The Transcendental Part of Chemistry

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Introduction

This is an essay on chemistry and its connection with world views in the nineteenth century, chiefly in Britain; where we find throughout the whole period a surprisingly close and shifting contact between chemical theories and philosophical positions, often explicitly presented. The great problem for chemists was the nature of matter. Some, but relatively few until the last quarter of the century, opted for an atomic theory. The standard chemical atomic theory was that of Dalton; who posited billiard-ball atoms, different in kind for each chemical element. Many of his contemporaries were unhappy with these atoms, which seemed to explain little except the definite composition of compounds. How the juxtaposition of oxygen and hydrogen atoms could produce water, differing exceedingly in its properties from these constituents, was a mystery; and it was not until after the middle of the century that chemists, following the hypothetico-deductive method proposed by Laurent, were able to test propositions about the structure of molecules.[1]

Dalton's contemporaries at the outset of the nineteenth century had recognised that an atomic theory must be transcendental; that is, that if it be assumed, then the laws of chemistry will follow deductively from it — but that the laws do not entail an atomic or any other theory of matter. That is why this essay is called The Transcendental Part of Chemistry. It was not until the beginning of the twentieth century, with the work particularly of Perrin and Einstein on Brownian movement, that independent lines of reasoning began to converge upon atoms, making it implausible to doubt their real existence. At the same time, the complex nature of the atom was revealed in the researches of J.J. Thomson on cathode rays, and of Mme. Curie and of Rutherford on radioactivity.

These last discoveries seemed to confirm what many of the greatest chemists of the nineteenth century had believed; that our simple and harmonious world was not constructed of atoms of numerous different kinds, but simply of particles of matter all of the same kind. In their different arrangements, these particles — of which the more-liberal world-definers allowed that there might be two or three kinds, rather than just one — gave rise to all the different substances which we find in the world. A belief in the unity, or very restricted diversity, of matter went back to the atomists of antiquity; and was prominent in the writings of Boyle and of Newton, who still enjoyed nearly a century after his death in 1727 an immense authority in the sciences. It is the survival of this belief from the time of Boyle to that of J.J. Thomson that we shall be especially following in this book.

We shall therefore be looking at chemical theory, and also at the background beliefs characteristic of chemists during the nineteenth century in particular. For the doctrine of the unity of matter is not really a theory; as we shall see, there were a number of theories, which were testable in various degrees, which were compatible with it. When they were falsified, as most of them were, or at least found to be in need of considerable modification, the doctrine nevertheless survived. To look at the metaphysical positions and wide-ranging theories of chemists is not to see the whole of chemistry, or even necessarily its most important part. As well as a transcendental part, which belongs to the realm of intellectual history, chemistry has a practical and a social part. The nineteenth century saw the rise of the chemical industry, which was the first science-based industry requiring a stream of trained men to work in it; and it also saw a transformation of chemical apparatus, so that chemists at the end of the century could readily carry out processes impossible to Dalton's contemporaries, and could do their analyses with very much smaller quantities. It was also during this period that chemistry emerged as something like a profession, with its own professional societies in Britain — the Royal Institute of Chemistry, and the Society of Public Analysts — as well as its learned society, the Chemical Society of London. At the beginning of the century, every chemist had to make his way as best he could; by the end, there was a regular system of chemical education, and a career structure for trained chemists.[2] This must not be forgotten in our story, but it is not our primary concern.

