XXIV.—*A Chemical Examination of the Metals and Alloys known to the Ancients.*

BY J. ARTHUR PHILLIPS, F.C.S.

Among the arts cultivated by mankind in the infancy of the world, Metallurgy appears to have held a very prominent situation ; for we read that Tubal Cain was an instructor of every artificer in brass and iron,* and consequently these, together with their uses, must have been well known to the antediluvians.

It is also probable that they were not the only metals in use at this remote period ; for the extraction of iron from its ores, of itself indicates great metallurgical skill and experience, as from the refractory nature of the materials employed, a very intense heat and skilful manipulation must have been necessary to its production. From these considerations we may infer that this metal could not have been discovered until the arts had attained a great degree of perfection, and long after the discovery of some others requiring less complicated apparatus and a lower temperature for their reduction. It would be quite impossible, after the lapse of so many ages, to trace the exact order in which the metals became known ; but it appears natural to suppose that those which are found in a native state, were the first to attract the attention and exercise the ingenuity of mankind ; and consequently, that gold, silver, and copper, were among the first with which the ancients became acquainted.† This, however, is but conjectural, as in the first mention of silver, Abraham is described as weighing unto Ephron, four hundred shekels of silver current money with the merchant,‡ thus indicating, that in those days, it was not only well known, but commonly used as a medium of exchange, for which purpose it was estimated by weight.

In the time of Moses, at least six metals were known, as in his direction for the purification of the spoils of the Midianites, he says : “ Only the gold and the silver, the brass, the iron, the tin, and the lead, every thing that may abide the fire, ye shall make it pass through the fire and it shall be clean.”§ Thus showing that the metallurgical

* Gen. IV, 22.

† It is true that iron is sometimes found in the native state, as large masses of meteoric origin have been occasionally met with ; these, however, occur but seldom, and in quantities far too small to have supplied this metal for the uses of the arts.

‡ Gen. XXIII, 16.

§ Numbers XXXI, 22.

arts had at that period attained considerable perfection, and that the metals were of frequent occurrence and constant employment. Of the processes practised in the early ages of the world, little can at present be known; but it would appear likely, from some passages in the sacred writings, as well as from the somewhat confused and obscure accounts of profane authors, that they differed but little from those which are employed at the present day.

That silver was at a very early period purified by means of lead, the following passages would seem to indicate: "The house of Israel is to me become dross; all they are brass, and tin, and iron, and lead in the midst of the furnace, they are even the dross of silver."* And again, "The bellows are burned, the lead is consumed of the fire, the founder melteth in vain."† We also read of silver being purified in a furnace of earth. Strabo quotes Polybius as speaking of a silver ore which after being washed seven times, was melted with lead and became pure silver.

That tin was not only well known, but also highly valued at the time of the Trojan War, we learn from Homer, who calls it *κασσίτερος*, and mentions it as forming part of the armour of Agamemnon,‡ and shield of Achilles,§ to make which, Vulcan is represented as throwing into the crucible brass unconquered, *κασσίτερος*, and honoured gold and silver.

Among the ancient Greeks and Romans, the workers of metal had attained a pitch of excellence, in some instances scarcely to be surpassed in the present day; but although many proofs of their skill have come down to us, in the form of coins, statues, and implements of war, yet their authors afford but scanty information relative to the methods employed in their production. This may be accounted for by the fact, that those who have written on the subject could have been but imperfectly acquainted with it; from the circumstance of the metals being generally found and extracted in mountainous countries, at a great distance from the large and populous cities in which the authors may be supposed to have usually resided, and who were, therefore, dependent for their facts on those who might be unable to enlighten them very fully on the subject.

Is it then to be wondered at, that our stock of information should be very limited, or that the ancient authors should treat rather of the uses of the metals, and the formation of alloys, than of their extraction from the ores?

* Ezek. XXII, 18.

‡ Iliad, 2.

† Jer. VI, 29.

§ Iliad, 18.

The art of working the alloys of copper was cultivated in Rome at a very early period after the foundation of that city, as we read that King Numa, the immediate successor of Romulus, founded a fraternity of brass founders, from which it may be inferred that the trade was even then in a flourishing condition.*

At the date in which Pliny wrote his *Natural History of the World*, the Romans had acquired a very extensive knowledge of the metals, and their uses; as we find him, in his thirty-third and thirty-fourth Books, not only describing gold, silver, brass, tin, iron, lead, antimony, mercury and cadmia; but he gives us also the proportions in which these various metals should be mixed in order to form suitable alloys for casting, soldering, and brazing, and moreover describes with a great degree of accuracy, the medicinal and other properties of some of their oxides and salts, as well as the method of their preparation and the localities in which they were found. But his descriptions of the means used for the extraction of these metals from their ores, are not only imperfect, but also frequently very obscure. This arises both from the abrupt transitions which continually occur, and also from frequent allusions to methods and apparatus long since obsolete, and on which at the present time we have no means of acquiring any knowledge.

In speaking of gold, Pliny says,† “In these parts of the world in which we live, gold mines are found, to say nothing of India, where the ants cast it up out of the ground, or that which the griffins gather in Scythia. The gold with us is procured in three ways; among the sands of some great rivers, such as the Tagus in Spain, the Po in Italy, Hebrus in Thrace, Pactolus in Asia, and the Indian Ganges, all of which yield gold. Neither is there any gold finer or more perfect, from being thoroughly polished, by the rubbing and attrition which it meets with in the course of the streams of water. There is also another method of obtaining gold, viz. by digging it out of pits which are sunk for that purpose, or else in the caverns and breaches which occur by the fall of mountains.” He also goes on to say, that the gold obtained by cleaving and opening mountains needs no trying or refining, as it is naturally fine and pure. In speaking of the value of gold, the same author remarks:‡ “The reputation which it has acquired is for the following reason, that it alone, of all things, loses nothing in the fire, but withstands its action without change. Indeed the oftener it has been in the fire the more refined and purer it becomes. One method of testing the quality of gold is by the

* Pliny, XXXIV, 1.

† Pliny, XXXIII, 4.

‡ Pliny, XXXIII, 3.

application of fire, of which it ought to take not only the colour, but to a certain extent the radiance also. This kind is called *Obryzum*. This is another astonishing property of gold, that a fire made of light straw or chaff will quickly melt it, whilst if it be thrown on the strongest fire of wood-charcoal, it will with difficulty yield to its intensity and melt. With respect to its purification, it should be melted with *lead*. The second property which causes gold to be so highly valued is, that it loses but little of its weight by use and attrition, whilst silver, lead, and copper, leave metallic stains on bodies which they touch, and soil the skin of those who handle them. Neither is there any metal which can be beaten out broader by the hammer, or divided more easily into parcels, as every ounce of it may be reduced into more than seven hundred and fifty leaves, each one of which being four fingers square. The other minerals, after their extraction, require the fire for their conversion into metal, but gold, of which we now treat, is gold as soon as it is found." Again, "neither rust nor canker alters the weight of gold, or affects in any way its quality. Salt and vinegar, though such active solvents, do not make the least impression on it."

The above quotations go to show, that many of the properties of gold were known at this period, and also that the methods of extracting it from the earth, were similar to those employed at the present day. Pliny, however, gives us but little information relative to its metallurgic treatment, except that lead was employed in its purification, and also that when found in lumps it was of itself pure, and required no artificial refining. He also states, when speaking of the properties of mercury,* "So penetrating is this liquor, that there is no vessel but it will eat and pass through. It supports everything which may be thrown into it, unless it be gold only, which sinks to the bottom. It is besides, very useful for the purpose of refining gold; to effect which object, that metal mixed with cinders is placed in an earthen pot, and shaken with mercury, which rejects all the impurities mixed with it, but in return takes hold of the gold itself. To expel it from the gold, the mixture is poured on skins, which on being pressed, allow the mercury to pass through them in drops, whilst the gold remains in all its purity." The above process differs little from those in general use, for the purposes of amalgamation, at the present day, but in this case also, Pliny's description is very imperfect, inasmuch as the solid amalgam remaining on the skins would require the separation of the combined mercury before the gold could exist in the pure and fine

* Pliny, XXXIII, 6.

state described. No mention is moreover made, of any means of separating gold from silver, or in fact of their ever being found associated, except in an alloy called *electrum** said to be found in veins, and of which an artificial kind was made by mixing one part of silver and four parts of gold, and which appears to have been anciently in great request, as Homer describes the palace of King Menelaus as glittering with gold, electrum, silver, and ivory. This alloy, though sometimes made by the direct mixture of the two metals, was, doubtless, in most instances, a natural production, as many gold ores also contain a certain portion of silver, and the ancients being apparently ignorant of the method of separating them, and without any knowledge of the stronger acids,† might have been in the habit of occasionally adding a certain quantity of silver to specimens of gold which already contained a proportion of that metal, thereby converting it into electrum, in preference to allowing it to remain as impure gold.

That silver was formerly, as at the present day, chiefly extracted from the ores of lead, we are distinctly informed by the author of the "Historia Naturalis," who adds, that those ores of silver which do not contain lead or an ore of lead, cannot be successfully worked without the addition of either one or the other. Tin and lead, he seems to regard as only two varieties of the same metal, as he describes them under the title of white lead, and black, and states that the white lead called in Latin *Plumbum candidum*, and by the Greeks *Cassiteros*, was much more valuable, and commanded a higher price than the black variety.

His description of the *Plumbum candidum*, and the state in which it was found, leaves no doubt that this much-valued metal was tin, it being represented as occurring among sand, in the dried-up beds of rivers, and as only known from the other substances with which it

* Pliny, XXXIII, 4.

† Nitric acid is first mentioned by Geber, who lived in the eighth century. He describes it under the name of "dissolving water," and prepared it by distilling in a retort one pound of sulphate of iron of Cyprus, half a pound of saltpetre, and a quarter of a pound of alum of Jameni. This process, although not economical, would certainly produce nitric acid, and to this when obtained, he added sal-ammoniac, in order to give it the property of dissolving gold. Raymond Lully, who lived in the early part of the thirteenth century, employed the same process, except that he omitted the alum. Basil Valentine, who was born about the year 1400, describes a method of obtaining "Spirits of Nitre," by distilling nitrate of potash with powdered porcelain or clay, with which the potash entering into combination the same result is obtained as by the former method. Basil Valentine is also the first who describes oil of vitriol, which he prepared by distilling sulphate of iron according to the method at present practised at Nordhausen in Saxony.

was found associated, by its dark colour and great weight.* “There is likewise found in the gold mines a kind of lead-ore which they call Elutia (stream tin). The water which is let into the mines washes, and carries down with it, certain little black stones, streaked and marked with white, and as heavy as the gold itself. It is gathered with it, and they remain together in the baskets in which the gold is collected. These are not separated from it until after melting in the furnace, when the fusion transforms them into white lead.” Again : “You cannot solder together two pieces of black lead without white lead, neither can this be united to the other without the aid of oil.” He also says of this metal : “Neither out of the white lead can any silver be extracted ; whereas out of the black this is commonly done.”

