the adoption of the more simple forms, in which the grinding is effected between horizontal flat surfaces instead of curved or conical bottoms, and in the pans now usually employed these flat grinding surfaces form an annular floor round a central cone through which a vertical shaft passes. The Knox pan, fig. 7, may be considered to be fairly typical. It is of cast-iron, 4 feet in diameter and 14 inches deep. It has a false bottom to form a hollow annular space through which steam can be introduced. The centre of the yoke *d* attached to the muller *m*, is keyed to a vertical wrought-iron shaft S, 2 inches in diameter, which can be brought in connexion with the driving gear G. The blocks *r*, *r* are of wood. In working the pan 100 ℔ of skimmings are introduced, and water added until the pulp will just adhere to a stick. After three hours grinding the pulp is heated with steam. About 5 ℔ of mercury are added for every charge, together with a cupful of equal parts of saltpetre and sal ammoniac. After three hours further working, water with a little caustic lime is added, and the pulp is discharged first through an upper and then through a lower hole.

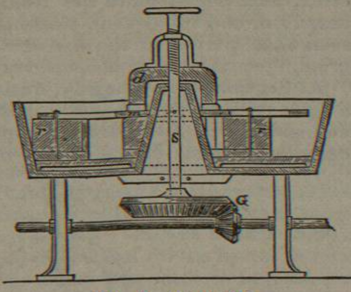

FIG. 7.—Knox Pan.

One of the greatest difficulties in the treatment of gold by amalgamation, and more particularly in the treatment of pyrites, arises from the so-called sickening or flouring of the mercury; that is, the particles, losing their bright metallic surfaces, are no longer capable of coalescing with or taking up other metals. Of the numerous remedies proposed the most efficacious is perhaps sodium amalgam. It appears that amalgamation is often impeded by the tarnish found on the surface of the gold when it is associated with sulphur, arsenic, bismuth, antimony, or tellurium. Wurtz[1] in America (1864) and Crookes in England (1865) made independently the discovery that, by the addition of a small quantity of sodium to the mercury, the operation is much facilitated. It is also stated that sodium prevents both the "sickening" and the "flouring" of the mercury which is produced by certain associated minerals. Cosmo Newberry has investigated with much care the action of certain metals in impeding amalgamation.[2] Wurtz recommends two amalgams, one containing 2 and the other 4 per cent. of sodium, and in practice 1 per cent. or less of these is added to the mercury in the amalgamator. Crookes employs three kinds, which he calls A, B, and C amalgams; each contains 3 per cent. of mercury, but the B variety has, in addition to the sodium, 20 per cent. of zinc, and C is mixed with 10 per cent. of zinc and 10 per cent. of tin. The addition of cyanide of potassium has been suggested to assist the amalgamation and to prevent "flouring," but Skey[3] has shown that its use is attended with loss of gold.

Separation of Gold from the Amalgam.—The amalgam is first pressed in wetted canvas or buckskin in order to remove excess of mercury. According to Rittinger, mercury will dissolve from 0·05 to 0·08 per cent. of native gold of standard 650 to 850 without loss of fluidity, the solubility of the gold increasing with its fineness; and until the point of saturation is reached, no separation of solid amalgam is possible. Lumps of the solid amalgam, about 2 inches in diameter, are introduced into an iron vessel lined with a paste of fire-clay and wood ashes, and provided with an iron tube that dips below the surface of water. The distillation is then effected by heating, care being taken that the retort does not become visibly red in daylight. The amalgam yields about 30 to 40 per cent. of gold. In California the amalgam is retorted in cast-iron pans placed in cast-iron cylinders 11 inches in diameter, 4 feet 6 inches long, supported on brick work. The bullion left in the retorts is then melted in black-lead crucibles, with the addition of small quantities of suitable fluxes.

[1] *American Journal of Science and Arts*, vol. xli., March 1866.
[2] Ure's *Dictionary of Arts*, supplement to 7th ed., p. 412
[3] *Transactions of the New Zealand Institute*, 1876.

The extraction of gold from auriferous minerals by fusion, except as an incident in their treatment for other metals, is very rarely practised. It was at one time proposed to treat the concentrated black iron obtained in the Ural gold washings, which consists chiefly of magnetite, as an iron ore, by smelting it with charcoal for auriferous pig-iron, the latter metal possessing the property of dissolving gold in considerable quantity. By subsequent treatment with sulphuric acid the gold could be recovered. Experiments on this point were made by Anossow in 1835, but they have never been followed in practice.

Gold in galena or other lead ores is invariably recovered in the refining or treatment of the lead and silver obtained. Pyritic ores containing copper are treated by methods analogous to those of the copper smelter. This is extensively done. In Colorado the pyritic ores containing gold and silver in association with copper are smelted in reverberatory furnaces for regulus, which, when desilverized by Ziervogel's method, leaves a residue containing 20 or 30 ounces of gold per ton. This is smelted with rich gold ores, notably those containing tellurium for white metal or regulus; and by a following process of partial reduction analogous to that of selecting in copper smelting, "bottoms" of impure copper are obtained in which practically all the gold is concentrated. By continuing the treatment of these in the ordinary way of refining, poling, and granulating, all the foreign matters other than gold, copper, and silver are removed, and, by exposing the granulated metal to a high oxidizing heat for a considerable time, the copper may be completely oxidized while the precious metals are unaltered. Subsequent treatment with sulphuric acid renders the copper soluble in water as sulphate, and the final residue contains only gold and silver, which is parted or refined in the ordinary way. This method of separating gold from copper, by converting the latter into oxide and sulphate, is also used at Oker in the Harz.