We are involved here in intellectual history. The Royal Institution in London, where Davy and

Faraday did their work, can be seen as a centre where landowners interested in improvements gathered to exchange ideas about stock and crops, and to hear lectures about methods of tanning or about fertilisers.[3] We shall simply be concerned with it as the locus of Davy and Faraday; for this is an essay in what is sometimes called internal history of science. No single perspective gives a complete view; but it is worth concentrating on one aspect of science if we can thus make sense of various episodes by close study of texts, even though we have to neglect complementary perspectives. We shall not however look simply at chemistry. Its boundaries have never been long constant, and at the beginning of the nineteenth century for example chemistry took over electricity following Volta's discovery of the battery, and soon afterwards took over mineralogy too as a branch of inorganic chemistry and crystallography. By the end of the century, electricity had been given up to physics; and many physicists believed or hoped that with their kind of atomic theory they would soon take over the theory of matter from chemists. Ever since the days of Newton, there had been those who hoped to reduce chemistry to mechanics; while there had also been upholders of a distinct chemical philosophy, who urged the autonomy of their science and pointed to the futility of many physicists' excursions into chemistry. Some of these pointed to parallels between chemistry and natural history; and in the last quarter of the nineteenth century chemists preoccupied with classifying the elements did indeed turn their attention to Darwinian biology.

We cannot confine our attention simply to science either, for the boundaries of science are not sharp and the sort of background beliefs with which we are concerned are not derived simply from experiments. Men making voyages in strange seas of thought, or wrestling with nature in the dark, have to feel their way as best they can. Nor shall we be confined to a single perspective, for this seems to be a story that cannot be simply told chronologically. We shall begin with two chapters to set the stage; leading up to about 1800, when Lavoisier's definition of a chemical element had become accepted despite its curious negative — empirical form — for an element is a substance that cannot be decomposed, and therefore this year's element might next year have to be removed from the list if somebody invents a new technique of analysis.

In the following chapters we follow the schema of Auguste Comte, for whom knowledge progresses as a theological stage gives way to a metaphysical, which in its turn gives way to a positive or really scientific stage. This is a thesis about which the historian ought to be completely agnostic, for he must not impose a thesis upon his evidence; and the Comtean schema here is simply a way of identifying three viewpoints from which distinct but overlapping perspectives on the doctrine of the unity of matter can be displayed.

The first of these is to see it in relation to materialism. Especially in Britain, the outbreak of the French Revolution and its development into the Reign of Terror, was attributed to the teachings of men such as Diderot, Voltaire, and d'Holbach; who had urged that there was nothing in the world but matter, and no room for human souls or for free choice. On this view, chemistry like everything else could be reduced to mechanics. Among Davy's great achievements in the early years of the nineteenth century, in his own eyes and in those of contemporaries, was to show that mechanics was not enough. Chemistry was a science of immaterial powers such as electricity as well as of matter; the same matter could form a diamond or a lump of charcoal, and it was the forces arranging the matter which determined its properties. Matter, on this analysis, was brutish and inert, and there was no real reason to suppose that there were different kinds of it.

The next perspective is to look at the fourth state of matter, a topic which features prominently in the writings on cathode rays of the great free-lance chemist William Crookes, writing in the last quarter of the nineteenth century. He got the idea that all matter might be put into a fourth state, as different from gases as gases are from liquids, from Faraday's early writings. In fact, it was a common-place in the early nineteenth century, being derived from Newton's corpuscular theory of light; for in one of the Queries at the back of his _Opticks_, Newton had asked whether all matter might not be converted into light, clearly expecting the answer 'yes'. Crookes absorbed from Faraday a firm belief in the unity of nature, and in the light of this metaphysical view and his doctrine of a fourth state, he interpreted the data from his cathode-ray tube and his spectroscope as indicating that the various chemical elements were all really different arrangements of particles of one prime matter.

The next chapters deal with the 'positive' phase of the inquiry; beginning with Davy's work on chlorine in which he demonstrated its analogies with oxygen. As more elements were discovered in the first half of the nineteenth century, it became increasingly implausible to suppose that such similar substances as sodium and potassium, or chlorine and iodine, were really quite irreducibly different. In chapter 6, we consider Prout's Hypothesis that all elements were composed of hydrogen; an attempt to move from analogical arguments to quantitative ones, for if it were true all atomic weights should be multiples of that of hydrogen. In the event, this turned out not to be true; but many were close to whole numbers, and although apparently refuted Prout's hypothesis lingered on throughout the century. In the next chapter, we see arguments derived from crystalline and molecular structures, which indicated that elements might be like the radicals of organic chemistry, stable groupings of atoms of only two or three kinds.