In speaking of common lead, the same author says : “It is much used for conduit pipes, and for being hammered into thin plates,” and then goes on to describe the mines of France, Spain and Britain, which he states, when quite worked out and exhausted, become as productive as ever, and indeed even more so, if allowed to remain a short time without being worked ; for which he accounts, by supposing the metal to be produced by the air, which has then free access into the mine. With regard to the state in which *Plumbum nigrum* occurs, we are informed : “Black lead has a double origin : for it is either produced in a vein of its own without any other metal ; or otherwise it is mingled with silver in the same mine, being mixed together in one stone of ore, and they are only separated by melting and refining in a furnace.† The first liquor that flows from the furnace is tin (*Stannum*), and the second silver. That part which remains behind is galena, the third element of the vein, which being again melted, after two parts of it are deducted, yields black lead.”

The above passage is very obscure : tin, lead and silver are not frequently found together in the same stone, and were they thus to

* “It is generally considered that the Greeks obtained their tin by means of the Phœnicians from the Scilly Islands or Cornwall, but there is no direct proof of this ; and it appears probable, from the Sanskrit derivation of the Greek word (*kassiteros*, from *kastīra*), that the Greeks originally obtained their tin from India. The Islands *Cassiterides*, however, the position of which was unknown to Herodotus (III, 115), are supposed to be the Scilly Islands, or the peninsula of Cornwall, though their position is not exactly defined by Strabo (III, 175). Still there can be little doubt that the *Cassiterides*, to which the Phœnicians from Gades (Cadiz) went for tin, and the Romans afterwards traded for the same commodity, were on the south-western angle of Great Britain.”—Pen. Cyc. art. ‘Hindustan.’

† Hist. Nat. XXXIV, 16.

occur, the tin certainly would not be the first to flow out of the furnace.

Professor John Phillips, in his excellent paper on "Ancient Metallurgy and Mining in Brigantia,"* seems to be of opinion that the method here described might have had some resemblance to that invented and patented by H. L. Pattinson, Esq. This, however, appears less probable when we consider that if, in Pattinson's process, the rich lead were run off, instead of dipping out the poor in the form of crystals, the metal thus obtained being but sparingly mixed with silver, would not have been called stannum, by which term an alloy of tin and lead is frequently expressed. It, therefore, does not seem impossible that the operation referred to was simply cupellation, in which process the "*abstrichs*" and first litharge flowing from the furnace is much more impure than that subsequently obtained, and, therefore, when reduced, would yield a harder lead, not unlike pewter or *Stannum*. The silver thus obtained would of course remain on the cupel, whilst the litharge which flowed from the furnace after it got into steady action, together with that absorbed by the cupel itself, would, on being melted with a reducing-agent, yield pure, or nearly pure lead. I think, therefore, the author intends to convey the idea that three parts of litharge and "*débris de coupelle*" yield only one part of lead.

That cupellation has long been employed for the extraction of silver from lead may be inferred from the works of Agricola,† who in his "*De Re Metallica*," describes and gives drawings of the furnaces used in his time for that purpose, and which exactly correspond in every respect with the old German cupels in use at the present day in many parts of the continent.

The Greeks and Romans have left no treatises relative to chemistry or metallurgy; but it is scarcely reasonable to suppose, that had the method of refining lead by crystallization been known to them, it should either have been lost or fallen into disuse, as its advantages are too obvious not to have been evident to the rudest operators. Another argument against the opinion of Pliny having referred to this method, is the fact that rich lead, and not pure silver as described by him, is obtained by the crystallizing process, and if this method were ever known, it must evidently have fallen into disuse before the time of Agricola, who makes no mention of any knowledge on the subject, but gives the old German furnace as that

* Proceedings of the Yorkshire Philosophical Society for March, 1848.

† Born A.D. 1494.

ordinarily employed for the extraction of silver, and which, from the circumstance of its having remained unchanged in every respect since the days of Agricola, may be inferred to have existed in the same form long prior to that time; and to have been probably not only used by the Greeks and Romans, but possibly even at a much earlier date.

Of all the metals employed by the ancients for the manufacture of objects of luxury, as well as for those adapted to the everyday usages of life, copper and its alloys were the most common; as by far the greater portion of the coins, tools and implements of war, which are occasionally brought to light, are composed of some modification of either bronze or brass; and consequently, the making of these alloys, and their adaptation to the various wants of mankind, must have formed a very important branch of the manufactures among the Greeks and Romans. Accordingly, the author of the "Natural History of the World," after describing the properties of this metal, and stating the localities in which that of the best quality was found, gives the composition and proportions employed in the various alloys then common in Rome, and informs us to what uses they were severally applied. He also states that copper was first found in the Island of Cyprus, from whence two distinct kinds were exported: * one called *Coronarium*, which when reduced into thin leaves and coloured with the gall of an ox, had a golden colour, and was employed for making coronets and tinsel ornaments for actors, from which circumstance it derived its appellation. Another variety, which was named *Regulaire*, is not particularly described, except that, like the former, it would stand hammering, and might be thus made to take any required form. The brass (copper) of the next best quality came from Campania, where it was the custom to add eight parts of lead to every 100 pounds of copper. It is also mentioned, that in France it was usual to melt copper among red-hot stones, for the purpose of obtaining a steady heat, as a quick fire was found to blacken the metal and render it brittle. He moreover informs us that the process was completed in one operation, but states that the quality would be improved by more frequent melting: "Moreover, it may not be amiss to state also, that all kinds of brass melt best in the coldest weather. For statues and tables brass is worked in the following manner: First the ore, or stone as it comes out of the mine, is melted, and as soon as this is done, they add to it a third part of scrap brass, consisting of broken pieces of vessels that have been

* Pliny, XXXIV, 8.

used; for it is time and use alone that bring brass to perfection, it is the rubbing which conquers the natural harshness of the metal. They then mix twelve pounds and a half of tin to every hundred pounds weight of the aforesaid melted ore. The softest alloy is called *Formall*, in which are incorporated a tenth of black lead, and one twentieth part of argentine lead; it is this mixture which best takes the colour called grecanic. The last alloy is that which is called *Ollaria*, or pot-brass, as it takes its name from the vessels for which it is mostly employed, and this is made by tempering every hundred pounds weight of brass with three or four pounds weight of argentine lead or tin.*

The alloys above described are merely modifications of bell-metal or bronze; but it is not improbable that the ancients were acquainted with zinc-brass long before this period. Aristotle tells us that the Mosynæci, a people who inhabited a country not far from the Euxine Sea, were said to make their copper of a splendid white colour, not by the addition of tin, but by mixing and cementing it with an earth found in that country.† We are also informed by Strabo, that in the neighbourhood of Andêra, a city of Phrygia, a remarkable kind of stone was met with, which being calcined became iron, and on being fluxed with a certain kind of earth, yielded drops of a silvery-looking metal, which when mixed with copper, formed an alloy called *Aurichalcum*.‡

Sextus Pompeius Festus, who abridged a work of Verrius Flaccus, a grammarian of considerable note in the time of Augustus, mentions *cadmia*, which he defines as an earth thrown upon copper, in order to convert it into *aurichalcum*.§

On this subject Pliny affords us but little information, merely stating where *cadmia* was found, and naming some of its medicinal properties, but he seems to have regarded it rather as an earth which gave a yellow colour to copper, than as the ore of a distinct metal, zinc being in no instance mentioned by him, although he speaks of a kind of brass which was manufactured in the Island of Cyprus from copper and *cadmia*.

If the foregoing quotations were not sufficient to show that the ancients were acquainted with the art of making zinc-brass, the fact has been fully proved by the analyses given in a subsequent part of this paper, by consulting which, zinc will be found to occur some

* Pliny, XXXIV, 9.

† Arist. de Mirab. Op. II, 721.

‡ Strabo, Geo. LXIII.

§ "Cadmia terra quæ in æs conjicitur ut fiat aurichalcum."—Fes. de ver. seq.

time previous to the Christian era, although at what precise period, it would be impossible to determine, without multiplying experiments to an unreasonable extent. That metallic zinc, however, was known to the ancients, there is no evidence to prove, since the metal mentioned by Strabo as given out in drops from a certain stone when heated, could scarcely have been zinc, which would, to a great extent, have been volatilized if treated in the way described, and we may therefore suppose, that if the stone referred to by him was an ore of zinc, it might also have contained some other metal, such as lead, with which it is often found associated, and which would produce the appearance in question. Ambrose, Bishop of Milan, describes the transformation of copper into aurichalcum as being effected by means of a drug,* and not by the addition of another metal, from which we may infer he was unacquainted with the metallic nature of the material employed, although from his calling it a drug, he was perhaps aware of its medicinal properties.

A similar description of the manufacture of brass is given by Primasius, Bishop of Andrumetum, in Africa, in the sixth century, and by Isidorus, Bishop of Seville, in the seventh. Agricola, who wrote in the sixteenth century, was also evidently ignorant that cadmia contained zinc, of which we have no authentic account until we find it mentioned by Paracelsus; and from which it is evident, that although the manufacture of zinc-brass is of great antiquity, the extraction of the metal itself is comparatively a modern discovery.

Iron, the last of the six metals known to the ancients, was not, in the earliest times, very extensively employed, as the primitive heroes are described as being armed with weapons of brass.

Pisander is represented as attacking Agamemnon with a pole-axe, of which Homer says:

“ An olive’s cloudy grain the handle made
Distinct with studs, and *brazen* was the blade.”†

Plutarch informs us that when Cimon, the son of Miltiades, conveyed the bones of Theseus from the Island of Scyros to Athens, he found interred with him, a bronze sword and a spear-head of the same metal.‡

Although generally used, however, brass was not universally employed for the manufacture of arms, as the celebrated robber, Periphetes, slain by Theseus, was named Korunetes (*Κορυήτης*) from

* Amb. in Apoc. CI.

† Iliad, V, 612, Pope’s Trans.

‡ Theseo.

using an iron club, and Areïthous is described by the author of the *Iliad* as :*

“ Great Areïthous, known from shore to shore,
By the huge knotted *iron* mace he bore ;
No lance he shook, nor bent the twanging bow ;
But broke with this the battle of the foe.”

In the days of Herodotus iron must have already come into general use, as when his interpreter reads to him an inscription on one of the Egyptian Pyramids relative to the amount of money expended on radishes, onions and garlic for the workmen employed in its construction, he makes the reflection, that if this were true, how much more must have been paid for *iron tools* and bread !†

It would again seem almost incredible that these stupendous structures could themselves have been erected without the aid of steel, both for quarrying and shaping the stone, as well as for cutting the hieroglyphics so common in the earliest specimens of Egyptian architecture. If then, we allow that iron tools were employed in building these monuments, we must suppose this metal to have been in common use during the reign of the shepherd kings who conquered Egypt and occupied the throne of the Pharaohs during some part of the interval which elapsed between the birth of Abraham and the captivity of Joseph.‡

In speaking of iron, Pliny says :§ “ After copper, comes iron, both the most useful and most fatal instrument of life. With iron man delves the earth, plants trees, prunes his orchards, trims his vines, cutting off the older branches, and thereby throwing more vigour into the grapes ; by its aid man builds houses, cuts stone, and prepares a thousand other implements ; but by it war, atrocity and villany is effected and rendered common.” He also describes iron as occurring in almost every part of the known world, but particularly in the Island of Elba, where the colour of the earth indicated the presence of the ore.