Chlorination Process.—Plattner suggested that the residues from certain mines at Reichenstein, in Silesia, should be treated with chlorine after the arsenical products had been extracted by roasting. The process, which depends upon the fact that chlorine acts rapidly upon gold, but does not attack ferric oxide, is now adopted in Grass Valley, California, where the waste minerals, principally pyrites from tailings, have been worked for a considerable time by amalgamation. The roasting is conducted at a low temperature in some form of reverberatory furnace. Salt is added in the roasting to convert all the metals present, except iron, into chlorides. The auric chloride is, however, decomposed at the elevated temperature into finely-divided metallic gold, which is then readily attacked by the chlorine gas. The roasted mineral, slightly moistened, is next introduced into a wooden vat, pitched inside, and furnished with a double bottom, as is shown in fig. 8. Chlorine

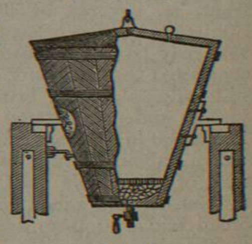

Fig. 8.

is led from a suitable generator beneath the false bottom, and rises through the moistened ore, resting on a bed of broken quartz below the false bottom, converting the gold into a soluble chloride, which is afterwards removed by washing with water. The precious metal is then precipitated as metallic gold by sulphate of iron. The process has been greatly improved in America by Küstel, Deetken, and Hoffmann; with proper care it is a very perfect one, and yields 97 per cent. of the gold originally present in the ore. It is stated not to cost more in California than 50s. a ton. Any silver originally present in the ore is of course converted into chloride of silver and remains with the residue, from which it may be extracted by the solvent action of brine or by amalgamation.

Refining or Parting Gold from other Metals.—Strabo states[1] that in his time a process was employed for refining and purifying gold in large quantities by cementing or burning it with an aluminous earth, which, by destroying the silver, left the gold in a state of purity. Pliny shows that for this purpose the gold was placed on the fire in an earthen vessel with treble its weight of salt, and that it was afterwards again exposed to the fire with two parts of salt and one of argillaceous rock, which, in the presence of moisture, effected the decomposition of the salt; by this means the silver became converted into chloride. In a similar process still practised in New Granada the granulated argentiferous gold is mixed with one part of common salt and two parts of brick dust. In the presence of moisture, effected by the passage of aqueous vapour through the porous pots in which the mixture is heated, the salt acts on the brick dust, producing silicate of soda, and the evolution of hydrochloric acid affords a source of chlorine for the silver. The chloride of silver formed fuses readily and drops off, exposing a fresh surface of the alloy to the action of the gas.

Various methods for separating gold from silver or other alloys appear to have been in use from ancient times. Among these may be mentioned prolonged oxidation by exposure to air, and treatment with sulphur, sulphide of antimony, and corrosive sublimate. In the Harz, 2 ounces of the granulated alloy of gold and silver were mixed and heated with 1 ounce of sulphur, litharge being added to separate the gold remaining in the sulphide of silver.

Parting by Nitric Acid, the old process of refining, is now practised in England by only one firm, although in some refineries both the nitric acid and the sulphuric acid processes are combined, the alloy being first treated with nitric acid. It used to be called "quartation," from the fact that 4 parts of the alloy best suited for the operation of refining contain 3 parts of silver and 1 of gold. The operation may be conducted in vessels of glass or platinum, and each pound of granulated metal is treated with a pound and a quarter of nitric acid of specific gravity 1·32. It is the method employed in the assay of gold (see ASSAYING).

Refining by Sulphuric Acid is the process usually adopted for separating gold from silver on the large scale. It appears to have been proposed in France by Dizé at the beginning of the present century. It was actually in use in France in 1820, and was introduced into the Mint refinery, London, by Mr Mathison in 1829.[2] It is based upon the facts that concentrated hot sulphuric acid converts silver and copper into soluble sulphates without attacking the gold, the sulphate of silver being subsequently reduced to the metallic state by copper plates with the formation of sulphate of copper.

About 80 ℔ of the granulated alloy are boiled for three or four hours in a platinum vessel (fig. 9) with 2·5 times its weight of sulphuric acid of specific gravity 1·84. The sulphurous acids which arise are partially condensed before being allowed to pass into the air. When the acid has

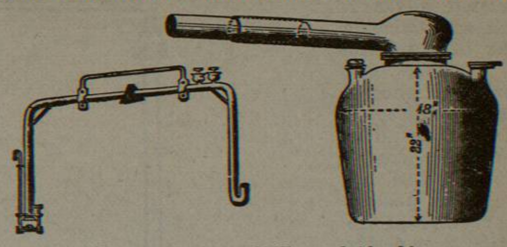

FIG. 9.—Refinery Siphon and Alembic.

ceased to act on the metal, a small quantity of sulphuric acid of specific gravity 1·53 is added, and, after a second boiling, the contents of the vessel are allowed to settle. The supernatant liquid is then withdrawn from the gold, which falls to the bottom of the vessel, and is diluted until its density is 1·21 or 1·26. The silver is usually precipitated from solution by copper plates, but sometimes iron is used, and the silver is roughly dried and compressed by an hydraulic press before it is melted into ingots. The gold, which is often again treated with sulphuric acid, is then washed and melted into ingots that contain from 997 to 998 parts of gold in 1000. The operation of parting may be conducted in iron or platinum vessels; the use of the former was advocated by M. Tocchi, and they are still extensively employed. Magnificent vessels of platinum have, however, been made in England by Messrs Johnson, Matthey, & Co. The alloys best suited for the operation contain from 800 to 950 of silver and 50 to 200 of copper and gold, but the proportion of gold must not exceed 200 parts in 1000. Refiners obtain alloys in suitable proportions by mixing together auriferous silver and argentiferous gold, the proportions of the respective metals having been previously indicated by assay. By such an arrangement, silver which contains but the 0·0004 part of gold, or 2·25 grains in the troy pound, may be profitably treated.

