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TRANSMUTATION

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I. Introduction

Recently, on an inside page of a newspaper, there was a small article headlined "Scientists transmute Gold into Purest Form of Mercury" (Philadelphia *Evening Bulletin,* Sept. 20, 1957). This article had hardly any effect on people; its newsworthiness is shown by the fact that it was printed on page 32!

However, it recalled to the writer that in *Miscellaneous Observations* there is a brief article "Reasons showing the impossibility of transmuting Metals, especially into Gold." As the work was published in 1722, the article is an example of some of Swedenborg's earliest studies in science.

He opens with the remarks:

"The idea of the possibility of transmuting metals, into gold especially, is deep seated in many minds. The hope of effecting this conversion is encouraged by numerous stories and anecdotes, and by a flood of alchemistic writers, who having for long lost their time and pains, but perhaps found something which in their imagination was a kind of philosopher's stone, wished to teach others, by the darkest enigmas, to travel over the same road, and to allure them onwards, until they too, like their masters before them, had wasted their substance."

One hundred and seventy-five years later, in the "Annual Report of the Smithsonian Institution for 1897" under the title "The Revival of Alchemy," H. Carrington Bolton writes in a similar vein:

"Fraud, folly, and failure have been deeply written into the annals of alchemy in all ages. It was early characterized as an 'art without art, beginning with deceit, continued by labor, and ending in poverty.' "

While in one place he acknowledges—without giving any details—that there is a "truly scientific aspect of alchemical theory," he goes on to say:

"There has arisen an extraordinary revival of the metaphysical side of the question; this goes hand in hand with the interest in chiromancy, astrology, theosophy, and occult sciences . . . ."

He indicates that alchemy is associated with crystal gazing, reading in magic mirrors, slate writing, planchette, the quasi-scientific study of apparitions, etc. . . . He says:

"It is not by sleight-of-hand that the revival of alchemy is now being engineered, but by a company of educated charlatans . . . . There is a growing belief among advanced chemists in the theory that the elementary bodies as known to us are compounds of a unique primary matter (protyle), and that transformation of one kind into a similar one is not beyond the bounds of possibility, but we do not think that the modern hermetists are pursuing the right path to accomplish this end; nor do we believe that the world of science is any nearer the coveted goal of alchemical avarice."

In 1930 Sir Ernest Rutherford wrote about the same thing, although his tone is a little more dignified.

"The idea of the artificial disintegration or transmutation of an element is one which has persisted since the Middle Ages. In the times of the alchemists the search for the 'philosopher's stone,' by the help of which one form of matter could be converted into another, was pursued with confidence and hope under the direct patronage of rulers and princes, who expected in this way to restore their finances and to repay the debts of the state. In spite of this encouragement the successful transmutation of some common matter into gold was but seldom reported. Even in these cases, the transmutation could not be repeated; either the alchemist had vanished or his supply of the 'philosopher's stone' had been exhausted. The failures were many, and the natural disappointment of the patron usually vented itself on the person of the alchemist; the search sometimes ended on a gibbet gilt with tinsel. But when the confidence of the patrons departed the hope of the alchemists still remained, for the idea of transmutation not only accorded with the desires of the man but was founded on the conceptions of the philosopher. According to Aristotle all bodies are formed from a fundamental substance, 'primordial matter,' and the four elements—water, earth, air, and fire—differed from each other only by possession of different combinations of the properties of cold, wet, warm, and dry. By changing the properties, one element should be changed into another. On this view, it was almost self-evident that bodies so closely allied as the metals could interchange their qualities. The experimental evidence was never more than meagre, and consisted mainly of such facts as that a trace of arsenic mixed with copper changed its red colour to grey-white. This was a first step towards the conversion of the copper into silver. Perhaps the most convincing evidence was that provided by an experiment in which a vessel of iron was changed into one of copper. This experiment consisted in immersing an iron vessel for several hours in certain natural springs. When removed, the shape of the vessel was the same but the iron had changed into copper. The water of the spring contained traces of a copper salt, in an amount which could not be detected by the methods of those times, and when the vessel was immersed in this solution metallic copper was deposited on the surface of the iron, the less noble metal. This experiment is often quoted in alchemistical treatises." (*Radioactive Substances,* Rutherford, Chadwick, Ellis, p. 281)

And so we are not surprised to read in *Miscellaneous Observations* (p. 77):

"Notwithstanding [the arguments against transmutation of metals] this, the herd of alchemists, by means of fire, would intrude into the particle of lead or mercury that most subtle matter, that cannot within myriads of degrees be dissolved by any sublunary fire: and still they think that the purpose can be effected by less than a farthing's worth of pitch."

