SWEDENBORG'S CHEMISTRY[*]

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In 1721, Swedenborg published, under the title *Prodromus Principiorum Rerum Naturalium, sive Novorum Testaminum Chymiam et Physicam Experimentalem Geometrice Explicandi* (A Forecast of the Principles of Natural Things or of New Attempts to explain Chemistry and Experimental Physics by Geometry), some of the results of his studies, observations, and experiments in the field of chemistry and physics up to this date.

We have seen that after his return from his first trip abroad, in the summer of 1715, he devoted himself extensively as well as intensely to observation and study in those fields of nature which were more directly related to his business as a civil and mining engineer. His unbounded intellectual interests and his insatiable thirst for knowledge, however, led him inevitably and deliberately into the whole body of the physical sciences. Besides his contributions to the *Daedalus Hyperboreus,* within the period of 1716 to 1719, he wrote on a great variety of subjects, physical, mathematical, and professional; at the same time, he devoted himself increasingly to systematic studies in the Philosophy of Nature. It seems that he devoted the latter part of this period and most of the year 1720 to writing out the results of his studies in what he refers to as his *Principles.* There is little record of his activities at this time; but in a letter from Brunsbo, dated May 2, 1720, he says :

> I am at present engaged in examining all the chemistry contained in the treasury of the Sudeman Library, which now belongs to Hesselius, for I have proposed to myself to examine thoroughly everything that concerns fire and metals, *a primis incunabilis usque ad maturitatem* (from the first beginnings to the mature stages), according to the plan of the memoran-

[*] Presidential Address given by Rev. L.F. Hite at the Thirty-second Annual Meeting of the Swedenborg Scientific Association held at Bryn Athyn, Pennsylvania, on Monday, June 10, 1929. Reprinted from *The New Philosophy* vol. XXXII §§ 1–4 (Jan.–Oct. 1929): 1–16.

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> dum which has already been communicated to you. I take the chemical experiments of Boyle, Becher, Hjärne, Lemery, and others, and trace out nature in the least things, instituting comparisons with geometry and mechanics. I am also encouraged every day by new discoveries as to the nature of these subtle substances; and as I am beginning to see that experience in an uninterrupted series seems to be inclined to agree therewith, I am becoming more and more confirmed in my ideas.

Here we get a glimpse of Swedenborg's interests and methods. First, we have another example of his deliberate and thorough preparation for the task in hand. It was his habit to make himself familiar with the best books and the latest results of investigation in the field he was entering upon. We note that he was giving special attention to the experiments of the gifted and accomplished Robert Boyle (1627–1691); at the same time, he was examining all the chemistry of the Sudeman Library, which he calls a treasury. It was characteristic of him that he proposed to examine thoroughly everything that concerned fire and the metals. This meant for him, beginning at the very beginning and going on to the completed processes under consideration. His search into the beginnings led him into the realm of the invisibles, to tracing out nature in the least things. It would be an interesting and important investigation to determine Swedenborg's historical position in this study of invisibles and the least things. The ordinary histories of science give us little information that is helpful; Swedenborg's studies were more like those of very recent times in the development of the atomic theory. This will appear more clearly and definitely as we proceed. Another point of characteristic significance was, that he tested his methods and results by the application of geometry and mechanics; of this too we are to have abundant demonstration.