Cost of Refining.—The charge to the public for refining depends in a great measure on the amount of metal to be operated upon and its richness. In England, however, it may be considered to be about 1d. per ounce for the silver and 4d. per ounce for gold. In France the charge is about 90 cents to 1 franc 25 cents for a kilogramme of silver.

The Lower Harz smelting works produce annually from 50 to 55 cwts. of test silver of an average fineness of 950 silver and 50 gold per 1000; the proportion of the latter metal is, however, variable, being lowest (3 per 1000) in the silver obtained from clean lead ores, and highest (10 per 1000) in that separated from argentiferous copper ores,—that from the mixed copper and lead ores being of intermediate richness. The silver, in quantities of 25 kilogrammes, is refined upon small tests in a muffle, and when sufficiently purified is granulated by ladling it into water, whereby thin flattened granules suitable for dissolving are obtained.

The parting vessels (fig. 10) are of porcelain which, to protect them against fracture by irregular heating, are covered with wire netting and plastered over with a mixture of clay and smithy scales. They are mounted in a frame and set loose in an iron pot with a hemispherical bottom, which is heated by a fire from below; the pot also serves to catch the contents of the porcelain vessel if the latter should be accidentally broken. The cover is perforated by a hole in the centre for the passage of a lead pipe to carry off the sulphurous acid fumes,

[1] Fabbroni, *Ann. Chim.*, t. lxxii. p. 25.
[2] *Report on the Royal Mint*, 1837, Appendix, p. 59.

and a smaller one at one side through which acid may be introduced. These, as well as other connexions on the pipes carrying off the vapours, are secured by water-joints. The charge of about 200 ounces (6·25 kilogrammes) of granulated silver is treated with twice its weight of sulphuric acid marking 66° Baumé, and, by careful firing, is dissolved in six hours. The proper management of the heat is of importance, as neglect in the conduct of the operation may easily lead to a breakage of the pot. When the charge is completely dissolved the liquid is allowed to settle for some time, and is then poured off into a lead pan, where the silver sulphate solidifies. This, when redissolved by an addition of water and careful warming, is treated with strips of copper, the separation of the silver being facilitated by agitating the liquid. When the latter is found to be completely free from silver the heating is stopped, and the contents of the pan are allowed to settle for eighteen hours, when the copper solution is drawn off by a siphon and sent to the vitriol crystallizers. In the precipitation of 100 kilogrammes of silver about 30 kilogrammes of sheet-copper are expended.

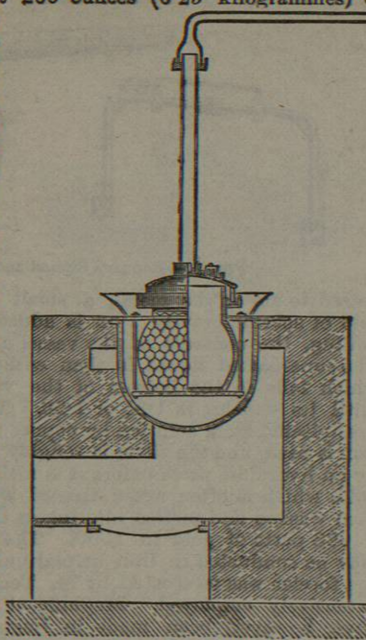

Fig. 10.

The precipitated silver is washed with water in a copper vessel upon a linen filter until the reaction of copper in the washings ceases, and then moulded in cylindrical blocks by screw pressure, to express the residual water. These when fire-dried are melted in black-lead pots, holding 75 lb, with the addition of a little soda nitre.

The parted gold remaining in the porcelain pot, though already sensibly finer than is usual when iron parting vessels are used, still contains silver, and is therefore boiled once more with sulphuric acid of 66° Baumé. Afterwards it is washed with water until silver can be no longer detected in the washings, when it is transferred to a porcelain dish and dried. When a quantity of about 10 lb of gold has been accumulated, it is mixed with a little borax glass, melted in a black-lead pot, and cast. The resulting bars average $\frac{996}{1000}$ fine.

Refining by Chlorine Gas.—F. Bowyer Miller[1] devised in 1867 the following method for separating silver from gold. The process, which is the one now adopted in the Australian mints,[2] consists in converting the silver into chloride by the passage of a stream of chlorine gas through the molten alloy. Clay crucibles are employed after having been saturated with a strong solution of borax and allowed to dry. The chlorine is introduced through the gold by a clay pipe passing to the bottom of the crucible, and connected with the chlorine generator in which the necessary pressure is obtained by a pressure tube 8 feet high. The chloride of silver is easily poured off from the surface of the molten metal, and by carefully fusing with a little carbonate of soda, the small amount of gold it retains is separated and falls to the bottom of the crucible. The gold operated upon contains from 3 to 12 per cent. of silver, and the average fineness of the refined gold is 994. The operation is now conducted on a considerable scale in Australia, and in the years 1871 and 1872 no less than 1,100,000 ounces of gold were refined by its aid in Sydney alone. The absolute loss of gold does not exceed 14 parts in 100,000.

