SWEDENBORG'S THEORY OF FIRE.[1]

THE history of scientific research contains few pages so interesting and instructive as those which describe the progress of theories concerning the nature of fire, flame, combustion, and related subjects. One theory has followed another, terminology has been so changed that the works of the older toilers in the field require to be most carefully studied if their statements are to be at all comprehended, and any one branch of the subject must be viewed in its proper historical perspective and with a proper regard for the changes in methods of research and in terminology which have taken place in a given period, if it is to be seen in its true proportions.

Let us now proceed to investigate Swedenborg's theory of fire in this way; and in order that a background may be furnished let us take a brief survey of the history of the discoveries and theories concerning fire.

The ancient division of nature into the four elements, fire, air, water, and earth, is true in a very general sense; and the important position held by fire in the ancient philosophies undoubtedly had its origin in a knowledge of the correspondence of the sun and fire. But it appears that but little was known of the nature of fire in the modern experimental sense, and during the days of alchemy and scholasticism endless confusion was introduced by a misunderstanding of the differences between gases and the phenomena of flame and combustion. One of the early experiments which was of the kind which long after led to the important deductions of Lavoisier, is contained in the works of Jean Baptiste Van Helmont (1577-1644). He says:

But the flame itself, which is nothing but a kindled smoke, being enclosed in a glass in the very instant perisheth into nothing.

The flame indeed is the kindled and enlightened smoke of a fat exhalation; be it so; but as the flame is such and true fire and not another matter, being kindled and not yet kindled, neither doth it differ from

[1] This article is an abridgment of a paper read in part at the Regular Meeting of the Principia Club of Bryn Athyn, Pa., May 20, and concluded at a special meeting held June 12, 1901.

itself; but that light being united in its centre, hath come upon a fat exhalation which is the same as to be inflamed.

Let two candles be placed which have first burned awhile, one indeed being lower than the other by a span; but let the other be of a little crooked situation; then let the flame of the lower candle be blown out; whose smoke, as soon as it shall touch the flame of the upper candle, behold the ascending smoke is enlightened, is burnt up into a smoky or sooty gas, and the flame descendeth by the smoke even unto the smoking candle. Surely there is there, the producing of a new being, to wit, of fire, of a flame, or of a connexed light; yet there is not a procreation of some new matter or substance.

For the fire is a positive artificial death, but not a privative one, being more than an accident and less than a substance.[2]

It appears then that Van Helmont thought flame to be a burning smoke, not a new substance, but the incandescence of a vapor or smoke that already existed.

Robert Hooke (1635-1703)—

—Speaks of that transient shining body which we call flame as nothing but a mixture of air and volatile sulphureous parts of dissoluble or combustible bodies which are acting upon each other whilst they ascend, an action so violent, he says, "that it imparts such a motion or pulse to the diaphanous parts of the air" as was requisite to produce light.[2]

Robert Boyle (1626-1691), in his *Memoirs for a General History of the Air,* in his *Suspicions about some hidden qualities of the Air,* in his *Skeptical Chymist,* and elsewhere, describes many experiments on air, fire and flame which show that he came very near making the conclusions afterwards made by Lavoisier. He noticed that substances grow heavier by calcination, that there is a direct relation between air and flame, that animals cannot live in an air vacuum, that fire burns better in compressed than in ordinary air, and that the contact of phosphorus and air seems to "mortify" the former.

Compare the following quotations with the theory of finites and actives given by Swedenborg, and with the best results of modern chemistry:

If it be true, which was the opinion of *Leucippus, Democritus,* and other prime anatomists of old, and is in our days revived by no mean

[2] Quoted from a lecture by Prof. Arthur Smithells, in *Nature,* 1893, pp. 86-92.

philosophers; namely, that our culinary fire, such as chymists use, consists of swarms of little bodies swiftly moving, which by their smallness and motion are able to permeate the solidest and compactest bodies, and even glass itself; if this (I say) be true, since we see, that in flints and other concretes, the fiery part is incorporated with the grosser, it will not be irrational to conjecture that multitudes of these fiery corpuscles, getting in at the pores of the glass, may associate themselves with the pores of the mixed body whereon they work, and with them constitute new kinds of compound bodies, according as the shape, size, and other affections of the parts of the dissipated body happen to dispose them, in reference to such combinations; of which also there may be the greater number, if it be likewise granted, that the corpuscles of the fire, though all exceeding minute, and very swiftly moved, are not all of the same bigness, nor figure: and if I had not weightier considerations to discourse to you of, I could name to you, to countenance what I have newly said, some particular experiments, by which I have been induced to think that the particles of an open fire working upon some bodies may really associate themselves therewith, and add to the quantity.[3]

Fire, which is the hottest body we know, consists of parts so vehemently agitated, that they perpetually and swiftly fly abroad in swarms, and dissipate or shatter all the combustible bodies they meet with in their way; fire making so fierce a dissolution, and great a dispersion of its own fuel, that we may see whole piles of solid wood (weighing perhaps many hundred pounds) so dissipated, in a very few hours, into flame and smoke, that oftentimes there will not be one pound of ashes remaining.[4]

Ramsay has truly said of Boyle that he "was one of the most distinguished scientific men of his own, or indeed of any age, and in his spirit of calm philosophical enquiry he was far in advance of his contemporaries." [5]

John Mayow (1645-1679), made experiments on air and metals and came to the conclusion that there were at least two kinds of gases in air, one of which, consisting of nitro-aerial particles, supporting life and the combustion of inflammable bodies, the other capable of supporting neither. He noticed that antimony gains in weight when set on fire by a lens and

[3] *The Works of the Honourable Robert Boyle in Six Volumes.* London, MDCCLXXII. Vol. I., pp. 523-4; cf. p. 527.

[4] *Op. cit.,* Vol. IV., p. 245. *On the Mechanical Origin of Heat and Cold.*

[5] *The Gases of the Atmosphere,* by William Ramsay; Macmillan & Co., 1896; p. 7.

burnt, and ascribed this gain in weight to the nitro-aerial particles and to the fire. Mayow made many other experiments,[6] but he was overshadowed by the fame of Boyle and Newton. Boyle appears to have read Mayow, but curiously enough "does not appear to have been favorably impressed by his conclusions." [7]

Of Jean Rey, Ramsay says:

Before leaving the seventeenth century, it is perhaps fitting to mention the name of Jean Rey, a French physician, who wrote in 1630 concerning the gain in weight of tin and lead when calcined. While Rey exhibited some leaning towards the modern methods of experimentation, he still lay fettered in the bonds of mediæval scholasticism. In discussing the weight of air and fire, he finds occasion to consider the question whether a vacuum can exist. His words are so quaint that they are worth quoting: "It is quite certain that in the bounds of Nature a vacuum, which is nothing, can find no place. There is no power in Nature from which nothing could have made the universe, and none which could reduce the universe to nothing: that requires the same virtue. Now, the matter would be otherwise if there could be a vacuum. For if it could be here, it could also be there; and being here and there, why not elsewhere? and why not everywhere? Thus the universe could reach annihilation by its own forces; but to Him alone who could make it is the glory of being able to compass its destruction." And since air cannot be drawn down by a vacuum, it must descend by virtue of its own weight when it fills a hole. And hence, as air has weight, tin and lead gain in weight when they combine with air. It will be admitted that this is very inferior to the speculations and deductions of Boyle and Mayow.[8]

