper sulphides	Copper glance	containing	79·7	per cent. copper.
	Chalcopyrite	,,	34·4	,,
	Bornite	,,	55·7	,,
	Bournonite	,,	13·0	,,
	Fahlerz	,,	30 to 48	,,
	Covelline	,,	66·7	,,
	Wolfsbergite	,,	24·9	,,
	Domeykite (copper arsenide)	,,	71·6	,,
Products containing copper sulphides	Copper regulus, copper speiss, &c.			
Oxidised copper ores and products	Red copper	containing	88·7	,,
	Malachite	,,	57·3	,,
	Azurite	,,	55·1	,,
	Cyanosite	,,	25·3	,,
	Phosphate of copper	,,	30 to 56	,,
	Arseniate	,,	25 ,, 50	,,
	Chromate, vanadate, and silicate of copper, slags, &c.			

Assay.

The assay for copper is divided into three classes, called *A*, *B*, and *C*.

Class A.

Consists of ores and products in which the copper is combined with volatile substances, such as sulphur, arsenic, and selenium.

Class B.

Consists of ores and products in which the copper exists as an oxide or is combined with chlorine.

Class C.

Consists of alloys containing copper.

Copper is separated by the blowpipe from its matrix or compounds by first freeing it from its combinations with sulphur, &c., by roasting the finely crushed substance with powdered charcoal or graphite. The oxidised mineral is then fused with soda, borax glass, and a small quantity of test lead. The soda reduces the copper oxides to metal, and the lead assists in the collection of the copper in the shape of a globule. The alloy of lead and copper is then fused on charcoal with boracic acid, which dissolves the lead and leaves a copper button.

The fire assay of copper is of great use to the smelter and miner. By observing the behaviour of the small assay sample under treatment, and by examining the copper prill or button obtained by the assay, a conclusion can be arrived at in regard to the quantity as well as the quality of the copper which will be produced from similar ores or products treated on a large scale in smelting works.

The fire assay always yields a smaller percentage of copper than that which is found by analysis or by assays made by the volumetric methods. With a little practice and care the following methods of assaying have been found to give equally as good results as the German fire assay. The latter is considered more accurate than the English fire assay:—

Class A.— Take $1\frac{1}{2}$ grain of the finely powdered ore and mix in the agate mortar with 3 to 4 times its *volume* of dry charcoal powder, or with $\frac{3}{4}$ grain graphite powder (N.B. the graphite used in an ordinary lead pencil answers very well); place the assay in a small clay capsule.

FIG. 73.
(Full size.)

The clay capsule should be painted with reddle before using (see fig. 73).

The assay is now ready for roasting.

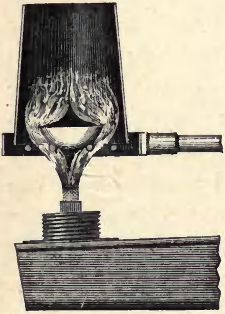
Place the roasting cup on the holder above the lamp flame (see fig. 74).

(The best fuel to use is common methylated spirit, as oil is apt to cover the cup with lampblack.)

Place over the roasting cup a small hollow cone made of thin sheet iron, which confines the heat and makes a mild form of a furnace.

The roasting is nearly complete in 10 minutes. Remove the assay again to the agate mortar, and mix it with 3 times its volume of dry powdered charcoal, or ½ a grain of graphite powder, and place it over the lamp as before, and continue the heat until no fumes of sulphur or arsenic are observed after stirring with a small piece of iron wire. For the success of the assay it is necessary that all the sulphur should be eliminated; therefore, to be certain of the assay, remove the cone, turn the support partly to one side and a little below or on a level with the lamp wick, and apply to the bottom of the cup a strong O.F. for a few moments.

FIG. 74. (Half nat. size).



The copper is now in the state of oxide mixed with various other metallic oxides and earthy matters, and the assay will be finished according to the plan adopted in Class *B*.

Class B.— The roasted ore, product, or mineral, having been reduced to the state of a fine powder, is mixed in the following proportions with a reducing flux :—

Ore[1]	1·5 grain.
Soda	3·0 grains.
Borax glass . .	0·5 grain.
Test lead . . .	0·5 ,,

---

[1] Ore belonging to Class *A* that has been weighed once need not be so again.

The assay is then removed to a small soda-paper cornet, previously placed in a deep bore on a piece of charcoal. A mild R.F. is first applied, and then finally a strong flame to unite all the metallic globules. This having been accomplished, the assay is allowed to cool, and the button is separated from the slag by enclosing it in a piece of thick paper and gently hitting it on the steel anvil with the hammer, after which it is treated as Class *C*.

Class C.—(*a*) Alloy of copper and lead.

The button obtained from Class *B* is now ready for refining, and will be assayed in a similar manner to a copper and lead alloy, viz. a small hole is made in a piece of sound charcoal, and boracic acid, equal in weight to the crude button containing copper, is melted on the charcoal. When the boracic acid is in a state of fusion the copper button is added. The R.F. is applied until the button and flux are dissolved; then an O.F. is applied, and continued until the lead has absorbed oxygen and has been taken into combination with the borax, and the remaining copper assumes a greenish colour.

The copper button is allowed to cool, and is separated from its surrounding impurities by folding it in a thick piece of paper and striking it gently on the steel anvil with a hammer.

The slag should be examined, to see if it has a reddish colour; if it has, it must be remelted with a strong R.F. on charcoal, and any globule of copper so obtained added to the larger button. A pure button of copper should be malleable.

If the copper ore or compound contains either gold or silver, they will be found alloyed with the button so obtained. To test for the above the button is cupelled and treated according to directions given in the Silver Assay.

(*b*) Alloy of copper and antimony.

Weigh out 1½ grain of the alloy and fuse in a small bore on charcoal. The O.F. alone is used after the assay melts, and it is continued until the antimony is burnt away.

The button obtained is then beaten on the anvil, and it should be malleable and not fracture if hammered out from two to three times its diameter. The button should also be tested for gold and silver.

N.B. Alloys of copper and tin, consisting of bronze, bell and gun metal, &c., also alloys consisting of copper with iron, nickel, cobalt, zinc, and bismuth, and sometimes containing lead, antimony, and arsenic, have afforded Plattner results not sufficiently satisfactory for a quantitative assay. The author has also experienced similar trouble in the quantitative separation of copper from the above alloys, and at present he cannot recommend any method to be used by the blowpipe beyond a qualitative determination.

LEAD.

Lead has occasionally been found native, but only in small quantities in the form of thin plates and small globules. It has a hardness of 1·5 and a specific gravity of 11·44 when pure, with a metallic lustre and a lead-grey colour, and is both malleable and ductile.

The ores of lead are numerous; the principal one, called galena, contains, when pure, lead 86·55 per cent. and sulphur 13·45 per cent.

For the purposes of assaying the ores of lead by the blowpipe the method adopted has been divided into two classes, according to the composition of the ore to be examined, and will be called *A* and *B*.

Class A.—Comprises galena and all lead ores containing either arsenic, phosphorus, or sulphur.

Class B.—Comprises all ores of lead and plumbiferous substances which are free from sulphur and arsenic, or contain only traces of the latter. Litharge, carbonate of lead and minium, are the chief substances which come under this class.

Assay.

Lead is extracted from its matrix by fusing the finely powdered mineral with metallic iron and a fluxing and reducing agent in a small crucible placed in the charcoal melting furnace. The earthy matters and non-reducible oxides and sulphides are slagged off, and a button of metallic lead will be found on the bottom of the crucible.

The assay of lead by fire is always attended with a heavy loss, as lead volatilises readily when strongly heated, and portions are also liable to be carried off in the slag.

Fire assays of lead ores, when compared with the results obtained by humid analysis, generally show a loss varying from 5 to 12 per cent. The fire assay, however, represents what is produced by smelting lead ores on a large scale, and it is therefore of great commercial use.

Class A.—Take of the finely crushed ore 2 grains, and mix with 3 grains dry carbonate of soda, 0·5 grain borax glass, 0·5 grain powdered charcoal, and 1 grain cyanide of potassium. In the small crucible (similar to what is used in the Silver Assay, p. 121) place two small pieces of wrought iron about the thickness and length of a small steel pen, and then pour in the assay; cover the assay with about 4 grains of common salt, but allow the ends of the iron pieces to project above the assay charge; put on the cover of the charcoal furnace, and screw the tightening pin; apply a R.F. through the opening made in the furnace, but apply it at first in a downward direction, so that the flame does not attack the bottom of the crucible. After a few minutes' blowing the assay commences to boil, and the furnace will be found to be at a good red heat. Do not increase the heat until, by a glance through the hole in the top of the furnace, the assay is found to be thoroughly fused; then increase the heat, and with a pair of iron pliers extract the pieces of iron one by one whilst the assay is in a thorough state of fusion. After the iron has been taken away allow the assay to cool slowly.

When cool, break the crucible between two pieces of paper on the steel anvil, and clean the lead button and weigh; examine the slag with a lens, and if any globules of lead are found add them to the larger button.

If numerous small globules are found in the slag the assay should be repeated. This assay only takes about 8 minutes, and if carefully made it will agree closely with fire assays made on a large scale.

The lead button frequently contains a large amount of copper. This can be ascertained by dissolving the lead with boracic acid in a deep bore on charcoal (see Copper Assay) and deducting the weight of the copper found from that already considered to be lead.

Lead nearly always contains silver, also gold; therefore the button should be cupelled and treated as silver lead (see Silver Assay). It should also be tested for gold (see Gold Assay).

Class B.—Mix the finely powdered material with 4 grains of carbonate of soda, and 1 grain of argol, and 0·5 grain borax glass

Place the mixture in a small crucible, and after covering with from 3 to 4 grains of common salt fuse and treat in a similar manner to Class *A*.

BISMUTH.

Bismuth native has a metallic lustre, the streak, and colour, silver white, with a reddish hue. It tarnishes readily. It has a hardness of 2–2·5 and specific gravity =9·72.

Native bismuth occurs in veins in gneiss and other crystalline rocks and in clay slate accompanying various ores of silver, cobalt, lead, and zinc.

The principal ores of bismuth are—

Sulphide: contains bismuth 81·3 per cent., sulphur 18·7 per cent.

Bismuth blende: contains oxide of bismuth 58·8 per cent., and is mixed with silica, arsenic, and small proportions of copper, iron, and cobalt.

Acicular bismuth: contains from 34 to 37 per cent. bismuth, combined with sulphur, copper, and lead.

Carbonate of bismuth: contains about 89·75 per cent. oxide of bismuth, combined with carbon dioxide and water.

Bismuth has also been found combined with tellurium, and exists in about the following proportions: bismuth 52 per cent., and tellurium 48 per cent.

The carbonates and oxides of bismuth, when mixed with their gangue, resemble in appearance some lead ores; and, as the assay is conducted in a similar manner, it often happens that until the button is examined for malleability, the difference is not discovered. Bismuth forms a brittle and coarsely crystalline button, having a bright fracture, which will not bear hammering on the anvil without breaking up into fragments, whilst lead is ductile and malleable.

The button, if pure, possesses, when fractured, a fine reddish colour.

If arsenic is present the button appears of a white colour.

Copper does not alloy with bismuth, but its presence can be detected by using a magnifying glass. When copper is present it will be found to be mixed and not alloyed.

Antimony gives the button a dull appearance, and the crystals are much finer.

Sulphur blackens bismuth.

Lead, when present, does not prevent bismuth from forming large crystals, but it is detected by the large crystals being studded all over with fine crystals

Assay.

Before making a determinative assay it is best to make a qualitative examination by taking about 1½ grain of the crushed ore or product and roasting at a gentle heat with powdered charcoal in a similar manner to the copper assay (see p. 147).

Then mix with 1½ grain soda, 1½ grain carbonate of potash, 0·5 grain borax glass, and a very small quantity of powdered charcoal. Place in the crucible two small pieces of metallic iron, add the assay charge, and cover with a thin layer of salt, and fuse according to directions given in the Lead Assay (p. 151). The difficulty in making the bismuth assay by this method is to obtain all the small shots of metal in one globule. It is seldom done, but the button or buttons which are formed can be separated from the flux and examined by hammering on the anvil, when the appearance of the fracture will, as described above, indicate the presence of other metals.

To collect bismuth in one button an addition of some other metal is necessary. Pure silver is considered the best and is generally employed.

The ores and products of bismuth are assayed in the following way:—

Take 1½ grain of the finely powdered mineral and roast on a small clay capsule in a similar manner to the copper assay. The heat required is not so great as that necessary in roasting copper ores, as bismuth is readily fusible and sinters if the heat applied is too great.

After roasting, mix the assay with 2 grains of finely precipitated pure silver, with 1½ grain soda, 1½ grain carbonate of potash, 0·5 grain borax glass, a small quantity of powdered charcoal, and place in the small crucible, in which two or three small pieces of iron have been previously placed; cover with a thin layer of salt and fuse as before directed. The button obtained consists of an alloy of silver and bismuth, but it is seldom clean enough to weigh without further treatment.

The button should be fused for a few moments on charcoal with a little borax glass. The flame employed must be a very mild R.F., as bismuth volatilises at a low temperature. When the surface of the assay becomes bright, stop blowing, allow it to cool, and then clean the button by brushing it.

Weigh, and deduct the weight of the silver previously added from the total found; the remainder should be bismuth.

Bismuth ores and products are generally associated with silver, and to ensure the assay being correct the author always makes a separate assay for silver by fusing 1½ grain of the mineral (see Silver Assay), and if any silver is present its weight is deducted from the button of bismuth silver found in the bismuth assay.

No fire assay of bismuth ores or products gives analytically accurate results. The blowpipe assay is made in less than half an hour, and is sufficiently accurate to guide the explorer or metallurgist in his practical estimation or treatment of the ores or products.

TIN.

Tin in a metallic state is probably only an artificial product.

J. A. Phillips states that tin has more than almost any other metal a characteristic mode of occurrence, being invariably found in the older crystalline and metamorphic rocks. This opinion is confirmed by Dana and others, and the author has observed the same peculiarity in the distribution of tin ores.

Metallic tin is a white metal with a lustre closely approaching that of silver and with a specific gravity of 7·29. It is easily distinguished from any other metal by the peculiar 'tin odour' which it gives to the hand or finger after it has been rubbed for a few moments.

The principal ore of tin is cassiterite, containing 78·62 tin and oxygen 21·38.

Tin has been found combined with sulphides of copper, iron, and zinc in Cornwall, in stannite, but the tin obtained was only 26 per cent.

The pure oxides of tin are readily assayed by a gentle fusion with a reducing flux in a small crucible before the blowpipe, when a pure metallic button is obtained; but, as many tin ores are combined with an excess of silica as well as some sulphur, arsenic, and tungsten, it is necessary to subject them to a preparatory treatment before fusing them in a crucible with a reducing flux.

Assay.

The tin assay is divided into four classes—

Class A.
Pure oxides of tin.
Class B.
Tin ores containing silica, also tin slags.

Class C.

Tin ores containing arsenic, sulphur, and tungsten.

Class D.

Ores containing under 5 per cent. of tin.

Class A.—Weigh out 1½ grain of the oxide, and intimately mix with 10 grains of cyanide of potassium and 1 grain of soda. Place the mixture in a crucible in the bottom of which has been previously placed and pressed down a small quantity of cyanide of potassium.

Remove the crucible to the charcoal furnace and fuse with a gentle heat. The time required to finish the assay is seldom more than 6 to 7 minutes. The assay can be watched, and the completion of the fusion ascertained by looking through the hole in the top of the furnace. When cold, break the crucible. The button should be of a silvery white colour. Dissolve the flux in warm water, and look carefully for any small shots of tin that may be present. If any are found they should be cleaned and then weighed with the large button.

The cyanide of potassium used for blowpipe assaying being pure, soda is added to secure the perfect fusion of any small quantities of silica or other impurities which generally accompany tin oxides.

The button of tin obtained should be rolled or hammered out, and then tested to see if it contains any lead or copper.

The above-described method, if carefully followed, affords accurate results.

Class B.—Silica being injurious to the extraction of tin by fusion, the ore to be examined should be first crushed up fine.

Take from 1 to 20 oz. of the crushed ore, according to its richness, and van carefully in the batéa.

Tin oxides have a specific gravity of about 7, and silica only a specific gravity of about 2·7; therefore the operator, by careful washing, can with safety separate the silica from the tin ore, or tin stone, as it is generally termed.

Remove the concentrated ore from the batéa to a small porcelain dish and carefully dry; then weigh; after weighing grind in the agate mortar and thoroughly mix. Then weigh out 1½ grain of the concentrated ore and proceed to melt, and determine as in Class *A*.

The percentage of tin in the original sample treated is ascertained by first noting the quantity weighed out for vanning, then noting the quantity of concentrated ore obtained, and then the amount of pure metallic tin extracted from 1½ grain of the concentrated ore.

Sometimes the tin ores cannot be washed down closely without a loss of tin; in such a case concentrate the ore as much as possible by washing, then dry and weigh.

Take 1½ grain of the concentrations and boil with hydrochloric acid in a platinum dish or porcelain capsule over the spirit lamp. The assay being finely powdered, the silica is dissolved. Tin oxide is insoluble in hydrochloric acid.

The dissolved silica is decanted off; the tin oxide is washed with a small quantity of water, then dried, and fused as in Class *A*.

Class C.—The removal of sulphur, arsenic, and tungsten from tin is necessary before tin can be extracted in a pure state from its ores by the blowpipe.

Take from 3 to 10 grains, according to the quality, of the finely powdered ore, and place it in a small flask; add a small quantity of nitro-hydrochloric acid (made up of 3 parts of hydrochloric to 1 part of nitric acid). Boil until the greater part of the mixed acids has evaporated. Allow the flask to cool, add water, settle, and decant, and so on until the water is free from acid. The insoluble residue consists of tin oxide, tungsten, and a little silica. Add a small quantity of caustic ammonia solution to the residue, and allow it to boil in the flask for about an hour; then decant and van the residue to remove the silica.

Dry the tin oxide and proceed to finish the assay according to the method adopted in Class *A*.

Class D.—Many ores of tin contain less than 5 per cent. of metallic tin.

To arrive at a correct assay of such ores it is necessary to treat a large quantity. Take about 5 lbs. in weight of the finely crushed ore and van carefully in the batéa, and afterwards treat according to the directions given in Classes *A*, *B*, and *C*.

IRON.

Native iron is rare. It has a hardness 4–5 and specific gravity = 7·3–7·8, with a metallic lustre and an iron-grey colour, also a streak shining. It is malleable, but has a hackly fracture and is strongly attracted by the magnet. Native iron must be considered only as a mineralogical curiosity, as it has rarely been found. Nearly all inorganic as well as organic substances that exist in nature contain more or less iron.

The principal ores from which iron is manufactured are those in which the iron is combined with oxygen and carbon, as oxides and carbonates.

Sulphides of iron are disseminated all over the globe, but they are rarely converted into metallic iron. *Magnetic* iron ore contains about 72·41 per cent. iron; the remainder is oxygen. *Specular* and red hematite ore contain about 70 per cent. iron and 30 per cent. oxygen.

Brown iron ore, or brown hematite, contains about 59·90 per cent. iron, and the rest consists of oxygen and water.

Carbonate of iron, or spathic iron, contains 48·22 per cent. iron, and the remainder carbon and oxygen.

Menaccanite (ilmenite), a titanic iron ore, varies in its composition; it contains about 36 per cent. of iron on the average.

Franklinite contains about 45·16 per cent. of iron, and the remainder is made up of zinc, manganese, and oxygen.

The assay of iron ores scarcely comes under the head of the blowpipe fire assay, as the most accurate as well as expeditious method of ascertaining the percentage of iron in a sample of ore is nearly all done by the humid process.

The reagents and apparatus required for the iron quantitative determination are necessary adjuncts to the blowpipe outfit; therefore, instead of using a tedious and a very unreliable method of extracting metallic iron by fire from its ores, the following plan has been adopted, as it affords correct results.