We are moreover informed that the ores of iron should be treated like those of copper, in order to extract the metal, and that it was a disputed point in Cappadocia, whether the principle of iron was aqueous or earthy in its nature, as the water of a certain river of that country, when thrown on the earth, produced iron, precisely similar to that obtained from a furnace. He then goes on to say, that there are two distinct kinds of forges, as some produce steel (*nucleus ferri*), which is best adapted for cutting-instruments ; whilst others,

* *Iliad*, V. 136, Pope's Trans.

‡ Russell's Egypt, 89.

† Herod. *Euterpe*, II, 125.

§ Pliny, XXXIII, 14.

shape it into instruments of common use, such as hammers and anvils; but that seasoning is the most important and delicate part of the operation. "It is a remarkable fact that, in the treatment of this mineral, the metal in melting is at first as liquid as the most limpid water, but becomes spongy in getting cold."*

From the extracts already quoted, it will be seen that the information which has come down to us relative to the metallurgy of the early ages, is both vague and to some extent uncertain; as those who describe the materials and methods employed, have themselves acquired their information from others, and were, therefore, more subject to commit errors, than if practically acquainted with the subjects of which they treated. This circumstance has induced me to believe, that a careful analytical examination of such productions of the early metallurgists, as have been discovered in different localities, would not be without interest, and I have therefore undertaken the following series of analyses.

From the advantage afforded for ascertaining dates, most of the analyses have been executed on coins, care being first taken to well establish their authenticity.

Some Celts and sword-blades have also been examined, and of these figures are given.

The analyses are placed consecutively, according to the supposed dates of the specimens examined, and the methods employed in their execution will be found fully described in the Appendix.

ANALYSES OF ANCIENT ALLOYS.

A.

COINS STRUCK PRIOR TO THE CHRISTIAN ERA.

Commerce in remote antiquity, was carried on by means of the mere exchange of commodities; and it is remarkable, that throughout the more ancient books of Scripture, as well as in the poems of Homer, no passage occurs from which it can be inferred, that stamped money was then in circulation, although mention is repeatedly made of purchases being effected through the medium of the metals, which, for that purpose, were estimated by the balance. Herodotus (I, 94) speaks of the Lydians as the first who coined gold and silver into

* Iron in Pliny's time was doubtless made by the direct, or Catalan process, and the spongy appearance above described must have arisen, not from its cooling, as he seems to suppose, but from combustion of the combined carbon, and the consequent conversion of the compound into malleable iron.

money. The Parian chronicle, however, ascribes the origin of coined money to the Æginetans, under Phidon, King of Argos, who reigned 895 years before the Christian era.* Ælian, in his "Various History," corroborates this statement, and the most competent numismatic authorities agree in considering the coins of Ægina as the most ancient specimens of stamped money which have come down to us. These are of silver, and bear on the upper side the figure of a turtle, and on the reverse an indented mark, as if the metal at the time of striking had been held on a puncheon, which, from the force of the blow, appears to have left a deep impression.

The coins of Lydia would seem to come next in point of antiquity, and after them, the early Darics of the Persian kings, which occur in both silver and gold. Pinkerton observes, "the first Grecian copper coins with which we are acquainted, were those of Gelo, King of Syracuse, about 490 years before the birth of Christ. These were called *Chalci*, or pieces of brass; others of a smaller size, were denominated *Lepta*, or *Kerma*, from being change for the poor." He is also of opinion, that the Greeks had no gold coinage before the time of Philip of Macedon, and that Athens had no gold money before the Peloponnesian war.†

The first Roman coinage was of brass, and is said to have taken place under Servius Tullius, about five centuries before the Christian era, and seems to have been confined to the *as* or *æs*, which on one side bore the two-faced head of Janus, and on the other the prow of a ship, a symbol always attending Janus, because he arrived in Italy by sea.

Varro,‡ however, informs us, that the first Roman coins bore the stamp of a bull, ram, or some other cattle, and it is therefore probable that the *As* with the head of Janus, was not the very first design issued from the Roman mint.

However this may be, soon after the first coinage of brass, the parts of the *As* of a value proportionate to their weight were also produced.§ The *Semis*, or half *As*, marked S., had commonly the head of Jupiter laureated; the *Triens*, or third, marked OOOO, as being originally

* This chronicle, as it is called, consists of a series of Greek inscriptions cut in Parian marble. It was discovered in the beginning of the seventeenth century in the island of Pharos, one of the Cyclades, and was bought and brought to England by the celebrated Thomas Earl of Arundel. It is proved by internal evidence that this chronicle was engraved 264 years before the birth of Christ, most likely for Athens.

† Pinkerton on Medals, I, 77.

‡ Varro de Re. Rust, I, 2.

§ Pinkerton on Medals, I, 101.

four ounces, had the head of Minerva ; the *Quadrans*, or quarter, 000, the head of Hercules, wrapt in a lion's skin ; the *Sextans*, or sixth, 00, that of Mercury with a cap and wings ; and finally the *Unica*, marked 0, had the head of Rome.

All the above coins were cast, as were also those of the Etruscans, from whom the Romans learnt the art of moulding their money ; and that several were usually obtained at each melting, is evident from the fact that three or four have occasionally been found joined by runners of the metal of which they are made. Most of the specimens also retain the marks produced, by cutting off these threads, as likewise the lines indicating the division of the two parts of which the mould was composed.

ROMAN AS OR ÆS. B.C. 500.*

Weight, 4150 grains. Specific gravity, 8·59.

Obverse : The head of Janus. Reverse : A ship.

The metal of which it was composed, presented an iron-grey appearance when broken, but if cut, the peculiar hue of copper was immediately perceived. Large cavities were also observed in the substance of the alloy, occasioned by bubbles of air, which being shut up in the mould, had caused numerous holes in the casting.

1^o. 21·80 grs. gave 18·99 grs. of oxide of copper = 69·51 per cent of copper.

1·97 grs. of peroxide of tin = 7·10 per cent of tin.

7·04 grs. of sulphate of lead = 22·02 per cent of lead.

·15 grs. of peroxide of iron = ·48 per cent of iron.

·13 grs. of metallic cobalt = ·59 per cent of cobalt.

2^o. 25·42 grs. gave 22·26 grs. of oxide of copper = 69·87 per cent of copper.

2·34 grs. of peroxide of tin = 7·23 per cent of tin.

8·06 grs. of sulphate of lead = 21·62 per cent of lead.

·17 grs. of peroxide of iron = ·46 per cent of iron.

·14 grs. of metallic cobalt = ·55 per cent of cobalt.

* M. Le Normand considers the Roman As of this type, to have been coined about B.C. 385. Other authors, however, regard the date above given, as being more correct.

	I.	II.
Copper . . .	69·51	69·87
Tin . . .	7·10	7·23
Lead . . .	22·02	21·62
Iron . . .	·48	·46
Cobalt . . .	·59	·55
Nickel and Sulphur	traces	traces
	<hr/> 99·70	<hr/> 99·73

SEMIS.

Same date as the foregoing.

This coin bears on one side the head of Jupiter laureated, and on the other the letter S. Its weight, although not quite perfect, was 1997 grains. Specific gravity, 8·64.

1^o. 37·10 grs. gave 15·96 grs. of sulphate of lead = 29·35 per cent of lead.

28·84 grs. of oxide of copper = 62·05 per cent of copper.

3·60 grs. of oxide of tin = 7·62 per cent of tin.

·085 grs. of cobalt = 0·23 per cent of cobalt.

·09 grs. of oxide of nickel = ·19 per cent of nickel.

·10 grs. of oxide of iron = ·17 per cent of iron.

2^o. 25·4 grs. gave 19·76 grs. of oxide of copper = 62·04 per cent of copper.

10·90 grs. of sulphate of lead = 29·29 per cent of lead.

2·50 grs. of oxide of tin = 7·71 per cent of tin.

·058 grs. of cobalt = ·23 per cent of cobalt.

·07 grs. of oxide of nickel = ·19 per cent of nickel.

·07 grs. of oxide of iron = ·19 per cent of iron.

	I.	II.
Copper . . .	62·05	62·04
Lead . . .	29·35	29·29
Tin . . .	7·62	7·71
Cobalt . . .	0·23	0·23
Nickel . . .	·19	0·19
Iron . . .	·17	0·19
Sulphur . . .	trace	trace
	<hr/> 99·61	<hr/> 99·65

QUADRANS.

This is supposed to be of the same date as the preceding, being of similar rude workmanship and brittle metal. The specimen examined bore on one side the head of Hercules, and on the other a design in which the marks 000 were conspicuous. Its weight was 970 grains; its specific gravity, 8·58.

1^o. 23·43 grs. gave 21·20 grs. of oxide of copper = 72·17 per cent of copper.

2·14 grs. of oxide of tin = 7·17 per cent of tin.

6·70 grs. of sulphate of lead = 19·52 per cent of lead.

0·15 grs. of peroxide of iron = ·41 per cent of iron.

0·07 grs. of cobalt = ·29 per cent of cobalt.

·06 grs. of oxide of nickel = ·20 per cent of nickel.

2^o. 25·50 grs. gave 23·10 grs. of oxide of copper = 72·27 per cent of copper.

2·33 grs. of oxide of tin = 7·18 per cent of tin.

7·32 grs. of sulphate of lead = 19·60 per cent of lead.

·13 grs. of peroxide of iron = ·36 per cent of iron.

·07 grs. of cobalt = ·28 per cent of cobalt.

·07 grs. of oxide of nickel = ·21 per cent of nickel.

			I.	II.
Copper	.	.	72·17	72·27
Tin	.	.	7·17	7·18
Lead	.	.	19·52	19·60
Iron	.	.	·41	·36
Cobalt	.	.	·29	·28
Nickel	.	.	·20	·21
Sulphur	.	.	trace	trace
			<hr/>	<hr/>
			99·76	99·90

HIERO I. B.C. 478.

Hiero I. succeeded his brother Gelo as King of Syracuse, 478 years before our era, and reigned eleven years.

The coin examined was of a yellow colour, and the metal bright and close in its grain, being extremely hard and difficult to cut. Specific gravity, 8·72.

268 MR. J. A. PHILLIPS' CHEMICAL EXAMINATION OF

1^o. 22·16 grs. gave 26·18 grs. of oxide of copper = 94·26 per cent of copper.

1·55 grs. of oxide of tin = 5·49 per cent of tin.

·10 grs. of peroxide of iron = ·31 per cent of iron.

2^o. 15·13 grs. gave 17·83 grs. of oxide of copper = 94·05 per cent of copper.

1·06 grs. of oxide of tin = 5·50 per cent of tin.

·07 grs. of peroxide of iron = ·33 per cent of iron.

		I.	II.
Copper	. .	94·26	94·05
Tin	. . .	5·49	5·50
Iron	. . .	·31	·33
		<hr/>	<hr/>
		100·06	99·88

ALEXANDER THE GREAT. About B.C. 335.

This coin weighed 108 grains, and the metal of which it was composed had a specific gravity of 8·69.

1^o. 26·6 grs. gave 28·90 grs. of oxide of copper = 86·729 per cent of copper.

4·45 grs. of oxide of tin = 13·146 per cent of tin.

23·0 grs. gave 0·13 grs. of sulphate of baryta = ·071 per cent of sulphur.

2^o. 23·81 grs. gave 25·91 grs. of oxide of copper = 86·839 per cent of copper.

3·89 grs. of oxide of tin = 12·839 per cent of tin.

23·70 grs. gave 0·13 grs. of sulphate of baryta = ·065 per cent of sulphur.