Stephen Hales (1677-1761), a country clergyman who was interested in botany, in order to understand the growth and development of plants made experiments on air. His methods were quite modern, for in his introduction he says:

And since we are assured that the all-wise Creator has observed the most exact proportions of *number, weight* and *measure* in the make of all things, the most likely way, therefore, to get any insight into the nature of those parts of the creation which come within our observation

[6] The title of Mayow's work is: *Tractatus quinque medico-physici, quorum primus agit de sal-nitro et spiritu nitreo-æreo; secundus, de respiratione; tertius, de respiratione fœtus in utero et ovo; quartus, de motu musculari, et spiritibus animalibus; ultimus, de rhachitide;* studio Joh. Mayow, LL. D. and Medici, nec non Coll. Omn. Anim. in Univ. Oxon. Socii. Oxonii e Theatro Sheldoniano, An. Dom. MDCLXXIV.

[7] For an account of Mayow's work see Ramsay, *op. cit.*, pp. 15-28.

[8] Ramsay, *op cit.*, pp. 27-8.

must in all reason be to number, weigh, and measure. And we have much encouragement to pursue this method of searching into the nature of things, from the great success which has attended any attempts of this kind. For God has "comprehended the dust of the earth in a measure, and weighed the mountains in scales, and the hills in a balance." [9]

Hales made experiments on a variety of substances, subjecting them to distillation and fermentation and collecting their "airs" over water. He used hog's blood, tallow, a fallow deer's horn, oyster-shell, oak, wheat, peas, amber, tobacco, camphor, aniseed oil, honey, beeswax, sugar, Newcastle coal, earth, chalk, pyrites, a mixture of salt and bone-ash, of nitre and bone-ash, tartar, compound aqua-fortis; grain, raisins and other fruits; he also generated "air" by the action of acids on metals. But, although he was aware of the work of Boyle and Mayow, and quotes them, he did not come to the conclusion that the "airs" which he produced were different, but thought that they were but modifications of an elastic "*Proteus* among the chymical principles." [10] How near he was to the truth may be seen from his conclusions as presented in the following extract:

The air is very instrumental in the production and growth of animals and vegetables, both by invigorating their several juices while in an elastick, active state, and also by greatly contributing in a fix'd state to the union and firm connection of several constituent parts of those bodies, viz., their water, salt, sulphur, and earth. This band of union, in conjunction with the external air, is also a very powerful agent in the dissolution and corruption of the same bodies; for it makes one in every fermenting mixture; the action and re-action of the aerial and sulphureous particles is, in many fermenting mixtures, so great as to excite a burning heat, and in others a sudden flame; and it is, we see, by the like action and re-action of the same principles, in fuel and the ambient air, that common culinary fires are produced and maintained.[11]

[9] Ramsay, *op. cit.*, pp. 29-30. The title of Hales' chief work is: *Statical Essays, containing Vegetable Staticks; or an account of Statical Experiments on the Sap in Vegetables, being an Essay towards a Natural History of vegetation: of use to those who are curious in the Culture and Improvement of Gardening, etc.: Also, a specimen of an attempt to analyse the air by a great Variety of Chymiostatical Experiments, which were read at several meetings before the Royal Society.* By Stephen Hales, D. D., F. R. S., Rector of Farringdon, Hampshire, and Minister of Teddington, Middlesex.

[10] Ramsay, *op. cit.*, p. 37.

[11] Quoted from Ramsay, *op. cit.*, p. 35.

From what is known today it is clear that Hales produced "mixtures of hydro-carbons, carbon dioxide, probably sulphur dioxide, hydrochloric acid and ammonia (both, however, dissolving in water as they were formed), oxides of nitrogen, possibly chlorine," [12] oxygen and hydrogen.

Lack of time will permit only a reference at this point to the important discoveries of "fixed air" (carbon dioxide), by Joseph Black (1728-1799), and of "mephitic air" (nitrogen), by Black's pupil, Daniel Rutherford (1749-1819).

The experimenters on the nature of fire and air were much hampered by the theory of phlogiston, which is an excellent example of how the most carefully made experiments may lose their proper meaning to minds dominated by prejudice. It took the critical, revolutionary genius of Lavoisier to overthrow this bugbear.

Van Helmont's gaseous principles—

—Apparently suggested to his successors, Becher and Stahl, the notion of a principle inherent in every combustible substance, which was lost during combustion. The development of this—the phlogistic—theory is almost wholly due to the latter chemist, and indeed it is difficult to trace Becher's share in it.

The fundamental conception of this doctrine is that all combustible bodies are compounds. During combustion one of these constituents, common to all, was dissipated and escaped, while the other, sometimes an acid, sometimes an earthy powder or calx, remained behind. Thus sulphur and phosphorus, when burnt, give acids; and the metals form *calces*. Non-combustible substances, such as lime, were imagined to be *calces*, and it was supposed that if phlogiston were restored to them, they too would be converted into metals. This combustible principle was thought to be inherent in all combustible bodies whatsoever; it corresponds in kind with the "sulphur" of more ancient writers, but differs from the latter inasmuch as no very precise ideas were entertained of the identity of the "sulphur" which conferred on the substances containing it as a constituent, or possessing it as a property, their power of combustion. It was also made more definite by Stahl that substances capable of burning or conversion into calces are compounds containing phlogiston in combination with other substances.

Stahl can hardly be credited with more than the invention of the term "phlogiston," and with bringing the subject in a clear and definite form before his contemporaries. For Stahl wrote in 1720; and we find Mayow, in 1674, entering into an elaborate argument to prove that

[12] *Ibid.*, p. 31.

sulphuric acid is not contained in sulphur, but that it is produced by the union of the sulphur with his fire-air particles. But Stahl amplified the doctrine which Mayow had controverted, in pointing out that if such substances as phosphorus, sulphur, or metals are heated, they burn, and are changed into phosphoric acid, sulphuric acid, or "calces;" and reciprocally, if phosphoric acid, sulphuric acid, or a calx such as that of tin or lead, is heated with matter rich in phlogiston, such as charcoal, pitcoal, sugar, flour, etc., phlogiston is restored to the burnt substance, and the original material, phosphorus, sulphur, tin, or lead, is reproduced. The idea at once captivated the minds of the chemists of that age, who received it with approbation, and devised experiments designed to extend the applications of the theory and to confirm its truth.

Substances were not supposed always to be completely deprived of phlogiston by combustion. Indeed, if the phlogiston were removed wholly, or nearly so, it was by no means easy to restore it. Thus the calx of zinc, or of iron, which was regarded as nearly devoid of phlogiston, is difficult to reduce to the metallic state by ignition with substances rich in phlogiston, such as coal or charcoal. The addition of phlogiston alters the appearance of the substance as regards colour or metallic lustre, and these vary according to the proportion of phlogiston present.