Assay.

Crush the iron ore in the steel mortar, and then grind to the finest possible powder in the agate mortar.

Weigh out 1½ grain of the finely powdered ore, and place the same in a small test tube; add a little hydrochloric acid. If the assay effervesces the ore is a carbonate, and the acid must be added little by little to avoid the loss of a portion of the assay; but if effervescence does not take place the acid can be poured over the assay at once. Heat the assay contained in the test tube over the spirit lamp until everything is in solution that the hydrochloric acid will take up. Then add a few drops of nitric acid and again boil the assay over the spirit lamp.

The assay having been thoroughly boiled, is allowed to cool, and the solution is diluted with distilled water.

If, on dilution, any sediment is found, it must be separated by filtration, and the filter must be examined with great care in regard to colour. If white, the sediment contains no iron. If red, yellowish, or grey, it contains undissolved iron, and it must be treated by carefully drying it on a procelain dish over the lamp. When dry, mix it with 3 times its volume of soda and an equal part of borax glass; wrap the mixture in a soda-paper cornet, and fuse it on charcoal in a deep bore with an O.F. until the mass is thoroughly fused and transparent.

When the fused mass is cold, remove it to the steel mortar and crush. After crushing, boil with HCl in a small porcelain dish, and add a few drops of nitric acid before the boiling is stopped, and heat slightly for a few moments to allow oxidation to take place. The solution is then slowly evaporated to dryness over the lamp. A few drops of HCl are added to the dry mass, and then some distilled water, and it is again warmed over the lamp.

After warming filter, and add the filtrate to the first solution. The residue, collected on the filter, should be silica.

Add a few drops of sulphuric acid to the solution and stir. If anything like a white precipitate is seen baryta is present, and the solution must be allowed to settle. The sulphate of baryta is separated from the iron solution by filtering.

If the iron ores are pure, the troublesome operations of dissolving the sediment and separating the baryta, &c., are dispensed with, and the assay is quickly finished. Add ammonia to the iron solution. Iron and alumina are both thrown down together by the above alkaline precipitant. To obtain an oxide of iron sufficiently pure to weigh, it is always necessary to separate alumina from the iron oxide.

Alumina is separated from the iron oxides by attacking the moist precipitate with caustic potash; the latter dissolves the alumina, leaving the iron oxide.

The assay is now proceeded with by drying the precipitate of iron oxides and alumina remaining on the filter paper.

Before the paper becomes quite dry remove the precipitate from the filter paper with a spatula or small knife. The filter paper should be placed in a porcelain dish with a little HCl and washed with a little warm water, and this solution added to the main precipitate. In a small beaker or large test tube boil the iron and alumina precipitate with a strong solution of caustic potash.

Then dilute with water and collect the sesquioxide of iron on a filter. Warm the filter containing the precipitate, and when the filter is nearly dry remove the iron oxide from the filter to a porcelain capsule. Burn the filter paper by the blowpipe over a porcelain or platinum dish, and add the ash and what iron oxide it contains to the main precipitate. Dry the precipitate and apply a good red heat to the capsule containing it.

The iron oxide is now weighed, and after deducting the weight of the ash contained in the filter paper the metallic iron may, according to Plattner, be estimated as follows:—

'100 parts of the sesquioxide of iron correspond almost exactly to 70 parts of metallic iron; so that it may be conveniently calculated as 70 parts. If the percentage of raw iron which a dry assay in a charcoal crucible would give is required, it may be easily calculated by assuming the raw iron from the crucible to contain on an average, in 100 parts, 96 parts of iron and 4 parts of carbon.'

The above-described method of assaying iron ores affords accurate results, and when such a small quantity as $1\frac{1}{2}$ grain is operated upon the assay can be completed in about 30 minutes and a correct report given.

NICKEL.

Nickel ores have generally a pale colour and a metallic lustre.

The principal ores of nickel are :—

Copper nickel (*kupfernickel*) has a specific gravity of 7·3 to 7·5, and consists of 44 per cent. of nickel and 56 per cent. of arsenic.

White nickel, an arsenical ore, contains from 20 to 30 per cent. of nickel.

Nickel glance is an arsenical ore, but contains sulphur. It carries from 20 to 38 per cent. of nickel.

Antimonial nickel contains about 29 per cent. of nickel and no sulphur.

Millerite is a brass-yellow sulphide of nickel, containing 64 per cent. of nickel.

Pentlandite is a double sulphide of iron and nickel, and contains from 10 to 21 per cent. of nickel.

Assay.

The assay for nickel alone will be confined to the ore called kupfernickel, and the remaining varieties will be treated fully under the head of 'Nickel and Cobalt.'

Kupfernickel, when pure, consists of arsenic 55·93, nickel 44·07, but it generally contains about 1 per cent. of foreign matter, such as iron, cobalt, lead, and sulphur.

Take 1 grain of the finely powdered ore and mix with $\frac{1}{4}$ grain of borax glass, and fuse on charcoal with the R.F. After the assay is in a state of fusion treat it with the outer point of the O.F. until the arseniate of nickel commences to oxidise; then dip the globule and slag whilst still hot in water, to separate the slag, which is easily done with the fingers; then heat the globule in a deep bore (in charcoal) with a weak R.F., keeping it in fusion with a bright surface until all excess of arsenic is volatilised. The globule that remains will weigh about 0·71 grain, and is Ni_4As, which contains arsenic 38·825 and nickel 61·175, and the impurities present account for the loss.

Care must be taken not to use an excess of borax glass, as sufficient surface would not be exposed for oxidation.

COBALT.

Cobalt ores generally have a tin-white to steel-grey colour. The principal ores:—

Smaltine has a specific gravity of 6·4 to 7·2, and contains from 3 to 14 per cent. of cobalt, with from 60 to 75 per cent. of arsenic; the remainder is generally nickel and iron, with sometimes a trace of copper.

Cobaltite, or glance cobalt, has a specific gravity of 6 to 6·3, and contains about 35·5 per cent. of cobalt, with sulphur 19·3 and arsenic 45·2. The cobalt is sometimes largely replaced by iron and sparingly by copper.

Erythrite (cobalt bloom) has a pinkish purple colour, resembling that of a peach blossom, and when scratched it affords a greenish streak. It is composed of about 39 per cent. of cobalt oxide, of 37 per cent. of arsenic anhydride, and 22 per cent. of water.

Cobalt sometimes is found in mispickel (arsenic pyrites).

Assay.

A full description of the assay of the ores of cobalt will be described under the head of 'Nickel and Cobalt,' and only one variety of cobalt ore will be treated separately for cobalt.

Skutterudite contains, when pure, arsenic 79·26 and cobalt 20·74, with the occasional replacement of about 2 per cent. of the cobalt by some nickel and iron.

Take 1 grain of the crushed ore and mix with 0·5 grain of soda and 0·15 grain of borax glass in a soda-paper cornet, and treat on charcoal with a R.F. until all the metallic particles are united in one globule. By this means the small quantity of iron present is slagged and the greater part of the arsenic volatilised. If sulphur is present it unites with the flux, but causes the latter to become in a great part absorbed in the charcoal.

If the metallic globule be now freed from adhering slag, and be heated in a deep bore in charcoal with a R.F., and kept fluid until no more arsenic volatilises, the globule left will weigh about 0·33 grain.

The R.F. must be only strong enough to keep the metal fluid with a bright surface. If too violent a flame is applied the assay will boil and spurt, causing a mechanical loss.

The globule now consists of cobalt 61·131, and arsenic 38·869.

NICKEL AND COBALT ASSAYS.

Plattner's method of conducting the above assay is the one chiefly adopted in this work, but with many modifications.

As cobalt and nickel cannot be separated from their compounds in the metallic state by fusion, like silver, gold, lead, &c., they are separated by combining them with arsenic.

The mixed combination of nickel, cobalt, and arsenic is weighed; the arsenide of cobalt is then slagged off, leaving an arsenide of nickel, which can be weighed as such, and the amount of metallic nickel calculated from it. The percentage of cobalt is estimated from the difference in weight between the mixed arsenides and that of the arsenide of nickel found. The assay is not only easy but accurate. The assay has been divided into two classes, called *A* and *B*.

Class A.

Consists of all nickel and cobalt ores and products which are *not* combined with arsenic.

Class B.

Consists of all nickel and cobalt ores and products which *are* in combination with arsenic.

Class A (a).—If nickel and cobalt compounds are not in the state of arsenides they require to be made so and then fused to form a button of metallic arsenides before they can be estimated quantitatively by the blowpipe; therefore Class *A* treats of the arsenides solely.

Take 1½ grain of the ore or product, and if any sulphides are present roast according to directions given in Copper Assay (p. 147). Finish the roasting (when all odour has ceased to be evolved) by an addition of 1 grain of carbonate of ammonia, which must be previously triturated with the assay in the agate mortar.

If sulphur is absent the roasting is dispensed with.

Take the oxidised assay and mix it with 1 to 2 grains of metallic arsenic in a small clay crucible; place the crucible in the charcoal furnace on an iron wire ring, and fuse at a mild heat. It is generally advisable to cover the crucible with a clay capsule. This assay should be conducted outside, as the arsenical fumes are poisonous in a room. The contents of the crucible are carefully detached, and are then treated according to Class *B*.

If the arsenicising must be done in the room, take 0·75 grain of the nickel and cobalt oxides and mix with 1·5 grain *powdered* metallic arsenic, and wrap in a small soda-paper cornet. Place the assay in the bottom of a small tube closed at one end.

Place in the mouth of the tube a small roll of dry filter paper, to absorb the moisture evolved from the charred soda paper. Heat the assay gradually over the spirit lamp to redness.

Turn the tube every now and then, to prevent the charred paper adhering to the sides of the tube. Continue the heat until no more sublimate of arsenic is found on the inside of the tube.

Cut off the lower portion of the tube (by using a file) containing the assay, and remove carefully.

The assay is now treated as Class *B*. If the oxide consists chiefly of protoxide of nickel and oxides of cobalt in which the former prevails, the resulting arsenides can easily be melted to one button during the fusion in the crucible; if, however, oxide of cobalt prevails, the resulting arsenides melt with difficulty, and about 0·25 grain of iron filings must be added, so as to form arsenide of iron, which produces a fusible combination with the arsenide of cobalt in the subsequent fusion.

Class B (*a*) consists of nickel and cobalt, combined with arsenic and some iron.

Take 1½ grain of the finely powdered mineral, and mix on the agate mortar with 0·8 grain soda, 0·20 grain borax glass. Place a soda-paper cornet in a deep bore in charcoal, and fuse with a moderate R.F. until the flux has become a slag and the metallic particles have united to a button. Cool the button in water to remove the slag. Fuse the button on a cavity in charcoal with a mild R.F. until the button shows a bright surface and assumes a rotary motion. The iron has then been slagged off. Continue to keep the button in fusion until all fumes of arsenic have ceased to be evolved.

Allow the button to cool, and weigh; the weight gives the sum of $(CoNi)_4As$.

The amount of metal in the weighed arsenides is as follows:—

Co_4As	61·5 per cent.	cobalt.
Ni_4As	60·7 ,,	nickel.

Sometimes it is difficult to slag off the last traces of the iron; in such a case add a little borax glass, and fuse until the button shows a perfectly bright surface.

The button having been weighed, the cobalt is next slagged off by fusing with a moderate R.F. in a cavity on charcoal, a small quantity of borax glass having been previously added.

Cobalt separates slowly, and until it is all gone the solidified button is always covered with a black crust of oxide. The brightening of the button continues on adding fresh borax so long as the arsenide of cobalt is present; but when all of the cobalt is separated, and the arsenide of nickel begins to oxidise, a film of basic arseniate of nickel forms, which moves slowly about the surface.

If the blast is stopped as soon as the phenomenon above described can be distinctly perceived, and a part of the glass immediately pinched out and slowly raised, remaining still connected with the main portion, it appears generally rather violet than blue against the daylight, provided it is not too strongly coloured with cobalt.

If all the cobalt had been separated the glass would only appear pale brown. On the surface of the remaining arsenide of nickel beside the purple glass is seen an apple-green film of basic arseniate of nickel, which indicates that only Ni_4As remains.

The Co_4As is completely slagged off, while the Ni_4As retains none of the arsenic from it, and therefore both metals can be quantitatively determined in the compounds.

If proper care is taken in making the above assay the loss of nickel (even if a large film is observed on the surface of the assay) is so small that it can scarcely be determined on the fine assay balance.

Class B (*b*) consists of ores and products in which nickel, cobalt, copper, and iron are combined with a small quantity of arsenic.

Take 1½ grain for assay and treat in a similar manner to Class *A*. After the cobalt has been slagged off any copper that is present will be found combined with the nickel compound as

Ni_4As and Co_6As.

If the amount of copper present exceeds that of nickel it must be treated by the humid method. After weighing the button of nickel, copper, and arsenic, add 1 grain of pure gold, and fuse with a moderate heat on a cavity on charcoal with a small quantity of salt of phosphorus.

Allow air to get access to the button. Arsenide of nickel soon dissolves in the glass, making the glass a pure yellow colour.

When the salt has become saturated, cool the button in water, remove the slag, and again fuse with a fresh portion of the salt, and treat until its surface ceases to be covered with a film of oxide and begins to show a bluish green colour. Cool the button in water, and then separate the last portions of arsenide of nickel by fusing as usual with a little borax on charcoal.

If the cupriferous gold button shows a clean, metallic, lustrous surface, and does not crack when beaten out cold, it is weighed, and the copper determined from the increase in weight.

Arsenide of copper has the following composition:—

Cu_6As . .	71·7 per cent.	copper.
	28·3 ,,	arsenic.

Class B (*c*) consists of arsenides of nickel, cobalt, iron, copper, also brass and products containing lead, bismuth, zinc, sulphur, and earthy matters.

1½ grain of the finely powdered mineral is roasted according to directions given in Class *A*, and also afterwards arsenicised as there directed.

Mix the assay with 3 grains soda, 2 grains potash, and 0·5 grain borax glass. Add 1 grain pure silver. Place the mixture in the clay crucible, in which a small piece of iron has been added, cover with a thin layer of salt, and, after covering with a clay cup, fuse as directed in the Lead Assay (p. 151).

The heat must be sharp towards the end, to collect the arsenide in one button.

In five or six minutes the arsenides collect in a round button at the bottom, and the earthy matters and oxides, which do not separate in the metallic state, are completely slagged off. The iron passes into the metallic arsenides, and the lead or bismuth passes into an alloy with the silver, which unites with the arsenides in one button, but which can be easily mechanically separated. The quantity of lead or bismuth present can be estimated by first weighing the alloy and then cupelling it, when the loss will be either lead or bismuth. The presence of either should be looked for by the qualitative test beforehand.

If any zinc or antimony is present it is volatilised when the arsenide of iron is removed with borax.

The assay is now finished according to instructions given in Class *B* (*b*) (p. 169).

Class B (*d*).—Some ores are so poor in nickel and cobalt that they require a collecting agent, which can afterwards be easily slagged off. Take 1½ grain of the powdered ore; mix with 0·40 grain of arsenide of iron (made by fusing iron filings with metallic arsenic in a clay crucible), 2 grains potash, 3 grains soda, and 0·5 grain borax glass; cover with a thin layer of salt, and finish as directed in *c* and *d*, Class *B*.

Alloys of copper and nickel in which copper predominates cannot be estimated by the fire assay, but have to be determined by the wet way. Alloys of nickel, cobalt, and antimony cannot be determined by the blowpipe.

COAL.

Coal (or rather mineral coal) occurs in beds interstratified with shales, sandstones, and conglomerates, and sometimes limestones, forming distinct layers, which vary from a fraction of an inch to 30 feet or more in thickness.

Its hardness varies from 0·5 to 2·5, and its specific gravity from 1 to 1·80. Lustre dull to brilliant, and either earthy, resinous, or submetallic. Colour black, greyish black, brownish black, and occasionally iridescent; also sometimes dark brown and opaque. Fracture conchoidal to uneven.

Brittle; rarely somewhat sectile. Without taste, except from impurities present.

The origin of coal is mainly vegetable, though animal life has contributed somewhat to the result.

Coal beds were once beds of vegetation, which have been buried during different geological ages. The carboniferous period furnishes the greatest and best supply, but it is also found in beds of the Triassic, Oolitic, Cretaceous, and Tertiary eras.

The principal varieties of coal are as follows:—

Anthracite, or Hard Coal.—Hardness 2–2·5; spec. grav. = 1·32–1·70. Contains volatile matter after drying, 3 to 6 per cent. Contains carbon, 80 to 95 per cent. It has a high lustre and burns without flame, as it contains little or no bitumen. It is totally devoid of impressions of plants, and is, geologically speaking, the oldest of all kinds of fossil charcoal and is regarded as the last stage of carbonisation. It yields from 1 to 7 per cent. of ash, but 3 per cent. may be called the average.

Brown Coal, or *Lignite*, contains from 57 to 70 per cent. of carbon, and represents the first stage of carbonisation, and is a coal of comparatively recent formation. It is composed of fossil plants more or less mineralised, and when burnt it evolves much smoke and affords a dull flame, and generally yields a large quantity of ash. It contains from 2 to 19 per cent. ash and gives from 30 to 50 per cent. coke.

Caking Coal.—A bituminous coal which softens and becomes pasty in the fire, and after the heat has been continued for a time the volatile ingredients are driven off, and a greyish black fretted mass is left. The coke obtained from this coal varies from 50 to 85 per cent.

Non-Caking Coal resembles the above in its external character, but burns freely without softening or showing any appearance of incipient fusion.

Cannel Coal.—A bituminous coal which generally cakes. It is compact, with little or no lustre, and has a dull black or greyish black colour. On distillation it affords, after drying, 40 to 66 per cent. of volatile matter.

When held in the flame of a candle it easily ignites, burning with a steady bright flame. It is used extensively for the manufacture of illuminating gas, of which it affords a better quality than any other species of coal.

Coal can be examined and its commercial properties determined by the blowpipe with great accuracy.

Assay.

The assay is divided into five heads :—

1st. The moisture determination.

Select from the mass of coal to be examined a few lumps representing as nearly as possible the average quality. Crush them up in the agate mortar into small pieces about the size of a mustard seed.

Weigh out 5 grains, place in a small porcelain dish, and dry at a gentle heat over the spirit lamp. Hard coals sometimes fly when heated, so it is best to cover the dish with a watch glass whilst heating. After about 5 minutes remove the assay and weigh; then repeat the heating and again weigh. As soon as the weights agree the assay is ready to be converted into coke. Plattner states that the percentage of moisture is lowest in anthracite; in bituminous coals it is usually 3 to 4 per cent., seldom 6 to 7, and reaches its maximum in lignite and brown coals, which contain 20 per cent. and sometimes more.

2nd. Determination of the coke production.

Take the dried coal and remove to a clay or platinum crucible, and cover with a small roasting clay dish or platinum cup. Place the crucible on a triangle of platinum wire on the blowpipe stand under the flame, using alcohol, and cover it with a small sheet-iron funnel (the same that is used in roasting copper ores). The heat is continued until all the volatile gas has escaped, when the assay generally will appear to possess a fused porous appearance, and to have a metallic lustre.

The coke so made is now removed and weighed. It should be weighed quickly, as coke absorbs moisture from the air rapidly. The coking takes about 10 minutes, and the crucible should not be allowed to get beyond a red heat.

3rd. The estimation of the amount of ash.

After the percentage of coke has been determined remove the assay to a small clay or platinum capsule, and, without using a cover, again heat over the lamp—this time to a bright red colour—until all the carbon has been consumed. The operation is much facilitated by occasionally stirring the assay with a piece of platinum wire, also by applying the blowpipe flame to the bottom of the cup when the assay is nearly finished.