However, whenever a new idea or a new tool was available in chemistry, an occasional thinker would advance the idea of the possibility that elements might be transmuted. For example, Prout in 1815, on the basis of the known properties and relative abundance of hydrogen, advanced the hypothesis that all substances were but the synthesis of hydrogen particles to a more or less degree of condensation.

Rutherford himself quotes Faraday and comments as follows:

" 'To decompose the metals, to re-form them, and to realize the once absurd notion of transmutation—these are the problems given to the chemist for solution.' The weapons at the disposal of the chemist were, however, not sufficiently powerful to overcome the forces holding the atoms together, and it seemed for some time that the transmutation of elements was a theoretical possibility rather than a practical one." (*ibid.* pp. 282)

According to the newspaper article, gold has been transmuted into mercury. Although this is the alchemist's dream—in reverse—it is nevertheless transmutation. Evidently the possibility of Rutherford has become a reality. Evidently the fire that was lacking in Swedenborg's day has been found. There are two chapters to the history since 1722. One of these is associated with the periodic table and the name of Mendeléeff. The other is associated with nuclear physics, and much of its early history with the name of Rutherford. The studies associated with the periodic table have to do with the atom and its orbital electrons.

II. The Periodic Table

There have been several periodic tables. The objective of each has been to arrange the atoms in numerical order according to some property, so that as they appear in a rectangular array other properties are emphasized across the rows and down the columns. The efforts to make such a table have done much to bring out the chemical characteristics of the elements. However, these studies at the same time have given more and more integrity to the individual elements.

Swedenborg listed three arguments against transmutation: 1) Every metal has particles of its own peculiar form. No known method of changing the metals, such as by dissolving or by melting, can change this peculiar form. 2) The gold particle is larger than that of any other, and also the space between the gold particles is larger than between other particles. 3) Even though the interstices between the gold particles are so large, yet he says "the weight of the mass exceeds that of other metals."

1) With respect to the first argument about the intrinsic form of the metals, this was the essential idea that led to the invention of the periodic table in 1869 by Meyer in Germany and Mendeléeff in Russia. No hint of any experimental evidence was ever available that an element by transmutation might move from one place in the periodic table to another until the discovery of natural radioactivity by Becquerel in 1896.

2) As for the second argument about the size and weight of the gold particle, we might be tempted today to think in terms of the nucleus of the gold atom. However, the term nucleus could not be used, and was not used until after Rutherford's alpha-particle scattering experiments by metal foils early in the Twentieth Century. According to the modern concept of the atomic nucleus, each of the elements in the periodic table having an atomic number higher than 79, the atomic number of gold, has heavier nuclei than gold. There are thirteen of these elements, including mercury, lead and uranium. Platinum is not among these because, although the density of platinum is greater than that of gold, its atomic weight is less. In the last few years ten more elements with nuclei heavier than uranium have been artificially created in the laboratory.

3) Concerning the third point, namely, that gold was the heaviest of the metals, it might be argued that Swedenborg erred here because platinum is denser than gold. The density of gold is about 19.3 gm/cm^3 whereas that of platinum is over 21.3. How-

ever, although there is evidence that grains of platinum found in alluvial sands of rivers were combined with gold to form artifacts by ancient peoples, platinum as a separate substance was not known in Swedenborg's day. Thus arguments based upon the superior weight of gold were correct in Swedenborg's day. However, Swedenborg's main point seems to be concerned with the essential form of the separate metals. And the history of the development of a periodic table is a history of the search for the nature of this essential form or fundamental property. One hundred and forty years after Swedenborg wrote his argument on this point, Mendeléeff was trying to select a characteristic by which the elements could be arranged. He says for example:

"The most frequent classification of the elements into metals and non-metals is based upon physical differences as they are observed for many simple bodies, as well as upon differences in character of the oxides and of the compounds corresponding to them. However, what at first acquaintance with the subject-matter appeared to be completely clear, lost its importance entirely when more detailed knowledge was obtained. Ever since it became known that an element such as phosphorus could appear in non-metallic as well as in metallic form, it became impossible to found a classification on physical differences. . . . Thus, there does not exist yet a single universal principle which can withstand criticism, that could serve as guide to judge the relative properties of elements and that would permit their arrangement in a more or less strict system" (Quoted in *Int. to Concepts and Theories in Physical Science,* Holton)

Nevertheless, for reasons we cannot here go into, Mendeléeff felt compelled to adopt some system for arranging the 63 elements known at the time, and so in 1872 he devised the version of the Periodic Table used up to very recent times. Some of us may have had this table taught us in our school chemistry 30 or 40 years ago, but it is well to observe that it was not a dogma for its inventor. Mendeléeff himself says:

"I shall now present one of the many systems of elements which are based upon atomic weight. They form but one attempt to represent the results which can be achieved in this direction. I am quite conscious of the fact that this attempt is not final . . ." (Quoted by Holton, p. 423).