There existed no very definite idea regarding the appearance or properties of phlogiston itself. Becher's name for it was *terra pinguis* and it was represented by Becher and by Stahl as a dry substance of an earthy nature, consisting of very fine particles, which were capable of being set into violent motion; this idea was derived partly from the fact that combustion is usually accompanied by flame, which was supposed to be produced by the motion of the particles of the body, communicated to it by the phlogiston.

It must not be forgotten that at this time it was perfectly well-known that metals gain weight on calcination. Jean Rey was quite aware of this, and Boyle relates an experiment to show that tin gains weight when converted into calx; and it will be remembered that Mayow made experiments on the ignition of antimony by the aid of a burning-glass, and rightly conjectured that the substance produced was the same as that formed by treating it with nitric acid, and subsequent ignition. Boyle's view was that calx of tin was a compound of *tin* and *heat;* Mayow's more correct view was that calx of antimony was a compound of *antimony* and *fire-air*. But in spite of these well-proved facts, the adherents of the theory of phlogiston ignored them, and it does not appear to have occurred to Becher or to Stahl that they were inconsistent with their theories.

When this difficulty was stated, which was not until a much later date, a lame explanation of a metaphysical nature, and in itself contradictory, was all that could be offered. It was that phlogiston is endowed with the contrary of gravity or weight, i. e., levity or absolute

lightness. This means, of course, that it is repelled by the earth. But if repelled by matter, how comes it that it enters into combination with matter? For it could not remain united if its property were to repel and not to attract. Notwithstanding this, however, the idea satisfied some as to the gain in weight which metals undergo in changing into calces.[13]

The theory of phlogiston, which dominated the chemistry of the eighteenth century and much retarded its progress, was destroyed by Lavoisier, who made use of the experiments of his contemporaries and convinced the scientific world of the new century of the truth of the doctrines which obtain today. This phase of our subject will now be considered.

Joseph Priestley (1733-1804), a theological controversialist,—the same who was engaged in controversy with Robert Hindmarsh,—vigorously prosecuted experiments on the nature of air and fire. He repeated Mayow's experiments of preparing nitric oxide by the action of nitric acid on iron, and investigated various kinds of airs, among which was gaseous hydrogen chloride. He thus acquired the idea that there were various kinds of "airs." He had previously concluded that—

—Atmospheric air is not an unalterable thing, for that the phlogiston with which it becomes loaded from bodies burning in it, and animals breathing in it, and various other chemical processes, so far alters and depraves it as to render it altogether unfit for inflammation, respiration, and other purposes to which it is subservient; and I had discovered that agitation in water, the process of vegetation, and probably other natural processes, by taking out the superfluous phlogiston, restore it to its natural purity. But I own that I had no idea of the possibility of going any farther in this way, and thereby procuring air purer than the best common air.[14]

In August, 1774, Priestley heated red oxide of mercury by means of a burning glass, and produced an air in which a candle burned brightly, and red-hot wood sparkled. He mixed nitric oxide with his new air and was surprised to find—

—That even after addition of nitric oxide and agitation with water, the residue still supported the combustion of a candle. A mouse, too, lived half an hour in the new air, and revived after being removed; whereas similar experiments with an equal volume of common air had

[13] Ramsay, *op. cit.*, pp. 40-4.
[14] Quoted from Ramsay, *op. cit.*, p. 76.

shown that, after respiring it for a quarter of an hour, a mouse was indisputable dead.[15]

He also produced similar air from "flowers of zinc" (zinc oxide), chalk, slaked lime, and other substances by distillation with nitric acid, which was "better" than common air and he called it "dephlogisticated" air.

Priestley had the curiosity to breathe his "good" air. He says: "My reader will not wonder that, after having ascertained the superior goodness of dephlogisticated air by mice living in it, and the other tests above mentioned, I should have the curiosity to taste it myself. I have gratified that curiosity by breathing it, drawing it through a glass syphon, and by this means I reduced a large jar full of it to the standard of common air. The feeling of it to my lungs was not sensibly different from that of common air, but I fancied that my breast felt peculiarly light and easy for some time afterwards. Who can tell but that in time this pure air may became a fashionable article in luxury? Hitherto only two mice and myself have had the privilege of breathing it.[16]

Carl Wilhelm Scheele (1742-1786), a Swedish chemist, made the discovery of oxygen gas two years before Priestley, as has been shown from his laboratory notes recently published by Baron Nordenskjold; but Priestley was prior in publication by a year. From Scheele's laboratory notes "it appears that before 1773 he had obtained oxygen by the ignition of silver carbonate, red mercuric oxide, nitre, magnesium nitrate, and from a mixture of arsenic acid and manganese dioxide." [17] Scheele discovered chlorine, and made a variety of interesting experiments, actually "reproducing Mayow's name 'fire-air particles' for the same substance of which Mayow had inferred the existence a century before, and which he had pointed out as being present in the acid of nitre, as well as in common air." [18]

Henry Cavendish (1731-1810), by his experiments on the constituents of air, in which he dealt with oxygen, nitrogen and carbon dioxide, was finally led to the discovery of the constituents of water by the composition of "dephlogisticated air"

[15] Ramsay, *op. cit.*, p. 78.
[16] Ramsay, *op. cit.*, pp. 81-2.
[17] *Ibid.*, p. 85.
[18] *Ibid.*, p. 94.

procured from red precipitate and "inflammable air," or hydrogen; thus drawing attention to the important part played by hydrogen in the phenomena of combustion. The series of experiments made by Cavendish are in the highest degree interesting, but lack of time forbids a recital of them.

Antoine Laurent Lavoisier (1743-1794), one of the greatest chemists of all ages, a man of the most versatile genius, brought to a climax the wonderful chemistry of the eighteenth century. In 1772 Lavoisier noticed that sulphur and phosphorus when oxidized gain in weight, and he communicated his discovery to the Secretary of the Academy, in a sealed note, which was to remain secret until the publication of his experiments. In 1774 he met Priestley, learned of his experiments, and shortly afterwards verified them. He calcined tin in hermetically-sealed retorts and observed the increase in weight of the calx, concluding that calx of tin is a compound of tin and air. In a paper, communicated to the Academy in 1775 and published in 1778, entitled "On the Nature of the Principle which combines with Metals during their Calcination, and which increases their Weight"—

—He describes experiments showing that when metallic calces are converted into metals by heating with charcoal, a quantity of fixed air is expelled; and here for the first time he points out that *fixed air is a combination of carbon with the elastic fluid contained in the calx.*[19]

The result of Lavoisier's experiments was that—

—He accounted for the phenomena of combustion without having recourse to the phlogistic hypothesis: the calx was produced by the union of the metal with the active constituent of air; and when carbonaceous material burned, the carbon united with this same constituent, producing fixed air. But there were still difficulties in his way: it was known that in dissolving metals in dilute vitriol or muriatic acid, a combustible and very light air was evolved; and that the metals were thereby converted into calces in combination with the respective acids. This fact was not explained even by the supporters of the phlogistic theory, but it had the effect of preventing them from accepting Lavoisier's views. Some considered that hydrogen and phlogiston were identical, and that on dissolving a metal the calx was formed by the escape of the phlogiston; while others had a hazy idea that hydrogen was a compound of water and phlogiston. . .