The eighth chapter is concerned with the coming of energetics into chemistry in the second half of the nineteenth century, and then with the chemical calculus of Benjamin Brodie, an attempt to rid chemistry of hypotheses which was in fact received as an argument for the unity of matter. Throughout these four chapters we shall meet attempts to achieve transmutations, which sometimes seemed to have been crowned with success, but which always turned out in the end to be false. The doctrine of unity of matter remained as potent as ever, despite these falsifications; for chemists were not so hard-headed as to give up hope of demonstrating the simplicity and harmony of nature.

The ninth, and last, chapter is concerned with chemical taxonomy; with the success ultimately in finding, in the Periodic Table, a system of classification of the chemical elements. Since this was achieved some ten years after the Origin of Species had come out in 1859, it was not surprising that the Table was interpreted in an evolutionary manner. Transmutations might not now be possible, but it seemed more than probable that all the elements were in some sense descended from hydrogen. The plausibility of this view became apparent with the researches of the atomic physicists around 1900, with their atomic models composed of protons and electrons. Belief in the unity of matter, held through thick and thin by chemists in the nineteenth century, seemed vindicated; and no doubt it was because of this background of thought that Rutherford's interpretation of radioactivity as transmutation found surprisingly ready reception – it was just what many chemists had been hoping for, and indeed asking for in Presidential Addresses and similar public occasions. Our story then comes to an end, for the transcendental part of chemistry has turned into atomic physics.

NOTES

1. J.H. Brooke. "Laurent, Gerhardt and the Philosophy of Chemistry", Hist.Studies Physical Sciences, VI(1975) 405-30.

2. C.A. Russell, N.G. Coley, and G.K. Roberts, Chemists by Profession (London,1977).

3. M. Berman, Social Change and Scientific Organization: the Royal Institution 1799-1844, (London,1978).

Hypotheses, treated as mere poetic fancies in one age, scouted as scientific absurdities in the next — preparatory only to their being altogether forgotten — have often, when least expected, received confirmation from indirect channels, and, at length, become finally adopted as tenets, deducible from the sober exercise of induction.

M. Faraday, Lectures on the non-metallic elements,
J.Scoffern, (ed.)
1853, p.23.

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The Is-Ought Question

A COLLECTION OF PAPERS ON THE CENTRAL PROBLEM IN MORAL PHILOSOPHY

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various denominations, and gentlemen of independent means, as much as by such professors of chemistry as there were.[2] Such men tended to be interested in the broader aspects of their science, and anyway could not find a large audience of narrow professionals for highly technical papers. The second point is that the pursuit of knowledge for its own sake, which we tend to take for granted as the basis for theoretical science, did not seem quite respectable until remarkably recently. The Orientalist Sir William Jones, and the neoplatonist Thomas Taylor,[3] who sought to restore the worship of the ancient gods in the England of Arkwright and Watt, proclaimed themselves devotees of truth, prepared to go wherever it might lead; but in studies of nature some further motive seems usually to have been expected. One should wish to improve the lot of one's fellow men, as the founders of the Royal Institution and the Mechanics' Institutes did; or going beyond this 'vulgar utility' — as Davy called it — one could use the science as a basis for a world-view.[4] The study of nature has always had its devotees; but a science that can cast light upon nature, man, and God cannot but be of immense importance and general interest. In examining the transcendental part of chemistry, therefore, we shall not be simply resurrecting that part of the science which dealt with entities which are not directly observable, but will be seeking to view chemistry in its relations to philosophy and theology.