Toughening Brittle Gold.—It will be seen from p. 751 that minute traces of certain metals, which do not exceed the $\frac{1}{1920}$th part of the mass, render gold brittle and unfit for coinage. Miller showed that the removal of the deleterious metals might be effected by converting them into volatile chlorides by a stream of chlorine gas. The process was introduced into the English mint by Roberts,[3] who successfully treated over 40,000 ounces of brittle gold with but trifling loss of precious metal. Wagner has suggested[4] that bromine may replace chlorine in Miller's process. Brittle gold may also be toughened by throwing a small quantity of corrosive sublimate on to the surface of the molten metal, but this method is wasteful, and the fumes evolved are deleterious. The late Mr Warington[5] proposed to toughen brittle gold by the addition of about 10 per cent. of black oxide of copper. The process is efficacious, but the crucibles become much corroded and even perforated; the standard fineness of the gold is, moreover, lowered by such copper as is reduced to the metallic state. If gold is but slightly brittle, it may be toughened by pouring it in a thin stream through atmospheric air into a crucible lined with borax, or by the addition of a small quantity of chloride of copper.

Preparation of Pure Gold.—Chemically pure gold may be prepared by several methods. The metal, either in the form of powder or "cornets" from the purest gold that can be obtained, is dissolved in nitro-hydrochloric acid. The excess of acid is driven off, alcohol and chloride of potassium added to precipitate platinum, and the chloride of gold is then dissolved in pure distilled water, the solution being diluted until each gallon does not contain more than half an ounce of the precious metal. The solution is allowed to stand for several weeks, and the supernatant liquid is carefully removed by a siphon from any chloride of silver that may have fallen to the bottom of the vessel. The gold may then be precipitated by a stream of carefully washed sulphurous anhydride, or by the addition of oxalic acid, formic acid, or ferrous sulphate. The spongy gold is washed with dilute hydrochloric acid, distilled water, ammonia water, and again with distilled water, after which it is melted in a clay crucible with a little bisulphate of potash and borax, and poured into a stone mould. Roberts[6] prepared by this method 70 ounces of gold of which the average purity was 999·96, the precipitant being oxalic acid. Gold precipitated by oxalic acid from an acid solution containing copper is always contaminated with cupric oxalate. E. Purgotti[7] has, however, shown that by heating the solution with the addition of potash, a soluble double oxalate of copper and potash is formed, and the gold is left in the pure state.

Alloys of Gold.—The most important alloys are those with silver and copper. Those used for coinage at the present day contain from 800 parts of gold in 1000, the standard of the Norwegian 2-kroner piece, to 986·6, that of the Austrian reichsducaten, the alloying metal being mainly copper. In England, when gold coins were first introduced by Henry III., in 1257, they were of pure gold. Edward III., in 1345, was the first to use a standard 994·8, and in 1526 Henry VIII. issued crowns of the double rose of the standard 916·6 for concurrent issue with sovereigns, and other coins of the original standard 994·8. In 1544 the standard for all gold coins was reduced to 916·6, and again in 1546 to 833·4, the lowest point ever reached in England. Mary restored the old standard 994·8. Elizabeth directed that coins of both standards, 916·6 and 994·8, should be issued, and the latter was employed at intervals until 1640. Since then the lower standard, 916·6, has been solely used, and, as is shown by the following extract from the Coinage Act of 1870, 33 Vic. c. 10, is the one now in use:—

Denomination of Coin.	Standard Weight.		Least Current Weight.		Standard Fineness.	Remedy Allowance.		
	Imperial Weight. Grains.	Metric Weight. Grams.	Imperial Weight. Grains.	Metric Weight. Grams.		Weight per piece. Imperial Grains.	Weight per piece. Metric Grams.	Millesimal Fineness.
GOLD—								
Five-Pound	616·37239	39·94028	612·50000	39·68935	Eleven-twelfths fine gold, one twelfth alloy; or millesimal fineness 916·66.	1·00000	0·06479	0·002
Two-Pound	246·54895	15·97611	245·00000	15·87574		0·40000	0·02592	
Sovereign	123·27447	7·98805	122·50000	7·93787		0·20000	0·01296	
Half-Sovereign	61·63723	3·99402	61·12500	3·96083		0·10000	0·00648	

In America and in those countries which have formed the "Latin Convention," the standard of gold coin is 900, with a "remedy" of $\pm\frac{2}{1000}$. M. Peligot suggested[1] that by employing a triple alloy containing 58·1 per cent. of gold, 36·1 of copper, and 5·8 of zinc, a coin might be produced which, while being of the value of 25 francs, would have the decimal weight of 10 grammes. The alloy is perfectly malleable and of good colour. In England the following standards are used for plate and jewellery, 375, 500, 625, 750, and 916·6, the alloying metal being silver and copper in varying proportions. In France three alloys of the following standards are used for jewellery, 920, 840, and 750. A greenish alloy used by goldsmiths contains 70 per cent. of silver and 30 per cent. of gold. "Blue gold" is stated to contain 75 per cent. of gold and 25 per cent. of iron. The Japanese use for ornament an alloy of gold and silver, the standard of which varies from 350 to 500, the colour of the precious metal being developed by "pickling" in a mixture of plum-juice, vinegar, and sulphate of copper. They may be said to possess a series of bronzes, in which gold and silver replace tin and zinc, all these alloys being characterized by patina having a wonderful range of tint. The common alloy, Shi-ya-ku-Do, contains 70 per cent. of copper and 30 per cent. of gold; when exposed to air it becomes coated with a fine black patina, and is much used in Japan for sword ornaments. Gold wire may be drawn of any quality, but it is usual to add 5 to 9 dwts. of copper to the pound.[2]

The "solders" used for red gold contain 1 part of copper and 5 of gold; for light gold, 1 part of copper, 1 of silver, and 4 of gold.