Lavoisier's objection to such a theory was that the calx was *heavier*

[19] Ramsay, *op. cit.*, p. 106.

than the metal, and that hydrogen, though light, still possessed weight. Moreover, he had ascertained that the calces of mercury, tin, and lead are compounds of these metals with active air, and that as fixed air is produced by heating such calces with carbon, fixed air must be a compound of carbon and vital air, or, as he named it, the "oxygine principle," inasmuch as its combination with phosphorus, sulphur, and carbon resulted in the formation of acids.[20]

Lavoisier also experimented with iron pyrites, and in 1783, hearing of the experimental results of Cavendish, he at once perceived their meaning in relation to the theory of phlogiston. He repeated the experiments of Cavendish, producing water, and in addition "performed the converse operation in decomposing steam by passing it over iron wire heated to redness in a porcelain tube." [21]

Lavoisier now possessed experimental data proving that the solution of metals in acids depended upon the decomposition of water, and the day for the new chemistry was won. Mendeléeff, in his *Principles of Chemistry,*[22] sums up the case as follows:

An Englishman, named Mayow, who lived a whole century before Lavoisier (in 1666), understood certain phenomena of oxidation in their true aspect, but was not able to develop his views with clearness, or support them by conclusive experiments; he cannot therefore be considered, like Lavoisier, as the founder of contemporary chemical learning. Science is a universal heritage, and, therefore, it is only just to give the highest honour in science, not to those who first enunciated a certain truth, but to those who are first able to convince others of its authenticity and establish it for the general welfare. But scientific discoveries are rarely made all at once; as a rule, the first teachers do not succeed in convincing others of the truth they have discovered; with time, however, a true herald comes forward, possessing every means for making the truth apparent to all, but it must not be forgotten that such are entirely indebted to the labours and mass of data accumulated by others. Such was Lavoisier, and such are all the great founders of science. They are the enunciators of all past and present learning, and their names will always be revered by posterity.

It should be noted that Priestley died with an implicit faith in the truth of the phlogistic theory; Cavendish made a careful examination of the two theories of Stahl and Lavoisier, and

[20] Ramsay, *op. cit.,* pp. 108-9.
[21] Ramsay, *op. cit.,* p. 112.
[22] Pp. 17-18, note 25.

with the facts before him deliberately chose the former; Black, however, became a convert. *The whole history of air and fire from Mayow to Lavoisier shows that the main thing in scientific progress is not an abundance of experiments, but true reasoning on the basis of such phenomena as are known.*

The latest extension of experimental knowledge of the properties of air has been made in our days by Lord Rayleigh and Professor William Ramsay. By careful weighing it was found that nitrogen prepared from ammonia is somewhat lighter than "atmospheric nitrogen." This was very puzzling, and led to very careful experimentation, resulting in the discovery of a new gas in the atmosphere, which the discoverers named "argon," on account of its inactivity. In addition Professor Ramsay has discovered helium, krypton, metargon, xenon and neon.

From the history of discoveries on the nature of fire and the theories concerning it, one thing stands out in strong relief, and that is that most of the work which has been done in this field is of a different nature from that done by Swedenborg. Although he made experiments himself, and drew upon those of others, Swedenborg abstracted his attention from the phenomena themselves to the causes of the phenomena, their hidden geometry and motion. His *Principia* describes the geometry and motion of the invisible things of nature, and is a statement of reasons why invisibles must be constituted in a certain way because visibles are constituted in an analogous manner. It is a theory of the nature of things which cannot be seen, based on the observation and experimental data of things which can be seen. Let us now follow the development of Swedenborg's theory of fire, first as presented in certain letters written to Eric Benzelius, Swedenborg's brother-in-law and early preceptor, and in the series of works written from 1717 to 1722; afterwards let us compare the later statements contained in the works written in 1734 and 1738 with those of the earlier period, comparing also some of the experimental results obtained by Tyndall and closing with a brief survey of the modern status of our subject.

As early as 1717 Swedenborg presented ideas of round par-

ticles in the interiors of nature, and thought that colour is produced by the modification of light in objects, that sight is caused by an undulation of the ether, and that fire is caused by a celerity of motion of something in the air or around its particles.[24] In 1718 he writes to Eric Benzelius:

I send you something new in Physics upon the particles of air and water, proving them to be round, which may militate against the philosophy of many; but as I base my theory upon experience and geometry, I do not expect that any one can refute it by arguments. . . . The use of this seems to me to enable us more thoroughly to investigate the nature of air and water in all its parts: for if the true shape of the particles is once discovered, we may obtain with it all the properties which belong to such a shape.[25]

In 1719 he writes:

What I have in hand consists, first, of a minute description of our Swedish blasting-furnaces; secondly, a theory or an investigation into the nature of fire and stoves where I have collected everything I could gather from black-smiths, charcoal-burners, roasters of ore, superintendents of iron-furnaces, etc., and upon this the theory is based.[26]

In 1720 he writes:

I have proposed to myself to examine thoroughly everything that concerns fire and metals, *a primis incunabilis usque ad maturitatem* (from the first attempts and experiments to the maturer results), according to the plan of the memorandum which has already been communicated to you. I take the chemical experiments of Boyle, Reucher, Hjarne, Simons (?), etc., and trace out nature in its 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. It seems to me that the immense number of experiments that have been made affords a good ground for building upon; and that the toil and expenses incurred by others may be turned to use by working up with head what they have collected with their hands. Many deductions may thus be made which will be of use in chemistry, metallurgy, and in determining the nature of fire and other things.[27]

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[24] Cf. *De Causis Rerum* and *Om Elden och fargornas natur; Documents concerning Swedenborg*, Vol. II., pp. 890, 892.
[25] *Documents*, Vol. I., pp. 296-7; cf. p. 299.
[26] *Ibid.*, p. 309.
[27] *Ibid.*, pp. 325-6.

The above quotations show that from 1718 to 1720 Swedenborg was engaged in studying the nature of fire and related subjects. The results of these studies are contained in a number of works written about this time which show Swedenborg's methods of work and how he laid the foundations of his *bullular hypothesis,* which received its final development in the *Principia.* As a member of the College of Mines, Swedenborg, in his duties as inspector, enjoyed abundant opportunity of studying the action of fire in the smelting furnaces, and he turned his observations to good account.

The works which present Swedenborg's theory of fire are especially the following:

1. *On the Nature of Fire and Colors* (1717);
2. *The Principles of Chemistry* (1721);
3. *New Observations and Discoveries on Iron and Fire* (1721);
4. *Miscellaneous Observations* (1722);
5. The *Principia* (1734);
6. The *Economy of the Animal Kingdom* (1738).

Swedenborg's theory of Fire, as contained in the works prior to the *Principia,* may be summed up in the following statements:

I. *Fire is the free motion of a substance or of "particles."*

II. *Flame is a phenomenon perceived by the eye on account of motion set up in the ether by fire.*

III. *Calcination by fire increases the weight of substances.*

IV. *There is a subtle igneous matter which when present among the particles of water produces fluidity, while its absence produces rigidity. This matter is the ether.*

V. *Phosphorescence is produced in a variety of ways by a motion set up in the ether.*

VI. *The Sun and Stars are fiery oceans.*

The points will now be taken up singly.