The usefulness of this system is evident in that Mendeléeff and others were able to forecast the discovery of other elements which had certain properties to fill certain blank spaces in the table. Today, however, the table follows an order based upon atomic numbers rather than atomic weights.

The idea behind men's faith in the periodic table is that there is some underlying principle that gives order and symmetry to the arrangement of the elements. That the table has made use of some component of the truth is evident from the fact that each of the versions, namely Mendeléeff's based upon atomic weight, and the more modern one which is based upon atomic numbers, led to the discovery of new things. The inert gases were not known until after 1894, yet all six fitted in very nicely to make an extra column in Mendeléeff's table. Holton says, "This harmonious fit was a considerable triumph for the scheme." Yet there were disturbing asymmetries and discrepancies in the table. There were places where an arrangement according to atomic weights would have created inversions in the arrangement demanded by chemical properties. For example, iodine, with atomic weight 126.92, would precede tellurium, with atomic weight 127.61. Thus iodine would have to be in the sulphur family and tellurium would be a halogen! Mendeléeff expected that future measurements in atomic weights would remove the discrepancies. Holton says: "The necessity of an inversion would have been to him not an inconvenience but a catastrophe." As Mendeléeff himself says:

> "The laws of nature admit of no exception. . . . It was necessary to do one or the other—either to consider the periodic law as completely true, and as forming a new instrument in chemical research, or refute it" (Holton, p. 429).

When, in the more modern table, the atomic number was taken as the guide for arranging the elements rather than atomic weight, many difficulties in the older version were eliminated. For example, in the case mentioned, tellurium with atomic number 52, and iodine 53, take their rightful places in the table in the sulphur and halogen families respectively. This new table met with tremendous success in satisfying some of the objections of the previous table. However, for reasons not yet understood this periodic table also contains certain asymmetries. The rare earths, all elements, must be fitted into a single place. That is, those elements from 58 to 71 must be listed separately outside the form of the table itself.

If the table is based upon a law of nature which admits no exception, it is evident that this law has not yet been correctly understood or defined. During the early Bohr era one could say that the original Mendeléeff table "had not yet received a physical explanation," with the implication that by using Bohr orbits the table based upon atomic number had received physical explanation. This implication was to be denied, however, with the development of quantum mechanics. Quantum mechanics substituted a scheme which permits only certain discrete-valued solutions of differential equations without physical explanation in the sense of a model.

Swedenborg as a very young man at the beginning of this development asserted observations in science in agreement with those ideas which lead to modern chemistry. No one would deny that the development of chemistry has been tremendously successful. Its results have been made to work for mankind. Chemists of this period shunned the alchemy of the elements, but on the other hand they developed an alchemy of their own through learning how the molecule is constructed. The changing of one molecular form into another became commonplace. The results of chemical analysis and synthesis are with us in almost every act of living. In fact, its products are changing much of our way of living. Yet the practical results seem to be based upon principles that do not satisfy the perfection demanded by Mendeléeff when he said, "the laws of nature admit of no exception."

What is it that is more fundamental than the ideas that went into making a periodic table? What is it that is more fundamental, or perhaps we should say, more elementary, in nature than the molecule or the atom? There is a hint in Swedenborg's own words when he says that the subtle matter of which mercury and gold are made "cannot within myriads of degrees be dissolved by any sublunary fire."

III. The Atomic Nucleus

If it was as Swedenborg said, that the purpose cannot be effected by "less than a farthing's worth of pitch," perhaps man might gather together much more than a farthing's worth of pitch. If it was as Swedenborg said, that the subtle matter in the elements themselves "cannot within myriads of degrees be dissolved by any sublunary fire," then perhaps man might be able to use a fire that has its origin beyond what is terrestrial—yes even in the stars themselves! But man could not go to the stars, even though he might someday talk about going to other earths. How, then, might he work with fire that was other than sublunary? And if the means became available to him, how indeed might he survive its heat? All men in 1958 know that the first question has been answered affirmatively. Men in 1958 do not yet know the answer to the second question. But they are beginning to suspect that its answer lies in the manner in which light is received and heat is controlled on a plane higher than the physical.

