

DISCOVERY OF THE ELEMENTS

by

MARY ELVIRA WEEKS

Research Associate in Scientific Literature at the Kresge-Hooker Scientific Library, Wayne University. With illustrations collected by F. B. Dains, Professor of Chemistry at the University of Kansas



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FOREWORD

The material blessings that man enjoys today have resulted largely from his ever-increasing knowledge of about ninety simple substances, the chemical elements, most of which were entirely unknown to ancient civilizations. In the luxurious thermæ of the Roman patrician, with all their lavish display of alabaster floors, porphyry walls, marble stairs, and mosaic ceilings, no nickel-plated or chromium fixtures were to be seen; among his artistic golden bowls and goblets no platinum or tantalum objects were ever to be found; with all his spoils of war he could not buy the smallest aluminum trinket.

Even the haughtiest Roman conqueror was earthbound, for he knew no light metal like aluminum or magnesium and no light gas like hydrogen or helium to make lofty flight possible. Without a lantern in his hand, he could not walk along the splendid lava pavements of the city streets at night, for the white glow of the tungsten filament and the crimson glow of the neon tube were lacking. The water that came to him from mountain springs, lakes, and rivers through miles of magnificent aqueducts was a menace to health, for there was no chlorine with which to kill the bacteria. When accident befell him, there was no iodine for the healing of the wound; when he lay gasping for breath, no cylinder of oxygen to save him.

The story of the disclosure, one by one, of the chemical elements has never been told as a connected narrative. The reports of these discoveries and the life stories of the discoverers are recorded for the most part in old chemical journals, biographical dictionaries, old letters, and obsolete textbooks that are seldom read by the busy modern chemist. It is hoped, therefore, that these chapters may not only render tribute to the honored men and women who helped to reveal the hidden chemical elements, but that they may also serve to acquaint chemists and others with these great achievements.

The task of selecting and eliminating material has been pleasant but difficult. It has frequently happened that two or more men have discovered the same element independently. In other instances various observers have recognized the existence of a new element long before it was actually isolated. In such cases an attempt has been made to relate all important steps in the discovery as fairly and completely as possible without ascribing the honor of discovery to any one person.

It is a pleasure to acknowledge the kind assistance given by the late Dr. E. H. S. Bailey and Dr. Selma Gottlieb Kallis, who read portions of the manuscript, by Dr. F. B. Dains, who made many helpful suggestions as to sources of material and furnished most of the illustrations, and by the late Dr. Max Speter, who read the proof for the fourth edition.

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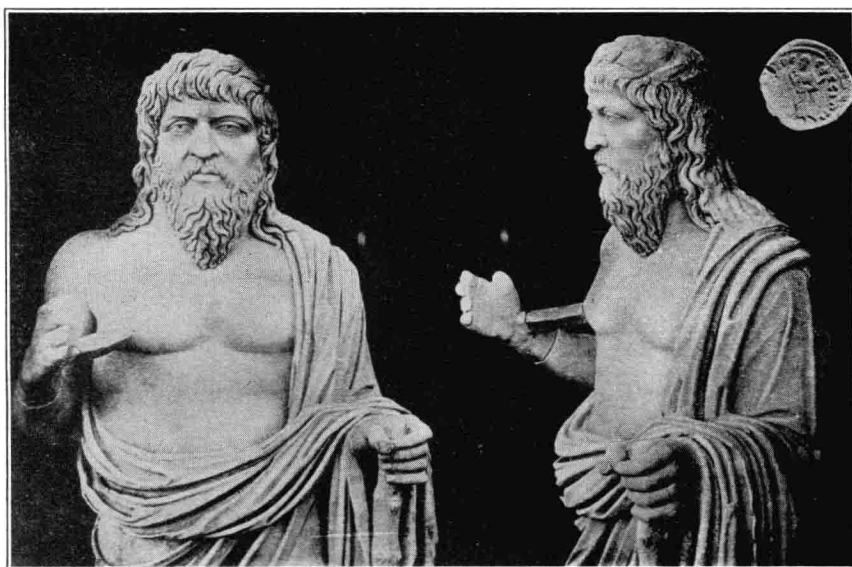
THE DISCOVERY OF THE ELEMENTS