Alloys of Gold and Silver.—Electrum, the natural alloy of gold and silver, has already been described, p. 740. Matthiessen observed that the density of those alloys, the composition of which varies from $AuAg_6$ to Au_6Ag, is greater than that calculated from the densities of the constituent metals. These alloys are harder, more fusible, and more sonorous than pure gold. The alloys of the formulæ AuAg, $AuAg_2$, $AuAg_4$, and $AuAg_{20}$ are perfectly homogeneous, and have been studied by Levol.[3] Hatchett has shown,[4] by a series of careful experiments, that certain metals, even when present in such small quantities as the $\frac{1}{1920}$th part of the mass, render standard gold brittle and unfit for rolling. These metals are bismuth, lead, antimony, arsenic, and zinc.

Gold and Zinc.—With regard to the latter metal, it may be remarked that, although its presence in small quantities renders gold brittle, it may be added to gold in larger quantities without destroying the ductility of the precious metal, for, as has been already stated, Peligot proved that a triple alloy of gold, copper, and zinc, which contains 5·8 per cent. of the last-named, is perfectly ductile. The alloy of 11 parts gold and 1 part of zinc is, however, stated to be brittle.

Gold and Tin.—Alchorne[5] showed that gold alloyed with $\frac{1}{37}$th part of tin is sufficiently ductile to be rolled and stamped into coin, provided the metal is not annealed at a high temperature. The alloys of tin and gold are hard and brittle, and the combination of the metals is attended with contraction; thus the alloy SnAu has a density 14·243, instead of 14·828 indicated by calculation. Matthiessen and Bose[6] obtained large crystals of the alloy Au_2Sn_5, having the colour of tin, which changed to a bronze tint by oxidation.

Gold and Iron.—Hatchett found that the alloy of 11 parts gold and 1 part of iron is easily rolled without annealing. In these proportions the density of the alloy is less than the mean of its constituent metals.

Gold and Palladium.—These metals are stated to alloy in all proportions. According to Chenevix,[7] the alloy composed of equal parts of the two metals is grey, is less ductile than its constituent metals, and has the specific gravity 11·08. The alloy of 4 parts of gold and 1 part of palladium is white, hard, and ductile. Graham has shown[8] that a wire of palladium alloyed with from 24 to 25 parts of gold does not exhibit the remarkable retraction which, in pure palladium, attends its loss of occluded hydrogen.

Gold and Platinum.—Clarke states that the alloy of equal parts of the two metals is ductile, and has almost the colour of gold.

Gold and Rhodium.—Gold alloyed with $\frac{1}{4}$th or $\frac{1}{3}$th of rhodium is, according to Wollaston, very ductile, infusible, and of the colour of gold.

Gold and Iridium.—Small quantities of iridium do not destroy the ductility of gold, but this is probably because the metal is only disseminated through the mass, and not alloyed, as it falls to the bottom of the crucible in which the gold is fused.

Gold and Nickel.—Eleven parts of gold and 1 of nickel yield an alloy resembling brass.

Gold and Cobalt.—Eleven parts of gold and 1 of cobalt form a brittle alloy of a dull yellow colour.

Assay of Gold.—It may be well to supplement the information given in the article ASSAYING with some additional details as to the assay of gold bullion, as practised in the Royal Mint, and of gold ores. The assay of bullion consists of six operations:—

(1.) The sample of metal taken for assay is flattened, and an assistant adjusts a portion of it to an exact weight by cutting or filing. This weight varies with different operators from 5 to 16 grains. The assayer then completes the adjustment on a more sensitive balance. The prepared assay piece is wrapped in lead foil, together with a certain amount of pure silver, which is generally equal to $2\frac{1}{2}$ times the amount of gold assumed to be present. In the case of standard gold, the weight of lead employed is to the weight of the alloy taken for assay as 8 to 1, and the ratio of the weight of lead to the weight of copper present is 100:1. Much diversity of opinion exists as to the amount of lead that should be employed. The proportions recommended by D'Arcet[9] are considerably less than those advocated by Kandelhardt;[10] and it may be stated, with regard to the silver, that the last mentioned authority and Chaudet recommend the proportion of 1 of gold to $2\frac{1}{2}$ of silver, but Pettenkofer states that the proportion need not exceed 1 to $1\frac{1}{3}$, provided that the subsequent boiling in nitric acid is sufficiently prolonged. The amount of gold lost in cupellation has been shown by Rossler to increase with the amount of lead used, and to decrease as the amount of silver is increased.[11]

(2.) The necessary number of cupels are arranged on the bottom of the muffle (fig. 2, ASSAYING), and the packets containing the silver and gold are transferred from a numbered wooden range to corresponding cupels. The furnace operations are then performed as is described in ASSAYING (p. 727), and the result is that each cupel contains a button of silver and gold.