This may seem an unlikely light in which to view chemistry; we know that astronomy, at least from Galileo, through the controversy between Leibniz and the Newtonian Samuel Clarke, to Laplace, raised such questions; and so did biology, most notoriously in the Darwinian controversy. Chemists, on the other hand, do not appear likely to provoke denunciation, nor merit commendation from the pulpit, nor to find their discoveries enshrined in poetry or employed as illustrations in works of philosophy. It was not always so; around 1800, great audiences flocked to hear lectures on chemistry, and tickets changed hands at inflated prices on the black market. These crowds did not simply go to see spectacular demonstration-experiments, though these were undoubtedly an attraction; they went to learn some natural – or chemical – philosophy. The sciences of chemistry and electricity, which at this time were closely linked through the discoveries of Galvani and Volta, promised to disclose the inner structure of matter and cast light upon the nature of the mysterious powers – chemical affinity, heat, light, electricity, magnetism, and gravity – by which matter was arranged into the various bodies which we see, and endowed with motion. Schelling and Coleridge were among those who took an immense interest in chemistry; and Goethe's novel Elective Affinities applied to marriages the dynamical theory which Bergman had developed to account for double-decomposition reactions in the inorganic realm.[5]

There were at least two features of the science which made it particularly attractive. The first was that it was theoretically incoherent. There was relatively little agreement upon chemical theory, though this made surprisingly little difference in the practical part of the science with which the multi-volume Systems of Chemistry of about 1800 are distended. Unless one was a chemist, there was no need to wade through such treatises on advanced cookery; one could instead take an interest at once in controversy. The Phlogiston theory had received a heavy blow from the researches of Lavoisier; but it was not dead, and there were widespread hopes and fears until at least 1810 that Davy would restore it and overthrow the French doctrines. The Newtonian dynamical theory, according to which chemistry was to be quantified as astronomy had been by measurements of forces, had led to studies on elective affinities by Bergman, by Berthollet, and by Thomas Young among others; but it was now showing signs of collapse as Dalton's statical atomism began to achieve a quantification of chemistry in terms not of forces but of weights.[6]

One way of interpreting the history of chemistry through the nineteenth century is as a struggle between the dynamical Newtonian atomism and the Daltonian chemical atomism. Berzelius' dualistic theory of chemical combination was a first attempt at a reconciliation; but it broke down when confronted with the data of organic chemistry. The work on molecular structure by Kekulé and his school represents the great triumph of Daltonian atomism; but J.J. Thomson's paper on cathode rays, which he interpreted as composed of corpuscles, put Newtonian atomism back in the forefront. While Dalton proposed irreducibly different atoms for each chemical element, requiring therefore that the world was composed of many different building-blocks; Newtonians believed in one prime matter, defined in terms of its mass and not of its chemical properties, which was arranged into different bodies by powers which it was the duty of natural philosophers to investigate. Both sides held that their world view was simpler; while others agreed, following Lavoisier, that any atomic theory was bound to be a matter of metaphysics, and that the chemist's task was not to arrange hypothetical particles but to discover facts and laws connecting them.

If there was considerable doubt then as to how the facts of chemistry should be interpreted, there was equal uncertainty as to their significance. This brings us to the second attractive feature of chemistry; that it promised to confirm or refute the doctrine of materialism. From at least the time of Hobbes, it had been feared, particularly in Britain, that the adoption of materialism must lead to immorality and civil disorder, or at best to a cold selfishness; the events in France as the Revolution led to the Reign of Terror and the Napoleonic tyranny served to confirm these melancholy predictions. By 'materialism' writers of the eighteenth century did not mean the theory denounced from pulpits in our day, that more possessions will bring happiness; but the doctrine that only matter existed,[7] and that there was no such thing as immaterial substance. Man hence had no immortal soul, and so there was no reason why he should not make himself comfortable.

More seriously, if matter was all that existed, it must have inherent in it the powers by which it was moved and arranged. Newton had argued that gravity could not be inherent in matter, in a passage that Faraday loved to quote; and it became a necessary part of the creed of the immaterialist to assert that matter existed, but was utterly inert and passive. The materialist, on the other hand, required matter to be active; and in the materialism of Joseph Priestley,