I. *Fire is the free motion of a substance or of "particles."*

The series of works which we are considering commonly speaks of fire as an element, but that the word "element" is neither used in its modern sense nor in the sense in which it is commonly used in the *Principia* is plain from the context and

also from the whole sweep of Swedenborg's philosophy. The expression "element" is evidently used in the same sense as in the *Principia,* where, in speaking of the fifth finites, Swedenborg says that "they constitute the surface of the particle of air, and supply fire with its element." [29] Compare this with the following from the *Miscellaneous Observations* (p. 108):

The sources from which the matter of fire may come have been pointed out in the preceding pages. 1. From the resolution or decomposition of air. 2. Its particles are inclosed in oily, nitrous, sulphurous substances, and in general in the small channels and pores of things. They are set free by any moving volume of the same igneous matter. 4. And they enter through the minutest pores, pass into the minutest cavities, and form bullæ, and then exhale through the larger orifices.

In the same work he says (pp. 92-3):

According to our hypothesis, then, let the particles of air be bullular, with exceedingly minute particles of fire on their surfaces as in Figs. 39 and 40, where *aaa* are particles of fire, very minute, and which we regard as not bullular, but round, and comparatively hard. But it may appear paradoxical to suppose that fire forms the crust of the air-particle, and at the same time a bulla; let us then consider the consequences of this assumption. 1. Let there be particles, similar to Fig. 39, on the surface of the atmosphere, where they are dilated, because there is no weight above them to press them into a smaller space. Hence, in the highest regions of the atmosphere, on the tops of mountains and above the clouds, we find that the air is very rare, and scarcely affords matter for respiration, or for supporting fire, and exhibits its usual phenomena in the poorest and thinnest manner: a great degree of cold is felt, flame is extinguished, menstrua do not act, and many other effects take place, according to experiment. . . . There is less fire where the particles of air are more rarefied or distended: but more fire where they are more compressed, as indeed follows from the hypothesis. . . . From the above figure of the particles it follows, that in our sublunary world there can be no flame without air; this likewise is proved by experience, for a candle goes out when the air is exhausted, and sulphur and other highly inflammable substances will not ignite at all in the vacuum of the air pump; furthermore, flame goes out gradually in very high situations. 5. In proportion to the renewal of fresh air, the flame is increased, as indeed appears from the shape of the particle. Thus if the crust of the particle of air consist of igneous matter, it follows that there is more fire when the supply of air is large, provided it be fresh, etc., etc.

[29] Part III., chap. vi (near the end).

We have here all the fundamental ideas of fire and combustion which obtain in modern times.

In the earliest work in which Swedenborg treats of fire, he presents substantially the same ideas and the same experiments. This work, written in 1717 and called *On the Nature of Fire and Colors,* says:

—That Fire consists in the elasticity, the rising [*gjasning*—leavening from yeast], and the fermentation of the atmosphere, is a proposition with great verisimilitude, since fire is nourished by the atmosphere, and it is the atmosphere which pours it out [or, exudes it],—which is what is meant by fermentation. . . . The proposition that fire and colors are caused by the activity [*hastighet*—swiftness, celerity] in the air, when it terminates in the ether, just as when water terminates in the air, or when compressed air terminates in air less compressed, amounts to the same as to say that colour and fire must consist in the outpourings of the atmosphere, or in its stronger motion.

Further references on this subject may be found in *Miscellaneous Observations,* pp. 46, 52, 53, 83, 84, 85, 87, 88, 94.

It appears that by fire Swedenborg sometimes meant heat; see *New Observations and Discoveries, etc.,* pp. 186, 189, 200 bis., 201, 204, 205.

II. *Flame is a phenomenon perceived by the eye on account of motion set up in the ether by fire.*

In the quotations under the preceding heading it was seen that Swedenborg understood the flamy quality of fire to be dependent upon the air. He says further that "flame is nothing more than the fire in hard particles which are flying off, or in fumes" (*Misc. Obs.,* p. 94), and that light is produced "by fire, whose particles are so amazingly subtle, and when undulating will cause an undulation in the rays, or a vibration in the ether." (*Ibid.,* p. 105; cf., p. 104.)

III. *Calcination by fire increases the weight of substances.*

In the *Miscellaneous Observations,* pages 101-2, Swedenborg says:

I shall show elsewhere, God willing, that the more fire a body contains, the heavier it is, and that the gravity of fire is increased by the quantity; or what amounts to the same thing, that fire is far more ponderous than ether, and consequently that the addition of fire is not the way to obtain levity (cf. p. 54).

IV. *There is a subtle igneous matter which when present among the particles of water produces fluidity, while its absence produces rigidity. This matter is the ether.*

A good general statement of Swedenborg's conclusions on this matter is contained in the *Miscellaneous Observations* (pp. 94-95), as follows:

> We find that water possesses the remarkable property of great fluidity when it is warm, and of great rigidity when cooled beyond a certain period; in fact, that the same particles present the phenomena of solidity as well as of the greatest mobility. No one, I presume, can deny that this change is owing to the presence of an interfluent matter; for as often as heat is applied, the ice thaws, and its particles become fluid; as happens when it is placed over the fire, or during the spring and summer: on the other hand, whenever the fluid is deprived of its fire, the particles collapse into a fixed position. This fact amply proves that the fluidity of the particles of water is caused by some very subtle igneous matter of great mobility, interfluent between them, which separates them from each other, and prevents them from becoming fixed, holding them floating in its bosom in a state of suspension, and communicating its own mobility to them.

In the *Principles of Chemistry* (p. 13) it is stated that the particles of water are in their natural position "when the subtle igneous matter flows between them;" also (p. 17):

> Since the particles of water are of a round shape, and their surfaces are occupied by round particles of a smaller kind, similar in nature, but differing in diameter and magnitude; and since, from the nature of fire, its subtle matter penetrates everywhere among the interstices of water, separates one particle from another, and thus gives a certain motion to each; (but when this heat flies off, the particles become spontaneously fixed and crystallized, as will be seen in the Theory of Ice); hence, if the forms of the particles be taken into account, as well as the motion of the subtle fire, it will be clear that the particles of flowing water are arranged in the natural, or fluid quadrilateral pyramidal position.

Now heat is a predicate of the ether. In the same work (p. 86) the subtle matter is said to be "susceptible of dilatation and compression," also a predicate of ether (cf. p. 199 and *Misc. Obs.*, p. 96 bis.).

See further *Principles of Chemistry*, pp. 26; *Miscellaneous Observations*, pp. 95, 96, 82, 83 bis. It should also be noted that Strutt, the translator of the *Principles of Chemistry*, came to the conclusion that by "the subtle igneous matter so fre-

quently mentioned in the chemical theory" Swedenborg meant "nothing more than the ether" (p. xxxv).

But that there may be no room for doubt a quotation will be made from the *Lesser Principia,* paragraph 166, which clearly defines Swedenborg's conclusions on this point:

The fluidity of these particles of the tenth kind depends upon the fluidity of the matter of the 7th and 4th kinds, which flows about.