(3.) The button *a* (fig. 11) is flattened by striking it with a hammer on a polished anvil, first in the centre, and then on the edge, a third blow being given on the opposite edge which elongates the metal. After annealing in an iron tray, the flattened buttons *b* are reduced by laminating rolls to the thickness of a visiting card *c*. They are again annealed and rolled into a spiral or cornet *d*.

(4.) These cornets are then treated with nitric acid of specific gravity 1·2, either separately in parting flasks, or together in cups

Footnotes (p. 750):

1 *Chem. Soc. Journ.*, v. xxi., 1868, p. 506.
2 *Fourth Annual Report of Deputy-Master of Mint*, 1873, p. 62.
3 *First and Second Annual Reports of Deputy-Master of Mint*, p. 1870-2, p. 93 and 34 respectively.
4 *Bull. Chem. Soc. Paris*, t. xxv., 1876, p. 138.
5 *Chem. Soc. Journ.*, xiii. 1860, p. 31.
6 *Fourth Annual Report of Royal Mint*, 1874, p. 46: *Committee of British Association Report*, 1873, p. 219.
7 *Zeitschr. Anal. Chem.*, ix. 127.

Footnotes (p. 751):

1 *Comptes Rendus*, t. lxxvi. p. 1441.
2 Ure's *Dictionary of Arts.* 7th edition. 1875. vol. i p 96.
3 *Ann. de Chim. et de Phys.* (3), t. xxxvi. p. 193, and t. xxxix. p. 163.
4 *Phil Trans.*, 1803. part 1, pp. 43–194.
5 *Phil. Trans.*, 1784.
6 *Proc. Roy. Soc.*, vol. xi. 1860-2, p. 433
7 Wurtz, *Dictionnaire de Chimie*, t. ii. p. 630.
8 *Proc. Roy. Soc.*, xvii. p. 503.
9 Bodemann's *Anleitung zur Berg- und Hüttenmännischen Probierkunst*, 2d ed., 1856, p. 360.
10 *Gold-Probirverfahren*, p. 3.
11 *Dingl. Polytech. Journ.*, 206, p. 185

of platinum, which are introduced into a suitable vessel of platinum, an arrangement by which it will be evident much time may be saved. The boiling is then continued for fifteen or twenty minutes, when the cornets are washed with distilled water, and treated with nitric acid of specific gravity 1·3, and in this the cornets remain for about the same period, after which they are again washed in distilled water and dried.

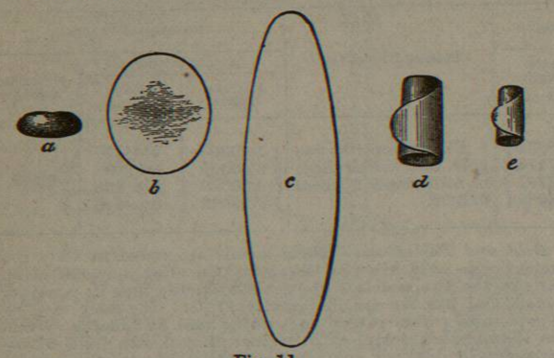

Fig. 11.

(5.) The cornets are annealed, separately, in little clay crucibles, or in the platinum cups in which they have been boiled, by heating them to bright redness. They then diminish considerably in bulk as *e* (fig 11), and are of a pure yellow colour.

(6.) The cornets are then weighed in comparison with "check assays" made on pure gold. These "checks" are necessary, as the accuracy of the result of an assay is liable to be affected either by retention of silver or copper, or by loss of gold by volatilization in the muffle, solution in the acid, or retention in the cupel. The weight of gold, therefore, indicated by the balance, may be either less or greater than the amount originally present in the alloy. The correction to be applied to a gold assay will be evident from the following formula:[1]—

Let 1000 be the weight of alloy originally taken;
p the weight of the piece of gold finally obtained;
x the actual amount of gold in the alloy expressed in thousandths;
a the weight of gold (supposed to be absolutely pure) taken as a check, which approximately equals x;
b the loss or gain in weight experienced by a during the process of assay, expressed in thousandths;
k the variation of "check gold" from absolute purity, expressed in thousandths;

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

If a be assumed to be equal to x this equation becomes

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

Example.—Let $p = 901·1$ thousandths.
$a = 920·0$,,
$b = 0·3$,, gain in weight.
$k = 0·1$,,

Then by the first formula—

$$x = 901·1 - \frac{920 \times 0·1}{1000} - 0·3;$$

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

$$x = 901·1 - 0·092 - 0·3$$
$$= 900·708.$$

And by the second formula—

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

Assay of Gold Ores.—500 grains of the finely powdered sample, which must be taken with the greatest care and accuracy, is passed through a sieve of fine wire gauze with at least 80 meshes to the linear inch. Any residue there may be of flattened particles of gold is set aside for subsequent treatment, usually by direct cupellation. Assay of the ore by *fusion with litharge* is best suited to ores which do not contain much iron pyrites. For auriferous quartz 500 grains of the ore are fused with 500 grains of red lead, 300 grains of sodic carbonate, 20 grains of powdered charcoal, and 250 grains of borax. The mixture is introduced into a clay crucible, which it should half fill, and is fused in an air furnace. The button of reduced lead may be removed, either by pouring the contents of the crucible into a mould, or by breaking the crucible when cold. If the ore contains much iron pyrites, or is of the nature of "sweep," the name given to carbonaceous residues which accumulate in mints and goldsmiths' shops, it will be necessary to roast it in a shallow fire-clay dish placed in a muffle. In the case of pyrites containing about 7 dwts. to the ton, the operation would be conducted on about 1000 grains. The roasted ore is then fused with about the same mixture of fluxes as has been given for quartz.