If alcohol cannot be obtained the assay for coke and ash can be conducted in the charcoal furnace by using the blowpipe flame, as in the copper assay, and if the ash amounts to more than 5 per cent. the value of the coal is much diminished. If the ash presents a brown, red, or grey colour, sesquioxide of iron has been formed by the oxidation of the pyrites in the coal.

4th. Determination of the absolute heating power by Berthier's process.

Take an average sample of the coal and crush it up to the finest powder. Weigh out 0·3 grain of the coal dust and mix it with 12 grains of oxychloride of lead, and after placing the mixture in the crucible cover it with an additional 12 grains of oxychloride of lead.

Oxychloride of lead fuses more readily than litharge; therefore, owing to the large quantity of material which must be brought into a state of fusion in this determination, it is employed instead of litharge.

The assay is next covered with a little powdered glass, also with a few spoonfuls of borax glass. A clay cup is placed over the crucible, and the assay is then fused in the charcoal furnace in a similar manner to the silver assay when litharge is used (see p. 122).

About 7 or 8 minutes suffices to melt the assay, and the lead button produced by the carbon in the coal acting on the lead oxychloride will be found lying upon the bottom of the crucible when the assay is cool and the crucible is broken.

The weight of the button, when cleaned from the slag, divided by 20, gives the quantity of lead that 1 part of the fuel under examination can reduce; and since 1 part of carbon reduces 34 parts of lead, the heating power of the fuel may be easily ascertained. The amount of lead reduced by 1 part of coal varies with the different pit coals between 21 and 32 parts, with the lignites between 16 and 25 parts. In making this assay the heat must be applied at first very gradually, and afterwards increased to a bright redness.

Dr. Ure's experiments, published in the 'Supplement to the Dictionary of Arts, Mines, and Manufactures,' have appeared to be unsatisfactory in regard to the accuracy of Berthier's method. Mitchell, however, has found the method correct, and the author has found it equally so. The lead oxychloride should always be pure.

5th. Estimation of sulphur in a sample of coal.

Sulphur generally exists in coal as a sulphide of iron, and as the presence of more than 2 per cent. of sulphur depreciates the market value of coal, owing to its destroying the iron boilers and grates under and over which the coal is consumed, it is always an important part of the examination of coal to ascertain the quantity present.

Mitchell, in his 'Manual of Practical Assaying,' recommends the following process:—

'Take 1 part of the finely pulverised coal and mix with 7 to 8 parts of nitre, and 16 parts of common salt, and 4 parts of carbonate of potash, all of which must be perfectly pure. The mixture is then placed in a platinum crucible and gently heated at a certain temperature; the whole ignites and burns quietly. The heat is then increased until the mass is fused; the operation is finished when the mass is white. It must, when cold, be dissolved in water, the solution slightly acidulated by means of hydrochloric acid, and chloride of barium added to it as long as a white precipitate forms. This precipitate is sulphate of baryta, which must be collected on a filter, washed, dried, ignited, the filter burnt away, and the remaining sulphate of baryta weighed: every 116 parts of it indicate 16 of sulphur.'

The above-described methods of examining coal are all that are required for commercial purposes. The assay may be carried on still further by estimating the iron oxide contained in the ash, according to the instructions given in the quantitative iron assay. The ash can also be examined qualitatively for silica, lime, soda, and potash (see 'Qualitative Determination').

PART IV.

TABLES OF ENGLISH AND AMERICAN VALUES OF GOLD ACCORDING TO ITS FINENESS;

ALSO THE

VALUE OF GOLD COINS IN THE UNITED STATES OF AMERICA.

Table of the English Mint Value of Gold per Ounce Troy, at Different Degrees of Fineness.

Fineness of Gold	Value per Ounce			Fineness of Gold	Value per Ounce		
	£	s.	d.		£	s.	d.
1000	4	4	11·4545	962	4	1	8·7152
999	4	4	10·4350	961	4	1	7·6958
998	4	4	9·4156	960	4	1	6·6763
997	4	4	8·3961	959	4	1	5·6569
996	4	4	7·3767	958	4	1	4·6374
995	4	4	6·3572	957	4	1	3·6179
994	4	4	5·3378	956	4	1	2·5985
993	4	4	4·3183	955	4	1	1·5790
992	4	4	3·2989	954	4	1	0·5596
991	4	4	2·2793	953	4	0	11·5401
990	4	4	1·2600	952	4	0	10·5207
989	4	4	0·2405	951	4	0	9·5012
988	4	3	11·2210	950	4	0	8·4818
987	4	3	10·2016	949	4	0	7·4623
986	4	3	9·1821	948	4	0	6·4429
985	4	3	8·1627	947	4	0	5·4234
984	4	3	7·1432	946	4	0	4·4039
983	4	3	6·1238	945	4	0	3·3835
982	4	3	5·1043	944	4	0	2·3650
981	4	3	4·0849	943	4	0	1·3456
980	4	3	3·0654	942	4	0	0·3261
979	4	3	2·0459	941	3	19	11·3067
978	4	3	1·0265	940	3	19	10·2872
977	4	3	0·0070	939	3	19	9·2678
976	4	2	10·9876	938	3	19	8·2483
975	4	2	9·9681	937	3	19	7·2289
974	4	2	8·9487	936	3	19	6·2094
973	4	2	7·9292	935	3	19	5·1899
972	4	2	6·9098	934	3	19	4·1705
971	4	2	5·8903	933	3	19	3·1510
970	4	2	4·8709	932	3	19	2·1316
969	4	2	3·8504	931	3	19	1·1121
968	4	2	2·8319	930	3	19	0·0927
967	4	2	1·8125	929	3	18	11·0732
966	4	2	0·7930	928	3	18	10·0538
965	4	1	11·7736	927	3	18	9·0343
964	4	1	10·7541	926	3	18	8·0149
963	4	1	9·7347	925	3	18	6·9954

Table of the English Mint Value of Gold—continued.

Fineness of Gold	Value per Ounce			Fineness of Gold	Value per Ounce		
	£	s.	d.		£	s.	d.
924	3	18	5·9759	882	3	14	11·1589
923	3	18	4·9565	881	3	14	10·1394
922	3	18	3·9370	880	3	14	9·1199
921	3	18	2·9176	879	3	14	8·1005
920	3	18	1·8981	878	3	14	7·0810
919	3	18	0·8787	877	3	14	6·0616
918	3	17	11·8592	876	3	14	5·0421
917	3	17	10·8398	875	3	14	4·0227
916	3	17	9·8203	874	3	14	3·0032
915	3	17	8·8009	873	3	14	1·9838
914	3	17	7·7814	872	3	14	0·9643
913	3	17	6·7619	871	3	13	11·9449
912	3	17	5·7425	870	3	13	10·9254
911	3	17	4·7230	869	3	13	9·9059
910	3	17	3·7036	868	3	13	8·8865
909	3	17	2·6841	867	3	13	7·8670
908	3	17	1·6647	866	3	13	6·8476
907	3	17	0·6452	865	3	13	5·8281
906	3	16	11·6258	864	3	13	4·8087
905	3	16	10·6063	863	3	13	3·7892
904	3	16	9·5869	862	3	13	2·7698
903	3	16	8·5674	861	3	13	1·7503
902	3	16	7·5479	860	3	13	0·7309
901	3	16	6·5285	859	3	12	11·7114
900	3	16	5·5090	858	3	12	10·6919
899	3	16	4·4896	857	3	12	9·6725
898	3	16	3·4701	856	3	12	8·6530
897	3	16	2·4507	855	3	12	7·6336
896	3	16	1·4312	854	3	12	6·6141
895	3	16	0·4118	853	3	12	5·5947
894	3	15	11·3923	852	3	12	4·5752
893	3	15	10·3729	851	3	12	3·5558
892	3	15	9·3534	850	3	12	2·5363
891	3	15	8·3339	849	3	12	1·5169
890	3	15	7·3145	848	3	12	0·4974
889	3	15	6·2950	847	3	11	11·4779
888	3	15	5·2756	846	3	11	10·4585
887	3	15	4·2561	845	3	11	9·4390
886	3	15	3·2367	844	3	11	8·4196
885	3	15	2·2172	843	3	11	7·4001
884	3	15	1·1978	842	3	11	6·3807
883	3	15	0·1783	841	3	11	5·3612

Table of the English Mint Value of Gold—continued.

Fineness of Gold	Value per Ounce			Fineness of Gold	Value per Ounce		
	£	s.	d.		£	s.	d.
840	3	11	4·3418	798	3	7	9·5247
839	3	11	3·3223	797	3	7	8·5052
838	3	11	2·3029	796	3	7	7·4858
837	3	11	1·3834	795	3	7	6·4663
836	3	11	0·2639	794	3	7	5·4469
835	3	10	11 2445	793	3	7	4·4274
834	3	10	10·2250	792	3	7	3·4979
833	3	10	9·2056	791	3	7	2·3885
832	3	10	8·1861	790	3	7	1·3690
831	3	10	7·1667	789	3	7	0·3496
830	3	10	6·1472	788	3	6	11·3301
829	3	10	5·1278	787	3	6	10·3107
828	3	10	4·1083	786	3	6	9 2912
827	3	10	3·0889	785	3	6	8·2718
826	3	10	2·0694	784	3	6	7·2523
825	3	10	1·0499	783	3	6	6·2329
824	3	10	0·0305	782	3	6	5·2134
823	3	9	11·0110	781	3	6	4·1939
822	3	9	9·9916	780	3	6	3·1745
821	3	9	8·9721	779	3	6	2·1550
820	3	9	7·9527	778	3	6	1·1356
819	3	9	6 9332	777	3	6	0·1161
818	3	9	5·9138	776	3	5	11·0967
817	3	9	4·8943	775	3	5	10 0772
816	3	9	3·8749	774	3	5	9·0578
815	3	9	2·8554	773	3	5	8·0383
814	3	9	1·8359	772	3	5	7·0189
813	3	9	0·8165	771	3	5	5·9994
812	3	8	11 7970	770	3	5	4·9799
811	3	8	10·7776	769	3	5	3·9605
810	3	8	9·7581	768	3	5	2·9410
809	3	8	8·7387	767	3	5	1·9216
808	3	8	7·7192	766	3	5	0 9021
807	3	8	6·6998	765	3	4	11·8827
806	3	8	5·6803	764	3	4	10·8632
805	3	8	4 6609	763	3	4	9·8438
804	3	8	3·6414	762	3	4	8·8243
803	3	8	2·6219	761	3	4	7·8049
802	3	8	1·6025	760	3	4	6·7854
801	3	8	0·5830	759	3	4	5 7659
800	3	7	11·5636	758	3	4	4·7465
799	3	7	10·5441	757	3	4	3·7270

Table of the English Mint Value of Gold—continued.

Fineness of Gold	Value per Ounce			Fineness of Gold	Value per Ounce		
	£	s.	d.		£	s.	d.
756	3	4	2·7076	714	3	0	7·8905
755	3	4	1·6881	713	3	0	6·8710
754	3	4	0·6687	712	3	0	5·8516
753	3	3	11·6492	711	3	0	4·8321
752	3	3	10·6298	710	3	0	3·8127
751	3	3	9·6103	709	3	0	2·7932
750	3	3	8·5909	708	3	0	1·7738
749	3	3	7·5714	707	3	0	0·7543
748	3	3	6·5519	706	2	19	11·7349
747	3	3	5·5325	705	2	19	10·7154
746	3	3	4·5130	704	2	19	9·6959
745	3	3	3·4936	703	2	19	8·6765
744	3	3	2·4741	702	2	19	7·6570
743	3	3	1·4547	701	2	19	6·6376
742	3	3	0·4352	700	2	19	5·6181
741	3	2	11·4158	699	2	19	4·5987
740	3	2	10·3963	698	2	19	3·5792
739	3	2	9·3769	697	2	19	2·5598
738	3	2	8·3574	696	2	19	1·5403
737	3	2	7·3379	695	2	19	0·5209
736	3	2	6·3185	694	2	18	11·5014
735	3	2	5·2990	693	2	18	10·4820
734	3	2	4·2796	692	2	18	9·4625
733	3	2	3·2601	691	2	18	8·4430
732	3	2	2·2407	690	2	18	7·4236
731	3	2	1·2212	689	2	18	6·4041
730	3	2	0·2018	688	2	18	5·3847
729	3	1	11·1823	687	2	18	4·3652
728	3	1	10·1629	686	2	18	3·3458
727	3	1	9·1434	685	2	18	2·3263
726	3	1	8·1239	684	2	18	1·3069
725	3	1	7·1045	683	2	18	0·2874
724	3	1	6·0850	682	2	17	11·2680
723	3	1	5·0656	681	2	17	10·2485
722	3	1	4·0461	680	2	17	9·2290
721	3	1	3·0267	679	2	17	8·2096
720	3	1	2·0072	678	2	17	7·1901
719	3	1	0·9878	677	2	17	6·1707
718	3	0	11·9683	676	2	17	5·1512
717	3	0	10·9489	675	2	17	4·1318
716	3	0	9·9294	674	2	17	3·1123
715	3	0	8·9099	673	2	17	2·0929

Table of the English Mint Value of Gold—continued.

Fineness of Gold	Value per Ounce			Fineness of Gold	Value per Ounce		
	£	s.	d.		£	s.	d.
672	2	17	1·0734	630	2	13	6·2563
671	2	17	0·0540	629	2	13	5·2369
670	2	16	11·0345	628	2	13	4·2174
669	2	16	10·0151	627	2	13	3·1979
668	2	16	8·9956	626	2	13	2·1785
667	2	16	7·9761	625	2	13	1·1590
666	2	16	6·9567	624	2	13	0·1396
665	2	16	5·9372	623	2	12	11·1201
664	2	16	4·9178	622	2	12	10·1007
663	2	16	3·8983	621	2	12	9·0812
662	2	16	2·8789	620	2	12	8·0618
661	2	16	1·8594	619	2	12	7·0423
660	2	16	0·8399	618	2	12	6·0229
659	2	15	11·8205	617	2	12	5·0034
658	2	15	10·8010	616	2	12	3·9839
657	2	15	9·7816	615	2	12	2·9645
656	2	15	8·7621	614	2	12	1·9451
655	2	15	7·7427	613	2	12	0·9256
654	2	15	6·7232	612	2	11	11·9061
653	2	15	5·7038	611	2	11	10·8867
652	2	15	4·6843	610	2	11	9·8672
651	2	15	3·6649	609	2	11	8·8478
650	2	15	2·6454	608	2	11	7·8283
649	2	15	1·6259	607	2	11	6·8089
648	2	15	0·6065	606	2	11	5·7894
647	2	14	11·5870	605	2	11	4·7699
646	2	14	10·5676	604	2	11	3·7505
645	2	14	9·5481	603	2	11	2·7311
644	2	14	8·5287	602	2	11	1·7116
643	2	14	7·5092	601	2	11	0·6921
642	2	14	6·4898	600	2	10	11·6727
641	2	14	5·4703	599	2	10	10·6532
640	2	14	4·4509	598	2	10	9·6338
639	2	14	3·4314	597	2	10	8·6143
638	2	14	2·4120	596	2	10	7·5949
637	2	14	1·3925	595	2	10	6·5754
636	2	14	0·3730	594	2	10	5·5559
635	2	13	11·3536	593	2	10	4·5365
634	2	13	10·3341	592	2	10	3·5170
633	2	13	9·3147	591	2	10	2·4976
632	2	13	8·2952	590	2	10	1·4781
631	2	13	7·2758	589	2	10	0·4587

Table of the English Mint Value of Gold—continued.

Fineness of Gold	Value per Ounce			Fineness of Gold	Value per Ounce		
	£	s.	d.		£	s.	d.
588	2	9	11·4392	546	2	6	4·6221
587	2	9	10·4198	545	2	6	3·6027
586	2	9	9·4003	544	2	6	2·5832
585	2	9	8·3809	543	2	6	1·5638
584	2	9	7·3614	542	2	6	0·5443
583	2	9	6·3419	541	2	5	11·5249
582	2	9	5·3225	540	2	5	10·5054
581	2	9	4·3030	539	2	5	9·4859
580	2	9	3·2836	538	2	5	8·4665
579	2	9	2·2641	537	2	5	7·4470
578	2	9	1·2447	536	2	5	6·4276
577	2	9	0·2252	535	2	5	5·4081
576	2	8	11·2058	534	2	5	4·3887
575	2	8	10·1863	533	2	5	3·3692
574	2	8	9·1669	532	2	5	2·3498
573	2	8	8·1474	531	2	5	1·3303
572	2	8	7·1279	530	2	5	0·3109
571	2	8	6·1085	529	2	4	11·2914
570	2	8	5·0890	528	2	4	10·2719
569	2	8	4·0696	527	2	4	9·2525
568	2	8	3·0501	526	2	4	8·2330
567	2	8	2·0307	525	2	4	7·2136
566	2	8	1·0112	524	2	4	6·1941
565	2	7	11·9918	523	2	4	5·1747
564	2	7	10·9723	522	2	4	4·1552
563	2	7	9·9529	521	2	4	3·1358
562	2	7	8·9334	520	2	4	2·1163
561	2	7	7·9140	519	2	4	1·0969
560	2	7	6·8945	518	2	4	0·0774
559	2	7	5·8751	517	2	3	11·0579
558	2	7	4·8556	516	2	3	10·0385
557	2	7	3·8361	515	2	3	9·0190
556	2	7	2·8167	514	2	3	7·9996
555	2	7	1·7972	513	2	3	6·9801
554	2	7	0·7778	512	2	3	5·9607
553	2	6	11·7583	511	2	3	4·9412
552	2	6	10·7389	510	2	3	3·9218
551	2	6	9·7194	509	2	3	2·9023
550	2	6	8·6999	508	2	3	1·8829
549	2	6	7·6805	507	2	3	0·8634
548	2	6	6·6611	506	2	2	11·8439
547	2	6	5·6416	505	2	2	10·8245

Table of the English Mint Value of Gold—continued.

Fineness of Gold	Value per Ounce			Fineness of Gold	Value per Ounce		
	£	s.	d.		£	s.	d.
504	2	2	9·8051	462	1	19	2·9879
503	2	2	8·7856	461	1	19	1·9685
502	2	2	7·7661	460	1	19	0·9490
501	2	2	6·7467	459	1	18	11·9296
500	2	2	5·7272	458	1	18	10·9101
499	2	2	4·7078	457	1	18	9·8907
498	2	2	3·6883	456	1	18	8·8712
497	2	2	2·6689	455	1	18	7·8518
496	2	2	1·6494	454	1	18	6·8323
495	2	2	0·6300	453	1	18	5·8129
494	2	1	11·6105	452	1	18	4·7934
493	2	1	10·5911	451	1	18	3·7739
492	2	1	9·5716	450	1	18	2·7545
491	2	1	8·5521	449	1	18	1·7351
490	2	1	7·5327	448	1	18	0·7156
489	2	1	1·5132	447	1	17	11·6961
488	2	1	5·4938	446	1	17	10·6767
487	2	1	4·4743	445	1	17	9·6572
486	2	1	3·4549	444	1	17	8·6378
485	2	1	2·4354	443	1	17	7·6183
484	2	1	1·4159	442	1	17	6·5989
483	2	1	0·3965	441	1	17	5·5794
482	2	0	11·3770	440	1	17	4·5599
481	2	0	10·3576	439	1	17	3·5405
480	2	0	9·3381	438	1	17	2·5211
479	2	0	8·3187	437	1	17	1·5016
478	2	0	7·2992	436	1	17	0·4821
477	2	0	6·2798	435	1	16	11·4627
476	2	0	5·2603	434	1	16	10·4432
475	2	0	4·2409	433	1	16	9·4238
474	2	0	3·2214	432	1	16	8·4043
473	2	0	2·2020	431	1	16	7·3849
472	2	0	1·1825	430	1	16	6·3654
471	2	0	0·1630	429	1	16	5·3459
470	1	19	11·1436	428	1	16	4·3265
469	1	19	10·1241	427	1	16	3·3070
468	1	19	9·1047	426	1	16	2·2876
467	1	19	8·0852	425	1	16	1·2681
466	1	19	7·0658	424	1	16	0·2487
465	1	19	6·0463	423	1	15	11·2292
464	1	19	5·0269	422	1	15	10·2098
463	1	19	4·0074	421	1	15	9·1903

Table of the English Mint Value of Gold—continued.