Among these particles of the 10th kind there flows interruptedly the matter of the 7th and fourth kinds, and because these kinds of particles are gifted with the greatest fluidity, hence also the particles of the 10th kind owe their fluidity to them; for by themselves they cannot be fluid, for they are ponderous and heavy, and have an envelope which does not yield, so that they cannot be compressed, but remain in their dimension continually; hence, since they are heavy and moreover cannot be compressed and consequently cannot be yielding to whatsoever pressure is given them, as the particles of the 9th, 7th, 6th, 4th, and 3d kinds, they cannot be fluid by themselves, but have their fluidity from the circumfluent matter of the 4th and 7th kinds.

From these things may be seen the difference of motion in the particles of the 9th and 10th kinds; the former have a yielding envelope, which has elasticity, which reacts in the degree that it is acted upon, which admits tremulation into itself, but the latter because the envelope does not yield, nor admit tremulation, nor react in a similar and elastic manner as the former, hence there is a great difference of motion; and whatever motion they have, they owe it to the circumfluent particles of the 7th and 4th kinds; the greater motion there is in these, so much the greater is the motion in the particles of the tenth kind.

Now when it is known that the 4th kind of particles is the first element of the *Principia* partly compressed, also that the 7th kind of particles is the ether partly compressed, it at once becomes clear that the interfluent igneous matter on which the mobility of water depends, as stated by Swedenborg in 1721 and the following years, is the ether.

V. *Phosphorescence is produced in a variety of ways by a motion set up in the ether.*

It will be unnecessary to repeat all the instances given by Swedenborg of animals, minerals, effluvia, etc., which produce the interesting phenomena of phosphorescence, but only to quote his conclusion:

According to the bullular hypothesis, it follows that light is nothing more than undulation of the rays, or than vibration of the ether. It has

already in some measure been shown that the rays undulate when the ether vibrates. In this fact we have the explanation of phosphorescence and of the ignis fatuus, both in cold substances and hot, in dry as in moist, etc. (*Misc. Obs.*, p. 104).

In this connection it may be noted that Swedenborg ascribes the phenomena of light to the activity of two ethers, the magnetic and electric. This is of especial interest when brought into correlation with the electro-magnetic theory of light.

Swedenborg's statement that phosphorescence is caused by the breaking up of salt particles in the sea has been criticized, and the true explanation of this phenomenon has been ascribed to living animalcules. Now there can be no doubt that phosphorescence is caused by such animalcules, and that a good deal is known about them; but this in no way conflicts with Swedenborg's general theory. The peculiar electrical phenomena and the production of ions attendant upon the electrolysis of salts in solution may throw light on this subject. It should be noted that the salt particles spoken of by Swedenborg are not crystals, but molecules. This subject needs careful investigation; the last word about it has by no means been said.

VI. *The Sun and Stars are fiery oceans.*

Swedenborg, in the *Miscellaneous Observations* (p. 28), speaking of the primeval matter of the earth, mentions "the fire oceans such as the sun and stars," and elsewhere he speaks of "solar fire" and "the fiery oceans of the world" (p. 117). Similar statements are to be found in the *Lesser Principia.* From this it may be seen that even at this early date Swedenborg conceived of suns as being large fiery spaces, a distinguishing feature of the *Principia.*

You will notice that the arguments, quotations and references adduced above in support of the positions advanced do not depend upon Swedenborg's later writings, but upon those written prior to the *Principia* and the physiological works. The reason for this manner of presentation is that the objection has been made that it will not do to interpret the earlier works by the later ones. Now the writer does not at all agree to that proposition; but in order to meet such objection it was decided to let those earlier works interpret themselves; for they are

quite capable of doing so; they can stand upon their own feet and need no props. If it be admitted that the positions advanced have been proven, and also that, as will presently be shown, the later works present the same views, it must also be admitted that in the present case Swedenborg's works are substantially, although not verbally, a unit; which would be a fundamental admission, since his theory of fire involves his whole philosophy. The proposition that Swedenborg's philosophical system is substantially a unit will be still more clear when the *Lesser Principia* shall have been properly studied, for it is evidently the central link connecting Swedenborg's earlier with his later productions.

In the *Principia* and the *Economy of the Animal Kingdom* Swedenborg restates his theory of fire, with greater fullness will now be shown to be in agreement with those advanced in the later works.

I. *Fire is the free motion of a substance or of "particles."*

While the subjects treated of in the *Principia* are largely on the same plane as those treated of in the earlier works, the terminology is quite different. Instead of "bullæ" or "particles," constant mention is now made of the finites, actives and elementaries defined in the earlier part of this paper. The five finites, successfully compounded from the first, when in a free local motion, are called actives. In the *Principia,* when treating of finites, actives and elementaries, Swedenborg says:

> We admit of entities only of a three-fold degree, namely, Finites, Actives, and those which are compounded of the two, namely, Composites or Elementaries. With respect to Finites we affirm, that one is generated by the other; and that all the Finites of the genus thus arising have the greatest possible similitude one to the other; and differ only in degree and dimensions. Hence the fifth Finite is similar to the fourth; the fourth to the third; the third to the second; the second to the first; the first to its own proper Simple: so that he who knows the nature of one knows the nature of all. In the same manner we affirm, that Actives have the greatest possible similitude the one to the other, that the fifth, fourth, third, second, and first Active are all of the same nature; differing *only in dimension and degree,* in the same way as Finites. That Elementaries also are similar one to the other, since they are compounded of the Finite and Active; the Finites occupying the superficies, the Actives occupying the interiors; that hence the first,

second, third, fourth, and fifth Element are all similar one to the other; so that he who knows the nature of one knows the nature of all.

When it is known in addition that the local activity of the five finites produces five kinds of fire, differing in subtlety, the following passage from the *Economy of the Animal Kingdom* will be understood:

Of the circumambient universe or world, there is a series of substances simply derived from the first substance by the order of succession. The second series is that which the same substances constitute when left to themselves and their own nature, or when endowed with the liberty of gyrating, whence comes fire, both solar and inferior elementary fire.

A more particular treatment of the nature of fire is found in n. 84 of the same work:

That *fire*, glowing and luminous, arises from the disengagement of the parts of the auras, and from the excitation of the parts thus liberated into their natural gyration; and that *flame* is the smoke or soot which consists of so many as it were molecular burning coals, or that it consists of small volant ignited particles, can be shown to ocular demonstration by experiment: and as the knowledge of one opposite may be derived from the knowledge of the other, we may hence deduce the nature of *cold*. It may thus be seen that nothing real exists in heat, fire, flame, or cold, since they are only the affections and qualities of trembling and gyrating substances, or on the contrary, of such as are quiescent.

In Swedenborg's *Corpuscular Philosophy in Brief* the theory of fire and substance is restated in the following compact form: "1. There is a first substance of the universe with others similar to it in order. 2. There is an activity of this substance, whence is fire."