What are the means by which man has experimented with energies so high that the alchemists' dream has come true? And why, at the same time, if the energies are so high, have not the body of man and his surroundings been annihilated by them?

This source of energy is indeed in a sense not sublunary, although it was found on the earth. This source is a substance which might well be the last product of the action that took place in that material which is the earth while it was still a part of the sun. This substance, which became known as radioactive substance, was provided in amounts so tiny that at first man could do little physical damage to himself.

Becquerel in France in 1895, working with the photographic effects of phosphorescence, discovered that certain uranium salts caused photographic effects through the usual wrappings of film, and even through rather thick sheets of other materials. He became convinced that this effect was distinct from either phosphorescence or X-rays. The property of giving off the rays causing the photographic effect was associated with uranium. Further experiments by himself and the Curies showed that the strength of the effect was constant for at least five years with the same sample. It was later discovered that the radiation from uranium was of three different kinds, named by Rutherford, alpha, beta, and gamma radiation. Still later, alpha radiation was identified as the nuclei of helium atoms; beta radiation came to be recognized as a stream of electrons; and gamma radiation was recognized as electro-magnetic vibrations similar to light but of much shorter wave lengths.

Immediately the discovery of radioactivity made it possible for people to make studies of the atom not possible before. Rutherford was able to show that the atom had a nucleus by experiments with the α-particle. The Curies were able to establish an alchemy of these nuclei by showing that when an atom emitted an α or β

particle or γ ray, it became a different atom. This new atom might itself emit a particle or gamma ray and thus become an atom of a different sort. Three such natural radioactive series were discovered. The Curies and others busied themselves with isolating the product atoms in quantities sufficient for studying their chemical properties. One of the important by-products of these studies was the discovery and isolation of elements that filled in blank spaces in Mendeléeff's table, for example, radium. By 1907, the year Mendeléeff died, it became evident that there were not enough places in the table of elements. A few years later Soddy in England made a systematic study of the newly discovered elements and advanced the suggestion that the original table allowing 92 places did indeed take care of the chemical properties. However, to answer for the nuclear properties as evidenced by radioactivity, additional spaces were needed. Those atoms which, as to their chemical properties, fitted into the same space in Mendeléeff's table, but differed as to their nuclear structure, were called isotopes, after the Greek roots "the same place."

It will be recalled that Swedenborg suggested that the alchemists were sure of failure because the subtle matter which distinguishes one metal from another "cannot within myriads of degrees be dissolved by any sublunary fire." Does this new alchemy, using natural radioactivity, bear out this argument. The fire from ordinary combustion is capable of producing many chemical processes. But as an agent for producing nuclear changes, Rutherford said before 1930 of radioactivity:

> "Of the three types of radiation from the radioactive bodies the α particle was likely to be the most effective in promoting disintegration, owing to its enormous energy and momentum corresponding to that of helium atoms at a temperature of 6×10^{10} degrees." (*ibid.* p. 282)

Not one example is known whereby "sublunary fire," as Swedenborg called it, or chemical action, or the application of ordinary mechanical forces, has accelerated or changed in any way the rate at which natural radioactivity takes place. Furthermore, radioactivity is unidirectional. The process whereby element A emits an α particle, and so becomes an element B, cannot be reversed. In 1919 the first induced nuclear reaction was observed by Rutherford. α-particles from a naturally radioactive substance were directed into nitrogen. The products were oxygen and hydrogen!

This was what can be called a semi-artificial transmutation. It was initiated by man, but he made use of the energy in particles which were the products of a naturally radioactive source.

During the next ten years electrical means were developed for accelerating particles up to the speeds of α particles from natural radioactive sources, that is, over two-thirds the speed of light. Shortly after 1930 developments came fast. In 1930 the first completely artificial transmutation was accomplished when Cockroft and Walton succeeded in accelerating hydrogen nuclei up to such velocities that their collision with lithium nuclei resulted in the formation of two helium atoms which separated with tremendous energy. The era of "atom smashing" was at hand.

Thus only 36 years after the article by Bolton in the Annual Report of the Smithsonian Institution, Arthur Compton in the same journal contributed an article entitled "The Battle of the Alchemists," in which he said, among other things:

"Long, long ago, when gods mingled among men, the god Hermes established the first laboratory on this earth and discovered many new and interesting substances by subjecting various kinds and mixtures of earth and rocks to the influence of fire or water. Not being blessed with the protection of the United States Patent Office, he kept his discoveries secret by putting his products into jars, which were carefully closed and sealed. Hence arose the term 'hermetically sealed,' and the chemistry and metallurgy which thus sprang from the god Hermes was long known as the 'hermetic art.'