Swedenborg was at this time greatly interested in the nature of fire. It is a curious fact that, although the phlogiston controversy was at its height all during his student days, and Boyle was one of those who did most to upset the theory and to force its final abandonment, Swedenborg never once refers to the theory nor even mentions the word. It is one of the most remarkable instances of the independence and originality of his scientific interests and activities. It shows that he was primarily interested in the fact, not in the current theories about the nature of the fact. Ever since the days of Heraclitus, fire had been considered one of the primal elements, and just as much a *thing* as earth and water. All during the period of the alchemists and early chemistry, fire was a puzzling fact; it was connected with sulphur, which was the inflammable element. Somewhat later, chemists thought of fire as the element which escaped from a burning substance. G.E. Stahl, one of the greatest chemists of his day, gave to this element the name of phlogiston, and elaborated the theory which furnished scientific interest and scientific method in the study of chemical processes. Stahl was professor of chemistry in the University of Halle from 1694 to 1716, the period when Swedenborg was a student at the University of Upsala and was later pursuing, so intently and systematically, his studies in natural philosophy. One of Swedenborg's authorities was Hermann Boerhaave (1668–1735), a famous lecturer on the natural sciences, and the author of the most popular book on chemistry of the period. These citations are enough to show that Swedenborg was abreast with the latest results of his day in this field, and we may assume that he was familiar with at least the early stages of the phlogiston controversy, although he seems to have taken no part in it. We may get some idea of Swedenborg's historical position in chemistry, by observing that his studies at this stage were contemporary with the productive period of such eminent chemists as Stahl, Boerhaave, Friedrich Hoffman, Johann Juncker, and Caspar Neumann. These, with the exception of Boerhaave, were phlogistonists, and they were followed a little later by J.T. Eller, J.H. Pott, and A.S. Marggraf. Somewhat later still, we have the names, Macquer, Bergman, Scheele, Black, Cavendish, Priestley, and Kirwin—all phlogistonists. This glance enables us to see that Swedenborg's work belongs to the transition stage of chemical progress—the stage through phlogistonism to the "new chemistry" inaugurated by Lavoisier. It was in one respect at least in advance of the new chemistry, and anticipated that of the present day; namely, his application of geometry to chemistry and, indeed, to natural science in general.

Perhaps enough has been said to establish the fact that Swedenborg was an educated chemist, though not, in the special sense, a professional one. He was also an educated mathematician and an educated scientist. That he was fully possessed of the scientific spirit, and that he approached his task in the full light of scientific progress and achievement, we are well assured in the words addressed "To the Reader," in his preface to this *Prodromus*. He says:

> The reader will be equally astonished with myself, that the knowledge of invisibles has remained hidden from the learned world up to the present time, when so many experiments respecting them are on record. If we look to *Physics,* we shall find that it abounds in experiments and discoveries ! More light has been shed upon it in the way of experiment during the last century than in any previous age; indeed, so far as facts are concerned, it has reached a meridian degree of brightness. If we consider *chemistry,* with what experiments is it not enriched! So greatly has it exercised the industry of the learned, that we possess thousands of guides toward penetrating its secrets. If *geometry,* to what a height has it not been carried by the men of genius of our time! It seems indeed to have scaled Parnassus, and for all human purposes, to have attained the summit of the art. If, therefore, a thousand signs indicate one thing, we must suppose, as the matter is purely geometrical, that it may be at length made known and demonstrated. For what are physics and chemistry? What is their inner nature, if not a *certain mechanism?* What is there new in nature, which is not *geometrical?* What is the variety of experiments but a variety *of positions, figures, weights,* and *motions* of particles? Since, then, we have several thousand experiments, indicating the nature of *metals, salts, elements,* etc.; and since there is nothing in a metal, salt, or element, but a mass of particles, and in these a variety of figures and positions, and in these again mechanism and geometry; we may therefore conclude that these properties can at last be demonstrated.

This sounds as though it might have been written by some advanced modern physicist, such as Eddington. Notice the emphasis that is placed on experiments, and the interest in the knowledge of invisibles. How familiar the statement, that more light has been shed on the field of physics in the last half century, or even quarter of a century, than in all previous ages. The immense accumulation of facts, experiments, and theories of today would seem to justify the claim. Think of the marvellous developments of geometry and mathematics in the last generation. We may well say with Swedenborg, that for all human purposes we seem to have attained utmost perfection in these subjects. Notice the argument for the expectation that, in view of all these results, the nature of invisibles may be made known and demonstrated. For what are physics and chemistry but a knowledge of positions, figures, weights, and motions of particles? Metals, salts, elements, etc., are masses of particles, varying in shape and position. These particles are the invisibles which it is the object of the above sciences to make known and demonstrate, and this is what Swedenborg is undertaking to do. It is this knowledge of invisibles which he says has remained hidden to his day. He thinks that the time has come in the progress of the sciences when the task may be successfully undertaken.