Compare Swedenborg's theory of fire and flame, and also that of Mayow and his successors given above, with the following from Tyndall's great work, *Heat, a Mode of Motion:*

Most of you know the scientific history of the diamond, that Newton, antedating intellectually the discoveries of modern chemistry, pronounced it to be an unctuous or combustible substance. Everybody now knows that this brilliant gem is composed of the same substance as common charcoal, graphite, or plumbago. A diamond is pure carbon, and carbon burns in oxygen. I have here a diamond, held fast in a loop of platinum wire; I will heat the gem to redness in this flame,

and then plunge it into this jar, which contains oxygen gas. See how it brightens on entering the jar of oxygen, and now it glows, like a little terrestrial star, with a pure white light. How are we to figure the action here going on? . . . You are to figure the atoms of oxygen showering against this diamond on all sides. . . . Every oxygen atom, as it strikes the surface, and has its motion of translation destroyed by its collision with the carbon, assumes the motion which we call heat: and this heat is so intense, the attractions exerted at these molecular distances are so mighty, that the crystal is kept white-hot, and the compound, formed by the union of its atoms with those of the oxygen, flies away as carbonic acid gas. . . . It is to the clashing together of the oxygen of the air and the constituents of our gas and candles that the light and heat of our flames are due. I scatter steel filings in this flame, and you see the star-like scintillations produced by the combustion of the steel. Here the steel is first heated, till the attraction between it and the oxygen becomes sufficiently strong to cause them to combine, and these rocket-like flashes are the result of their collision. It is the impact of the atoms of oxygen against the atoms of sulphur which produces the flame observed when sulphur is burned in oxygen or in air; to the collision of the same atoms against phosphorus are due the intense heat and dazzling light which result from the combustion of phosphorus in oxygen gas. It is the collision of chlorine and antimony which produces the light and heat observed where these bodies are mixed together; and it is the clashing of sulphur and copper which causes the incandescence of the mass when these substances are heated together in a Florence flask. In short, all cases of combustion are to be ascribed to the collision of atoms which have been urged together by their mutual attractions.

Swedenborg uses similar language when describing the active motion of finites, herein anticipated the modern theories of combustion and the nature of oxygen and related substances. We will close this section by quoting the important definitions of fire and flame given in Part II., Chap. VII., of the *Principia:*

The actives themselves, which constitute the bright and living fire, can in no way impede the fluxion or gyration of the magnetic element; as will be shown in our theory of the fourth and fifth active. For the fire, which is luminous and acts by flame, consists in the motion of actives highly compounded; which in the volume of the particles of the most subtle magnetic element are capable of perfectly performing their gyres without restraint or retardation; just as masses can, or highly compound bodies, in the air or ether.

II. *Flame is a phenomenon perceived by the eye on account*

of motion set up in the ether by fire. That this statement, as also the one under V that *Phosphorescence is produced in a variety of ways by a motion set up in the ether,* contains the statements of the *Principia* on these subjects, will be evident on a study of Part II., Chap. VII., on Fire, where, among a great many important statements, is found the following:

That the actives of the fifth finite may in their space urge an ethereal volume into such a high degree of motion that this volume may give rise to modifications which have the appearance of light.

The actives of the fifth finite set in motion the fourth finites, which form the envelope of the ethereal elementary, and since the eye is the organ of the ether, when this motion is sufficiently strong, the eye sees a light. This subject, especially in reference to phosphorescence, is further treated in Part III., Chap. V., n. 21, of the *Principia,* as follows:

Motion diffused from a given centre through a contiguous medium (*per contiguum*) or volume of particles of ether, produces light. . . There are corpuscles which resemble a species of effluvia, and which are so small as to be enabled to move only a volume of ether, but not a volume of air; and these, if spontaneously moved, excite light to a certain distance. If they are not spontaneously moved, but are put in motion by means of the tremulation of the parts in any hard body in which they reside; in this case also light is excited, and in like manner electricity, so long as the tremulation continues. That the motion of the ether, when diffused in all directions from a given centre, or when diffused to equidistant circumferences, occasions the representation of light, is evident from what we have stated; for ether, when put into a general motion or nisus toward the peripheries, occasions itself to be reflected from every object it encounters according to its angle of incidence, and forms as many centres as there are objects to meet it. Hence arises a representation of the species and effigies of things by light; a representation which could not be effected unless the contiguous volume of ether were put into the state of general motion, or effort to general motion, which we have already mentioned. . . . Since therefore local motion, or the effort to local motion, in the ether, is the cause of light, and light is the cause of the species of things represented to the eye, it follows that light may arise from either warmth or cold as a cause.

With respect to phosphoric or meteoric light, as also with respect to electricity, we may observe that both proceed from the same source; namely, from the ether either put into a state of local motion, or else in an effort toward it. The *ignis fatuus,* as it is called, is only a motion

dispersed through the volume or contiguous area of the ether, without any rigid extension of its particles. For if there be any corpuscles so small as to move only the ether, like the corpuscles or effluvia for instance proceeding from the magnet, and which move only the second or magnetic element, then I would observe, that, by means of the motion of these corpuscles or effluvia, light exists; and if these corpuscles circumgyrate, whether spontaneously or not, provided there be some cause or other to occasion circumgyration, they immediately put the ether in motion and cause light, without the expansion of any ethereal particle; just as is the case with air, which may be moved in volume and contiguously to a distance without the expansion of any particle, and may thus produce sound. The *ignis fatuus* therefore is a local motion of the ether produced by the motion of certain smaller corpuscles, so that the cause of warm and cold light is one and the same. The corpuscles or effluvia we have mentioned may be put into a gyration and motion either spontaneously, that is to say, *ex se,* or from some internal cause; or else by the tremulation of some hard body, in which they are and from which they proceed.

IV. *There is a subtle igneous matter which when present among the particles of water produces fluidity, while its absence produces rigidity. This matter is the ether.*

The truth of this proposition was established above by evidence drawn from the earlier works. A similar course will now be taken with the later works, where Swedenborg himself calls the matter in question "the ether," and moreover defines his earlier statements. In the *Principia,* Part III., Chap. IX., n. 2, he says:

That particles of water, or finites of this kind, cannot move one among the other like elementaries, unless there be interfluent elementaries to carry these particles with them, and thus set them in motion. That the particles of water thus owe their motion and fluidity entirely to the interfluent ether. That æqueous particles are the more mobile and fluid, in proportion as the circumfluent ethereal particles are the more mobile, extended, and rigid; and the less mobile and fluid in proportion as the circumfluent ethereal particles are the less mobile, extended, and rigid, but as it were flaccid. That in proportion to the want of mobility and tension in the ethereal particles, the æqueous particles are torpid and languid, uniting and concreting into a hard mass. That finites of this kind or aqueous particles owe their fluidity or mobility to the interfluent ether, which in its own nature is mobile because it is elementary, is evident *a priori,* or from the principles already laid down; for the particles of water do not possess an even (*levi*) and uniform surface, but one which commonly coheres in a state of