		I.	II.
Copper	. .	86·729	86·839
Tin	. . .	13·146	12·839
Sulphur	. .	·071	·065
		<hr/>	<hr/>
		99·946	99·743

PHILIPPUS III.

Natural son of Philip II. and half brother of Alexander, whom he succeeded as King of Macedonia, in the year 323 before our era.

THE METALS AND ALLOYS KNOWN TO THE ANCIENTS. 269

The coin examined weighed 83·3 grains, and bore on one side a head, and on the other a man on horseback. This metal resembled that of which the coin of Alexander was composed, and had a specific gravity=8·71.

1^o. 23·40 grs. gave 26·50 grs. of oxide of copper=90·34 per cent of copper.

2·80 grs. of oxide of tin=9·40 per cent of tin.

2^o. 15·63 grs. gave 17·68 grs. of oxide of copper=90·21 per cent of copper.

1·89 grs. of oxide of tin=9·46 per cent of tin.

		I.	II.
Copper	. . .	90·34	90·21
Tin	. . .	9·40	9·46
		<hr/>	<hr/>
		99·74	99·67

PHILIPPUS V. B.C. 200.

Weight about 164 grains. Specific gravity=8·59.

1^o. 19·96 grs. gave 21·30 grs. of oxide of copper=85·15 per cent of copper.

2·82 grs. of oxide of tin=11·10 per cent of tin.

·84 grs. of sulphate of lead=2·87 per cent of lead.

·13 grs. of peroxide of iron=0·45 per cent of iron.

2^o. 8·89 grs. gave 9·50 grs. of oxide of copper=85·16 per cent of copper.

1·26 grs. of oxide of tin=11·14 per cent of tin.

·37 grs. of sulphate of lead=2·83 per cent of lead.

·05 grs. of peroxide of iron=0·39 per cent of iron.

		I.	II.
Copper	. . .	85·15	85·16
Tin	. . .	11·10	11·14
Lead	. . .	2·87	2·83
Iron	. . .	0·45	0·39
Sulphur	. . .	trace	trace
		<hr/>	<hr/>
		99·57	99·52

COPPER COIN OF ATHENS.

Weight=89·5 grs. Specific gravity=8·61.

Obverse: Head of Minerva. Reverse: A naked figure, represented in the act of hurling a thunderbolt. Metal, very hard.

270 MR. J. A. PHILLIPS' CHEMICAL EXAMINATION OF

1^o. 21·0 grs. gave 23·26 grs. of oxide of copper = 88·41 per cent of copper.

2·66 grs. of oxide of tin = 9·95 per cent of tin.

·21 grs. of sulphate of lead = ·68 per cent of lead.

·08 grs. of peroxide of iron = ·26 per cent of iron.

·18 grs. of oxides of nickel and cobalt = ·67 per cent of metal.*

2^o. 18·38 grs. gave 20·34 grs. of oxide of copper = 88·34 per cent of copper.

2·33 grs. of oxide of tin = 9·96 per cent of tin.

·16 grs. of sulphate of lead = ·59 per cent of lead.

·07 grs. of peroxide of iron = ·26 per cent of iron.

·15 grs. of oxides of nickel and cobalt = ·63 per cent of metal.

	I.	II.
Copper . . .	88·41	88·34
Tin . . .	9·95	9·96
Lead . . .	·68	·59
Iron . . .	·26	·26
Nickel and cobalt .	·67	·63
	<hr/> 99·97	<hr/> 99·78

EGYPTIAN. PTOLEMY IX. About B.C. 70.

AULETES (THE FLUTE PLAYER).

This coin was made of a very brittle metal, and weighed 337 grs. On one side it bore the impression of a bearded head, and on the other an eagle holding a thunderbolt. Specific gravity = 8·81.

1^o. 17·34 grs. gave 18·30 grs. of oxide of copper = 84·21 per cent of copper.

3·44 grs. of oxide of tin = 15·59 per cent of tin.

2^o. 13·66 grs. gave 2·73 grs. of oxide of tin = 15·70 per cent of tin.
Oxide of copper lost.

	I.	II.
Copper	84·21	84·30
Tin	15·59	15·70
Iron, cobalt and sulphur .	traces	traces
	<hr/> 99·80	<hr/> 100·00

* In this instance, the quantity of the mixed oxides being small, no attempt was made to separate them, and as their equivalent is nearly the same, the amount of the two metals together was calculated directly from the weight of the oxides found.

POMPEY. FIRST BRASS. B.C. 53.

Weight 309 grs. Specific gravity 8·70.

Obverse: Head of Janus. Reverse: Prow of a ship.

This coin was evidently cast, and the metal is very hard and brittle, resembling in this respect the alloy employed in the original *as*, before its reduction in weight.

1^o. 19·93 grs. gave 18·51 grs. of oxide of copper = 74·11 per cent of copper.

2·17 grs. of oxide of tin = 8·56 per cent of tin.

4·7 grs. of sulphate of lead = 16·08 per cent of lead.

·09 grs. of peroxide of iron = ·31 per cent of iron.

2^o. 18·90 grs. gave 17·58 grs. of oxide of copper = 74·23 per cent of copper.

2·03 grs. of oxide of tin = 8·38 per cent of tin.

4·50 grs. of sulphate of lead = 16·23 per cent of lead.

·07 grs. of peroxide of iron = ·26 per cent of iron.

	I.	II.
Copper . . .	74·11	74·23
Tin . . .	8·56	8·38
Lead . . .	16·08	16·23
Iron . . .	·31	·26
	<hr/> 99·06	<hr/> 99·10

COIN OF THE ATILIA FAMILY. B.C. 45.

This coin bears, on one side, the head of Janus; and on the other, the prow of a ship, with the word *ROMA* beneath it. The metal is extremely hard and brittle, but has been struck with a die.

Weight = 466 grs. Specific gravity = 9·02.

1^o. 30·10 grs. gave 25·92 grs. of oxide of copper = 68·72 per cent of copper.

1·80 grs. of oxide of tin = 4·77 per cent of tin.

11·22 grs. of sulphate of lead = 25·42 per cent of lead.

·06 grs. of peroxide of iron = ·13 per cent of iron.

2^o. 28·52 grs. gave 24·54 grs. of oxide of copper = 68·66 per cent of copper.

1·77 grs. of oxide of tin = 4·95 per cent of tin.

10·64 grs. of sulphate of lead = 25·44 per cent of lead.

·04 grs. of peroxide of iron = ·09 per cent of iron.

	I.	II.
Copper . . .	68.72	68.66
Tin . . .	4.77	4.95
Lead . . .	25.42	25.44
Iron . . .	.13	.09
Cobalt and nickel .	traces	traces
	<hr/> 99.04	<hr/> 99.14

JULIUS AND AUGUSTUS. About B.C. 42.

Weight 342 grains. Specific gravity 8.64.

1^o. 21.04 grs. gave 20.80 grs. of oxide of copper=78.88 per cent of copper.

2.13 grs. of oxide of tin=7.95 per cent of tin.

3.95 grs. of sulphate of lead=12.80 per cent of lead.

2^o. 17.56 grs. gave 17.39 grs. of oxide of copper=79.39 per cent of copper.

1.80 grs. of oxide of tin=8.05 per cent of tin.

3.30 grs. of sulphate of lead=12.81 per cent of lead.

	I.	II.
Copper . . .	78.88	79.39
Tin . . .	7.95	8.05
Lead . . .	12.80	12.81
Iron and sulphur .	traces	traces
	<hr/> 99.63	<hr/> 100.25

AUGUSTUS AND AGRIPPA. B.C. 30.

CONQUEST OF EGYPT.

Weight 238 grs. Specific gravity=8.65.

This coin bears two heads on one side; and on the other, a crocodile, with COL: NEM. Metal very hard and brittle.

1^o. 25.26 grs. gave 24.90 grs. of oxide of copper=78.58 per cent of copper.

4.15 grs. of oxide of tin=12.91 per cent of tin.

3.16 grs. of sulphate of lead=8.53 per cent of lead.

2^o. 17.93 grs. gave 17.60 grs. of oxide of copper=78.33 per cent of copper.

2.97 grs. of oxide of tin=13.01 per cent of tin.

2.29 grs. of sulphate of lead=8.71 per cent of lead.

THE METALS AND ALLOYS KNOWN TO THE ANCIENTS. 273

	I.	II.
Copper . . .	78·58	78·33
Tin . . .	12·91	13·01
Lead . . .	8·53	8·71
Iron and sulphur .	traces	traces
	<hr/>	<hr/>
	100·02	100·05

LARGE BRASS OF THE CASSIA FAMILY. About B.C. 20.

Weight 365 grains. Specific gravity=8·52.

Metal of a yellow colour, and softer than any of the foregoing.

1^o. 15·73 grs. gave 16·27 grs. of oxide of copper=82·47 per cent of copper.

3·37 grs. of oxide of zinc=17·16 per cent of zinc.

·08 grs. of peroxide of iron=·35 per cent of iron.

2^o. 16·243 grs. gave 16·70 grs. of oxide of copper=82·06 per cent of copper.

3·54 grs. of oxide of zinc=17·46 per cent of zinc.

·35 grs. of peroxide of iron=·36 per cent of iron.

	I.	II.
Copper . . .	82·47	82·06
Zinc . . .	17·16	17·46
Iron . . .	·35	·36
Sulphur . . .	faint trace	faint trace
	<hr/>	<hr/>
	99·98	99·88

B.

ANALYSES OF ANCIENT ARMS AND CUTTING INSTRUMENTS.

It would be impossible to determine the dates of these relics of former times with the same accuracy with which we may ascertain the ages of coins; and I shall therefore merely give the weight and dimensions of the various specimens which have been examined, and endeavour to adduce such evidence as may show their great antiquity, without attempting to specify the precise dates at which they were employed. The ancient authors who have written on this

subject, all agree that brass was used for the manufacture of arms before the discovery of iron. Lucretius says:*

“Arma antiqua manus, ungues, dentesque fuerunt,
Et lapides, et item silvarum fragmina rami,
Et flammæ, atque ignes, postquam sunt cognita primum
Posterior ferri vis est ærisque reperta
Sed prius æris erat quam ferri cognitus usus.”

Hesiod also informs us that, “In remote ages, the earth was worked by brass, because iron had not been discovered.” The Etrurians were acquainted with the use of copper, and appear to have used it for the purposes of agriculture at a very early period, as when the boundaries of their city were marked out, it was done with a ploughshare of bronze.† Numerous other authorities might, if necessary, be quoted in support of the above statements; but the opening of divers Scandinavian tumuli, of very remote antiquity, in Denmark, fully establishes the accuracy of these accounts. From these barrows have been collected specimens of swords, daggers, knives, and implements of industry, since preserved and arranged in the Museum of Copenhagen, and among them are instruments of flint, resembling in their shapes, our wedges, axes, chisels, hammers, and knives; which we may infer, from their rude workmanship, as well as from the materials of which they are formed, to have been the first description of edge-tools used by mankind for the several purposes for which they were adapted. Specimens of swords, daggers and knives were also found, of which the blades are made of gold, whilst the cutting edges only are of iron. Some of these objects are composed principally of copper, with edges of iron; and in the whole of them, the profuse application of copper and gold, in comparison with the parsimony evident in the expenditure of iron, seems to prove that at that early, though unknown period, both gold and copper were more plentiful, and less highly valued than iron, among the now-forgotten people who manufactured these implements.‡

Although we have the best evidence for believing that copper and bronze were employed for the purpose of making cutting instruments before the discovery of iron, it would be more difficult to ascertain at what date and among what nation this metal first came into general use. That it was known at a very early period we learn from various passages in the Books of Moses; and that it was used in the days of Job (about B.C. 1400) for the manufacture of arms, is evident from

* Lib. I, 1282.