Fineness of Gold	Value per Ounce			Fineness of Gold	Value per Ounce		
	£	*s.*	*d.*		£	*s.*	*d.*
420	1	15	8·1709	378	1	12	1·3538
419	1	15	7·1514	377	1	12	0·3343
418	1	15	6·1319	376	1	11	11·3142
417	1	15	5·1125	375	1	11	10·2954
416	1	15	4·0930	374	1	11	9·2759
415	1	15	3·0736	373	1	11	8·2565
414	1	15	2·0541	372	1	11	7·2370
413	1	15	1·0347	371	1	11	6·2176
412	1	15	0·0152	370	1	11	5·1981
411	1	14	10·9958	369	1	11	4·1787
410	1	14	9·9763	368	1	11	3·1592
409	1	14	8·9569	367	1	11	2·1398
408	1	14	7·9374	366	1	11	1·1203
407	1	14	6·9179	365	1	11	0·1009
406	1	14	5·8985	364	1	10	11·0814
405	1	14	4·8790	363	1	10	10·0620
404	1	14	3·8596	362	1	10	9·0425
403	1	14	2·8401	361	1	10	8·0230
402	1	14	1·8207	360	1	10	7·0036
401	1	14	0·8012	359	1	10	5·9841
400	1	13	11·7818	358	1	10	4·9647
399	1	13	10·7623	357	1	10	3·9452
398	1	13	9·7429	356	1	10	2·9258
397	1	13	8·7234	355	1	10	1·9063
396	1	13	7·7039	354	1	10	0·8869
395	1	13	6·6845	353	1	9	11·8674
394	1	13	5·6651	352	1	9	10·8479
393	1	13	4·6456	351	1	9	9·8285
392	1	13	3·6261	350	1	9	8·8090
391	1	13	2·6067	349	1	9	7·7896
390	1	13	1·5872	348	1	9	6·7701
389	1	13	0·5678	347	1	9	5·7507
388	1	12	11·5483	346	1	9	4·7312
387	1	12	10·5289	345	1	9	3·7118
386	1	12	9·5094	344	1	9	2·6923
385	1	12	8·4899	343	1	9	1·6729
384	1	12	7·4705	342	1	9	0·6534
383	1	12	6·4511	341	1	8	11·6339
382	1	12	5·4316	340	1	8	10·6145
381	1	12	4·4121	339	1	8	9·5951
380	1	12	3·3927	338	1	8	8·5756
379	1	12	2·3732	337	1	8	7·5561

Table of the English Mint Value of Gold—continued.

Fineness of Gold	Value per Ounce			Fineness of Gold	Value per Ounce		
	£	s.	d.		£	s.	d.
336	1	8	6·5367	294	1	4	11·7196
335	1	8	5·5172	293	1	4	10·7011
334	1	8	4·4978	292	1	4	9·6807
333	1	8	3·4783	291	1	4	8·6612
332	1	8	2·4589	290	1	4	7·6418
331	1	8	1·4394	289	1	4	6·6223
330	1	8	0·4199	288	1	4	5·6029
329	1	7	11·4005	287	1	4	4·5834
328	1	7	10·3811	286	1	4	3·5639
327	1	7	9·3616	285	1	4	2·5445
326	1	7	8·3421	284	1	4	1·5251
325	1	7	7·3227	283	1	4	0·5056
324	1	7	6·3032	282	1	3	11·4861
323	1	7	5·2838	281	1	3	10·4667
322	1	7	4·2643	280	1	3	9·4472
321	1	7	3·2449	279	1	3	8·4278
320	1	7	2·2254	278	1	3	7·4083
319	1	7	1·2059	277	1	3	6·3889
318	1	7	0·1865	276	1	3	5·3694
317	1	6	11·1670	275	1	3	4·3499
316	1	6	10·1476	274	1	3	3·3305
315	1	6	9·1281	273	1	3	2·3110
314	1	6	8·1087	272	1	3	1·2916
313	1	6	7·0892	271	1	3	0·2721
312	1	6	6·0698	270	1	2	11·2527
311	1	6	5·0503	269	1	2	10·2332
310	1	6	4·0309	268	1	2	9·2138
309	1	6	3·0114	267	1	2	8·1943
308	1	6	1·9919	266	1	2	7·1749
307	1	6	0·9725	265	1	2	6·1554
306	1	5	11·9530	264	1	2	5·1351
305	1	5	10·9336	263	1	2	4·1165
304	1	5	9·9141	262	1	2	3·0970
303	1	5	8·8947	261	1	2	2·0776
302	1	5	7·8752	260	1	2	1·0581
301	1	5	6·8558	259	1	2	0·0387
300	1	5	5·8363	258	1	1	11·0192
299	1	5	4·8169	257	1	1	9·9998
298	1	5	3·7974	256	1	1	8·9803
297	1	5	2·7779	255	1	1	7·9609
296	1	5	1·7585	254	1	1	6·9414
295	1	5	0·7390	253	1	1	5·9219

Table of the English Mint Value of Gold—continued.

Fineness of Gold	Value per Ounce			Fineness of Gold	Value per Ounce		
	£	s.	d.		£	s.	d.
252	1	1	4·9025	210	0	17	10·0854
251	1	1	3·8830	209	0	17	9·0659
250	1	1	2·8636	208	0	17	8·0465
249	1	1	1·8441	207	0	17	7·0270
248	1	1	0·8247	206	0	17	6·0076
247	1	0	11·8052	205	0	17	4·9881
246	1	0	10·7858	204	0	17	3·9687
245	1	0	9·7663	203	0	17	2·9492
244	1	0	8·7469	202	0	17	1·9298
243	1	0	7·7274	201	0	17	0·9103
242	1	0	6·7079	200	0	16	11·8909
241	1	0	5·6885	199	0	16	10·8714
240	1	0	4·6690	198	0	16	9·8519
239	1	0	3·6496	197	0	16	8·8325
238	1	0	2·6301	196	0	16	7·8130
237	1	0	1·6107	195	0	16	6·7936
236	1	0	0·5912	194	0	16	5·7741
235	0	19	11·5718	193	0	16	4·7547
234	0	19	10·5523	192	0	16	3·7352
233	0	19	9·5329	191	0	16	2·7158
232	0	19	8·5134	190	0	16	1·6963
231	0	19	7·4939	189	0	16	0·6769
230	0	19	6·4745	188	0	15	11·6574
229	0	19	5·4551	187	0	15	10·6379
228	0	19	4·4356	186	0	15	9·6185
227	0	19	3·4161	185	0	15	8·5990
226	0	19	2·3967	184	0	15	7·5796
225	0	19	1·3772	183	0	15	6·5601
224	0	19	0·3578	182	0	15	5·5407
223	0	18	11·3383	181	0	15	4·5212
222	0	18	10·3189	180	0	15	3·5018
221	0	18	9·2994	179	0	15	2·4823
220	0	18	8·2799	178	0	15	1·4629
219	0	18	7·2605	177	0	15	0·4434
218	0	18	6·2410	176	0	14	11·4239
217	0	18	5·2216	175	0	14	10·4045
216	0	18	4·2021	174	0	14	9·3851
215	0	18	3·1827	173	0	14	8·3656
214	0	18	2·1632	172	0	14	7·3461
213	0	18	1·1438	171	0	14	6·3267
212	0	18	0·1243	170	0	14	5·3072
211	0	17	11·1049	169	0	14	4·2878

Table of the English Mint Value of Gold—continued.

Fineness of Gold	Value per Ounce			Fineness of Gold	Value per Ounce		
	£	s.	d.		£	s.	d.
168	0	14	3·2683	126	0	10	8·4512
167	0	14	2·2489	125	0	10	7·4318
166	0	14	1·2294	124	0	10	6·4123
165	0	14	0·2099	123	0	10	5·3929
164	0	13	11·1905	122	0	10	4·3734
163	0	13	10·1710	121	0	10	3·3530
162	0	13	9·1516	120	0	10	2·3345
161	0	13	8·1321	119	0	10	1·3151
160	0	13	7·1127	118	0	10	0·2956
159	0	13	6·0932	117	0	9	11·2761
158	0	13	5·0738	116	0	9	10·2567
157	0	13	4·0543	115	0	9	9·2372
156	0	13	3·0349	114	0	9	8·2178
155	0	13	2·0154	113	0	9	7·1983
154	0	13	0·9959	112	0	9	6·1789
153	0	12	11·9765	111	0	9	5·1594
152	0	12	10·9570	110	0	9	4·1399
151	0	12	9·9376	109	0	9	3·1205
150	0	12	8·9181	108	0	9	2·1010
149	0	12	7·8987	107	0	9	1·0816
148	0	12	6·8792	106	0	9	0·0621
147	0	12	5·8598	105	0	8	11·0427
146	0	12	4·8403	104	0	8	10·0232
145	0	12	3·8209	103	0	8	9·0038
144	0	12	2·8014	102	0	8	7·9843
143	0	12	1·7819	101	0	8	6·9649
142	0	12	0·7625	100	0	8	5·9454
141	0	11	11·7430	99	0	8	4·9259
140	0	11	10·7236	98	0	8	3·9065
139	0	11	9·7041	97	0	8	2·8870
138	0	11	8·6847	96	0	8	1·8676
137	0	11	7·6652	95	0	8	0·8481
136	0	11	6·6458	94	0	7	11·8287
135	0	11	5·6263	93	0	7	10·8092
134	0	11	4·6069	92	0	7	9·7898
133	0	11	3·5874	91	0	7	8·7703
132	0	11	2·5679	90	0	7	7·7509
131	0	11	1·5485	89	0	7	6·7314
130	0	11	0·5290	88	0	7	5·7119
129	0	10	11·5096	87	0	7	4·6925
128	0	10	10·4901	86	0	7	3·6730
127	0	10	9·4707	85	0	7	2·6536

Table of the English Mint Value of Gold—continued.

Fineness of Gold	Value per Ounce			Fineness of Gold	Value per Ounce		
	£	*s.*	*d.*		£	*s.*	*d.*
84	0	7	1·6341	42	0	3	6·8170
83	0	7	0·6147	41	0	3	5·7976
82	0	6	11·5952	40	0	3	4·7781
81	0	6	10·5758	39	0	3	3·7587
80	0	6	9·5563	38	0	3	2·7392
79	0	6	8·5369	37	0	3	1·7198
78	0	6	7·5174	36	0	3	0·7003
77	0	6	6·4979	35	0	2	11·6809
76	0	6	5·4785	34	0	2	10·6614
75	0	6	4·4590	33	0	2	9·6419
74	0	6	3·4396	32	0	2	8·6225
73	0	6	2·4201	31	0	2	7·6030
72	0	6	1·4007	30	0	2	6·5836
71	0	6	0·3812	29	0	2	5·5641
70	0	5	11·3618	28	0	2	4·5447
69	0	5	10·3423	27	0	2	3·5252
68	0	5	9·3229	26	0	2	2·5058
67	0	5	8·3034	25	0	2	1·4863
66	0	5	7·2839	24	0	2	0·4669
65	0	5	6·2645	23	0	1	11·4474
64	0	5	5·2451	22	0	1	10·4279
63	0	5	4·2256	21	0	1	9·4085
62	0	5	3·2061	20	0	1	8·3890
61	0	5	2·1867	19	0	1	7·3696
60	0	5	1·1672	18	0	1	6·3501
59	0	5	0·1478	17	0	1	5·3307
58	0	4	11·1283	16	0	1	4·3112
57	0	4	10·1089	15	0	1	3·2918
56	0	4	9·0894	14	0	1	2·2723
55	0	4	8·0699	13	0	1	1·2529
54	0	4	7·0505	12	0	1	0·2334
53	0	4	6·0310	11	0	0	11·2139
52	0	4	5·0116	10	0	0	10·1945
51	0	4	3·9921	9	0	0	9·1750
50	0	4	2·9727	8	0	0	8·1556
49	0	4	1·9532	7	0	0	7·1361
48	0	4	0·9338	6	0	0	6·1167
47	0	3	11·9143	5	0	0	5·0972
46	0	3	10·8949	4	0	0	4·0778
45	0	3	9·8754	3	0	0	3·0583
44	0	3	8·8559	2	0	0	2·0389
43	0	3	7·8365	1	0	0	1·0194

GOLD COINS IN THE UNITED STATES OF AMERICA.

The following table of gold coins is taken from the annual report of the Director of the United States Mint.

From the value of the gold coins a deduction of a half of one per cent. is made to cover the cost of recoinage.

The weights of coins are usually expressed in grains, but in this table they have been reduced to troy ounces and decimals; but these weights are readily converted into grains again by multiplying them by 480, or grains into ounces and decimals by dividing them by 480.

U.S.A. gold eagle, weighing 258 grs. or 0·5375 oz., is worth $10·00.

Table of the Value of Gold Coins in the United States of America.

Country	Denominations	Weight	Fineness	Value	Value after Deduction
		Oz. Dec.	1000ths	$	$
Australia	Pound of 1852	0·281	916·5	5·32·37	5·29·71
Australia	Sovereign of '55–60	0·256·5	916	4·85·58	4·83·16
Austria	Ducat	0·112	986	2·28·28	2·27·04
Austria	Souverain	0·363	900	6·75·35	6·71·98
Austria	New Union Crown (assumed)	0·357	900	6·64·19	6·60·87
Belgium	Twenty-five francs	0·254	899	4·72·03	4·69·67
Bolivia	Doubloon	0·867	870	15·59·25	15·51·46
Brazil	Twenty milreis	0·575	917·5	10·90·57	10·85·12
Central America	Two escudos	0·209	853·5	3·68·75	3·66·91
Central America	Four reals	0·027	875	0·48·8	0·48·6
Chili	Old doubloon	0·867	870	15·59·26	15·51·47
Chili	Ten pesos 'condor'	0·492	900	9·15·35	9·10·78
Denmark	Ten thaler	0·427	895	7·90·01	7·86·06
Ecuador	Four escudos	0·433	844	7·55·46	7·51·69
England	Pound or sovereign, new	0·256·7	916·5	4·86·34	4·83·91
England	Pound or sovereign, average	0·256·2	916	4·84·92	4·82·50
France	Twenty francs, new	0·207·5	899·5	3·85·83	3·83·91
France	Twenty francs, av.	0·207	899	3·84·69	3·82·77

Table of the Value of Gold Coins—continued.

Country	Denominations	Weight	Fineness	Value	Value after Deduction
		Oz. Dec.	1000ths	$	$
Germany, North	Ten thaler	0·427	895	7·90·01	7·86·06
Germany, North	Ten thaler, Prussian	0·427	903	7·97·07	7·93·09
Germany, North	Krone (crown)	0·357	900	6·64·20	6·60·88
Germany, South	Ducat	0·112	986	2·28·28	2 27·14
Greece	Twenty drachms	0·185	900	3 44·19	3·42·47
Hindostan	Mohur	0·374	916	7·08·18	7·04·64
Italy	Twenty lire	0·207	898	3·84·26	3·82·34
Japan	Old cobang	0·362	568	4·44·0	4·41·8
Japan	New cobang	0·289	572	3·57·6	3·55·8
Mexico	Doubloon, average	0·867·5	866	15·52·98	15·45·22
Mexico	Doubloon, new	0·867·5	870·5	15·61·05	15·53·25
Naples	Six ducati, new	0·245	996	5·04·43	5·01·91
Netherlands	Ten guilders	0·215	899	3·99·56	3·97·57
New Granada	Old doubloon (Bogota)	0·868	870	15·61·06	15·53·26
New Granada	Old doubloon (Popayan)	0·867	858	15·37·75	15·30·07
New Granada	Ten pesos, new	0·525	891·5	9·67·51	9·62·68
Peru	Old doubloon	0·867	868	15·55·67	15 47·90
Peru	Twenty soles (solde oro)	1·035	898	19·21·8	19·12·2
Portugal	Gold crown	0·308	912	5·80·66	5·77·76
Prussia	New Union crown (assumed)	0·357	900	6·64·19	6·60·87
Rome	2½ scudi, new	0·140	900	2·60·47	2·59·17
Russia	Five roubles	0·210	916	3·97·64	3·95·66
Spain	100 reals	0·268	896	4·96·39	4·93·91
Spain	80 reals	0·215	869·5	3·86·44	3·84·51
Sweden	Ducat	0·111	975	2·23·72	2·22·61
Tunis	25 piastres	0·161	900	2·99·54	2·98·05
Turkey	100 piastres	0·231	915	4·36 93	4·34·75
Tuscany	Sequin	0·112	999	2·31·29	2·30·14

Explanation of Gold Table.

The values per oz. of gold in the following tables are computed from the simple *formula* that 387 oz. of *pure* gold (1,000 fine) are worth $8,000. Hence 1 oz. is worth $20·671834625 and the $\frac{1}{100}$ of an oz. (decimally expressed as ·001 fine) is worth $0·020671834625.

What we usually call *fineness*, therefore, is simply the *weight* of *fine* metal contained in any given quantity of mixed metals or alloys. For instance, in a gold or silver bar which is reported to be 850 fine, it is simply meant that in 1,000 parts *by weight* 850 are *fine* gold or *fine* silver, as the case may be.

In our mints the value of gold is computed from *standard* weight—that is, gold which is 900 fine, that being the *fineness* of our gold coin as required by law. The *formula* in this case is, 43 oz. of *standard* gold are worth $800. Hence multiply standard ozs. by 800 and divide by 43, and you obtain the value.

Example.—Take $123\frac{13}{100}$ oz. at 843 fine, and we obtain the result thus:—

123·13 oz. gross weight.
843 fineness of gold.

36939
49252
98504

U.S. standard 900) 103798·59 oz. of fine gold.

115331
800

43) 92264·800

$2145·69 value.

To find value per oz., divide total value (2145·69) by standard ozs. (115·331), and you have $18·60.46, which will be seen, by reference to the table, is the value of 1 oz. of gold at 900 fine.

The value in this case would have been ascertained thus:—By reference to the gold table and opposite ·843 the value of 1 oz. ·843 fine is $17·4264. Hence

```
      123·13
      174264
   ──────────
      492·52
     73878
    24626
   49252
  86191
 12313
   ──────────
 $2145·69  value.
```

Table of the Value of Gold per Ounce Troy, at Different Degrees of Fineness, in the United States of America.

Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents
0	0	00·00	10	0	20·67	20	0	41·34	30	0	62·02	40	0	82·69
½	0	01·03	½	0	21·71	½	0	42·38	½	0	63·05	½	0	83·72
1	0	02·07	11	0	22·74	21	0	43·41	31	0	64·08	41	0	84·75
½	0	03·10	½	0	23·77	½	0	44·44	½	0	65·12	½	0	85·79
2	0	04·13	12	0	24·81	22	0	45·48	32	0	66·15	42	0	86·82
½	0	05·17	½	0	25·84	½	0	46·51	½	0	67·18	½	0	87·86
3	0	06·20	13	0	26·87	23	0	47·55	33	0	68·22	43	0	88·89
½	0	07·24	½	0	27·91	½	0	48·58	½	0	69·25	½	0	89·92
4	0	08·27	14	0	28·94	24	0	49·61	34	0	70 28	44	0	90·96
½	0	09·30	½	0	29·97	½	0	50·65	½	0	71·32	½	0	91·99
5	0	10·34	15	0	31·01	25	0	51·68	35	0	72·35	45	0	93·02
½	0	11·37	½	0	32·04	½	0	52·71	½	0	73·39	½	0	94·06
6	0	12·40	16	0	33·07	26	0	53·75	36	0	74·42	46	0	95·09
½	0	13·44	½	0	34·11	½	0	54·78	½	0	75·45	½	0	96·12
7	0	14·47	17	0	35·14	27	0	55·81	37	0	76·49	47	0	97·16
½	0	15·50	½	0	36·18	½	0	56·85	½	0	77·52	½	0	98·19
8	0	16·54	18	0	37·21	28	0	57·88	38	0	78·55	48	0	99·22
½	0	17·57	½	0	38·24	½	0	58·91	½	0	79·59	½	1	00·26
9	0	18·60	19	0	39·28	29	0	59·95	39	0	80·62	49	1	01·29
½	0	19·64	½	0	40·31	½	0	60·98	½	0	81·65	½	1	02·33

Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents
50	1	03·36	60	1	24·03	70	1	44·70	80	1	65·37	90	1	86·05
½	1	04·39	½	1	25·06	½	1	45·74	½	1	66·41	½	1	87·08
51	1	05·43	61	1	26·10	71	1	46·77	81	1	67·44	91	1	88·11
½	1	06·46	½	1	27·13	½	1	47·80	½	1	68·48	½	1	89·15
52	1	07·49	62	1	28·17	72	1	48·84	82	1	69·51	92	1	90·18
½	1	08·53	½	1	29·20	½	1	49·87	½	1	70·54	½	1	91·21
53	1	09·56	63	1	30·23	73	1	50·90	83	1	71·58	93	1	92·25
½	1	10·59	½	1	31·27	½	1	51·94	½	1	72·61	½	1	93·28
54	1	11·63	64	1	32·30	74	1	52·97	84	1	73·64	94	1	94·32
½	1	12·66	½	1	33·33	½	1	54·01	½	1	74·68	½	1	95·35
55	1	13·70	65	1	34·37	75	1	55·04	85	1	75·71	95	1	96·38
½	1	14·73	½	1	35·40	½	1	56·07	½	1	76·74	½	1	97·42
56	1	15·76	66	1	36·43	76	1	57·11	86	1	77·78	96	1	98·45
½	1	16·80	½	1	37·47	½	1	58·14	½	1	78·81	½	1	99·48
57	1	17·83	67	1	38·50	77	1	59·17	87	1	79·84	97	2	00·52
½	1	18·86	½	1	39·53	½	1	60·21	½	1	80·88	½	2	01·55
58	1	19·90	68	1	40·57	78	1	61·24	88	1	81·91	98	2	02·58
½	1	20·93	½	1	41·60	½	1	62·27	½	1	82·95	½	2	03·62
59	1	21·96	69	1	42·64	79	1	63·31	89	1	83·98	99	2	04·65
½	1	23·00	½	1	43·67	½	1	64·34	½	1	85·01	½	2	05·68

Table of the Value of Gold—continued.

Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents
100	2	06·72	110	2	27·39	120	2	48·06	130	2	68·73	140	2	89·41
½	2	07·75	½	2	28·42	½	2	49·10	½	2	69·77	½	2	90·44
101	2	08·79	111	2	29·46	121	2	50·13	131	2	70·80	141	2	91·47
½	2	09·82	½	2	30·49	½	2	51·16	½	2	71·83	½	2	92·51
102	2	10·85	112	2	31·52	122	2	52·20	132	2	72·87	142	2	93·54
½	2	11·89	½	2	32·56	½	2	53·23	½	2	73·90	½	2	94·57
103	2	12·92	113	2	33·59	123	2	54·26	133	2	74·94	143	2	95·61
½	2	13·95	½	2	34·63	½	2	55·30	½	2	75·97	½	2	96·64
104	2	14·99	114	2	35·66	124	2	56·33	134	2	77·00	144	2	97·67
½	2	16·02	½	2	36·69	½	2	57·36	½	2	78·04	½	2	98·71
105	2	17·05	115	2	37·73	125	2	58·40	135	2	79·07	145	2	99·74
½	2	18·09	½	2	38·76	½	2	59·43	½	2	80·10	½	3	00·78
106	2	19·12	116	2	39·79	126	2	60·46	136	2	81·14	146	3	01·81
½	2	20·16	½	2	40·83	½	2	61·50	½	2	82·17	½	3	02·84
107	2	21·19	117	2	41·86	127	2	62·53	137	2	83·20	147	3	03·88
½	2	22·22	½	2	42·89	½	2	63·57	½	2	84·24	½	3	04·91
108	2	23·26	118	2	43·93	128	2	64·60	138	2	85·27	148	3	05·94
½	2	24·29	½	2	44·96	½	2	65·63	½	2	86·30	½	3	06·98
109	2	25·32	119	2	45·99	129	2	66·67	139	2	87·34	149	3	08·01
½	2	26·36	½	2	47·03	½	2	67·70	½	2	88·37	½	3	09·04

Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents
150	3	10·08	160	3	30·75	170	3	51·42	180	3	72·09	190	3	92·76
½	3	11·11	½	3	31·78	½	3	52·45	½	3	73·13	½	3	93·80
151	3	12·14	161	3	32·82	171	3	53·49	181	3	74·16	191	3	94·83
½	3	13·18	½	3	33·85	½	3	54·52	½	3	75·19	½	3	95·87
152	3	14·21	162	3	34·88	172	3	55·56	182	3	76·23	192	3	96·90
½	3	15·25	½	3	35·92	½	3	56·59	½	3	77·26	½	3	97·93
153	3	16·28	163	3	36·95	173	3	57·62	183	3	78·29	193	3	98·97
½	3	17·31	½	3	37·98	½	3	58·66	½	3	79·33	½	4	00·00
154	3	18·35	164	3	39·02	174	3	59·69	184	3	80·36	194	4	01·03
½	3	19·38	½	3	40·05	½	3	60·72	½	3	81·40	½	4	02·07
155	3	20·41	165	3	41·09	175	3	61·76	185	3	82·43	195	4	03·10
½	3	21·45	½	3	42·12	½	3	62·79	½	3	83·46	½	4	04·13
156	3	22·48	166	3	43·15	176	3	63·82	186	3	84·50	196	4	05·17
½	3	23·51	½	3	44·19	½	3	64·86	½	3	85·53	½	4	06·20
157	3	24·55	167	3	45·22	177	3	65·89	187	3	86·56	197	4	07·24
½	3	25·58	½	3	46·25	½	3	66·93	½	3	87·60	½	4	08·27
158	3	26·61	168	3	47·29	178	3	67·96	188	3	88·63	198	4	09·30
½	3	27·65	½	3	48·32	½	3	68·99	½	3	89·66	½	4	10·34
159	3	28·68	169	3	49·35	179	3	70·03	189	3	90·70	199	4	11·37
½	3	29·72	½	3	50·39	½	3	71·06	½	3	91·73	½	4	12·40

Table of the Value of Gold—continued.

Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents
200	4	13·44	210	4	34·11	220	4	54·78	230	4	75·45	240	4	96·12
½	4	14·47	½	4	35·14	½	4	55·81	½	4	76·49	½	4	97·16
201	4	15·50	211	4	36·18	221	4	56·85	231	4	77·52	241	4	98·19
½	4	16·54	½	4	37·21	½	4	57·88	½	4	78·55	½	4	99·22
202	4	17·57	212	4	38·24	222	4	58·91	232	4	79·59	242	5	00·26
½	4	18·60	½	4	39·28	½	4	59·95	½	4	80·62	½	5	01·29
203	4	19·64	213	4	40·31	223	4	60·98	233	4	81·65	243	5	02·33
½	4	20·67	½	4	41·34	½	4	62·02	½	4	82·69	½	5	03·36
204	4	21·71	214	4	42·38	224	4	63·05	234	4	83·72	244	5	04·39
½	4	22·74	½	4	43·41	½	4	64·08	½	4	84·75	½	5	05·43
205	4	23·77	215	4	44·44	225	4	65·12	235	4	85·79	245	5	06·46
½	4	24·81	½	4	45·48	½	4	66·15	½	4	86·82	½	5	07·49
206	4	25·84	216	4	46·51	226	4	67·18	236	4	87·86	246	5	08·53
½	4	26·87	½	4	47·55	½	4	68·22	½	4	88·89	½	5	09·56
207	4	27·91	217	4	48·58	227	4	69·25	237	4	89·92	247	5	10·59
½	4	28·94	½	4	49·61	½	4	70·28	½	4	90·96	½	5	11·63
208	4	29·97	218	4	50·65	228	4	71·32	238	4	91·99	248	5	12·66
½	4	31·01	½	4	51·68	½	4	72·35	½	4	93·02	½	5	13·70
209	4	32·04	219	4	52·71	229	4	73·39	239	4	94·06	249	5	14·37
½	4	33·07	½	4	53·75	½	4	74·42	½	4	95·09	½	5	15·76

Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents
250	5	16·80	260	5	37·47	270	5	58·14	280	5	78·81	290	5	99·48
½	5	17·83	½	5	38·50	½	5	59·17	½	5	79·84	½	6	00·52
251	5	18·86	261	5	39·53	271	5	60·21	281	5	80·88	291	6	01·55
½	5	19·90	½	5	40·57	½	5	61·24	½	5	81·91	½	6	02·58
252	5	20·93	262	5	41·60	272	5	62·27	282	5	82·95	292	6	03·62
½	5	21·96	½	5	42·64	½	5	63·31	½	5	83·98	½	6	04·65
253	5	23·00	263	5	43·67	273	5	64·34	283	5	85·01	293	6	05·68
½	5	24·03	½	5	44·70	½	5	65·37	½	5	86·05	½	6	06·72
254	5	25·06	264	5	45·74	274	5	66·41	284	5	87·08	294	6	07·75
½	5	26·10	½	5	46·77	½	5	67·44	½	5	88·11	½	6	08 79
255	5	27·13	265	5	47·80	275	5	68·48	285	5	89·15	295	6	09·82
½	5	28·17	½	5	48·84	½	5	69·51	½	5	90·18	½	6	10·85
256	5	29·20	266	5	49·87	276	5	70·54	286	5	91·21	296	6	11·89
½	5	30·23	½	5	50·90	½	5	71·58	½	5	92·25	½	6	12·92
257	5	31·27	267	5	51·94	277	5	72·61	287	5	93·28	297	6	13·95
½	5	32·30	½	5	52·97	½	5	73·64	½	5	94·32	½	6	14·99
258	5	33·33	268	5	54·01	278	5	74·68	288	5	95·35	298	6	16·02
½	5	34·37	½	5	55·04	½	5	75·71	½	5	96·38	½	6	17·05
259	5	35·40	269	5	56·07	279	5	76·74	289	5	97·42	299	6	18·09
½	5	36·43	½	5	57·11	½	5	77·78	½	5	98·45	½	6	19·12

Table of the Value of Gold—continued.

Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents
300	6	20·16	310	6	40·83	320	6	61·50	330	6	82·17	340	7	02·84
½	6	21·19	½	6	41·86	½	6	62·53	½	6	83·20	½	7	03·88
301	6	22·22	311	6	42·89	321	6	63·57	331	6	84·24	341	7	04·91
½	6	23·26	½	6	43·93	½	6	64·60	½	6	85·27	½	7	05·94
302	6	24·29	312	6	44·96	322	6	65·63	332	6	86·30	342	7	06·98
½	6	25·32	½	6	45·99	½	6	66·67	½	6	87·34	½	7	08·01
303	6	26·36	313	6	47·03	323	6	67·70	333	6	88·37	343	7	09·04
½	6	27·39	½	6	48·06	½	6	68·73	½	6	89 41	½	7	10·08
304	6	28·42	314	6	49·10	324	6	69·77	334	6	90·44	344	7	11·11
½	6	29·46	½	6	50·13	½	6	70·80	½	6	91·47	½	7	12·14
305	6	30·49	315	6	51·16	325	6	71·83	335	6	92·51	345	7	13·18
½	6	31·52	½	6	52·20	½	6	72·87	½	6	93·54	½	7	14·21
306	6	32·56	316	6	53·23	326	6	73·90	336	6	94·57	346	7	15·25
½	6	33·59	½	6	54·26	½	6	74·94	½	6	95·61	½	7	16·28
307	6	34·63	317	6	55·30	327	6	75·97	337	6	96 64	347	7	17·31
½	6	35·66	½	6	56·33	½	6	77·00	½	6	97·67	½	7	18·35
308	6	36·69	318	6	57·36	328	6	78·04	338	6	98·71	348	7	19·38
½	6	37·73	½	6	58·40	½	6	79·07	½	6	99·74	½	7	20·41
309	6	38·76	319	6	59·43	329	6	80·10	339	7	00·78	349	7	21·45
½	6	39·79	½	6	60·47	½	6	81·14	½	7	01·81	½	7	22·48

Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents
350	7	23·51	360	7	44·19	370	7	64·86	380	7	85·53	390	8	06·20
½	7	24·55	½	7	45·22	½	7	65·89	½	7	86·56	½	8	07·24
351	7	25·58	361	7	46·25	371	7	66·93	381	7	87·60	391	8	08·27
½	7	26·61	½	7	47·29	½	7	67·96	½	7	88·63	½	8	09·30
352	7	27·65	362	7	48·32	372	7	68·99	382	7	89·66	392	8	10·34
½	7	28·68	½	7	49·35	½	7	70·03	½	7	90·70	½	8	11·37
353	7	29·72	363	7	50·39	373	7	71·06	383	7	91·73	393	8	12·40
½	7	30·75	½	7	51·42	½	7	72·09	½	7	92·76	½	8	13·44
354	7	31·78	364	7	52·45	374	7	73·13	384	7	93·80	394	8	14·47
½	7	32·82	½	7	53·49	½	7	74·16	½	7	94·83	½	8	15·50
355	7	33·85	365	7	54·52	375	7	75·19	385	7	95·87	395	8	16·54
½	7	34·88	½	7	55·56	½	7	76·23	½	7	96·90	½	8	17·57
356	7	35·92	366	7	56·59	376	7	77·26	386	7	97·93	396	8	18·60
½	7	36·95	½	7	57·62	½	7	78·29	½	7	98·97	½	8	19·64
357	7	37·98	367	7	58·66	377	7	79·32	387	8	00·00	397	8	20·67
½	7	39·02	½	7	59·69	½	7	80·36	½	8	01·03	½	8	21·71
358	7	40·05	368	7	60·72	378	7	81·39	388	8	02·07	398	8	22·74
½	7	41·09	½	7	61·76	½	7	82·43	½	8	03·10	½	8	23·77
359	7	42·12	369	7	62·79	379	7	83·46	389	8	04·13	399	8	24·81
½	7	43·15	½	7	63·82	½	7	84·50	½	8	05·17	½	8	25·84

Table of the Value of Gold—continued.

Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents
400	8	26·87	410	8	47·55	420	8	68·22	430	8	88·89	440	9	09·56
½	8	27·91	½	8	48·58	½	8	69·25	½	8	89·92	½	9	10·59
401	8	28·94	411	8	49·61	421	8	70·28	431	8	90·96	441	9	11·63
½	8	29·97	½	8	50·65	½	8	71·32	½	8	91·99	½	9	12·66
402	8	31·01	412	8	51·68	422	8	72·35	432	8	93·02	442	9	13·70
½	8	32·04	½	8	52·71	½	8	73·39	½	8	94·06	½	9	14·73
403	8	33·07	413	8	53·75	423	8	74·42	433	8	95·09	443	9	15·76
½	8	34·11	½	8	54·78	½	8	75·45	½	8	96·12	½	9	16·80
404	8	35·14	414	8	55·81	424	8	76·49	434	8	97·16	444	9	17 83
½	8	36·18	½	8	56·85	½	8	77·52	½	8	98·19	½	9	18·86
405	8	37·21	415	8	57·88	425	8	78·55	435	8	99·22	445	9	19·90
½	8	38·24	½	8	58·91	½	8	79·59	½	9	00·26	½	9	20·93
406	8	39·28	416	8	59·95	426	8	80·62	436	9	01·29	446	9	21·96
½	8	40·31	½	8	60·98	½	8	81·65	½	9	02·33	½	9	23·00
407	8	41·34	417	8	62·02	427	8	82·69	437	9	03·36	447	9	24·03
½	8	42·38	½	8	63·05	½	8	83·72	½	9	04·39	½	9	25·06
408	8	43·41	418	8	64·08	428	8	84·75	438	9	05·43	448	9	26·10
½	8	44·44	½	8	65·12	½	8	85·79	½	9	06·46	½	9	27·13
409	8	45·48	419	8	66·15	429	8	86·82	439	9	07·49	449	9	28·17
½	8	46·51	½	8	67·18	½	8	87·86	½	9	08·53	½	9	29·20

Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents
450	9	30·23	460	9	50·90	470	9	71·58	480	9	92·25	490	10	12·92
½	9	31 27	½	9	51·94	½	9	72·61	½	9	93·28	½	10	13·95
451	9	32·30	461	9	52·97	471	9	73 64	481	9	94·32	491	10	14·99
½	9	33·33	½	9	54·01	½	9	74·68	½	9	95·35	½	10	16·02
452	9	34·37	462	9	55·04	472	9	75·71	482	9	96·38	492	10	17·05
½	9	35·40	½	9	56·07	½	9	76·74	½	9	97·42	½	10	18·09
453	9	36·43	463	9	57·11	473	9	77·78	483	9	98·45	493	10	19·12
½	9	37·47	½	9	58·14	½	9	78·81	½	9	99·48	½	10	20·16
454	9	38·50	464	9	59·17	474	9	79·84	484	10	00·52	494	10	21·19
½	9	39·53	½	9	60·21	½	9	80·88	½	10	01·55	½	10	22·22
455	9	40·57	465	9	61·24	475	9	81·91	485	10	02·58	495	10	23·26
½	9	41·60	½	9	62·27	½	9	82·95	½	10	03·62	½	10	24·29
456	9	42·64	466	9	63·31	476	9	83·98	486	10	04·65	496	10	25·32
½	9	43·67	½	9	64·34	½	9	85·01	½	10	05·68	½	10	26·36
457	9	44·70	467	9	65·37	477	9	86·05	487	10	06·72	497	10	27·39
½	9	45·74	½	9	66·41	½	9	87·08	½	10	07·75	½	10	28·42
458	9	46·77	468	9	67·44	478	9	88·11	488	10	08·79	498	10	29·46
½	9	47·80	½	9	68·48	½	9	89·15	½	10	09·82	½	10	30·49
459	9	48·84	469	9	69·51	479	9	90·18	489	10	10·85	499	10	31·52
½	9	49·87	½	9	70·54	½	9	91·21	½	10	11·89	½	10	32·56

Table of the Value of Gold—continued.

Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents
500	10	33·59	510	10	54·26	520	10	74·94	530	10	95·61	540	11	16·28
½	10	34·63	½	10	55·30	½	10	75·97	½	10	96·64	½	11	17·31
501	10	35·66	511	10	56·33	521	10	77·00	531	10	97·67	541	11	18·35
½	10	36·69	½	10	57·36	½	10	78·04	½	10	98·71	½	11	19·38
502	10	37·73	512	10	58·40	522	10	79·07	532	10	99·74	542	11	20·41
½	10	38·76	½	10	59·43	½	10	80·10	½	11	00·78	½	11	21·45
503	10	39·79	513	10	60·47	523	10	81·14	533	11	01·81	543	11	22·48
½	10	40·83	½	10	61·50	½	10	82·17	½	11	02·84	½	11	23·51
504	10	41·86	514	10	62·53	524	10	83·20	534	11	03·88	544	11	24·55
½	10	42·89	½	10	63·57	½	10	84·24	½	11	04·91	½	11	25·58
505	10	43·93	515	10	64·60	525	10	85·27	535	11	05·94	545	11	26·61
½	10	44·96	½	10	65·63	½	10	86·30	½	11	06·98	½	11	27·65
506	10	45·99	516	10	66·67	526	10	87·34	536	11	08·01	546	11	28·68
½	10	47·03	½	10	67·70	½	10	88·37	½	11	09·04	½	11	29·72
507	10	48·06	517	10	68·73	527	10	89·41	537	11	10·08	547	11	30·75
½	10	49·10	½	10	69·77	½	10	90·44	½	11	11·11	½	11	31·78
508	10	50·13	518	10	70·80	528	10	91·47	538	11	12·14	548	11	32·82
½	10	51·16	½	10	71·83	½	10	92·51	½	11	13·18	½	11	33·85
509	10	52·20	519	10	72·87	529	10	93·54	539	11	14·21	549	11	34·88
½	10	53·23	½	10	73·90	½	10	94·57	½	11	15·25	½	11	35·92

Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents
550	11	36·95	560	11	57·62	570	11	78·29	580	11	98·97	590	12	19·64
½	11	37·98	½	11	58·66	½	11	79·33	½	12	00·00	½	12	20·67
551	11	39·02	561	11	59·69	571	11	80·36	581	12	01·03	591	12	21·71
½	11	40·05	½	11	60·72	½	11	81·40	½	12	02·07	½	12	22·74
552	11	41·09	562	11	61·76	572	11	82·43	582	12	03·10	592	12	23·77
½	11	42·12	½	11	62·79	½	11	83·46	½	12	04·13	½	12	24·81
553	11	43·15	563	11	63·82	573	11	84·50	583	12	05·17	593	12	25·84
½	11	44·19	½	11	64·86	½	11	85·53	½	12	06·20	½	12	26·87
554	11	45·22	564	11	65·89	574	11	86·56	584	12	07·24	594	12	27·91
½	11	46·25	½	11	66·93	½	11	87·60	½	12	08·27	½	12	28·94
555	11	47·29	565	11	67·96	575	11	88·63	585	12	09·30	595	12	29·97
½	11	48·32	½	11	68·99	½	11	89·66	½	12	10·34	½	12	31·01
556	11	49·35	566	11	70·03	576	11	90·70	586	12	11·37	596	12	32·04
½	11	50·39	½	11	71·06	½	11	91·73	½	12	12·40	½	12	33·07
557	11	51·42	567	11	72·09	577	11	92·76	587	12	13·44	597	12	34·11
½	11	52·45	½	11	73·13	½	11	93·80	½	12	14·47	½	12	35·14
558	11	53·49	568	11	74·16	578	11	94·83	588	12	15·50	598	12	36·18
½	11	54·52	½	11	75·19	½	11	95·87	½	12	16·54	½	12	37·21
559	11	55·56	569	11	76·23	579	11	96·90	589	12	17·57	599	12	38·24
½	11	56·59	½	11	77·26	½	11	97·93	½	12	18·60	½	12	39·28

Table of the Value of Gold—continued.

Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents
600	12	40·31	610	12	60·98	620	12	81·65	630	13	02·33	640	13	23·00
½	12	41·34	½	12	62·02	½	12	82·69	½	13	03·36	½	13	24·03
601	12	42·38	611	12	63·05	621	12	83·72	631	13	04·39	641	13	25·06
½	12	43·41	½	12	64·08	½	12	84·75	½	13	05·43	½	13	26·10
602	12	44·44	612	12	65·12	622	12	85·79	632	13	06·46	642	13	27·13
½	12	45·48	½	12	66·15	½	12	86·82	½	13	07·49	½	13	28·17
603	12	46·51	613	12	67·18	623	12	87·86	633	13	08·53	643	13	29·20
½	12	47·55	½	12	68·22	½	12	88·89	½	13	09·56	½	13	30·23
604	12	48·58	614	12	69·25	624	12	89·92	634	13	10·59	644	13	31·27
½	12	49·61	½	12	70·28	½	12	90·96	½	13	11·63	½	13	32·30
605	12	50·65	615	12	71·32	625	12	91·99	635	13	12·66	645	13	33·33
½	12	51·68	½	12	72·35	½	12	93·02	½	13	13·70	½	13	34·37
606	12	52·71	616	12	73·39	626	12	94·06	636	13	14·73	646	13	35·40
½	12	53·75	½	12	74·42	½	12	95·09	½	13	15·76	½	13	36·43
607	12	54·78	617	12	75·45	627	12	96·12	637	13	16·80	647	13	37·47
½	12	55·81	½	12	76·49	½	12	97·16	½	13	17·83	½	13	38·50
608	12	56·85	618	12	77·52	628	12	98·19	638	13	18·86	648	13	39·53
½	12	57·88	½	12	78·55	½	12	99·22	½	13	19·90	½	13	40·57
609	12	58·91	619	12	79·59	629	13	00·26	639	13	20·93	649	13	41·60
½	12	59·95	½	12	80·62	½	13	01·29	½	13	21·96	½	13	42·64

Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents
650	13	43·67	660	13	64·33	670	13	85·01	680	14	05·68	690	14	26·36
½	13	44·70	½	13	65·37	½	13	86·05	½	14	06·72	½	14	27·39
651	13	45·74	661	13	66·41	671	13	87·08	681	14	07·75	691	14	28·42
½	13	46·77	½	13	67·44	½	13	88·11	½	14	08·79	½	14	29·46
652	13	47·80	662	13	68·48	672	13	89·15	682	14	09·82	692	14	30·49
½	13	48·84	½	13	69·51	½	13	90·18	½	14	10·85	½	14	31·52
653	13	49·87	663	13	70·54	673	13	91·21	683	14	11·89	693	14	32·56
½	13	50·90	½	13	71·58	½	13	92·25	½	14	12·92	½	14	33·59
654	13	51·94	664	13	72·61	674	13	93·28	684	14	13·95	694	14	34·63
½	13	52·97	½	13	73·64	½	13	94·32	½	14	14·99	½	14	35·66
655	13	54·01	665	13	74·68	675	13	95·35	685	14	16·02	695	14	36·69
½	13	55·04	½	13	75·71	½	13	96·38	½	14	17·05	½	14	37·73
656	13	56·07	666	13	76·74	676	13	97·42	686	14	18·09	696	14	38·76
½	13	57·11	½	13	77·78	½	13	98·45	½	14	19·12	½	14	39·79
657	13	58·14	667	13	78·81	677	13	99·48	687	14	20·16	697	14	40·83
½	13	59·17	½	13	79·84	½	14	00·52	½	14	21·19	½	14	41·86
658	13	60·21	668	13	80·88	678	14	01·55	688	14	22·22	698	14	42·89
½	13	61·24	½	13	81·91	½	14	02·58	½	14	23·26	½	14	43·93
659	13	62·27	669	13	82·95	679	14	03·62	689	14	24·29	699	14	44·96
½	13	63·31	½	13	83·98	½	14	04·65	½	14	25·32	½	14	45·99

Table of the Value of Gold—continued.

Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents
700	14	47·03	710	14	67·70	720	14	88·37	730	15	09·04	740	15	29·72
½	14	48·06	½	14	68·73	½	14	89·41	½	15	10·08	½	15	30·75
701	14	49·10	711	14	69·76	721	14	90·44	731	15	11·11	741	15	31·78
½	14	50·13	½	14	70·80	½	14	91·47	½	15	12·14	½	15	32·82
702	14	51·16	712	14	71·83	722	14	92·51	732	15	13·18	742	15	33·85
½	14	52·20	½	14	72·87	½	14	93·54	½	15	14·21	½	15	34·88
703	14	53·23	713	14	73·90	723	14	94·57	733	15	15·25	743	15	35·92
½	14	54·26	½	14	74·94	½	14	95·61	½	15	16·28	½	15	36·95
704	14	55·30	714	14	75·97	724	14	96·64	734	15	17·31	744	15	37·98
½	14	56·33	½	14	77·00	½	14	97·67	½	15	18·35	½	15	39·02
705	14	57·36	715	14	78·04	725	14	98·71	735	15	19·38	745	15	40·05
½	14	58·40	½	14	79·07	½	14	99·74	½	15	20·41	½	15	41·09
706	14	59·43	716	14	80·10	726	15	00·78	736	15	21·45	746	15	42·12
½	14	60·47	½	14	81·14	½	15	01·81	½	15	22·48	½	15	43·15
707	14	61·50	717	14	82·17	727	15	02·84	737	15	23·51	747	15	44·18
½	14	62·53	½	14	83·20	½	15	03·88	½	15	24·55	½	15	45·22
708	14	63·57	718	14	84·24	728	15	04·91	738	15	25·58	748	15	46·25
½	14	64·60	½	14	85·27	½	15	05·94	½	15	26·61	½	15	47·29
709	14	65·63	719	14	86·30	729	15	06·98	739	15	27·65	749	15	48·32
½	14	66·67	½	14	87·34	½	15	08·01	½	15	28·68	½	15	49·35

Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents
750	15	50·39	760	15	71·06	770	15	91·73	780	16	12·40	790	16	33·07
½	15	51·42	½	15	72·09	½	15	92·76	½	16	13·44	½	16	34·11
751	15	52·45	761	15	73·13	771	15	93·80	781	16	14·47	791	16	35·14
½	15	53·49	½	15	74·16	½	15	94·83	½	16	15·50	½	16	36·18
752	15	54·52	762	15	75·19	772	15	95·87	782	16	16·54	792	16	37·21
½	15	55·56	½	15	76·23	½	15	96·90	½	16	17·57	½	16	38·24
753	15	56·59	763	15	77·26	773	15	97·93	783	16	18·60	793	16	39·28
½	15	57·62	½	15	78·29	½	15	98·97	½	16	19·64	½	16	40·31
754	15	58·66	764	15	79·33	774	16	00·00	784	16	20·67	794	16	41·34
½	15	59·69	½	15	80·36	½	16	01·03	½	16	21·71	½	16	42·38
755	15	60·72	765	15	81·40	775	16	02·07	785	16	22·74	795	16	43·41
½	15	61·76	½	15	82·43	½	16	03·10	½	16	23·77	½	16	44·44
756	15	62·79	766	15	83·46	776	16	04·13	786	16	24·81	796	16	45·48
½	15	63·82	½	15	84·50	½	16	05·17	½	16	25·84	½	16	46·51
757	15	64·86	767	15	85·53	777	16	06·20	787	16	26·87	797	16	47·55
½	15	65·89	½	15	86·56	½	16	07·24	½	16	27·91	½	16	48·58
758	15	66·93	768	15	87·60	778	16	08·27	788	16	28·94	798	16	49·61
½	15	67·96	½	15	88·63	½	16	09·30	½	16	29·97	½	16	50·65
759	15	68·99	769	15	89·66	779	16	10·34	789	16	31·01	799	16	51·68
½	15	70·03	½	15	90·70	½	16	11·37	½	16	32·04	½	16	52·71

Table of the Value of Gold—continued.

Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents
800	16	53·75	810	16	74·42	820	16	95·09	830	17	15·76	840	17	36·43
½	16	54·78	½	16	75·45	½	16	96·12	½	17	16·80	½	17	37·47
801	16	55·81	811	16	76·49	821	16	97·16	831	17	17·83	841	17	38·50
½	16	56·85	½	16	77·52	½	16	98·19	½	17	18·86	½	17	39·53
802	16	57·88	812	16	78·55	822	16	99·22	832	17	19·90	842	17	40·57
½	16	58·91	½	16	79·59	½	17	00·26	½	17	20·93	½	17	41·60
803	16	59·95	813	16	80·62	823	17	01·29	833	17	21·96	843	17	42·64
½	16	60·98	½	16	81·65	½	17	02·33	½	17	23·00	½	17	43·67
804	16	62·02	814	16	82·69	824	17	03·36	834	17	24·03	844	17	44·70
½	16	63·05	½	16	83·72	½	17	04·39	½	17	25·06	½	17	45·74
805	16	64·08	815	16	84·75	825	17	05·43	835	17	26·10	845	17	46·77
½	16	65·12	½	16	85·79	½	17	06·46	½	17	27·13	½	17	47·80
806	16	66·15	816	16	86·82	826	17	07·49	836	17	28·17	846	17	48·84
½	16	67·18	½	16	87·86	½	17	08·53	½	17	29·20	½	17	49·87
807	16	68·22	817	16	88·89	827	17	09·56	837	17	30·23	847	17	50·90
½	16	69·25	½	16	89·92	½	17	10·59	½	17	31·27	½	17	51·94
808	16	70·28	818	16	90·96	828	17	11·63	838	17	32·30	848	17	52·97
½	16	71·32	½	16	91·99	½	17	12·66	½	17	33·33	½	17	54·01
809	16	72·35	819	16	93·02	829	17	13·70	839	17	34·37	849	17	55·04
½	16	73·39	½	16	94·06	½	17	14·73	½	17	35·40	½	17	56·07

Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents
850	17	57·11	860	17	77·78	870	17	98·45	880	18	19·12	890	18	39·79
½	17	58·14	½	17	78·81	½	17	99·48	½	18	20·16	½	18	40·83
851	17	59·17	861	17	79·84	871	18	00·52	881	18	21·19	891	18	41·86
½	17	60·21	½	17	80·88	½	18	01·55	½	18	22·22	½	18	42·89
852	17	61·24	862	17	81·91	872	18	02·58	882	18	23·26	892	18	43·93
½	17	62·27	½	17	82·95	½	18	03·62	½	18	24·29	½	18	44·96
853	17	63·31	863	17	83·98	873	18	04·65	883	18	25·32	893	18	45·99
½	17	64·34	½	17	85·01	½	18	05·68	½	18	26·36	½	18	47·03
854	17	65·37	864	17	86·05	874	18	06·72	884	18	27·39	894	18	48·06
½	17	66·41	½	17	87·07	½	18	07·75	½	18	28·42	½	18	49·10
855	17	67·44	865	17	88·11	875	18	08·79	885	18	29·46	895	18	50·13
½	17	68·48	½	17	89·15	½	18	09·82	½	18	30·49	½	18	51·16
856	17	69·51	866	17	90·18	876	18	10·85	886	18	31·52	896	18	52·20
½	17	70·54	½	17	91·21	½	18	11·89	½	18	32·56	½	18	53·23
857	17	71·58	867	17	92·25	877	18	12·92	887	18	33·59	897	18	54·26
½	17	72·61	½	17	93·28	½	18	13·95	½	18	34·63	½	18	55·30
858	17	73·64	868	17	94·32	878	18	14·99	888	18	35·66	898	18	56·33
½	17	74·68	½	17	95·35	½	18	16·02	½	18	36·69	½	18	57·36
859	17	75·71	869	17	96·38	879	18	17·05	889	18	37·73	899	18	58·40
½	17	76·74	½	17	97·42	½	18	18·09	½	18	38·76	½	18	59·43

Table of the Value of Gold—continued.

Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents
900	18	60·46	910	18	81·14	920	19	01·81	930	19	22·48	940	19	43·15
½	18	61·50	½	18	82·17	½	19	02·84	½	19	23·51	½	19	44·19
901	18	62·53	911	18	83·20	921	19	03·88	931	19	24·55	941	19	45·22
½	18	63·57	½	18	84·24	½	19	04·91	½	19	25·58	½	19	46·25
902	18	64·60	912	18	85·27	922	19	05·94	932	19	26·61	942	19	47·29
½	18	65·63	½	18	86·30	½	19	06·98	½	19	27·65	½	19	48·32
903	18	66·67	913	18	87·34	923	19	08·01	933	19	28·68	943	19	49·35
½	18	67·70	½	18	88·37	½	19	09·04	½	19	29·72	½	19	50·39
904	18	68·73	914	18	89·41	924	19	10·08	934	19	30·75	944	19	51·42
½	18	69·77	½	18	90·44	½	19	11·11	½	19	31·78	½	19	52·45
905	18	70·80	915	18	91·47	925	19	12·14	935	19	32·82	945	19	53·49
½	18	71·83	½	18	92·51	½	19	13·18	½	19	33·85	½	19	54·52
906	18	72·87	916	18	93·54	926	19	14·21	936	19	34·88	946	19	55·56
½	18	73·90	½	18	94·57	½	19	15·25	½	19	35·92	½	19	56·59
907	18	74·94	917	18	95·61	927	19	16·28	937	19	36·95	947	19	57·62
½	18	75·97	½	18	96·64	½	19	17·31	½	19	37·98	½	19	58·66
908	18	77·00	918	18	97·67	928	19	18·35	938	19	39·02	948	19	59·69
½	18	78·04	½	18	98·71	½	19	19·38	½	19	40·05	½	19	60·72
909	18	79·07	919	18	99·74	929	19	20·41	939	19	41·08	949	19	61·76
½	18	80·10	½	19	00·78	½	19	21·45	½	19	42·12	½	19	62·79

Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents	Fine	Dollars	Cents
950	19	63·82	960	19	84·50	970	20	05·17	980	20	25·84	990	20	46·51
½	19	64·86	½	19	85·53	½	20	06·20	½	20	26·87	½	20	47·55
951	19	65·89	961	19	86·56	971	20	07·23	981	20	27·91	991	20	48·58
½	19	66·93	½	19	87·60	½	20	08·27	½	20	28·94	½	20	49·61
952	19	67·96	962	19	88·63	972	20	09·30	982	20	29·97	992	20	50·65
½	19	68·99	½	19	89·66	½	20	10·34	½	20	31·01	½	20	51·68
953	19	70·03	963	19	90·70	973	20	11·37	983	20	32·04	993	20	52·71
½	19	71·06	½	19	91·73	½	20	12·40	½	20	33·07	½	20	53·75
954	19	72·09	964	19	92·76	974	20	13·44	984	20	34·11	994	20	54·78
½	19	73·13	½	19	93·80	½	20	14·47	½	20	35·14	½	20	55·81
955	19	74·16	965	19	94·83	975	20	15·50	985	20	36·18	995	20	56·85
½	19	75·19	½	19	95·87	½	20	16·54	½	20	37·21	½	20	57·88
956	19	76·23	966	19	96·90	976	20	17·57	986	20	38·24	996	20	58·91
½	19	77·26	½	19	97·93	½	20	18·60	½	20	39·28	½	20	59·95
957	19	78·29	967	19	98·97	977	20	19·64	987	20	40·31	997	20	60·98
½	19	79·33	½	20	00·00	½	20	20·67	½	20	41·34	½	20	62·02
958	19	80·36	968	20	01·03	978	20	21·70	988	20	42·38	998	20	63·05
½	19	81·40	½	20	02·07	½	20	22·74	½	20	43·41	½	20	64·08
959	19	82·43	969	20	03·10	979	20	23·77	989	20	44·44	999	20	65·12
½	19	83·46	½	20	04·13	½	20	24·81	½	20	45·48	½	20	66·15
												1000	20	67·18

INDEX.

Spottiswoode & Co., Printers, New-street Square, London.

SCIENTIFIC BOOKS

PUBLISHED BY

D. VAN NOSTRAND,

23 Murray Street and 27 Warren Street,

NEW YORK

Any Book in this Catalogue, sent free by mail on receipt of price.

Weisbach's Mechanics.

Fourth Edition, Revised. 8vo. Cloth. $10.00.

A Manual of Theoretical Mechanics. By Julius Weisbach, Ph. D. Translated from the fourth augmented and improved German edition, with an introduction to the Calculus, by Eckley B. Coxe, A. M., Mining Engineer. 1100 pages and 902 wood-cut illustrations.

Francis' Lowell Hydraulics.

Third Edition. 4to. Cloth. $15.00.

Lowell Hydraulic Experiments—being a Selection from Experiments on Hydraulic Motors, on the Flow of Water over Weirs, and in open Canals of Uniform Rectangular Section, made at Lowell, Mass. By J. B. Francis, Civil Engineer. Third edition, revised and enlarged, including many New Experiments on Gauging Water in Open Canals, and on the Flow through Submerged Orifices and Diverging Tubes. With 23 copperplates, beautifully engraved, and about 100 new pages of text.

Kirkwood on Filtration.

4to. Cloth. $15.00.