Assay by Scorification.—Scorification resembles cupellation, but the oxide of lead produced in the operation, instead of sinking into a porous cup, is held in a flat saucer of fire-clay, and dissolves the earthy constituents of the ore, leaving the precious metal to pass into another portion of lead which remains in the metallic state. About 200 grains of the roasted ore are placed in the scorifier, intimately mixed with 500 grains of granulated and 50 grains of borax lead; 500 grains of lead are then distributed over the surface of the mixture; the contents of the scorifier are fused in a muffle; air is admitted to oxidize the greater portion of the lead; and, at the conclusion of the operation, the litharge should be perfectly fluid and cover the molten lead. The slag may be freed from particles of precious metal by the addition at the conclusion of the operation of a small quantity of powdered anthracite, which reduces a portion of the litharge to metallic globules, which fall through the slag and unite with the lead button. The gold is then separated by cupellation, and the silver with which it is nearly always associated is removed by parting in nitric acid.

Assay by means of the Spectroscope.—Lockyer and Roberts[2] state, as the result of a careful spectroscopic investigation of the alloys of gold and copper, that it is possible to distinguish between alloys of these metals which only differ in proportion by $\frac{1}{10000}$th part. Their experiments have been repeated in America by A. E. Outerbridge.[3]
(W. C. R.—H. B.)

It will be convenient to give here, in connexion with the article GOLD, rather than in their proper alphabetical place, the articles GOLDBEATING and GOLD LACE.

GOLDBEATING. The art of goldbeating is of great antiquity, being referred to by Homer; and Pliny states that one ounce of gold was extended to 750 leaves, each leaf being four fingers square, which is three times the thickness of the ordinary leaf gold of the present time. In all probability the art originated among Oriental communities, where the working of gold and the use of gold ornaments have been distinguishing characteristics from the most remote periods; and in India goldbeating is still carried on as a craft involving many mysteries and great difficulties. On the coffins of the Theban mummies specimens of original leaf-gilding are met with, where the gold is in so thin a state that it resembles modern gilding. The Incas of Peru do not appear to have been able to reduce gold further than to plates which could be nailed for ornamentation on the walls of their temples. In England goldbeating was confined to London until within the present entury. It was introduced into Scotland and the United States within that period, and it is now practised in most towns of any considerable size; but so far as concerns Great Britain it is principally centred in London. One grain of gold has been beaten out to the extent of 75 square inches, and the same weight of silver to 98 square inches. Taking a cubic inch of gold at 4900 grains, this gold-leaf is the 367,650th part of an inch in thickness, or about 1200 times thinner than ordinary printing paper. The silver, though spread over a larger surface, was thicker, owing to the difference in its specific gravity; but, calculated by weight, silver is the most malleable metal with which we are acquainted, in that respect considerably exceeding gold. This experiment does not, however, determine the extent of the malleability of either metal, as the means employed to test it were found to fail before there was any appearance of the malleability of the metals

[1] *Fourth Annual Report of the Deputy-Master of the Mint*, 1873, p. 42.

[2] *Phil. Trans.*, 1874, vol. clxiv. p. 495.

[3] *Journal of the Franklin Institute*, 1874

being exhausted. In practice the average degree of tenuity to which the gold is reduced is not nearly so great as the example above quoted. A "book of gold" containing 25 leaves measuring each 3¼ inches, equal to an area of 264 square inches, generally weighs from 4 to 5 grains.

The gold used by the goldbeater is variously alloyed, according to the variety of colour required. Fine gold is commonly supposed to be incapable of being reduced to thin leaves. This, however, is not the case, although its use for ordinary purposes is undesirable on account of its greater cost. It also adheres on one part of a leaf touching another, thus causing a waste of labour by the leaves being spoiled; but for work exposed to the weather it is much preferable, as it is more durable, and does not tarnish or change colour. The external gilding on many public buildings, such, *e.g.*, as the Albert Memorial in Hyde Park, London, is done with pure gold. The following is a list of the principal classes of leaf recognized and ordinarily prepared by British beaters, with the proportions of alloy per ounce they contain.

Name of Leaf	Proportion of Gold.	Proportion of Silver.	Proportion of Copper.
	Grains.	Grains	Grains.
Red	456-460	...	20-24
Pale red	464	...	16
Extra deep	456	12	12
Deep	444	24	12
Citron	440	30	10
Yellow	408	72	...
Pale yellow	384	96	...
Lemon	360	120	...
Green or pale	312	168	...
White	240	240	...