† Macrob. Saturn. V, 19.

‡ Jacob on the Precious Metals, I, 3.

the following passage : " He shall flee from the iron weapon and the bow of steel shall strike him through."*

It is nevertheless probable that bronze might have been in common use long after the discovery of the harder metal, as the preparation of iron must have been a very tedious and expensive operation, to a people having but a scanty knowledge of the metallurgic arts, and we accordingly find a kind of compromise between its known utility and high commercial value in the case above-quoted, in which the cutting edge alone is made of steel. At the present day, a valuable discovery made in any part of the world would speedily become known and appreciated throughout its whole extent, but at the remote time in which iron was first reduced from its ore, so little communication existed between the various nations, that that which might be well known and highly valued by the inhabitants of one country or state, might be quite unheard of in another, and consequently the uses of this metal may for a long time have been limited to a few districts where accident, or the smelting of some other mineral, had first revealed its presence. In the earliest ages of recorded history, when the world was divided into numerous petty states and principalities, the constant feuds, which were the principal occupation of mankind, would certainly cause a demand for arms and weapons of defence. Such a state of things must, however, operate most unfavourably on the cultivation of the arts ; and it is not reasonable to suppose that a conquering army on entering a foreign territory would have sufficient leisure to acquire the arts of the conquered nation, and consequently, although they might find the arms of their enemies superior to their own, they would still be ignorant of the means by which they were manufactured ; and thus the secret would remain for a long period in the possession of its first discoverers. At what precise epoch weapons of iron came into general use among the Romans, we have not sufficient information to decide, but in the time of Augustus,† iron mines were worked to a considerable extent in the Noric Alps (now Illyria), and from them iron of the first quality was obtained. This was used for making the best weapons, and hence " *Noricus ensis*," was as much synonymous for a good sword, as a Toledo, or Andrea Ferrara blade in more modern times.‡ In this sense it is used by Horace, Book I, Ode XVI, v. 9. At the time in which Pliny wrote his " *Historia Naturalis*," iron was almost universally employed, not only for the blades of swords, but also for the manufacture of the different cutting instruments used for

* Job, XX, 24.

† B.C. 30.

‡ Jacob on the Precious Metals, I, 88.

the purposes of daily life, as he both describes the metal and the means of forging it, and also refers to the difficulty of tempering steel in order to give it the requisite degree of hardness.

From these considerations, it is evident that the various weapons of bronze must be of great antiquity, since iron was in common use prior to the Christian era, and I have therefore placed the analyses of these instruments, in a part of the series which corresponds to that period, notwithstanding that in all probability some of them may belong to a much earlier date.

SWORD-BLADE, (FIG. 1.)

Found under Chertsey Bridge, Thames. Weight, 1 lb.; length, 17 inches; breadth at widest part, $1\frac{3}{4}$ inches; breadth where broken, $1\frac{1}{8}$ inches.

1^o. 35.2 grs. gave 39.70 grs. of oxide of copper = 90.00 per cent of copper.

4.28 grs. of oxide of tin = 9.54 per cent of tin.

·17 grs. of peroxide of iron = .33 per cent of iron.

2^o. 35.8 grs. gave 40.10 grs. of oxide of copper = 89.38 per cent of copper.

4.40 grs. of oxide of tin = 9.63 per cent of tin.

·17 grs. of peroxide of iron = .33 per cent of iron.

		I.	II.
Copper	. .	90.00	89.38
Tin	. . .	9.54	9.63
Iron	. . .	.33	.33
Sulphur	. .	trace	trace
		<hr/>	<hr/>
		99.87	99.34

BROKEN SWORD-BLADE, (FIG. 2.)

Found in Ireland. Weight, 4 oz.; length, 8 inches; breadth at the hilt, $1\frac{3}{4}$ inches; breadth where broken, 1 inch.

1^o. 21.40 grs. gave 22.98 grs. of oxide of copper = 85.70 per cent of copper.

2.73 grs. of oxide of tin = 10.02 per cent of tin.

·91 grs. of sulphate of lead = 2.89 per cent of lead.

·13 grs. of peroxide of iron = .42 per cent of iron.

THE METALS AND ALLOYS KNOWN TO THE ANCIENTS. 277

2^o. 22·08 grs. gave 23·67 grs. of oxide of copper=85·55 per cent of copper.

2·82 grs. of oxide of tin=10·03 per cent of tin.

·96 grs. of sulphate of lead=2·96 per cent of lead.

·15 grs. of peroxide of iron=·47 per cent of iron.

	I.	II.
Copper . . .	85·70	85·55
Tin . . .	10 02	10·03
Lead . . .	2·89	2·96
Iron . . .	·42	·47
	<hr/> 99·03	<hr/> 99·01

FRAGMENT OF A SWORD-BLADE, (FIG. 3)

Found in Ireland. Weight, 6 oz.; length, 8½ inches; width at the broadest part, 1¾ inches; at the narrowest, 1¼ inches.

1^o. 27·20 grs. gave 31·15 grs. of oxide of copper=91·39 per cent of copper.

2·90 grs. of oxide of tin=8·38 per cent of tin.

2^o. 25·62 grs. gave 29·60 grs. of oxide of copper=92·19 per cent of copper.

2·60 grs. of oxide of tin=7·96 per cent of tin.

	I.	II.
Copper . . .	91·39	92·19
Tin . . .	8·38	7·96
Iron and sulphur .	traces	traces
	<hr/> 99·77	<hr/> 100·15

BROKEN SPEAR-HEAD, (FIG. 4.)

Found in Ireland. Weight, 11½ oz.

1^o. 29·05 grs. gave ·60 grs. of sulphate of baryta=·28 per cent of sulphur.

2^o. 29·40 grs. gave ·65 grs. of sulphate of baryta=·29 per cent of sulphur.

	I.	II.
Copper . . .	99·72	99·71
Sulphur . . .	·28	·29
	<hr/> 100·00	<hr/> 100·00

CELT, (FIG. 5.)

Found in Ireland. Weight, about 10 oz.

1^o. 26·0 grs. gave 29·40 grs. of oxide of copper = 90·23 per cent of copper.

2·49 grs. of oxide of tin = 7·50 per cent of tin.

·50 grs. of sulphate of lead = 1·31 per cent of lead.

2^o. 27·0 grs. gave 30·84 grs of oxide of copper = 91·14 per cent of copper.

2·55 grs. of oxide of tin = 7·37 per cent of tin.

·50 grs. of sulphate of lead = 1·26 per cent of lead.

	I.	II.
Copper	90·23	91·14
Tin	7·50	7·37
Lead	1·31	1·26
Iron, cobalt, nickel and sulphur	traces	traces
	<hr/> 99·04	<hr/> 99·77

CELT, (FIG. 6.)

Weight, about 1 lb.

1^o. 14·87 grs. gave 1·86 grs. of oxide of tin = 9·82 per cent of tin.

2^o. 13·93 grs. gave 1·74 grs. of oxide of tin = 9·81 per cent of tin.

	I.	II.
Copper	90·18	90·19
Tin	9·82	9·81
Iron	trace	trace
	<hr/> 100·00	<hr/> 100·00

CELT, (FIG. 7.)

Weight, 4 oz.

1^o. 30·80 grs. gave 34·50 grs. of oxide of copper = 89·38 per cent of copper.

3·60 grs. of oxide of tin = 9·18 per cent of tin.

·15 grs. of oxide of iron = ·34 per cent of iron.

26·40 grs. gave ·47 grs. of sulphate of baryta = ·24 per cent of sulphur.

2⁰. 25·00 grs. gave 27·97 grs. of oxide of copper = 89·28 per cent of copper.

2·93 grs. of oxide of tin = 9·21 per cent of tin.

·12 grs. of oxide of iron = ·33 per cent of iron.

13·99 grs. gave ·24 grs. of sulphate of baryta.

		I.	II.
Copper	. .	89·38	89·28
Tin	. . .	9·18	9·21
Iron	. . .	·34	·33
Sulphur	. .	·24	·24
		<hr/>	<hr/>
		99·14	99·06

CELT, (FIG. 8.)

Weight, about $5\frac{3}{4}$ oz. Specific gravity = 8·09.

1⁰. 11·43 grs. gave 11·96 grs. of oxide of copper = 83·53 per cent of copper.

1·56 grs. of oxide of tin = 10·95 per cent of tin.

·54 grs. of sulphate of lead = 3·22 per cent of lead.

·10 grs. of peroxide of iron = ·61 per cent of iron.

·06 grs. of oxides of nickel and cobalt = ·41 per cent of metal.

2⁰. 11·36 grs. gave 11·92 grs. of oxide of copper = 83·76 per cent of copper.

1·57 grs. of oxide of tin = 11·09 per cent of tin.

·53 grs. of sulphate of lead = 3·18 per cent of lead.

·09 grs. of peroxide of iron = ·55 per cent of iron.

·04 grs. of oxides of nickel and cobalt = ·27 per cent of metal.

		I.	II.
Copper	. .	83·53	83·76
Tin	. . .	10·95	11·09
Lead	. . .	3·22	3·18
Iron	. . .	·61	·55
Nickel and cobalt	. .	·41	·27
		<hr/>	<hr/>
		98·72	98·85

C.

COINS STRUCK SINCE THE COMMENCEMENT OF THE CHRISTIAN ERA.

LARGE BRASS OF NERO. A.D. 60.

Reverse : Rome seated.

Weight 435 grs. Specific gravity=8.59. Metal of a bright yellow colour.

	I.	II.
Copper . . .	81.07	— *
Tin . . .	1.06	1.04
Zinc . . .	17.73	17.90
	<hr/>	
	99.86	

TITUS. A.D. 79.

Weight 178 grains. Specific gravity=8.5 Metal yellow and soft.

1°. 20.41 grs. gave 21.30 grs. of oxide of copper=83.27 per cent of copper.

4.06 grs. of oxide of zinc=15.93 per cent of zinc.

.15 grs. of peroxide of iron=.51 per cent of iron.

2°. 20.68 grs. gave 21.46 grs. of oxide of copper=82.81 per cent of copper.

4.07 grs. of oxide of zinc=15.76 per cent of zinc.

.15 grs. of peroxide of iron=.50 per cent of iron.

	I.	II.
Copper . . .	83.27	82.81
Zinc . . .	15.93	15.76
Iron . . .	.51	.50
	<hr/>	<hr/>
	99.71	99.07

HADRIAN. A.D. 120.

Fortunæ reduci.

Weight=365 grains. Specific gravity=8.30. This coin is finely patinated, and the metal of a fine yellow colour.

* Copper lost. This analysis was made for me by Mr. H. How.

1^o. 15·07 grs. gave 16·20 grs. of oxide of copper=85·78 per cent of copper.

·23 grs. of oxide of tin=1·19 per cent of tin.

·40 grs. of sulphate of lead=1·81 per cent of lead.