I. ELEMENTS KNOWN TO THE ANCIENT WORLD

Although the ancient conception of an element was quite different from the modern one, a few of the substances now recognized as chemical elements have been known and used since the dawn of history. Although no one knows who discovered these ancient "building-stones of the universe," the writings of Pliny the Elder and Dioscorides and the Hebrew and Hindu Scriptures abound in interesting allusions to the metals, gold, silver, copper, iron, lead, tin, and mercury, and the non-metals, sulfur and carbon.

.

"The world of chemical reactions is like a stage, on which scene after scene is ceaselessly played. The actors on it are the elements" (1).



From Delbrueck's "Antike Porträts"

HERACLITUS, 540-475 B.C.

Ascetic Greek philosopher and founder of metaphysics. He believed that fire is the primary substance, and that change is the only actuality in Nature.

The chemical elements, those primeval building materials from which Nature has constructed all her varied forms, have been discovered, one by one, through the ages, by patient searchers in many lands. The ancient



SEVENTEENTH-CENTURY SYMBOL FOR
IRON

*(From Peters' "Aus pharmazeutischer
Vorzeit in Bild und Wort")*

SEVENTEENTH-CENTURY SYMBOL FOR
SILVER

*(From Peters' "Aus pharmazeutischer
Vorzeit in Bild und Wort")*



Greek philosophers, Thales, Xenophanes, and Heraclitus, believed that all substances were composed of a single element, but they did not agree as to its nature. Thales thought that water was the element which, upon evaporating and condensing, produced all substances. Heraclitus, however, believed that fire was the one fundamental building material.

The conception of four simple substances (earth, air, water, and fire) had its origin in the mind of Empedocles about four hundred and forty years before the birth of Christ, and held sway for many centuries. Every one knows today that neither earth nor air, water nor fire is an element. Earth is the most complex of all, for it can be separated into many chemical compounds, whose natures vary according to the locality from which the soil has been taken. From air can be obtained a number of simple gases, among them nitrogen, oxygen, and argon. Water, also, can be easily decomposed into the two gaseous elements, oxygen and hydrogen; and fire, far from being an element, consists of the incandescent gases or glowing embers of the fuel which is being burned. Simple as these facts may seem to the modern mind, the world's best intellects once debated them and established them. During the centuries, man's conception of what constitutes a chemical element has undergone many other changes, which were ably discussed by the late B. N. Menschutkin in the *Journal of Chemical Education* for February, 1937 (82).

The story of the "defunct elements," those short-lived "elements" which were later found to be complex, is most interesting, but the present narrative will be confined to the simple substances now recognized by chemists. The curious false elements, considerably more than a hundred in number, have been described in a fascinating article by the late Charles Baskerville (2).

The chemical elements which were undoubtedly known to the ancient world are the metals: gold, silver, copper, iron, lead, tin, and mercury, and the non-metals: sulfur and carbon. The ancient Jews, as one learns from the Old Testament, were certainly acquainted with the first four of these metals, and probably with the first six. The ancient Hindus used them also, for Sir Praphulla Chandra Rây quotes from the Charaka: "Gold and the five metals . . . silver, copper, lead, tin, and iron" (3).



PLINY THE ELDER, 23-79 A.D.
Roman philosopher. Author of a "Natural History" in 37 books, in which he discussed the astronomy, geology, zoölogy, botany, agriculture, mineralogy, and medicine of his time.