> To this end [he says], I have collected experiments from the most learned and experienced men, such as those of Boyle, my own countryman Hjaerne, Boerhaave, Lemery, and others, which I have added to and partly repeated. I have also applied geometry to the investigation of causes, and have at length formed principles which agree with experiments. What I have done is for you to judge, my most highly lettered readers. In *the work itself I will* exhibit the theory of the remaining metals, salts, and elements, according to the same connection and order. In this Prodromus, I present only a specimen.

The mention here of "the work itself," in contrast with "this *Prodromus*," raises a perplexing question of historical importance. The work is referred to in the future, either as something yet to be written, or as something already written but not yet published. A few pages further on, in the fragment on the primeval ocean, he makes a statement about the origin of salt mountains which, he says, is "according to what is declared in our principles"; and, at the end of the fragment, he says : "If, then, an ancient ocean stood so high above the earth, and if the dry land owes its surface appearance and, as it were, its origin to this parent, surely it may thence be concluded that salt mountains must have originated at its bottom, as also rocks and all solid bodies composed of saline particles; which particles are set free by calcination, crystallization, and other chemical processes, concerning which see the *Principles*."

In both these instances, the "Principles" referred to seems to be a treatise actually existent and accessible. Furthermore, there are specific references to the several numbered parts of the treatise. For example, in § I, part IX, we read : "So that according to the demonstrations in our *Principles,* Parts II, III, and IV, the particles are not only round but also hollow." Again, at the end of the section, "but for these particulars, see the *Principles,* Parts II, III, and IV." The same form of reference is repeated in § 6. As a still more specific reference, in § 5, "the reader is referred to Part III, treating of the motion of round particles in the natural position." But the most comprehensive and conclusive reference is given in § 6: "As we have already treated in the *Principles* from Part I to Part VIII of the motion of round particles," et cetera. This makes the present work a part of the *Principles.* We gather from these references, that Parts I to VII of the *Principles* treated of the nature and behavior of particles and especially of the particles and behavior of water. There seems no doubt, then, that the book in hand, which Swedenborg published as the *Prodromus*, is a selected portion of the whole treatise called the *Principles,* namely, Parts VIII to XIV together with Part XXV, and an Appendix. Why the selection was made, and why the whole book was not published, we cannot say; but, we may surmise that the discussion of particles and water in the first seven parts was tentative and not satisfactory. The additional expense may also have been considered, for during the whole of this period Swedenborg was much straitened in his finances. Another perplexing fact is, that there seems to be no trace of the manuscript of the early part. It would be a very important aid to our reading of this selected portion and of the subsequent cosmological writings if we had the whole of the "Principles." Mr. Strutt, the translator, says in his Introduction, that "it forms a part of a work still existing in manuscript in Sweden, but which has not yet been published." This seems to refer to the manuscript of what we now call the *Lesser Principia.* But if we compare the indicated contents of Parts I to VII of the *Principles* with those of the *Lesser Principia,* we find that they are quite different. In the *Documents,* Chronological Account, n. 26 (vol. II, pp. 899–900) Dr. R.L. Tafel says: "This work (the *Lesser Principia)* seems to be Part I of that which Swedenborg published in *1721,* under the title, *Prodromus Principiorum Naturalium,* etc. (n. 28); for on page 532, he speaks of a work on 'salt and the metals' which is to follow." This suggestion seems to be quite groundless, for, as was said above, the contents of the two works are different. As we have seen, Parts I to VII of the *Principles* treat specifically of the nature and behavior of water and water particles; whereas, there is very little about water and water particles in the *Lesser Principia,* and that occurs near the end of the book in n. 161. Dr. Tafel's reference to the Theory of Salts and Metals is inconclusive, for there are frequent references to the Theory of Salts, the Theory of Metals, and to other theories in the body of the *Prodromus*, and these references indicate that Swedenborg intended to write detailed and exhaustive treatises on these subjects but never carried out his plans, unless they were partly carried out in volumes II and III of the *Opera Philosophica et Mineralia,* the volumes on iron and copper.

