Transmutation of Metals.

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No one can observe and reflect upon even the simplest facts of nature, without soon coming to the conclusion that the thousands of different types of matter which we find about us in this world are not all independent and distinct substances; for at every turn we see one form of matter being transformed into another, or two or three forms coming together and giving rise to a third. Thus, we heat water, and it changes into steam; we touch a match to gunpowder, and it is gone; but the smoke and odours in the air quickly inform us that some new substances have been produced. How many ultimate forms of matter are there then? And how many of the manifold substances in the world are only compounds of these elementary substances?

This question was first propounded thousands of years ago, and an absolutely certain answer has not yet been found. This does not mean, however, that no progress has been made towards its solution. My purpose in the present article is to give a brief record of the attempts of man to unlock this most profound of nature's secrets, and to show to what extent he has thus far succeeded, and what remains still unknown.

GREEK SPECULATIONS

The earliest Greek philosopher, Thales, about 600 B.C., taught that water is the fundamental principle of all things. Xenophanes, who came a hundred years later, held that there were two

PROF. J. J. THOMSON, OF CAMBRIDGE UNIVERSITY. BORN IN MANCHESTER, ENGLAND, IN 1856. THE MOST CONSPICUOUS FIGURE IN THE INVESTIGATIONS UPON THE CONNECTION BETWEEN ELECTRICITY AND MATTER.

fundamental principles—air and water; while Hippocrates (460 to 377 B.C.), the "Father of Medicine," first launched the doctrine that there were four elementary substances—earth, air, fire, and water. His argument for a number of elements, instead of one, is rather naive. It was something like this:—If man were composed of a single element, he could never be ill, but since he is at times ill, and requires complex remedies to keep him well, he must himself be complex. Aristotle, (380 to 322 B.C.) added to the four elements of Hippocrates a fifth—the ether, eternal and unchangeable, the ultimate substance of which the four elements are formed. And this Aristotelian philosophy of matter held sway throughout the Greek and Roman worlds, and down through the Middle Ages to the very dawn of modern science in about 1600 A.D.

THE ANSWER OF ALCHEMY.

According to the Aristotelian philosophy, not only are all substances composed of earth, air, fire, and water, but the properties of different substances depend upon the proportion in which these four elements are mixed. Furthermore, all substances were supposed to be transmutable into these four elements, and these four elements, in turn, transmutable into one another.

Let us pause for a moment upon this seemingly strange doctrine, since in it is found the explanation of the search for gold and the elixir of life, pursued so untiringly for fifteen hundred years by the ancient and mediæval alchemists. If we could forget the discoveries of the last two hundred years, the doctrine would not seem to us at all absurd. Apply fire to ordinary water and what happens? The water disappears into the air, and an earthy deposit is left in the vessel. In other words, when you mix fire and water in right proportions, you get earth and air. Similarly, since nearly all substances can be volatilised by heat, and since nothing remains after the volatilisation except an ash or powder, is it not evident that mixing fire with any substance in the right proportion causes it to change into the elementary substances, earth and water? Or, again, if we put salt or sugar into water, is it not apparently soon changed to water? And if we add more fire, will not a larger and larger amount change into water? Or, still again, if we take copper, or almost any metal, and put it into a strong acid, (a kind of water) does it not in time apparently disappear?—that is, is it not apparently changed into a form of water? Is it strange, then, that for so many years earth, air, fire, and water were considered the four elements, which only had to be mixed in the right proportions to produce any and all known substances?

The alchemists, then, were not all charlatans. They were simply men who were striving—most of them earnestly and seriously—to find the secret of producing any desired transformation of matter. They were trying to convert one substance into another by varying the proportions of the constituent elements. It was not unnatural that the principal object of their efforts should be the production of the substances which men most covet—namely, the precious metals, gold and silver. This however, was not their sole aim. They sought, rather, to find the great secret of the combination of the elements, not alone so that they might become rich, but so that they might learn to control matter, to prevent its disintegration when they wished—that is, to prevent death and disease. In the sixteenth century, especially, their attention was directed towards finding what they called sometimes the "Universal Solvent," sometimes the "Philosophers' Stone," and sometimes the "Elixir of Life," which are only different ways of describing that magic something which they honestly believed to exist, and which would have the power, when used under the control of the human will, of converting any form of matter into any other form.