Ancient Metals

Gold ornaments have been found in Egyptian tombs of the prehistoric stone age, and the Egyptian goldsmiths of the earliest dynasties were skilful artisans. The metal was used as a medium of exchange in the days of Abraham, and is mentioned in Exodus, Deuteronomy, the First Book of Kings, Job, the Psalms, the Proverbs, Isaiah, Lamentations, Haggai, and Zechariah (4). Pliny the Elder (A.D. 23–79) said that grains of gold were found in the stream-beds of the Tagus in Spain, the Po in Italy, the Hebrus in Thracia, the Pactolus in Asia Minor, and the Ganges in India (5). In the second century before Christ, a cupellation process was used for refining the metal, and in Pliny's time the mercury process was well known (6).



From Biringuccio's "Pirotechnia"

AN ASSAY FURNACE, 1540

Vitruvius, who lived in the reign of Augustus, mentioned the use of mercury to recover finely divided gold. "When gold has been woven into a garment," said he, "and the garment becomes worn out with age so that it is no longer respectable to use, the pieces of cloth are put into earthen pots, and burned up over a fire. The ashes are then thrown into water and quicksilver added thereto. This attracts all the bits of gold, and makes them combine with itself. The water is then poured off, and emptied into a cloth and squeezed in the hands, whereupon the quicksilver, being a liquid, escapes through the loose texture of the cloth, but the gold, which has been brought together by the squeezing, is found inside in a pure state" (47).

Silver, since it rarely occurs uncombined, did not come into use as early as did gold (29). In Egypt between the thirtieth and fifteenth centuries before Christ, it was rarer and more costly than gold. It must have been used as a medium of exchange long before it was coined, for it is related in Genesis that when Abraham purchased a burial place for Sarah he weighed

out the silver in the presence of witnesses (7). Jagnaux states that when the Phœnicians made their first voyage to Spain they found more silver than their ships could carry, and that, for this reason, they weighted their wooden anchors with silver instead of lead (8). When the Spaniards conquered Peru they found many silver utensils that had been made by the ancient inhabitants (9), (28).

In his "Natural and Moral History of the Indies," Father José de Acosta wrote in 1590: "The Creator hath furnished the West Indies with so great a treasure of silver, as all that which we reade of in antient Histories and that which is spoken of the mines of Spaine, and other provinces, is not comparable to that we see in those partes.... The maner to purge and refine siluer (sic) which the Indians have vsed was by melting, in dissolving this masse of mettall by fire, which casts the earthly drosse aparte, and by his force separates silver from lead, tinne from copper, and other mettalls mixt.

"To this end," continued Father de Acosta, "they did build small furnaces in places whereas the wind did commonly blow, and with wood and cole made their refining, the which furnaces in Peru they call *huayras*. Since the Spaniards entred, besides this manner of refining which they vse to this day, they likewise refine silver with quick-silver, and draw more by this means then (sic) in refining it by fire. For there is some kind of silver mettall found which can by no means be purged and refined by fire, but onely with quicksilver..." (45).

According to Father de Acosta, "the chief places of the Indies from which they draw silver are New Spaine [Mexico] and Peru; but the mines of Peru farre surpass the rest; and amongst all others of the worlde, those of Potosí [now in Bolivia]" (45). "At this day," he said, "the most vsuall maner of refining in Potosí is by quickesilver, as also in the mines of Zacatecas, and others of New Spaine. There were in old time, vpon the sides and toppes of Potosí, above six thousand *Huayras*, which are small furnaces where they melt their mettall, the which were placed like lightes (a pleasant sight to behold by night) casting a light a farre off like a flame of fire.... But at this day there are not above two thousand..." (45).

Of the assay-masters, Father de Acosta said, "Their ballaunce and weights are so delicate, and their graines so small, as they cannot take them vppe with the hand, but with a small paire of pincers: and this triall they make by candle light, that no ayre might moove the ballance. For of this little the price of the whole barre dependeth" (45).

In the seventeenth century, Father Alvaro Alonso Barba of Potosí said that some of the mines there had been worked by the Incas and that, since the coming of the Spaniards, the wealth of this hill had been distributed to all parts of the world (46).

Copper, in the opinion of Berthelot, has been mined for at least five