2·04 grs. of oxide of zinc=10·81 per cent of zinc.

·16 grs. of peroxide of iron=·74 per cent of iron.

2^o. 12·17 grs. gave 13·05 grs. of oxide of copper=85·57 per cent of copper.

·17 grs. of oxide of tin=1·09 per cent of tin.

·295 grs. of sulphate of lead=1·65 per cent of lead.

1·65 grs. of oxide of zinc=10·86 per cent of zinc.

·13 grs. of peroxide of iron=·74 per cent of iron.

	I.	II.
Copper . . .	85·78	85·57
Tin . . .	1·19	1·09
Lead . . .	1·81	1·65
Zinc . . .	10·81	10·86
Iron . . .	·74	·74
	<hr/> 100·33	<hr/> 99·91

FAUSTINA, JUN. A.D. 165.

Pietas.

Weight=362 grains. Specific gravity=8·83.

Coin without patina. Metal of a whitish colour and very brittle.

1^o. 17·55 grs. gave 17·40 grs. of oxide of copper=79·11 per cent of copper.

1·14 grs. of oxide of tin=5·10 per cent of tin.

2·35 grs. of sulphate of lead=9·13 per cent of lead.

1·41 grs. of oxide of zinc=6·43 per cent of zinc.

·06 grs. of peroxide of iron=·24 per cent of iron.

2^o. 15·73 grs. gave 15·61 grs. of oxide of copper=79·19 per cent of copper.

·97 grs. of oxide of tin=4·84 per cent of tin.

2·13 grs. of sulphate of lead=9·23 per cent of lead.

1·20 grs. of oxide of zinc=6·11 per cent of zinc.

·05 grs. of peroxide of iron=·22 per cent of iron.

	I.	II.
Copper . . .	79.11	79.19
Tin . . .	5.10	4.84
Lead . . .	9.13	9.23
Zinc . . .	6.43	6.11
Iron . . .	.24	.22
	<hr/> 100.01	<hr/> 99.59

GREEK IMPERIAL SAMOSATA. About A.D. 212.

Reverse : The city seated.

Weight=274 grains. Specific gravity=8.53. Metal of a greyish colour ; very coarse and brittle. No patina.

1^o. 23.85 grs. gave 21.12 grs. of oxide of copper=70.66 per cent of copper.

2.06 grs. of oxide of tin=6.78 per cent of tin.

7.70 grs. of sulphate of lead=22.01 per cent of lead.

2^o. 17.74 grs. gave 15.82 grs. of oxide of copper=71.16 per cent of copper.

1.52 grs. of oxide of tin=6.73 per cent of tin.

5.70 grs. of sulphate of lead=21.91 per cent of lead.

	I.	II.
Copper . . .	70.66	71.16
Tin . . .	6.78	6.73
Lead . . .	22.01	21.91
Iron . . .	faint trace	faint trace
	<hr/> 99.45	<hr/> 99.80

SMALL BRASS OF THE TIME OF THE THIRTY TYRANTS.

About A.D. 260.

VICTORINUS, SEN. (No. 1.)

Providentia Aug.

Weight=37.7 grains. Specific gravity=8.77. Metal rather hard, and not patinated.

14.96 grs. gave 17.88 grs. of oxide of copper = 95.37 per cent of copper.

0.19 grs. of oxide of tin=.99 per cent of tin.

THE METALS AND ALLOYS KNOWN TO THE ANCIENTS. 283

Copper	95·37
Tin	·99
Lead	trace
Silver	1·60
Iron	trace
	<hr/>
	97·96

VICTORINUS, SEN. (No. 2.)

Salus Aug.

Weight=37·6 grains. Specific gravity=8·73. Coin not patinated.

15·83 grs. gave 0·02 grs. of oxide of tin=·10 per cent of tin.
 ·23 grs. of peroxide of iron=1·00 per cent of iron.

Copper	97·13*
Tin	·10
Lead	trace
Silver	1·76
Iron	1·01
	<hr/>
	100·00

TETRIUS, SEN. A.D. 267. (No. 1.)

Weight=37·3 grains.

21·07 grs. gave 26·01 grs. of oxide of copper = 98·50 per cent of copper.

·10 grs. of oxide of tin=·37 per cent of tin.
 ·14 grs. of peroxide of iron=·46 per cent of iron.

Copper	98·50
Tin	·37
Lead	trace
Silver	·76
Iron	·46
	<hr/>
	100·09

* Copper lost, estimated by difference.

TETRIUS, SEN. A.D. 268. (No. 2)

Weight = 45.25 grains.

26.15 grs. gave 32.15 grs. of oxide of copper = 98.00 per cent of copper.

·17 grs. of oxide of tin = .50 per cent of tin.

·02 grs. of peroxide of iron = .05 per cent of iron.

Copper	.	.	.	.	98.00
Tin	.	.	.	.	·50
Silver	.	.	.	.	1.15
Iron	.	.	.	.	·05
					<hr/>
					99.70

CLAUDIUS GOTHICUS. A.D. 268. (No. 1.)

Spes publica.

Weight = 52.2 grains. Specific gravity = 8.81. Coin thinly covered with red patina. Metal rather hard.

18.23 grs. gave 18.65 grs. of oxide of copper = 81.60 per cent of copper.

1.72 grs. of oxide of tin = 7.41 per cent of tin.

2.17 grs. of sulphate of lead = 8.11 per cent of lead.

Copper	.	.	.	.	81.60
Tin	.	.	.	.	7.41
Lead	.	.	.	.	8.11
Silver	.	.	.	.	1.86
					<hr/>
					98.98

CLAUDIUS GOTHICUS. A.D. 268. (No. 2.)

Juno Regina.

Weight = 58.3 grains. Specific gravity = 8.71.

22.44 grs. gave 23.82 grs. of oxide of copper = 84.70 per cent of copper.

·86 grs. of oxide of tin = 3.01 per cent of tin.

·88 grs. of sulphate of lead = 2.67 per cent of lead.

·10 grs. of peroxide of iron = .31 per cent of iron.

THE METALS AND ALLOYS KNOWN TO THE ANCIENTS. 285

Copper	84.70
Tin	3.01
Lead	2.67
Silver	7.93
Zinc	trace
Iron	.31
	<hr/>
	98.62

TACITUS. A.D. 275. (No. 1.)

Libertas Aug.

Weight=62.3 grains. Specific gravity=8.72.

18.17 grs. gave 19.60 grs. of oxide of copper = 86.08 per cent of copper.

.84 grs. of oxide of tin = 3.63 per cent of tin.

1.30 grs. of sulphate of lead = 4.87 per cent of lead.

Copper	86.08
Tin	3.63
Lead	4.87
Silver	4.40
	<hr/>
	98.98

TACITUS. (No. 2.)

Pax publica.

Weight=49.5 grains. Specific gravity=8.70.

13.61 grs. gave 15.60 grs. of oxide of copper = 91.46 per cent of copper.

.45 grs. of peroxide of iron = 2.31 per cent of iron.

Copper	91.46
Silver	5.92
Iron	2.31
	<hr/>
	99.69

PROBUS. (No. 1)

Succeeded Tacitus, who reigned only six months.

Clementia Temp.

Weight of coin, 52·2 grains. Specific gravity=8·72.

16·06 grs. gave 18·25 grs. of oxide of copper = 90·68 per cent of copper.

·41 grs. of oxide of tin = 2·00 per cent of tin.

·55 grs. of sulphate of lead = 2·33 per cent of lead.

·28 grs. of oxide of zinc = 1·39 per cent of zinc.

·14 grs. of peroxide of iron = ·61 per cent of iron.

Copper	.	.	.	.	90·68
Tin	.	.	.	.	2·00
Lead	.	.	.	.	2·33
Silver	.	.	.	.	2·24
Zinc	.	.	.	.	1·39
Iron	.	.	.	.	·61
<hr/>					99·25

PROBUS. (No. 2.)

Mars Victor.

Weight=49 grains. Specific gravity=8·74.

12·14 grs. gave 14·40 grs. of oxide of copper = 94·65 per cent of copper.

·07 grs. of oxide of tin = ·45 per cent of tin.

·08 grs. of sulphate of lead = ·44 per cent of lead.

·14 grs. of peroxide of iron = ·80 per cent of iron.

Copper	.	.	.	.	94·65
Tin	.	.	.	.	·45
Lead	.	.	.	.	·44
Silver	.	.	.	.	3·22
Iron	.	.	.	.	·80
<hr/>					99·56

THE METALS AND ALLOYS KNOWN TO THE ANCIENTS. 287

In addition to the foregoing analyses, the following estimations of silver were made by direct cupellation :

	Legend.	Weight of coin.	Percentage amount of silver.
		grs.	
Aurelian	Restituti orbis	57·20	2·90
"	Fortuna redux	50·50	2·96
Severina	Providentia Deorum . .	54·5	4·37
"	Concordia militum . .	54·0	5·80
Tacitus	Libertas Aug :	61·4	4·90
Victorinus Sen. . .	Pax Aug :	38·0	2·20
"	Providentia Aug : . .	35·7	1·10
Tetrius, Jun. . .	Pietas Aug :	31·5	·38
"	" "	44·0	·41
Quintillus	Fides militum	52·4	2·32
"	" "	33·8	2·25
Marius	" "	43·7	5·15

TABLE, SHOWING THE MEAN COMPOSITIONS OF THE SPECIMENS ANALYSED.