It seems that we must conclude, therefore, that Swedenborg certainly wrote the book he so frequently refers to as his *Principles;* that he published parts of it; that the manuscript of the unpublished parts has disappeared, temporarily at least; and, that the nature, contents, and whereabouts of the manuscript is still a problem.

As to the published parts of the *Principles,* the *Prodromus,* we note that it was translated into English by Charles Edward Strutt, in 1847, and that the Latin text was republished in 1727 and in 1754; and more recently, in 1911, in the third volume of Swedenborg's Scientific Works, under the auspices of the Swedish Royal Academy of Sciences.

The general theme of the book is the development of the particle theory, especially of the theory of the water particle. Then follow, in order, the theories of salt, acid, nitre, oil and lead, and some fragmentary discussions on other subjects. These theories all depend upon the theory of water and its particles. One of the most important historical investigations in the study of Swedenborg's *Chemistry* is that of determining the source, or sources, of his views as to the nature of water and of water particles.

There was of course the familiar tradition that the early Greek philosopher, Thales, held that all things come from water; and we may easily imagine the considerations which led him to that belief. It is a matter of common observation that water abounds everywhere, and that it is a large constituent of the bodies of plants and animals, of the soil beneath and of the air above. Water seems to be the most important and all pervading element. We cannot say how far these considerations weighed with

Swedenborg, but, as a matter of fact, he advances a serious argument to show that water is the primal element, and that other bodies, rocks and minerals are produced from water. The argument is based upon the evidences, that in long past ages a deep ocean was spread over the entire surface of the earth, and that at the bottom of this ocean the water was subjected to immense pressure. Beginning with the fact that our present land was once under a great depth of water, Swedenborg gives a preliminary section On the Primeval Ocean and the effects of deep water action. He then takes up Part VIII of the *Principles,* and discusses the different possible positions of round particles. Among these positions he distinguishes (1) the vertical position, (2) the triangular position of the first kind, (3) the triangular position of the second kind, (4) the triangular position of the third kind, (5) the fixed triangular pyramidal position, (6) the fluid triangular position, (7) the fixed quadrilateral pyramidal position, and (8) the fluid quadrilateral pyramidal or natural position. He goes carefully into the geometry and physics of the particles in each of these several positions. It is of fundamental importance, for the intelligent reading of the rest of the book, to follow the details of the mathematics involved in these discussions. When particles are arranged in the vertical position, they take the form of a cube. There are then three volumes to be measured: (1) the space of the whole cube, (2) the space occupied by the particles, and (3) the amount of empty space between the particles. Swedenborg calculates these volumes, and determines the ratios between them; and he does this for all the positions above enumerated. He also compares the several positions with each other with respect to the magnitude of the space occupied, and gets numerical values for their relations. A close reading of these discussions increases our admiration of Swedenborg's indefatigable thoroughness and accuracy.

The next topic is the theory of water, that is, the particle constitution of water. Here we seem to get at Swedenborg's central and original interest. The ultimate constitution of matter, or the constitution of bodies, has been a problem of philosophy from the earliest dawn of metaphysical curiosity. The early Greeks were driven to the atomic theory by the contradiction between the nature of body and the principle of infinite divisibility. Democritus, Epicurus, Lucretius, Gassendi, and Dalton kept the theory alive down to our own day. Plato and Aristotle apparently, and certainly

Leibnitz, rejected the theory because of the contradictions involved in the conception of body. Leibnitz based his rejection on the composite nature of body, and on the argument that the composite implies the simple. Swedenborg rejected the theory of hard particles, and adopted instead the bullular hypothesis, the theory of composition and recomposition. The theory comes like a bolt from the clear sky. Perhaps, if we had the missing first seven parts of the "Principles," we might get a hint as to the considerations which led him to adopt his particle theory; but, as it stands, we have no clue as to its historical origin.