"According to another legend, a group of wicked angels were expelled from heaven and settled on the earth, taking unto themselves human wives. To these wives the fallen angels disclosed the magic secrets of science, and the wives recorded these secrets in a book which was called 'Chema'—the first handbook of chemistry. Thereafter those who practiced this art were called 'alchemists.' "

Compton goes on to explain how the modern alchemists are not too much unlike the earlier ones. If they have earth, water, air, and fire, we in our time have our prima materia: electricity. He says:

"We must not despise the efforts of these alchemists. Among them were numbered such great minds as Newton, Leibnitz, and Boyle, all of whom studied and practiced alchemy, though they were beginning to realize its defects. But from this mixed ancestry of legend, experiment, and magic was born the modern science of chemistry."

Having given an outline of some of the experiments from Becquerel's discovery up to 1933, he concludes:

"... But we should not be surprised if the next generation should uncover the most exciting and far-reaching developments in the whole history of science. Meanwhile, Rutherford, Chadwick, Cockroft, and Walton, Lawrence, Van de Graaff, Bothe, and many others continue the work. They are the modern alchemists, direct descendants of the alchemists of the middle ages and tracing their ancestry back to Hermes and the fallen angels."

Even as Compton wrote, his remarks, for example, that the "helium nucleus consists of 4 protons and 2 electrons," were being corrected by one of these "alchemists," Chadwick, who was in the process of discovering the neutron. After this discovery it was said that the helium nucleus was made of two protons and two electrons.

The newly discovered neutrons became a new tool as important to nuclear chemistry as electricity had been to molecular chemistry. The collision of bombarding neutrons with atomic nucleii produces so-called compound nucleii—usually unstable. Two possibilities arise, both of which have been verified. Either the new nucleus may be radioactive, that is, it becomes an artificially created radioactive nucleus and decays rather soon into a stable isotope of the new nucleus, sometimes of atomic weight higher than the original nucleus; or the new nucleus is so unstable that almost immediately it breaks up into moderate sized fragments and additional neutrons. If there are more than one of these additional neutrons for each of the original bombarding neutrons it can be seen that the process can be rapidly reproduced as long as the target material is at hand. This is the process known as fission.

IV. Conclusion

Transmutation is so commonplace today that the newspaper announcement that the alchemist's dream has been accomplished in reverse causes little interest.

Man now is apparently interested only in transmutation when it is accompanied by a big bang. Man has forgotten that only a few short years ago alchemy was regarded as one of the hoaxes of science. However, the idea of alchemy rested originally upon a concept of cosmology, a concept of how the universe is put together, upon the idea that there was in creation a primordial substance or particle out of which all other matter is composed. If such a primordial substance exists, why would it not be possible for man by a simple rearrangement of this substance, to make gold out of mercury? This idea has appealed to many.

Compton said in 1933: "The field is open, and relatively so little explored that we cannot predict what will be discovered." Within months he himself was writing of the neutron that was to usher in fission and its products in the new alchemy, as well as the creation of new so-called transuranic elements—elements whose atomic weights were beyond 92. Nor was this all. At the same time, studies were being made with cosmic rays. If energies of the order of millions of electron volts could be responsible for what had happened since Mendeléeff's time to the periodic table, which must now be extended to over 1000 places to include the transuranic elements and all the isotopes now discovered, what could be done with energies that were present in certain cosmic ray which were of the order of a few billion electron volts?

Now the so-called elementary particles themselves, the electron, neutron, and proton and still others discovered since 1930 such as the positron and the mesons seem to have their chemistry. There is an alchemy associated with this study in which man speaks familiarly of transmutation. Man even speaks of particle annihilation and creation—if only the energy of the order of a billion electron volts is available. Machines are being built, and the date is set for their completion to accomplish this end.

To the reader of Swedenborg's early works it might appear that it is not Swedenborg's science as such that is the important thing, but rather the thought he brought to bear upon problems in terms of the science of his day. The means the alchemist had before 1900 were inadequate, and indeed their objective was wrong, as Swedenborg said. Yet given the means and further knowledge about the more subtle parts of nature, transmutation of the atomic nucleus became a reality.

Perhaps the reader of Swedenborg might go further in his reading into the *Principia* and there see the doctrine of discrete degrees unfolded, the creation of grosser matter from the activity of higher substances. Perhaps the idea of a primordial substance might be found there which would be more closely verified by these new experiments than by the more gross substances for which the periodic table was constructed.