	Date.		Copper.	Tin.	Lead.	Iron.	Zinc.	Silver.	Sulphur.	Nickel.	Cobalt.
	B.C.	A.D.									
ÆS	500	—	69.69	7.16	21.82	.47	—	—	trace	trace	.57
Semis	500	—	62.04	7.66	29.32	.18	—	—	trace	.19	.23
Quadrans	500	—	72.22	7.17	19.56	.40	—	—	trace	.20	.28
Hiero I.	470	—	94.15	5.49	—	.32	—	—	—	—	—
Alexander the Great	335	—	86.77	12.99	—	—	—	—	.06	—	—
Philippus III.	323	—	90.27	9.43	—	—	—	—	—	—	—
Philippus V.	200	—	85.15	11.12	2.85	.42	—	—	trace	—	—
Copper coin of Athens	?	—	88.34	9.95	.63	.26	—	—	—	trace	—
Pompey, Ptolemy IX.	70	—	84.21	15.64	—	trace	—	—	trace	—	—
Pompey, First Brass	53	—	74.17	8.47	16.15	.29	—	—	—	—	—
Coin of the Attilia Family	45	—	68.69	4.86	25.43	.11	—	—	—	trace	—
Julius and Augustus	42	—	79.13	8.00	12.81	trace	—	—	trace	—	—
Augustus and Agrippa	30	—	78.45	12.96	8.62	trace	—	—	trace	—	—
Large Brass of the Cassia Family	20	—	82.26	—	—	.35	17.31	—	—	—	—
Sword-blade (Fig. 1.)	—	—	89.69	9.58	—	.33	—	—	—	—	—
Broken sword-blade (Fig. 2.)	—	—	85.62	10.02	—	.44	—	—	—	—	—
Fragment of a sword-blade (Fig. 3.)	—	—	91.79	8.17	—	trace	—	—	—	—	—
Broken spear-head (Fig. 4.)	—	—	99.71	—	—	—	—	—	—	—	—
Celt, (Fig. 5.)	—	—	90.68	7.43	1.28	trace	—	—	—	—	—
Celt, (Fig. 6.)	—	—	90.18	9.81	—	trace	—	—	—	—	—
Celt, (Fig. 7.)	—	—	89.33	9.19	—	.33	—	—	—	—	—
Celt, (Fig. 8.)	—	—	83.61	10.79	3.20	.58	—	—	—	—	—
Large Brass of Nero	—	60	81.07	1.05	—	—	17.81	—	—	—	.34
Titus	—	79	83.04	—	—	.50	15.84	—	—	trace	—
Hadrian	—	120	85.67	1.14	1.73	.74	10.85	—	—	—	—
Faustina, Jun.	—	165	79.14	4.97	9.18	.23	6.27	—	—	—	—
Greek Imperial Samosata	—	212	79.91	6.75	21.96	trace	—	—	—	—	—
Victorinus, Sen. (No. 1.)	—	262	95.37	.99	trace	trace	—	1.60	—	—	—
Victorinus, Sen. (No. 2.)	—	262	97.13	.10	trace	1.01	—	1.76	—	—	—
Tetrus, Sen. (No. 1.)	—	267	98.50	.37	trace	.46	—	.76	—	—	—
Tetrus, Sen. (No. 2.)	—	268	98.00	.51	—	.05	—	1.15	—	—	—
Claudius Gothicus, (No. 1.)	—	—	81.60	7.41	8.11	—	—	1.86	—	—	—
Claudius Gothicus, (No. 2.)	—	268	84.70	3.01	2.67	.31	trace	7.93	—	—	—
Tacitus, (No. 1.)	—	—	86.08	3.63	4.87	—	—	4.42	—	—	—
Tacitus, (No. 2.)	—	275	91.46	—	—	2.31	—	5.92	—	—	—
Probus, (No. 1.)	—	—	90.68	2.00	2.33	.61	1.39	2.24	—	—	—
Probus, (No. 2.)	—	275	94.65	.45	.44	.80	—	3.22	—	—	—

D.

DEDUCTIONS.

We learn from the foregoing analyses that the metals entering into the composition of the brass of the earliest ages were copper, tin and lead, although the latter seldom occurs in any considerable quantity, except in the oldest specimens, and in many even of these, particularly in the early Macedonian coins, it is entirely wanting. The iron, cobalt and nickel, together with traces of sulphur, which sometimes occur, are evidently too small in quantity to have been intentionally added to the mixture, and consequently their presence must be rather ascribed to the localities from which the ancients drew their supply of ores, and the imperfect methods employed for their reduction, than to any design on the part of the artists. The cutting instruments which have been examined, are uniformly composed of copper and tin, with the occasional admixture of a small quantity of lead, which was probably added for the purpose of communicating a certain degree of toughness to the alloy, and it is also remarkable that the proportion of tin to that of copper, both in the celts and sword-blades, is very nearly as one to ten.

Zinc first makes its appearance a short time previous to the Christian era, and is continued in all the subsequent coins, although occasionally associated with lead and tin, until it almost entirely disappears in the small brass of the period of the Thirty Tyrants, when its place is supplied by a quantity of silver, varying from 0·76 to nearly 8 per cent, and which may perhaps have been intentionally added for the purpose of increasing the value of the metal.

In speaking of these coins, Pinkerton remarks: "It may be proper to observe, before leaving this part of my subject, that the metal used in the Parts of the Assarion, or in the small brass coins, is, as may be supposed, very little attended to by the ancients. In those of the first emperors, yellow brass is sometimes employed, but it is always of a refuse, or bad kind; as in the Semis of Nero, for instance, GENIO AVGVSTI. But copper is the general metal used in parts of the As, from the earliest times down to the latest; and if

sometimes brass be employed, it is never such as appears in the Sestertii and Dupondiarrii, which is very fine and beautiful; but only the refuse. Yellow brass of the right sort seems to have totally ceased in the Roman coinage, with the Sestertius, under Gallienus; though a few small coins of very bad metal, of that hue, appear so late as Julian II.*

On referring to the table of analyses, we shall, however, perceive, that although the results obtained seem to confirm the assertions made relative to yellow brass, in the above quotation, yet that in no one instance, has a coin been found to consist of copper alone; and the only case in which this metal proved to be unalloyed, was in the spear-head, Fig. 4, found in Ireland. The largest proportion of lead occurs in the ancient Roman As, and its parts, in which it was probably employed for the purpose of rendering the alloy of which they consist easily fusible; for these coins being originally cast and not stamped like other money, a metal melting at a low temperature, would materially facilitate this operation.

The later coins, containing a large proportion of tin, seem to have been struck whilst the metal was still warm, as it would be impossible to obtain such sharp impressions as they usually bear, by the force of any blow applied on a metal so very hard and brittle, at ordinary temperatures.

Pinkerton states, that in the Roman mint, the alloy was first cast into the form of bullets, and that these were afterwards flattened and struck by the die, until an impression of sufficient depth was obtained. The appearance of many both of the Greek and Roman coins, indicates that the form of the blank pieces was spherical, but the metal of these very coins, is frequently so brittle, that they may easily be broken by a blow from the hammer, and could not have received their present form without being previously heated and struck whilst the metal was in a pasty state. That this was the method actually employed, is rendered very probable from some of the devices on the coins themselves, particularly on a Denarius of the Carisia family, bearing on the obverse, the head of Moneta, with name; and on the reverse, the implements used by the Romans in their coinage, viz., two dies, with the hammer and pincers; which is doubtless a correct representation of the apparatus employed in the Roman mint.† From the presence of the pincers in this design, it is almost certain that the metal was struck hot, as the blank could

* Vol. I, 126.

† Till on Coins, 7.

otherwise be more conveniently placed on the die by the hand, than through the intervention of tongs, which would rather embarrass than facilitate the operation.

With respect to the furnaces employed by the ancients, little information can be obtained, as these arts were formerly either held as secrets by a few individuals, who made a mystery of their operations, or they were too much despised by ancient authors, to afford them a subject for their writings; and we are consequently more indebted for our scanty knowledge of ancient metallurgy to the vestiges of primitive foundries, which have occasionally been brought to light in various parts of the world, than to any accounts which may have been transmitted to us from those remote times.

The first method of smelting ores, doubtless consisted in placing the mineral in heaps, together with several successive layers of wood, which being kindled, first roasted, and then reduced a portion of the material with which it was mixed. In Macedonia, where lead mines were worked in the time of Philip, the father of Alexander, large heaps of slag are found so far above the level of the rivers of the country, that the furnaces in which they were produced must have been worked either by bellows moved by human labour, or by the force of the prevailing winds alone.* We are also told, that the Peruvians were in the habit of melting their ores by the simple application of fire, or when they were of a very refractory nature, by means of furnaces so constructed on high ground as to yield a draught without the aid of bellows, a machine with which they were totally unacquainted.†

The boles of Derbyshire, many of which from the pigs of Roman lead found in their vicinity, may be presumed to be of great antiquity, were worked in a nearly similar manner, and continued to be thus carried on during several centuries, as this method of smelting was, according to Childrey, not quite extinct in the seventeenth century, who, in speaking of the Peak, says: "The lead-stones in the Peak, lie but just within the ground, next to the upper crust of the earth. They melt the lead on the top of the hills that lie open to the west wind; making their fires to melt it as soon as the west wind begins to blow, which wind, by long experience, they find to hold longest of all others. But for what reason I know not, since I should think lead

* Watson's Chemical Essays, III, 265.

† Alonso Barhu.—Treatise on Metals, French translation, I, 272.

were the easiest of all metals to melt, they make their fires extraordinary great.”*

Discoveries made by various travellers in Russia, during the last century, throw considerable light on the subject of mining and metallurgy as anciently practised in that part of the world. The remains of numerous mines have been traced by Gmelin, Lepechin and Pallas, on the southern and eastern borders of the Ural Mountains; and in them were found hammers and chisels of copper, as well as various instruments of the same metal, of which the uses are at present unknown. From the absence of any remains of masonry in the neighbourhood, these excavations are inferred to have been made by a nomadic people, probably the Scythians; and from no iron tools having been found in any of them, we may conclude that these operations were carried on before the conquest of Siberia by the Tartars, who effected the subjugation of that part of Asia, about 150 years before our era.† Sledges made of large stones, to which handles had been attached, were also discovered, together with boars' fangs, with which the gold appears to have been collected, and leathern bags or pockets in which it was preserved. With such imperfect tools, the progress made must necessarily have been exceedingly slow, and in one instance, after reaching a band of rock and penetrating it for a short distance, the miners seem to have lost patience and abandoned the works. The pits or shafts are well made, about seven feet in diameter, and of a circular form, some of them being twenty fathoms in depth. The passages and props are also well executed, but the former so low and narrow, that they could only have been excavated with the greatest difficulty to the workmen. The ores when extracted, were carried to the nearest rivulet for the purpose of being crushed and washed, which operations were probably dispensed with in the richest varieties, which were sometimes melted in the mines themselves, metallic copper, together with slag, and the tools employed in melting and refining, having been found in some of them.

Lumps of copper, which contain no traces of gold, have also been discovered, although the copper ores of the districts are found associated with that metal, and it is therefore evident that the ancient people who worked these mines were acquainted with a method of refining gold.

* Childrey's Britain, 1661.

† Histoire Généalogique des Tartares.

The smelting was effected in small furnaces made of red bricks, and of which Gmelin found nearly a thousand in the eastern parts of Siberia. The height and breadth of these were about two feet, and the width three. They were also furnished with holes in two of their opposite sides, the one for the introduction of bellows, and the other for the escape of the metal and slags. In the neighbourhood of the furnaces were found large quantities of broken pottery, together with numerous heaps of scorïæ, which indicate that operations to a very considerable extent, have at some period been carried on in that locality.

Gmelin likewise found in the same districts the remains of various furnaces which had been employed for the extraction of silver, and remarked that the lead with which it was associated had been thrown away in the scorïæ, whilst the whole of the silver was carefully extracted. By what means this was effected, in this particular case, is of course impossible for us to say, although it is highly probable that cupellation in some form was resorted to. Diodorus, [III, 14,] informs us, that gold was purified, by being melted and heated in earthen pots, together with an alloy of tin and lead, to which salt and barley-bran were added, and that the fire was kept up during five successive days. Another ancient author* states, that gold was melted by a gentle fire with the addition of salt, nitre and alum, and that the same process was employed for refining silver. It is, however, difficult to understand what action these substances, with the exception of the nitre, could have on the purification of silver and gold, and we may therefore conclude, that the action of the air was after all the chief means of oxidation employed.†

In Britain, silver mines were worked before the invasion of the island by the Romans, and gold must also have been well-known to the inhabitants before the arrival of Cæsar, since coins of that metal were then in circulation. Cæsar and Strabo both state that the Britons obtained their copper from foreign countries, and we may hence infer that the art of refining this metal was either unknown, or little cultivated by our forefathers at that remote period. Iron is described by Cæsar as being so rare, that pieces of it were sometimes used as a medium of exchange, and almost as highly valued as gold; but a century afterwards it had become very common, as in Strabo's

* Hippocrates de Diæta, 193.