Some of the ablest minds of the Middle Ages were engaged in this search. Roger Bacon, Spinoza, Luther, and Leibnitz, all believed in the Philosophers' Stone and in the transmutation of the metals.

Now what did this search yield? Did the alchemists find what they were after—the secret of the combination of the elements? In a sense they did. They learned that their efforts to transform the *metals* into one another were vain, but at the same time, they learned that they could transform at will many kinds of substances into other substances. In other words, they learned the laws of the combination of *many* of the substances which with they worked, but not of *all*. They learned to control certain transformations of matter, but they learned that there were certain other forms which baffled all attempts to reduce them to any thing simpler; and this is where alchemy began to pass over into modern chemistry. They learned that the old conception of the elements—earth, air, fire, and water—was quite insufficient to account for the results of their experiments, and toward the last of the eighteenth century, the last of the alchemists and the first of the chemists began to call all those substances which they were unable to reduce to any simpler forms, the *elements*. The number of these elements has grown continually as investigation has progressed until to-day we recognise about eighty such substances. These eighty odd elements are nothing more or less than substances which we have thus far been unable to reduce to simpler substances by means of any of the chemical reagents known to us. They are, however, the eighty substances into which we can easily transmute all of the two or three hundred thousand different kinds of substances which we are able to distinguish.

It is obvious from this survey that the eighty odd substances which we now call the elements bear no trace of a resemblance to the elements of the ancients, so that when we speak to-day of the possibility of the transmutability of the elements, we have in mind something entirely different from what the ancient alchemists had when they used a similar expression. However, since all the *metals* known to the alchemists have now taken their places among the *elements* of modern chemistry, when we raise the question as to whether or not our modern elements are transmutable, we do indeed include in it one of the foremost queries of the alchemists—namely, are the *metals* transmutable? This is the question which they answered from *a priori* considerations, in the affirmative, because they believed the metals to be nothing but combinations in different proportions of the four elements, earth, air, fire, and water.

Now, what sort of answer does modern science give to this same question? Let me divide the question into two parts. First, have the elements been produced in nature's laboratory from a common substance, or from common substances? In other words, have they been transmuted one into another in the making of the world? That is are they *fundamentally* transmutable? Second, are they *practically* transmutable? That is, can man ever hope to transmute them?—can he hope to duplicate with the agencies at his command, in his own little pygmy laboratories, the processes which may be going on in the laboratories of nature?

I shall not be able to give an absolutely positive reply to either of these questions, but I shall attempt to show what the modern trend of scientific opinion is, and to show something of the foundation upon which this opinion rests.

THE ANSWER OF MODERN CHEMISTRY.

Doubtless, many a chemist who has worked for years with chemical reactions, and who knows all

PROF. ERNEST RUTHERFORD, A NEW ZEALAND SCIENTIST NOW AT MCGILL UNIVERSITY, MONTREAL, DISCOVERED THAT THE RADIO-ACTIVE ELEMENTS ARE IN A CONTINUAL PROCESS OF DISINTEGRATION.

the futile attempts which have been made during the past one hundred years to reduce the so-called elements to simpler forms, has come to feel that these elements are indeed ultimate, independent things, the original foundation stones out of which the universe is made. But this has not been the view of the most far-seeing investigators in the domain of physical science. In 1811, the great Sir Humphry Davy wrote —

"It is the duty of every chemist to be bold in pursuit. To enquire whether the metals be capable of being decomposed and composed is the grand object of true philosophy."

And Faraday, to whom physics and chemistry perhaps owe as much as to any other one man, said in 1815:—

'To decompose the metals, to re-form them and to realise the once absurd notion of transmutation are the problems now given to the chemist for solution."

Also, in 1815, Prout put forward what is now