The process of goldbeating is thus conducted. The gold, having been alloyed according to the colour desired, is melted in a crucible, at a higher temperature than is simply necessary to fuse it, as its malleability is improved by exposure to a greater heat; sudden cooling does not interfere with its malleable properties, gold differing in this respect from some other metals. It is then cast into an ingot, and flattened, by rolling between a pair of powerful smooth steel rollers, into a ribbon of 1½ inch wide and 10 feet in length to the ounce. After being flattened it is annealed and cut into pieces of about 6½ grs. each, or about 75 per ounce, and placed between the leaves of a "cutch," which is about half an inch thick and 3½ inches square, containing about 180 leaves of a tough paper manufactured in France. Formerly fine vellum was used for this purpose, and generally still it is interleaved in the proportion of about one of vellum to six of paper. The cutch is beaten on for about 20 minutes with a 17-pound hammer, which rebounds by the elasticity of the skin, and saves the labour of lifting, by which the gold is spread to the size of the cutch; each leaf is then taken out, and cut into four pieces, and put between the skins of a "shoder," 4½ inches square and ¾ths of an inch thick, containing about 720 skins, which have been worn out in the finishing or "mould" process. The shoder requires about two hours' beating upon with a 9-pound hammer. As the gold will spread unequally, the shoder is beaten upon after the larger leaves have reached the edges. The effect of this is that the margins of larger leaves come out of the edges in a state of dust. This allows time for the smaller leaves to reach the full size of the shoder, thus producing a general evenness of size in the leaves. Each leaf is again cut into four pieces, and placed between the leaves of a "mould," composed of about 950 of the finest gold-beaters' skins, five inches square and three-quarters of an inch thick, the contents of one shoder filling three moulds. The material has now reached the last and most difficult stage of the process; and on the fineness of the skin and judgment of the workman the perfection and thinness of the leaf of gold depend. During the first hour the hammer is allowed to fall principally upon the centre of the mould. This causes gaping cracks upon the edges of the leaves, the sides of which readily coalesce and unite without leaving any trace of the union after being beaten upon. At the second hour, when the gold is about the 150,000th part of an inch in thickness, it for the first time permits the transmission of the rays of light. In pure gold, or gold but slightly alloyed, the green rays are transmitted; and in gold highly alloyed with silver, the pale violet rays pass. The mould requires in all about four hours' beating with a 7-pound hammer, when the ordinary thinness for the gold leaf of commerce will be reached. A single ounce of gold will at this stage be extended to $75 \times 4 \times 4 = 1200$ leaves, which will trim to squares of about 3¼ inches each. The finished leaf is then taken out of the mould, and the rough edges are trimmed off by slips of the ratan fixed in parallel grooves of an instrument called a waggon, the leaf being laid upon a leathern cushion for that purpose. The sizes to which British leaf is cut are 3, 3⅛, 3¼, 3⅜, and 3½ inches. The leaves thus prepared are placed into "books" capable of holding 25 leaves each, which have been rubbed over with red ochre to prevent the gold clinging to the paper. The leaf is used for gilding picture-frames, and for other ornamental purposes. See GILDING.

The fine membrane called goldbeaters' skin, used for making up the shoder and mould, is the outer coat of the cæcum or blind gut of the ox. It is stripped off in lengths about 25 or 30 inches, and freed from fat by dipping in a potash solution and scraping with a blunt knife. It is afterwards stretched on a frame; two membranes are glued together, treated with a solution of aromatic substances or camphor in isinglass, and subsequently coated with white of egg. Finally they are cut into squares of 5 or 5½ inches; and to make up a mould of 950 pieces the gut of about 380 oxen is required, about 2½ skins being got from each animal. A skin will endure about 200 beatings in the mould, after which it is fit for use in the shoder alone.

The dryness of the cutch, shoder, and mould is a matter of extreme delicacy. They require to be hot-pressed every time they are used, although they may be used daily, to remove the moisture which they acquire from the atmosphere, except in extremely frosty weather, when they acquire so little moisture that then a difficulty arises from their over-dryness, whereby the brilliancy of the gold is diminished, and it spreads very slowly under the hammer. On the contrary, if the cutch or shoder be damp, the gold will become that which is technically termed hollow or sieve-like; that is, it is pierced with innumerable microscopical holes; and in the moulds in its more attenuated state it will become reduced to a pulverulent state. This condition is more readily produced in alloyed golds than in fine gold. It is necessary that each skin of the mould should be rubbed over with calcined gypsum (the fibrinated variety) each time the mould may be used, in order to prevent the adhesion of the gold to the surface of the skin in beating. Dentist gold is gold leaf carried no further than the cutch stage, and should be perfectly pure gold.

By the above process also silver is beaten, but not so thin, the inferior value of the metal not rendering it commercially desirable to bestow so much labour upon it. Copper, tin, zinc, palladium, lead, cadmium, platinum, and aluminium can be beaten into thin leaves, but not to the same extent as gold or silver.

GOLD AND SILVER LACE. Under this heading a general account may be given of the use of the precious metals in textiles of all descriptions into which they enter. That these metals were used largely in the sumptuous textiles of the earliest periods of civilization there is abundant testimony; and to this day, in the Oriental centres whence a knowledge and the use of fabrics inwoven, ornamented, and embroidered with gold and silver first spread, the passion for such brilliant and costly textiles is still most strongly and generally prevalent. The earliest mention of the use of gold in a woven fabric occurs in the description of the ephod made for Aaron (Exod. xxxix. 2, 3)—"And he made the ephod of gold, blue, and purple, and scarlet, and fine twined linen. And they did beat the gold into thin plates, and cut it into wires (strips), to work it in the blue, and in the purple, and in the scarlet, and in the fine linen, with cunning work." In both the *Iliad* and the *Odyssey* distinct allusion is frequently made to inwoven and embroidered golden textiles. Many circumstances point to the conclusion that the art of weaving and embroidering with gold and silver originated in India, where it is still principally prosecuted, and that from one great city to another the practice travelled westward,—Babylon, Tarsus, Baghdad, Damascus, the islands of Cyprus and Sicily, Con-