† The nitre of the ancients was probably carbonate of soda.

time, it was an article of exportation.* Tin was anciently the most celebrated product of Britain, and appears even at that time to have been extracted in considerable abundance, since it was the desire of obtaining possession of these mines, and becoming thereby independent of the Phœnician monopoly, which first induced the Romans to visit the island. Before the conquest of their country, the Ancient Britons extracted this metal from its ores by methods which they had themselves discovered, and which were probably improved on by their conquerors.† The smelting process would seem to have been very simply conducted. The broken ore was placed in a hole in the ground, the sides of which were lined with pieces of wood, which, on being ignited, reduced the lead and tin, which were separated from the slags by being run off through a narrow channel into another receptacle. Many of these rude furnaces have been found in various parts of Cornwall and elsewhere, in which not only charcoal and slags have been discovered, but also portions of the reduced metal, which in many instances, had, from long exposure to oxidising influences, again become partially converted into tin ore.‡ This very rude method must have been attended with considerable success, as the slags resulting from it have proved on examination to contain but a small amount of metal.§

From these and many other relics which have been met with in different parts of the world, we may infer, that although the arts of working the metals were carried on formerly on a much smaller scale than at the present day, the operations of the early metallurgists were tolerably successful, and that in spite of the rude apparatus which they employed, the results obtained by them were generally of a satisfactory nature.

That a great degree of attention was at a very early period bestowed on the manufacture of alloys destined for particular purposes, is proved by the uniform composition of the several cutting instruments examined; although it is evident that but little care was taken to obtain a correct standard for the early brass money, as many pieces of nearly the same date, and of similar value, differ materially in the amounts of the metals of which they consist. On this subject I shall offer no observations, as the object of the present paper is rather to show the composition and proportions of the ancient alloys, than to enter into a discussion on the coins of antiquity, and I therefore leave

* Strabo, IV, 305.

‡ Jews' house tin.

† Strabo, I.

§ Pennant, I, 58.

this matter for the consideration of the numismatist and antiquarian, whose labours in that direction may possibly be, in some measure, aided by the facts elicited from the foregoing analyses.

No. 1. Sword-blade, found under Chertsey Bridge, Thames.

„ 2. A broken sword-blade, from Ireland.

„ 3. „ „ also found in Ireland.

„ 4. A broken spear-head, from Ireland, presenting the only specimen of unalloyed copper examined.

„ 5. A celt, with a socket for the introduction of a wooden handle and an eye, probably for the purpose of attaching a string.

Nos. 6 and 7. Celts, composed of a harder alloy, and without sockets.

No. 8. A celt, with socket and loop, found in Ireland, and made of a hard alloy. This specimen appears to have been sharpened by grinding.

E.

APPENDIX.

In connexion with the foregoing investigation, it was thought necessary to ascertain the most correct and expeditious methods of separating and estimating the different metals of which the various specimens examined were composed; and for this purpose, an alloy was prepared of copper, tin, silver and lead, in the following proportions:

Copper	.	.	.	.	880	.
Tin	.	.	.	.	100	
Lead	.	.	.	.	10	
Silver	.	.	.	.	10	
					<hr/>	
					1000	

On fusing this and examining the resulting button, it proved to have lost nearly 2 per cent of its weight, and by repeating the operation several times, with the addition of borax, tartar and carbonate of soda, it was found impossible to obtain one which had not lost above $1\frac{1}{2}$ per cent in weight of the metals employed, and therefore this mode of proceeding was ultimately abandoned.

Twenty grains of electrolytically prepared copper were next taken, and to this were added two parts of tin obtained by the same means, and a grain each of pure lead and silver. These were placed together in a flask, and attacked by strong nitric acid; the excess of which was subsequently evaporated off. Water was then added, and the oxide of tin thrown on a filter and washed. The silver was afterwards precipitated as chloride, by hydrochloric acid, so diluted as not to cause a turbidity in solutions of salts of lead—washed by decantation—and collected, fused and weighed, in a small porcelain capsule.

From the liquor decanted from the chloride of silver, the lead was precipitated by means of an excess of dilute sulphuric acid. The whole was then evaporated to dryness, the residue treated with water, and the sulphate of lead washed first with water containing a little sulphuric acid, and afterwards with alcohol. The filtrate from the sulphate of lead was then evaporated nearly to dryness, in order to get rid of the alcohol and nitric acid; and to the solution of the copper-salts in water, ammonia was added in excess. The blue liquor was then poured into a well-ground stoppered bottle, which being filled with boiling distilled water, and a weighed piece of pure copper placed in

THE METALS AND ALLOYS KNOWN TO THE ANCIENTS. 297

it was set aside according to the method of Levol, until it became colourless. Two experiments were made on the foregoing weights, and the following results obtained :

1 ^o . Tin	. 2·027	=	Oxide of tin	. 2·58
Silver	. ·948	=	Chloride of silver	1·26
Lead	. ·982	=	Sulphate of lead	1·44
Copper	. 24·030			

27·987

2 ^o . Tin	. 2·012	=	Oxide of tin	. 2·56
Silver	. ·956	=	Chloride of silver	1·27
Lead	. ·995	=	Sulphate of lead	1·46
Copper	. 23·620			

27·583

In the above analyses, it will be observed that there is a small excess on the tin, occasioned by the tendency of the peroxide of that metal to form stannates, and the consequent difficulty of obtaining the metastannic acid quite free from the oxides of the metals with which it was associated. A slight loss also occurs both on the silver and lead, occasioned in the former by the difficulty of collecting and estimating small quantities of the chloride, and in the latter case from sulphate of lead being slightly soluble in the copper filtrate.

The amount of copper given, is from fifteen to twenty per cent above the truth, as it was found impossible in practice to exclude the air from the bottles, and expel it from the solution with which they were filled, so perfectly as would be necessary, in order to obtain good results.

Several trials were afterwards made both by myself and an assistant, in order to test the correctness of this method, but in every case, a considerable excess was obtained.*

This way of estimating the copper, not having proved sufficiently accurate, I next tried the method of Pelouze. For this purpose, a solution of sulphuret of sodium was prepared ; so diluted, that, in the first experiment, sixty divisions of the graduated burette with which it was measured, represented one grain of pure copper ; in the second, 60 $\frac{3}{4}$ divisions were required to precipitate this amount of metal ; and

* Mr. Hutchison, in his experiments, always got an excess of at least 2 per cent.

in the third operation, a quantity corresponding to nearly 62 graduations to the grain was employed before the whole of the copper was thrown down. These determinations were continued until, at the tenth experiment, rather more than 65 divisions were required to precipitate from the ammoniacal solution of copper one grain of metal. The absorption of oxygen from the air, and the consequent conversion of a portion of the sulphuret into hyposulphite of soda, having been found to proceed with such rapidity, this method of estimation was also abandoned; and on examining, on the following day, the air contained in the half-emptied bottle of solution, the oxygen had become completely absorbed.

The next experiment was made on a mixture of copper, tin, lead and silver, in the same proportions as in the foregoing analyses; and the operations were conducted in a precisely similar manner as far as regards the tin and lead, except that the latter was in this instance thrown down as sulphate, before the precipitation of the silver by hydrochloric acid, and that dilute sulphuric acid only was used for washing. The precipitated chloride, instead of being washed by decantation and afterwards fused and weighed, was collected on a filter, dried, and the filter incinerated without carrying the heat so far as to melt the chloride and cause it to attach itself to the sides of the crucible. The filter-ash and chloride were then mixed with about five grains of carbonate of soda, and one of tartrate of potash, carefully enveloped in a hundred grains of pure lead-foil, placed in a crucible containing a mixture of borax and carbonate of soda, and fused into a button which was afterwards passed to the muffle. This method of treatment, although not possessing the advantages with regard to accuracy which are offered by direct cupellation, is nevertheless more easily conducted and freer from sources of error than weighing such a minute quantity of the chloride; and in cases where the small amount of materials to operate on excludes the possibility of a separate determination of that metal, as in the case of the small brass coins, I have found this modification succeed extremely well. The quantity of lead should, however, be large in proportion to the amount of chloride of silver, and if the lead-foil be in any degree argentiferous, the extent should be ascertained by a separate operation, and its weight deducted from the result.

The copper was precipitated by pure alcoholic potash in the state of oxide, which after being completely washed, was ignited and weighed in the usual way. This experiment gave the following results:

THE METALS AND ALLOYS KNOWN TO THE ANCIENTS. 299

1 ^o . Tin	. 2·027	=	Oxide of tin	. 2·58
Silver	. ·970			
Lead	. ·982	=	Sulphate of lead	1·44
Copper	. 20·009	=	Oxide of copper	25·10
<hr/>				
23·988				

2 ^o . Tin	. 2·027	=	Oxide of tin	. 2·58
Lead	. ·975	=	Sulphate of lead	1·43
Silver	. ·975			
Copper	. 19·981	=	Oxide of copper	25·04
<hr/>				
23·958				

The above results being considered satisfactory, this method was adopted in the whole of the analyses.* Small quantities of iron, together with traces of cobalt and nickel, generally made it necessary to precipitate the copper first as sulphuret, which was afterwards re-dissolved and precipitated by caustic potash; the iron was then separated from cobalt and nickel by means of benzoate of ammonia, and the two latter, when not estimated together, were separated by cyanide of potassium. I have not, however, thought that such small quantities of these two metals can be separated with any great degree of accuracy, and have, therefore, been sometimes content to weigh them together.

* A paper was read January 28th, 1850, before the Royal Irish Academy, on "The Analysis of certain gold-coloured Bronze Antiquities," by Mr. Donovan, who employed a very different method to obtain his results. The author of the paper referred to, is of opinion that in the ordinary process of attacking such alloys, by means of nitric acid in a glass flask, a certain amount of loss is sustained, and that this is occasioned by a portion of the copper being carried off in combination with the gaseous oxides of nitrogen evolved. To obviate this inconvenience, and render his analyses more accurate, this gentleman made his attacks in a tubulated retort, to which he adapted a series of Woulfe's bottles, containing liquid ammonia, which on being evaporated to dryness, yielded a trace of oxide of copper, to be added to that obtained either in the usual way, by precipitation, or by the direct decomposition of the nitrate.

On repeating these experiments, I failed to obtain the smallest quantity of copper, even in the first Woulfe's bottle, when care was taken to use a large retort, and to prevent violent effervescence by the cautious addition of the acid. When this was not sufficiently attended to, or a retort of too small capacity was employed, faint traces of copper could be detected in the first bottle, but never in the second. It would therefore appear that the copper is then carried over mechanically by the gases given off, and the most simple means of preventing loss would be to employ a tolerably large flask for the attack, and to avoid, as much as possible, any very violent action on the alloy.

The presence of sulphur was detected, and its amount estimated, when lead was not present in the alloy, by the addition of chloride of barium to the filtrate from the metastannic acid, and the subsequent weighing of the sulphate of baryta formed. When lead was present, a trace of sulphuric acid was also sometimes found in the form of the sulphate of the oxide of that metal. This was of course precipitated, and, on filtration, remained with the oxide of tin on the filter. On digesting this, together with the trace of sulphate of lead, in a solution of carbonate of soda, carbonate of lead and sulphate of soda were obtained. On neutralizing the excess of carbonate of soda by nitric acid and evaporating to dryness, the filtrate from the residue taken up by water yielded, on the addition of chloride of barium, a faint turbidity; but in a very few instances only were the amounts of sulphate of baryta sufficient to allow of its being weighed.