Report on the Filtration of River Waters, for the Supply of Cities, as practised in Europe, made to the Board of Water Commissioners of the City of St. Louis. By James P. Kirkwood. Illustrated by 30 double-plate engravings.

Rogers' Geology of Pennsylvania.

3 Vols. 4to, with Portfolio of Maps. Cloth. $30.00.

THE GEOLOGY OF PENNSYLVANIA. A Government Survey. With a general view of the Geology of the United States, Essays on the Coal Formation and its Fossils, and a description of the Coal Fields of North America and Great Britain. By HENRY DARWIN ROGERS, Late State Geologist of Pennsylvania. Splendidly illustrated with Plates and Engravings in the Text

Merrill's Iron Truss Bridges.

Third Edition. 4to. Cloth. $5.00.

IRON TRUSS BRIDGES FOR RAILROADS. The Method of Calculating Strains in Trusses, with a careful comparison of the most prominent Trusses, in reference to economy in combination, etc., etc. By Bvt. Col. WILLIAM E. MERRILL, U.S.A., Corps of Engineers. Nine lithographed plates of illustrations.

Shreve on Bridges and Roofs.

8vo, 87 wood-cut illustrations. Cloth. $5.00.

A TREATISE ON THE STRENGTH OF BRIDGES AND ROOFS—comprising the determination of Algebraic formulas for Strains in Horizontal, Inclined or Rafter, Triangular, Bowstring, Lenticular and other Trusses, from fixed and moving loads, with practical applications and examples, for the use of Students and Engineers. By Samuel H. Shreve, A. M., Civil Engineer.

The Kansas City Bridge.

4to. Cloth. $6.00

WITH AN ACCOUNT OF THE REGIMEN OF THE MISSOURI RIVER,--and a description of the Methods used for Founding in that River. By O Chanute, Chief Engineer, and George Morison, Assistant Engineer Illustrated with five lithographic views and twelve plates of plans.

Clarke's Quincy Bridge.

4to. Cloth. $7.50.

DESCRIPTION OF THE IRON RAILWAY. Bridge across the Mississippi River at Quincy, Illinois. By Thomas Curtis Clarke, Chief Engineer With twenty-one lithographed plates.

Whipple on Bridge Building.

New edition. 8vo. Illustrated. Cloth. $4.

An Elementary and Practical Treatise on Bridge Building. By S. Whipple, C. E.

Roebling's Bridges.

Imperial folio. Cloth. $25.00.

Long and Short Span Railway Bridges. By John A. Roebling, C. E. With large copperplate engravings of plans and views.

Dubois' Graphical Statics.

8vo. 60 Illustrations. Cloth. $1.50.

The New Method of Graphical Statics. By A. J. Dubois, C. E., Ph. D.

Eddy's Graphical Statics.

8vo. Cloth. 122 pages. $1.50.

Researches in Graphical Statics, embracing New Constructions in Graphical Statics, a new General Method in Graphical Statics, and the Theory of Internal Stress in Graphical Statics. By Prof. Henry T. Eddy, of the University of Cincinnati.

Bow on Bracing.

156 Illustrations on Stone. 8vo. Cloth. $1.50.

A Treatise on Bracing,—with its application to Bridges and other Structures of Wood or Iron. By Robert Henry Bow, C. E.

Stoney on Strains.

New and Revised Edition, with numerous illustrations. Royal 8vo, 664 pp. Cloth. $12.50.

The Theory of Strains in Girders—and Similar Structures, with Observations on the Application of Theory to Practice, and Tables of Strength and other Properties of Materials. By Bindon B. Stoney, B. A.

Henrici's Skeleton Structures.

8vo. Cloth. $1.50.

Skeleton Structures, especially in their Application to the building of Steel and Iron Bridges. By Olaus Henrici.

Burgh's Modern Marine Engineering.

One thick 4to vol. Cloth. $25.00. Half morocco. $30.00.

MODERN MARINE ENGINEERING, applied to Paddle and Screw Propulsion. Consisting of 36 Colored Plates, 259 Practical Wood-cut Illustrations, and 403 pages of Descriptive Matter, the whole being an exposition of the present practice of the following firms: Messrs. J. Penn & Sons; Messrs. Maudslay, Sons & Field; Messrs. James Watt & Co.; Messrs. J. & G. Rennie; Messrs. R. Napier & Sons; Messrs. J. & W. Dudgeon; Messrs. Ravenhill & Hodgson; Messrs. Humphreys & Tenant; Mr. J. T. Spencer, and Messrs. Forrester & Co. By N. P. BURGH, Engineer.

King's Notes on Steam.

Nineteenth Edition. 8vo. $2.00.

LESSONS AND PRACTICAL NOTES ON STEAM,—the Steam Engine, Propellers, &c., &c., for Young Engineers. By the late W. R. KING, U. S. N. Revised by Chief-Engineer J. W. KING, U. S. Navy.

Link and Valve Motions, by W. S. Auchincloss.

Sixth Edition. 8vo. Cloth. $3.00.

APPLICATION OF THE SLIDE VALVE and Link Motion to Stationary, Portable, Locomotive and Marine Engines. By WILLIAM S. AUCHINCLOSS. Designed as a hand-book for Mechanical Engineers. Dimensions of the valve are found by means of a Printed Scale, and proportions of the link determined *without* the assistance of a model. With 37 wood-cuts and 21 lithographic plates, with copperplate engraving of the Travel Scale.

Bacon's Steam-Engine Indicator.

12mo. Cloth. $1.00 Mor. $1.50.

A TREATISE ON THE RICHARDS STEAM-ENGINE INDICATOR,—with directions for its use. By CHARLES T. PORTER. Revised, with notes and large additions as developed by American Practice, with an Appendix containing useful formulæ and rules for Engineers. By F. W BACON, M. E., Illustrated. Third Edition, Enlarged.

Isherwood's Engineering Precedents.

Two Vols. in One. 8vo. Cloth. $2.50.

ENGINEERING PRECEDENTS FOR STEAM MACHINERY.—By B. F ISHERWOOD, Chief Engineer, U. S. Navy. With illustrations.

Slide Valve by Eccentrics, by Prof. C. W. MacCord.

4to. Illustrated. Cloth, $3.00

A Practical Treatise on the Slide Valve by Eccentrics,—examining by methods the action of the Eccentric upon the Slide Valve, and explaining the practical processes of laying out the movements, adapting the valve for its various duties in the steam-engine. For the use of Engineers, Draughtsmen, Machinists, and Students of valve motions in general. By C. W. MacCord, A. M., Professor of Mechanical Drawing, Stevens' Institute of Technology, Hoboken, N. J.

Stillman's Steam-Engine Indicator.

12mo. Cloth. $1.00

The Steam-Engine Indicator,—and the Improved Manometer Steam and Vacuum Gauges ; their utility and application. By Paul Stillman. New edition.

Porter's Steam-Engine Indicator.

Third Edition. Revised and Enlarged. 8vo. Illustrated. Cloth. $3.50.

A Treatise on the Richards Steam-Engine Indicator,—and the Development and Application of Force in the Steam-Engine. By Charles T. Porter.

McCulloch's Theory of Heat.

8vo. Cloth. $3.50.

A Treatise on the Mechanical Theory of Heat, and its Applications to the Steam-Engine. By Prof. R. S. McCulloch, of the Washington and Lee University, Lexington, Va.

Van Buren's Formulas.

8vo. Cloth. $2.00.

Investigations of Formulas,—for the Strength of the Iron parts of Steam Machinery. By J. D. Van Buren, Jr., C. E. Illustrated.

Stuart's Successful Engineer.

18mo. Boards. 50 cents.

How to Become a Successful Engineer. Being Hints to Youths intending to adopt the Profession. By Bernard Stuart, Engineer. Sixth Edition

Stuart's Naval Dry Docks.

Twenty-four engravings on steel. Fourth edition. 4to. Cloth. $6.00.

The Naval Dry Docks of the United States. By Charles B. Stuart, Engineer in Chief U. S. Navy.

Ward's Steam for the Million.

8vo. Cloth. $1.00.

Steam for the Million. A Popular Treatise on Steam and its Application to the Useful Arts, especially to Navigation. By J. H. Ward, Commander U. S. Navy.

Tunner on Roll-Turning.

1 vol. 8vo. and 1 vol. folio plates. $10.00.

A Treatise on Roll-Turning for the Manufacture of Iron, by Peter Tunner. Translated by John B. Pearse, of the Pennsylvania Steel Works. With numerous wood-cuts, 8vo., together with a folio atlas of 10 lithographed plates of Rolls, Measurements, &c.

Grüner on Steel.

8vo. Cloth. $3.50.

The Manufacture of Steel. By M. L. Grüner; translated from the French. By Lenox Smith, A.M., E.M.; with an Appendix on the Bessemer Process in the United States, by the translator. Illustrated by lithographed drawings and wood-cuts.

Barba on the Use of Steel.

12mo. Illustrated. Cloth. $1.50.

The Use of Steel in Construction. Methods of Working, Applying, and Testing Plates and Bars. By J. Barba, Chief Naval Constructor. Translated from the French, with a Preface, by A. L. Holley, P.B.

Bell on Iron Smelting.

8vo. Cloth. $6.00.

Chemical Phenomena of Iron Smelting. An experimental and practical examination of the circumstances which determine the capacity of the Blast Furnace, the Temperature of the Air, and the Proper Condition of the Materials to be operated upon. By I. Lowthian Bell.

The Useful Metals and their Alloys; Scoffren, Truran, and others.

Fifth Edition. 8vo. Half calf. $3.75.

The Useful Metals and their Alloys, employed in the conversion of Iron, Copper, Tin, Zinc, Antimony, and Lead Ores, with their applications to the Industrial Arts. By John Scoffren, William Truran, William Clay, Robert Oxland, William Fairbairn, W. C. Aitkin, and William Vose Pickett.

Collins' Useful Alloys.

18mo. Flexible. 50 cents.

The Private Book of Useful Alloys and Memoranda for Goldsmiths, Jewellers, etc. By James E. Collins.

Joynson's Metal Used in Construction.

12mo. Cloth. 75 cents.

The Metals Used in Construction: Iron, Steel, Bessemer Metal, etc., etc. By Francis H. Joynson. Illustrated.

Dodd's Dictionary of Manufactures, etc.

12mo. Cloth. $1.50.

Dictionary of Manufactures, Mining, Machinery, and the Industrial Arts. By George Dodd.

Plympton's Blow-Pipe Analysis.

12mo. Cloth. $1.50.

The Blow-Pipe: A Guide to its Use in the Determination of Salts and Minerals. Compiled from various sources, by George W. Plympton, C.E., A.M., Professor of Physical Science in the Polytechnic Institute, Brooklyn, N.Y.

Plattner's Blow-Pipe Analysis.

Third Edition. Revised. 568 pages. 8vo. Cloth. $5.00.

Plattner's Manual of Qualitative and Quantitative Analysis with the Blow-Pipe. From the last German edition, Revised and enlarged. By Prof. Th. Richter, of the Royal Saxon Mining Academy. Translated by Professor H B. Cornwall; assisted by John H. Caswell. With eighty-seven wood-cuts and Lithographic Plate.

Pynchon's Chemical Physics.

New Edition. Revised and enlarged. Crown 8vo. Cloth. $3.00.

Introduction to Chemical Physics; Designed for the Use of Academies, Colleges, and High Schools. Illustrated with numerous engravings, and containing copious experiments, with directions for preparing them. By Thomas Ruggles Pynchon, M.A., President of Trinity College, Hartford.

Eliot and Storer's Qualitative Chemical Analysis.

New Edition. Revised. 12mo. Illustrated. Cloth. $1.50.

A Compendious Manual of Qualitative Chemical Analysis By Charles W. Eliot and Frank H. Storer. Revised, with the coöperation of the Authors, by William Ripley Nichols, Professor of Chemistry in the Massachusetts Institute of Technology.

Rammelsberg's Chemical Analysis.

8vo. Cloth. $2.25.

Guide to a Course of Quantitative Chemical Analysis, Especially of Minerals and Furnace Products. Illustrated by Examples. By C. F. Rammelsberg. Translated by J. Towler, M.D.

Naquet's Legal Chemistry.

Illustrated. 12mo. Cloth. $2.00.

Legal Chemistry. A Guide to the Detection of Poisons, Falsification of Writings, Adulteration of Alimentary and Pharmaceutical Substances; Analysis of Ashes, and Examination of Hair, Coins, Fire-arms, and Stains, as Applied to Chemical Jurisprudence. For the Use of Chemists, Physicians, Lawyers, Pharmacists, and Experts. Translated, with additions, including a List of Books and Memoirs on Toxicology, etc., from the French of A. Naquet. By J. P. Battershall, Ph. D., with a Preface by C. F. Chandler, Ph. D., M D., LL.D

Prescott's Qualitative Chemistry.

12mo. Cloth. $1.50.

First Book in Qualitative Chemistry. By Albert B. Prescott, Professor of Organic and Applied Chemistry in the University of Michigan.

Prescott's Proximate Organic Analysis.

12mo. Cloth. $1.75.

Outlines of Proximate Organic Analysis, for the Identification, Separation, and Quantitative Determination of the more commonly occurring Organic Compounds. By Albert B. Prescott, Professor of Organic and Applied Chemistry in the University of Michigan.

Prescott's Alcoholic Liquors.

12mo. Cloth. $1.50.

Chemical Examination of Alcoholic Liquors.—A Manual of the Constituents of the Distilled Spirits and Fermented Liquors of Commerce, and their Qualitative and Quantitative Determinations. By Albert B. Prescott, Professor of Organic and Applied Chemistry in the University of Michigan.

Prescott and Douglas's Qualitative Chemical Analysis.

Second Edition. Revised. 8vo. Cloth. $3.50.

A Guide in the Practical Study of Chemistry and in the Work of Analysis.

Mott's Chemists' Manual.

8vo. 650 pages. Cloth. $6.00.

A Practical Treatise on Chemistry (Qualitative and Quantitative Analysis), Stoichiometry, Blowpipe Analysis, Mineralogy, Assaying, Pharmaceutical Preparations, Human Secretions, Specific Gravities, Weights and Measures, etc., etc., etc. By Henry A. Mott, Jr., E. M., Ph. D.

Beilstein's Chemical Analysis.

12mo. Cloth. 75c.

An Introduction to Qualitative Chemical Analysis. By F. Beilstein. Third edition, translated by I. J. Osbun.

Caldwell & Breneman's Chemical Practice.

8vo. Cloth. 188 pages. Illustrated. New and Enlarged edition. $1.50.

Manual of Introductory Chemical Practice, for the use of Students in Colleges and Normal and High Schools. By Prof. Geo. C. Caldwell and A. A. Breneman, of Cornell University. Second edition, revised and corrected.

Gillmore's Limes and Cements.

Fifth Edition. Revised and Enlarged. 8vo. Cloth. $4.00.

PRACTICAL TREATISE ON LIMES, HYDRAULIC CEMENTS, AND MORTARS. By Q. A. GILLMORE, Lt.-Col. U. S. Corps of Engineers Brevet Major-General U. S. Army.

Gillmore's Coignet Beton.

Nine Plates, Views, etc. 8vo. Cloth. $2.50.

COIGNET BETON AND OTHER ARTIFICIAL STONE.—By Q. A. GILLMORE, Lt.-Col. U. S. Corps of Engineers, Brevet Major-General U.S. Army.

Gillmore on Roads.

Seventy Illustrations. 12mo. Cloth. $2.00.

A PRACTICAL TREATISE ON THE CONSTRUCTION OF ROADS, STREETS, AND PAVEMENTS. By Q. A. GILLMORE, Lt.-Col. U. S. Corps of Engineers, Brevet Major-General U. S. Army.

Gillmore's Building Stones.

8vo. Cloth. $1.00.

REPORT ON STRENGTH OF THE BUILDING STONES IN THE UNITED STATES, etc.

Holley's Railway Practice.

1 vol. folio. Cloth. $12.00.

AMERICAN AND EUROPEAN RAILWAY PRACTICE, in the Economical Generation of Steam, including the materials and construction of Coal-burning Boilers, Combustion, the Variable Blast, Vaporization, Circulation, Super-heating, Supplying and Heating Feed-water, &c., and the adaptation of Wood and Coke-burning Engines to Coal-burning; and in Permanent Way, including Road-bed, Sleepers, Rails, Joint Fastenings, Street Railways, etc., etc. By ALEXANDER L. HOLLEY, B.P. With 77 lithographed plates.

Useful Information for Railway Men.

Pocket form. Morocco, gilt. $2.00.

Compiled by W. G. HAMILTON, Engineer. New Edition, Revised and Enlarged. 577 pages.

Stuart's Civil and Military Engineers of America.

8vo. Illustrated. Cloth. $5.00.

The Civil and Military Engineers of America. By General Charles B. Stuart, Author of "Naval Dry Docks of the United States," etc., etc. Embellished with nine finely-executed Portraits on steel of eminent Engineers, and illustrated by Engravings of some of the most important and original works constructed in America.

Ernst's Manual of Military Engineering.

193 Wood-cuts and 3 Lithographed Plates. 12mo. Cloth. $5.00

A Manual of Practical Military Engineering. Prepared for the use of the Cadets of the U. S. Military Academy, and for Engineer Troops. By Capt. O. H. Ernst, Corps of Engineers, Instructor in Practical Military Engineering, U. S. Military Academy.

Simms' Levelling.

12mo. Cloth. $2.50.

A Treatise on the Principles and Practice of Levelling, showing its application to purposes of Railway Engineering and the Construction of Roads, etc. By Frederick W. Simms, C.E. From the fifth London edition, Revised and Corrected, with the addition of Mr. Law's Practical Examples for Setting-out Railway Curves. Illustrated with three lithographic plates and numerous wood-cuts.

Jeffers' Nautical Surveying.

Illustrated with 9 Copperplates and 31 Wood-cut Illustrations. 8vo. Cloth. $5.00

Nautical Surveying. By William N. Jeffers, Captain U. S. Navy.

Text-book of Surveying.

8vo. 9 Lithograph Plates and several Wood-cuts. Cloth. $2.00.

A Text-book on Surveying, Projections, and Portable Instruments, for the use of the Cadet Midshipmen, at the U. S. Naval Academy.

The Plane Table.

8vo. Cloth. $2.00.

Its Uses in Topographical Surveying. From the papers of the U. S. Coast Survey.

Chauvenet's Lunar Distances.

8vo. Cloth. $2.00.

New Method of Correcting Lunar Distances, and Improved Method of Finding the Error and Rate of a Chronometer, by equal altitudes. By Wm. Chauvenet, LL.D., Chancellor of Washington University of St. Louis.

Burt's Key to Solar Compass.

Second Edition. Pocket-book form. Tuck. $2.50.

Key to the Solar Compass, and Surveyor's Companion; comprising all the Rules necessary for use in the Field; also Description of the Linear Surveys and Public Land System of the United States, Notes on the Barometer, Suggestions for an Outfit for a Survey of Four Months, etc. By W. A. Burt, U. S. Deputy Surveyor.

Howard's Earthwork Mensuration.

8vo. Illustrated. Cloth. $1.50.

Earthwork Mensuration on the Basis of the Prismoidal Formulæ. Containing simple and labor-saving method of obtaining Prismoidal Contents directly from End Areas. Illustrated by Examples, and accompanied by Plain Rules for practical uses. By Conway R. Howard, Civil Engineer, Richmond, Va.

Morris' Easy Rules.

78 Illustrations. 8vo. Cloth. $1.50.

Easy Rules for the Measurement of Earthworks, by means of the Prismoidal Formula. By Elwood Morris, Civil Engineer.

Clevenger's Surveying.

Illustrated Pocket Form. Morocco, gilt. $2.50.