contact with those which are in proximity with it; neither do they possess a yielding elastic surface; for which reason they cannot reciprocally act upon each other by their force of elasticity and yieldance, and thus become similar and uniform in every state of motion and compression; nor can one particle apply itself to another in the manner of elementaries, which cannot become reciprocally fixed and colligated; but still in whatever motion they may be, they are, solely by reason of their change in dimension (their figure being in other respects exactly preserved), enabled to maintain a mobility. For when the ether is in its most mobile and rigid state, that is to say, when its temperature is warmest, it renders the water most highly mobile, and makes it undulate and boil from the top to the bottom. The ether moreover circulates itself in water, forms itself into vapours, and under the appearance of air continually seeks the surface, and ejects itself in the same manner as when steam carries a body upwards. Still in a perfectly quiet and serene state of the ether, when its particles, from being flaccid as it were, are unable to move the aqueous particles from one place to another or to keep them separate, it is impossible but that the aqueous particles should become confluent and attach themselves one to the other; the ether itself partly escaping, inwardly glomerating partly into vapour, partly into larger particles, and by the solution of its flaccid and highly yielding surfaces inclosing itself like air and variously occupying the spaces within, from which it is unable to escape as long as it is between its own larger or else congealed vaporous surfaces of the water. This is evident *a posteriori*, because when there is no motion between the ethereal particles, the æqueous particles coalesce into a certain hard and material mass, from which they cannot be liberated except by the ether being put into motion and a state of rigidity. The essentials, therefore, and numerous elementary qualities which we have observed in the wave and current of our finites, we must not attribute to their own nature or virtue, but to the interfluent element. . . . It appears then that we cannot consider the aqueous particle as any other than a certain hard body rendered fluid by an extremely small degree of heat; for some hard bodies there are which become liquid by a smaller, some by a larger and more intense degree of heat: water commonly yields to the smallest degree, which softens its rigidity and causes it to flow as a liquid.

That by the "subtle fiery matter" of the earlier works is meant the "ether" of the later ones is evident from a comparison of n. 75 and the context, in the *Economy of the Animal Kingdom;* with the statements of the *Principles of Chemistry* respecting oil. In the *Chemistry* it is stated several times that the "subtle fiery matter," or the "subtle matter," when surrounded by ramenta of the fourth kind of hard material, con-

stitutes oil. In the *Economy* the same thing is stated, and the "ether" is said to occupy the internal cavity. Nothing could be more conclusive.

In order that it may be seen how modern experiment bears out Swedenborg's theories of ice, water, and ether, a quotation will now be made from Tyndall, where, in analyzing the process by which water is frozen, by sending a beam of light through a block of ice and watching the stages of melting, he says:

> And now I have to draw your attention to two points connected with this experiment, of great minuteness, but of great interest. You see these flowers by transmitted light—by the light which has passed through both the flowers and the ice. But when you examine them, by allowing a beam to fall upon them and to be reflected from them to your eye, you find in the centre of each flower a spot which shines with the lustre of burnished silver. You might be disposed to think this spot a bubble of air; but you can, by immersing it in hot water, melt away the ice all around the spot; and the moment the spot is thus laid bare, it collapses, and no trace of a bubble of air is to be seen. *The spot is a vacuum.*

Swedenborg would have said that the space was filled with ether.

VI. *The Sun and Stars are fiery oceans.*

This is a familiar concept of the *Principia,* where the first and second actives, or the first two degrees of fire, are said to constitute solar spaces.

From what has been said it may be seen how erroneous is the opinion of those who suppose that Swedenborg's theories of fire and air were exploded by Priestley's discovery of oxygen gas. Only a very superficial examination could lead to such a conclusion; we would draw the attention of all earnest students to the development of Swedenborg's *bulbular hypothesis,* and especially its final statement in the *Principia.* Swedenborg's theory of fire makes its first appearance as activity (*hastighet*) of the atmosphere, then it is the motion of a particle on the surface of the air particle, it is the "element" fire, and finally it makes its appearance as the fifth finite and the other finites in local activity, one of the fundamental concepts of the *Principia.*

Limitations of time will allow only a reference here to the progress which has been made in our subject, both experimentally and theoretically in recent years. The action of electricity and magnetism on flames, the phenomena of vacuum tubes,[30] the questions relating to the temperature of ignition and experiments on light, color and heat open up a wonderful vista of investigation in which will be found interior correspondences.

A great number of the phenomena of fire, flame and combustion may be observed in the burning of a candle, and it has been well said that "to understand the occurrences included in the everyday process of burning a candle is to understand the whole of chemistry and no small part of physics." [31] Some of the principal things to be observed are, that the candle is composed of hydrogen and carbon. These substances when sufficiently heated combine with the oxygen of the air and produce water and carbonic acid gas. Experiment shows that the flame of a candle is composed of several parts. When the substance of the candle is drawn up by the wick by reason of the heat [32] it is converted into gaseous hydrocarbons; these constitute a zone by themselves. Surrounding this zone is another, where a partial combustion of the gases takes place, and on the outside is still another where combustion is complete. If an inflammable substance be inserted into the first zone it will not burn, because the oxygen of the air is not present; but if a tube be inserted in which the gaseous hydrocarbons may be led away they may be lighted at the other end of the tube. The middle zone is the one where light is principally produced and this is ascribed to the presence of particles of carbon, heated to a white heat; a platinum wire in flame, and the lime-light, present similar phenomena. In the outmost zone, where combustion is

[30] A carbon monoxide Geissler tube, with an electric discharge passing through it, presents an appearance strikingly similar to that of a flame of carbon monoxide.

[31] *The Chemistry of Fire, by* M. M. Pattison Muir, M. A.; Methuen & Co. 1893.

[32] Van 'T. Hoff says that "reaction occurs more or less rapidly below the temperature of ignition" and gives as instances phosphorus, phosphine, arsenic, sulphur, hydrogen, hydriodic acid, carbon monoxide, ether and paraffin. See his *Studies in Chemical Dynamics*, Chemical Publishing Co., Easton, Pa., on the *Temperature of Ignition*, pp. 136-142.

complete, there is not so much light, but a great degree of heat. That heat depends upon the relative completeness of combustion may be seen from the Bunsen burner.

Besides flames produced by the combination of hydrogen and carbon and many other substances, with oxygen, there are others produced by the combustion of hydrogen and antimony in chlorine, and of strips of copper in sulphur vapor.

The state of investigation at the present time in the field which has been examined in this article is a most interesting one, and when the methods of analysis and the appliances in use today shall have been still further perfected the investigator may expect to determine by experiment the accuracy of the numerous positions which have hitherto been advanced by scientists and philosophers as probable theories and hypotheses.

ALFRED H. STROH.

NOTE AND COMMENT.

Owing to the limited space at our disposal, two of the reviews under this head have been carried over from last April. The fact that this issue and the preceding both exceed the number of pages that have been regularly provided for sufficiently indicates the constraint under which the magazine is laboring.

The following note was received from the Secretary of the Association too late for publication in July.

"The original Swedish of Swedenborg's earliest poem (see minute 263 of proceedings of Swedenborg Scientific Association) will shortly appear in *Morning Light*. Mr. Hyde writes that all other particulars will be found in his Bibliography of Swedenborg's works, which he hopes to complete in the near future."

In accordance with this promise the original was published in *Morning Light* for July 26.

A translation of a lecture delivered before the Seventy-third Session of German Scientists and Physicians in Hamburg, by Dr. Max Neuburger, of Vienna, a translation of which was also read at the last annual meeting of the Swedenborg Scientific Association (see minute 319 in *The New Philosophy* for October, 1902), was published in *The New Church Messenger*, August 13 last. In the issue of that paper for August 27 the following information was added:

"Dr. Max Neuberger, Privat-docent of the Vienna University and editor of the Vienna Journal of Medicine, the author of the address