The theory is introduced abruptly in the first paragraph of Part IX, on the nature of water. The passage is fundamental to the understanding of the book and of the chemistry which follows. Referring to the

> demonstration in what has preceded, it may be seen (he says) : (1) That the particle of water is round. (2) That on its surface there are crustals of the fifth kind. (3) That on their surface again there are crustals of the fourth kind, and so on to the first kind, and at length to mathematical points, or to a composition of points. (4) That all those which are on the surfaces are hard and of the same nature as the larger particle, that is, as water. (5) That in the middle of the particle of water there is a cavity, the space of which is equal to the space of its crustals, or to the space of its superficial particles. (6) That in the same way, there is a cavity in the particles of the fifth kind, the space of which is equal to the space of its crustals, and so on in particles of whatever dimension. So that according to the demonstrations in Parts II, III, and IV of our *Principles,* the particles are not only round but also hollow, and the superficial ones, of whatever kind, are of the same nature as the larger particle.

Such is the first published announcement of this revolutionary theory—a theory which seems to stand alone in the history of science, and one to which he held throughout his scientific and subsequent career. According to this theory, contrary to appearance, water consists of round particles, and these particles have an immensely complicated structure; a structure somewhat paralleled by the latest developments of the atomic theory. The water particle is a bubble whose surface is made up of smaller particles, which are also bubbles whose surfaces are made up of stili smaller particles. This structure is repeated until we come to the simple particle, which Swedenborg calls the mathematical point or a composition of points. By mathematical point here, Swedenborg seems to mean a particle which is uncompounded, and which, therefore, is not a body in the strict sense of the word. He was to deal with this point more elaborately in the *Principia,* his final work on the structure of matter.

If we take a mass of water particles, we may consider their *arrangement,* their *motion,* and the *pressure* they are subjected to in the mass. Swedenborg goes into a minute discussion of each of these features. His diagrams remind us of the models we see in the chemical and physical laboratories of today. When particles are arranged in the several possible positions, it is plain that there will be empty spaces between them. These interstices, Swedenborg next proceeds to consider; he determines the shapes, and measures the dimensions. Then he supposes that these interstices are filled with matter and other particles, and determines the relative weights of the interstitial matter and globules. When the mass of water particles is submitted to great pressure, as it is at the bottom of the ocean, the contents of these interstitial spaces become of critical importance. It is at this point that Swedenborg begins his theory of salt and of other bodies. The theory of salt is fundamental, as the conditions and processes are repeated with the acids, nitre, oil, lead, and other metals. In brief, the theory is, that owing to the great pressure at the bottom of the ocean, some of the particles of water are disrupted, and the smaller particles of which they are constituted are forced into the interstices and become salt and other bodies, according to the pressure, arrangement, and motion of the particles so compressed.

This is a very condensed statement of what Swedenborg's chemistry is. There are many features of it which need to be developed and discussed at length, but this synopsis may serve as a beginning.

The appearance of strangeness, and its remoteness from our ordinary experience and conceptions, may be relieved by making a distinction between what may be called a pictorial interpretation of our experience, and this scientific interpretation in terms of particles. For our ordinary experience, water is a continuous fluid mass with no empty spaces in it; just as salt is a continuous crystalline body which completely fills the space it occupies. Viewed in the light of physical and chemical theory, however, water is a mass of particles with empty spaces in between; and so with salt and all other bodies. The difference between these bodies is a difference in the arrangement and motion of the particles. When, therefore, Swedenborg says that salt is produced from water by the pressure of the superposed particles which disrupts some of the water particles and forces the smaller constituent particles into the interstices with a more compact distribution, he is speaking of salt as it is viewed in the eyes of the scientist who thinks of particles, and not of salt as we picture it for ordinary purposes. So in the case of the other bodies. Thus, we should constantly bear in mind the fact that Swedenborg's particle theory is by no means consistent with the facts of experience; no more nor less consistent than is the latest atomic theory of the present day. Which theory is ultimately true must be decided by further experience and experiment. In any case, Swedenborg's theory, just as modern theories, should be tested by the facts, not by the language of modern principles.

As a matter of scientific interest, we should appreciate that Swedenborg's chemistry is just as much a problem of science and natural philosophy as is the modern atomic theory of protons and electrons. They are both particle theories, and in principle are very similar; and both need critical and exhaustive study in the light of experiment and fact. ❑