A Treatise on the Method of Government Surveying, as prescribed by the U. S. Congress and Commissioner of the General Land Office. With complete Mathematical, Astronomical, and Practical Instructions for the use of the U. S. Surveyors in the Field, and Students who contemplate engaging in the business of Public Land Surveying. By S. V. Clevenger, U. S. Deputy Surveyor.

Hewson on Embankments.

8vo. Cloth. $2.00.

Principles and Practice of Embanking Lands from River Floods, as applied to the Levees of the Mississippi. By William Hewson, Civil Engineer

Minifie's Mechanical Drawing.

Ninth Edition. Royal 8vo. Cloth. $4.00.

A TEXT-BOOK OF GEOMETRICAL DRAWING, for the use of Mechanics and Schools. With illustrations for Drawing Plans, Sections, and Elevations of Buildings and Machinery ; an Introduction to Isometrical Drawing, and an Essay on Linear Perspective and Shadows. With over 200 diagrams on steel. By WILLIAM MINIFIE, Architect. With an Appendix on the Theory and Application of Colors.

Minifie's Geometrical Drawing.

New Edition. Enlarged. 12mo. Cloth. $2.00

GEOMETRICAL DRAWING. Abridged from the octavo edition, for the use of Schools. Illustrated with 48 steel plates.

Free Hand Drawing.

Profusely Illustrated. 18mo. Boards. 50 cents.

A GUIDE TO ORNAMENTAL, Figure, and Landscape Drawing. By an Art Student.

The Mechanic's Friend.

12mo. Cloth. 300 Illustrations. $1.50.

THE MECHANIC'S FRIEND. A Collection of Receipts and Practical Suggestions, relating to Aquaria—Bronzing—Cements—Drawing—Dyes—Electricity—Gilding—Glass-working—Glues—Horology—Lacquers—Locomotives—Magnetism—Metal-working—Modelling—Photography—Pyrotechny—Railways — Solders — Steam-Engine — Telegraphy—Taxidermy—Varnishes—Waterproofing—and Miscellaneous Tools, Instruments, Machines, and Processes connected with the Chemical and Mechanical Arts. By WILLIAM E. AXON, M.R.S.L.

Harrison's Mechanic's Tool-Book.

44 Illustrations. 12mo. Cloth. $1.50.

MECHANICS' TOOL BOOK, with Practical Rules and Suggestions, for the use of Machinists, Iron Workers, and others. By W. B. HARRISON.

Randall's Quartz Operator's Hand-Book.

12mo. Cloth. $2.00.

QUARTZ OPERATOR'S HAND-BOOK. By P. M. RANDALL. New edition. Revised and Enlarged. Fully illustrated

Joynson on Machine Gearing.

8vo. Cloth. $2.00.

The Mechanic's and Student's Guide in the designing and Construction of General Machine Gearing, as Eccentrics, Screws, Toothed Wheels, etc., and the Drawing of Rectilineal and Curved Surfaces. Edited by Francis H. Joynson. With 18 folded plates.

Maxwell's Matter and Motion.

16mo. Boards. 216 pages. 50c.

Matter and Motion. By Prof. J. Clark Maxwell.

Barnes' Submarine Warfare.

8vo. Cloth. $5.00.

Submarine Warfare, Defensive and Offensive. Descriptions of the various forms of Torpedoes, Submarine Batteries and Torpedo Boats actually used in War. Methods of Ignition by Machinery, Contact Fuzes, and Electricity, and a full account of experiments made to determine the Explosive Force of Gunpowder under Water. Also a discussion of the Offensive Torpedo system, its effect upon Iron-clad Ship systems, and influence upon future Naval Wars. By Lieut.-Com. John S. Barnes, U.S.N. With twenty lithographic plates and many wood-cuts.

Foster's Submarine Blasting.

4to. Cloth. $3.50.

Submarine Blasting, in Boston Harbor, Massachusetts—Removal of Tower and Corwin Rocks. By John G. Foster, U. S. Eng. and Bvt. Major-General U. S. Army. With seven plates.

Plympton's Aneroid Barometer.

16mo. Boards, illustrated, 50c. Morocco, $1.00.

The Aneroid Barometer: Its Construction and Use, compiled from several sources.

Williamson on the Barometer.

4to. Cloth. $15.00.

On the Use of the Barometer on Surveys and Reconnaissances. Part I.—Meteorology in its Connection with Hypsometry. Part II.—Barometric Hypsometry. By R. S. Williamson, Bvt. Lt.-Col. U. S. A., Major Corps of Engineers. With illustrative tables and engravings.

Williamson's Meteorological Tables.

4to. Flexible Cloth. $2.50.

PRACTICAL TABLES IN METEOROLOGY AND HYPSOMETRY, in connection with the use of the Barometer. By Col. R S. WILLIAMSON, U.S.A.

Modern Meterology.

12mo. Cloth. $1.50.

A SERIES OF SIX LECTURES, delivered under the auspices of the Meterological Society in 1878. Illustrated.

Benét's Chronoscope.

Second Edition. Illustrated. 4to. Cloth. $3.00.

ELECTRO-BALLISTIC MACHINES, and the Schultz Chronoscope. By Lt.-Col. S. V. BENÉT, Chief of Ordnance U. S. A.

Michaelis' Chronograph.

4to. Illustrated. Cloth. $3.00.

THE LE BOULENGÉ CHRONOGRAPH. With three lithographed folding plates of illustrations. By Bvt. Captain O. E. MICHAELIS, Ordnance Corps, U. S. A.

Nugent's Optics.

12mo. Cloth. $1.50.

TREATISE ON OPTICS; or, Light and Sight, theoretically and practically treated; with the application to Fine Art and Industrial Pursuits. By E. NUGENT. With 103 illustrations.

Peirce's Analytic Mechanics.

4to. Cloth. $10.00.

SYSTEM OF ANALYTIC MECHANICS. By BENJAMIN PEIRCE, Professor of Astronomy and Mathematics in Harvard University.

Craig's Decimal System.

Square 32mo. Limp. 50c.

WEIGHTS AND MEASURES. An Account of the Decimal System, with Tables of Conversion for Commercial and Scientific Uses. By B. F. CRAIG, M.D.

Alexander's Dictionary of Weights and Measures.

New Edition. 8vo. Cloth. $3.50.

Universal Dictionary of Weights and Measures, Ancient and Modern, reduced to the standards of the United States of America. By J. H. Alexander.

Elliot's European Light-Houses.

51 Engravings and 21 Wood-cuts. 8vo. Cloth. $5.00.

European Light-House Systems. Being a Report of a Tour of Inspection made in 1873. By Major George H. Elliot, U. S. Engineers.

Sweet's Report on Coal.

With Maps. 8vo. Cloth. $3.00.

Special Report on Coal. By S. H. Sweet.

Colburn's Gas Works of London.

12mo. Boards. 60 cents.

Gas Works of London. By Zerah Colburn.

Walker's Screw Propulsion.

8vo. Cloth. 75 cents.

Notes on Screw Propulsion, its Rise and History. By Capt. W. H Walker, U. S. Navy.

Pook on Shipbuilding.

8vo. Cloth. Illustrated. $5.00.

Method of Preparing the Lines and Draughting Vessels Propelled by Sail or Steam, including a Chapter on Laying-off on the Mould-loft Floor. By Samuel M. Pook, Naval Constructor.

Saeltzer's Acoustics.

12mo. Cloth. $2.00.

Treatise on Acoustics in connection with Ventilation. By Alexander Saeltzer.

Eassie on Wood and its Uses.

250 Illustrations. 8vo. Cloth. $1.50.

A Hand-book for the Use of Contractors, Builders, Architects, Engineers, Timber Merchants, etc., with information for drawing up Designs and Estimates.

Wanklyn's Milk Analysis.

12mo. Cloth. $1.00.

Milk Analysis. A Practical Treatise on the Examination of Milk, and its Derivatives, Cream, Butter, and Cheese. By J. Alfred Wanklyn, M.R.C.S.

Rice & Johnson's Differential Functions.

Paper, 12mo. 50 cents.

On a New Method of Obtaining the Differentials of Functions, with especial reference to the Newtonian Conception of Rates or Velocities. By J. Minot Rice, Prof. of Mathematics, U. S. Navy, and W. Woolsey Johnson, Prof. of Mathematics, St. John's College, Annapolis.

Coffin's Navigation.

Fifth Edition. 12mo. Cloth. $3.50.

Navigation and Nautical Astronomy. Prepared for the use of the U. S. Naval Academy. By J. H. C. Coffin, Professor of Astronomy, Navigation and Surveying; with 52 wood-cut illustrations.

Clark's Theoretical Navigation,

8vo. Cloth. $3.00.

Theoretical Navigation and Nautical Astronomy. By Lewis Clark, Lieut.-Commander, U. S. Navy. Illustrated with 41 woodcuts, including the Vernier.

Clark's Combustion of Fuel.

12mo. Cloth. $1.50.

Fuel: its Combustion and Economy, consisting of Abridgements of Treatise on the Combustion of Coal and the Prevention of Smoke, by C. W. Williams; and the Economy of Fuel, by T. S. Prideaux, with extensive additions on recent practice in the Combustion and Economy of Fuel: Coal, Coke, Wood, Peat, Petroleum, etc. By the Editor, D. Kinnear Clark, C. E.

Rose's Pattern Maker.

8vo. Cloth. 350 pages. $2.50.

The Pattern Makers' Assistant, embracing Lathe Work, Branch Work, Core Work, Sweep Work, and Practical Gear Construcions, the Preparation and Use of Tools, together with a large collection of useful and valuable Tables. By Joshua Rose, M. E. Illustrated with 250 Engravings.

Scribner's Pocket Companion.

16mo. 264 pages. Full Morocco. $1.50.

Engineers' and Mechanics' Companion, comprising United States Weights and Measures; Mensuration of Superfices and Solids; Tables of Squares and Cubes; Square and Cube Roots; Circumference and Areas of Circles; the Mechanical Powers; Centers of Gravity; Gravitation of Bodies; Pendulums; Specific Gravity of Bodies; Strength Weight and Crush of Materials; Water Wheels; Hydrostatics; Hydraulics; Statics; Centers of Percussion and Gyration; Friction Heat; Tables of the Weight of Metals; Scantling, etc.; Steam and the Steam Engine. By J. M. Scribner, A. M. Eighteenth edition, revised.

Scribner's Table-Book.

16mo. 264 pages. Full Morocco. $1.50.

Engineers', Contractors' and Surveyors' Pocket Table-Book: Comprising Logarithms of Numbers, Logarithmic Signs and Tangents, Natural Signs and Natural Tangents, the Traverse Table, and a full and complete set of Excavation and Embankment Tables, together with numerous other valuable tables for Engineers, etc. By T. M. Scrib-, A. M. Tenth edition, revised.

Fanning's Water-supply Engineering.

8vo. Cloth. 619 pages. $6.00.

Treatise on the Theory and Practice of Gathering and Storing Water for Power and Domestic Use. Fully Illustrated with Designs and Diagrams.

Plympton's Planisphere.

Printed in Colors on fine Card Board, and in accordance with Proctor's Star Atlas. $1.00.

The Star Finder or Planisphere, with Movable Horizon. Arranged by Prof. G. W. Plympton, A. M.

Schumann's Heating and Ventilation.

12mo. Morocco. $1.50.

A Manual of Heating and Ventilation in its Practical Application for the use of Engineers and Architects, embracing a series of Tables and Formulæ for dimensions of Heating, flow and return Pipes for steam and hot water boilers, flues, etc., etc. By F. Schumann, C. E., U. S. Treasury Dept. Illustrated.

Clark's Complete Book of Reference for Mechanical Engineers.

Large 8vo. 1012 pages. Cloth. $7.50. Half Morocco. $10.00.

A Manual of Rules, Tables and Data for Mechanical Engineers. Based on the most recent investigations. By Daniel Kinnear Clark. Illustrated with numerous Diagrams.

Weyrauch's Iron and Steel Constructions.

12mo. Cloth. $1.00.

Strength and Calculation of Dimensions of Iron and Steel Constructions, with reference to the latest experiments. By J. J. Weyrauch, Ph. D., Professor Polytechnic School of Stuttgart, with four folding plates.

Jannettaz on Rocks.

12mo. Cloth. 168 pages. $2.00.

A Guide to the Determination of Rocks, being an Introduction to Lithology. By Edward Jannettaz. Translated from the French by Geo. W. Plympton, C. E., A. M. Illustrated. $1.50.

Shield's Notes on Engineering Construction.

12mo. Cloth. $1.50.

Embracing Discussions of the Principles involved and Descriptions of the Material employed in Tunneling, Bridging, Canal and Road Building, etc., etc. By J. E. Shields, C. E.

Watt's Electro Metallurgy.

12mo. Cloth. $1.00.

Electro Metallurgy, Practically Treated. By Alexander Watt, F. R. S., S. A. Lecturer on Electro Metallurgy, etc. Formerly one of the editors of "The Chemist." Sixth Edition, with considerable additions.

Half Hours with Modern Scientists.

2 vols. 12mo. Cloth. Illustrated. $2.50.

Lectures and Essays. By Professors Huxley, Barker, Stirling, Cope, Tyndall, Wallace, Roscoe, Huggins, Lockyer, Young, Mayer, and Reed. Being the University Series bound up. With a general introduction by Noah Porter, President of Yale College.

Shunk's Engineers Pocket Book.

12mo. Morocco. Tucks. Gilt edge. $2.50.

The Field Engineer. A handy book of Practice in the Survey, Location, and Trackwork of Railroads, containing a large collection of Rules and Tables, original and selected, applicable to both the Standard and Narrow Gauge, and prepared with special reference to the wants of the Young Engineer. By Wm. Findlay Shunk, C. E., Chief Engineer of the Construction of the Metropolitan Elevated Railroad.

Adams' Sewers and Drains.

Octavo. Cloth. $2.50.

Sewers and Drains for Populous Districts. Embracing Rules and Formulas for the dimensions and construction of works of Sanitary Engineers. By Julius Adams, C. E.

McElroy's Papers on Hydraulic Engineering.

8vo. Paper. 50 cents.

The Hempstead Storage Reservoir of Brooklyn, its Engineering Theory and Results. By Samuel McElroy, C. E.

Spinoza's Ethics.

8vo. Cloth. $3.00.

The Ethics of Benedict de Spinoza. Demonstrated after the method of Geometers, and Divided into Five Parts. From the Latin ; with an introductory Sketch of his Life and Writings.

VAN NOSTRAND'S SCIENCE SERIES.

It is the intention of the Publisher of this Series to issue them at intervals of about a month. They will be put up in a uniform, neat, and attractive form, 18mo, fancy boards. The subjects will be of an eminently scientific character, and embrace as wide a range of topics as possible, all of the highest character.

Price, 50 Cents Each.

I. CHIMNEYS FOR FURNACES, FIRE-PLACES, AND STEAM BOILERS. By R. ARMSTRONG, C.E.

II. STEAM BOILER EXPLOSIONS. By ZERAH COLBURN.

III. PRACTICAL DESIGNING OF RETAINING WALLS. By ARTHUR JACOB A.B. With Illustrations.

IV. PROPORTIONS OF PINS USED IN BRIDGES. By CHARLES E BENDER, C.E. With Illustrations.

V. VENTILATION OF BUILDINGS. By W. F. BUTLER. With Illustrations.

VI. ON THE DESIGNING AND CONSTRUCTION OF STORAGE RESERVOIRS. By ARTHUR JACOB. With Illustrations.

VII. SURCHARGED AND DIFFERENT FORMS OF RETAINING WALLS By JAMES S. TATE, C.E.

VIII. A TREATISE ON THE COMPOUND ENGINE. By JOHN TURNBULL. With Illustrations.

IX. FUEL. By C. WILLIAM SIEMENS, to which is appended the value of ARTIFICIAL FUELS AS COMPARED WITH COAL. By JOHN WORMALD, C.E.

X. COMPOUND ENGINES. Translated from the French of A. MALLET. Illustrated.

XI. THEORY OF ARCHES. By Prof. W. ALLAN, of the Washington and Lee College. Illustrated.

XII. A PRACTICAL THEORY OF VOUSSOIR ARCHES. By WILLIAM CAIN, C.E Illustrated.

XIII. A PRACTICAL TREATISE ON THE GASES MET WITH IN COAL MINES. By the late J. J. ATKINSON, Government Inspector of Mines for the County of Durham, England.

XIV. FRICTION OF AIR IN MINES. By J. J. ATKINSON, author of "A Practical Treatise on the Gases met with in Coal Mines."

XV. SKEW ARCHES. By Prof. E. W. HYDE, C.E. Illustrated with numerous engravings and three folded plates.

XVI. A GRAPHIC METHOD FOR SOLVING CERTAIN ALGEBRAIC EQUATIONS. By Prof. GEORGE L. VOSE. With Illustrations.

XVII. WATER AND WATER SUPPLY. By Prof. W. H. CORFIELD, M.A., of the University College, London.

XVIII. SEWERAGE AND SEWAGE UTILIZATION. By Prof. W. H. CORFIELD, M.A., of the University College, London.

XIX. STRENGTH OF BEAMS UNDER TRANSVERSE LOADS. By Prof. W. ALLAN, author of "Theory of Arches." With Illustrations

XX. BRIDGE AND TUNNEL CENTRES. By JOHN B. MCMASTERS, C.E. With Illustrations.

XXI. SAFETY VALVES. By RICHARD H. BUEL, C.E. With Illustrations.

XXII. HIGH MASONRY DAMS. By JOHN B. MCMASTERS, C.E. With Illustrations.

XXIII. THE FATIGUE OF METALS under Repeated Strains, with various Tables of Results of Experiments. From the German of Prof. LUDWIG SPANGENBERG. With a Preface by S. H. SHREVE, A.M. With Illustrations.

XXIV. A PRACTICAL TREATISE ON THE TEETH OF WHEELS, with the theory of the use of Robinson's Odontograph. By S. W. ROBINSON, Prof. of Mechanical Engineering, Illinois Industrial University.

XXV. THEORY AND CALCULATIONS OF CONTINUOUS BRIDGES. By MANSFIELD MERRIMAN, C.E. With Illustrations.

XXVI. PRACTICAL TREATISE ON THE PROPERTIES OF CONTINUOUS BRIDGES. By CHARLES BENDER, C.E.

XXVII. On Boiler Incrustation and Corrosion. By F. J. Rowan. With Illustrations.

XXVIII. On Transmission of Power by Wire Rope. By Albert W. Stahl. With Illustrations.

XXIX. Injectors. The Theory and Use. Translated from the French of M. Leon Pochet. With Illustrations.

XXX. Terrestrial Magnetism and the Magnetism of Iron Ships. By Prof. Fairman Rogers. With Illustrations.

XXXI. The Sanitary Condition of Dwelling Houses in Town and Country. By George E. Waring, Jr. With Illustrations.

XXXII. Cable Making of Suspension Bridges as Exemplified in the East River Bridge. By Wilhelm Hildenbrand, C. E. With Illustrations.

XXXIII. Mechanics of Ventilation. By George W. Rafter, Civil Engineer.

XXXIV. Foundations. By Prof. Jules Gaudard, C. E. Translated from the French, by L. F. Vernon Harcourt, M. I. C. E.

XXXV. The Aneroid Barometer, Its Construction and Use. Compiled by Prof. George W. Plympton. Illustrated.

XXXVI. Matter and Motion. By J. Clerk Maxwell, M. A.

XXXVII. Geographical Surveying. Its Uses, Methods and Results. By Frank De Yeaux Carpenter, C. E.

XXXVIII. Maximum Stresses in Framed Bridges. By Prof. Wm. Cain, A. M., C. E. Illustrated.

XXXIX. A Hand Book of the Electro Magnetic Telegraph. By A. E. Loring. Illustrated.

XL. Transmission of Power by Compressed Air. By Robert Zahner, M. E. Illustrated.

XL1 On the Strength of Materials. By Wm. Kent, C. E.

XLIII. Wave and Vortex Motion. By Dr. Thomas Craig.