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CHAPTER THREE

Dalton's Atomic Symbols

John Dalton is well known as the early nineteenth-century English chemist who advocated an atomic theory of chemistry. Closely connected with the atomic theory was a system of symbols in which Dalton denoted the atoms of different elements by circles containing a distinguishing pattern or letter. The important difference between Dalton's symbols and those used earlier was that the former represented a definite quantity of an element, whilst the latter signified any amount of the substance in question. Thus Dalton's symbol ⊕ stood for *one atom* of sulphur to which he assigned a definite weight compared with that of hydrogen, whereas the symbol 🜍 had previously denoted sulphur in general. This quantitative aspect of Dalton's symbols was inherited by the symbols of Berzelius and they still have this quantitative meaning to-day.

Dalton's formulation of the atomic theory was closely connected with his meteorological interests and in particular the study of the atmosphere and his interests in the properties of gases in general. In a paper read to the Manchester Literary and Philosophical Society in October 1803 Dalton observed:

> A particle of gas pressing on the surface of water is analogous to a single shot, pressing upon the summit of a square pile of them.[75]

To illustrate this idea he drew a black sphere, which represented a particle of air, resting on white spheres which he chose to represent particles of water. Five years later in his *New System of Chemical Philosophy,* Dalton was still prepared to assign a spherical shape to the particles or atoms, at least when they were joined with the hypothetical caloric:

> Whatever, therefore, may be the shape or figure of the solid atom abstractedly, when surrounded by such an atmosphere [i.e. of heat] it must be globular; but as all globules in any small given volume are subject to the same pressure, they must be equal in bulk, and will therefore be arranged in horizontal strata, like a pile of shot.[76]

It seems clear from the above that Dalton's reason for representing atoms by circles was not arbitrary, but rather it was a deliberate attempt to picture the atoms as he imagined they really were. This applies also to the compound atoms which he usually drew symmetrically in accordance with his ideas on the repulsive influence of the atmosphere of caloric surrounding each atom. Thus, in Dalton's view, the formula ○●○ represented the actual arrangement of the atoms in carbonic acid, since the two oxygen atoms repelled each other while being attracted by the carbon atom. Dalton actually made 3-dimensional models of compound atoms, in which each elementary atoms was represented by a ball with suitable holes to carry pins to join it to the other atoms.[77] This was in conformity with Dalton's pedagogical opinion that

> no conception was clearly grasped by the intellect, if it could not be visibly depicted or embodied to the external sense.[78]

The first record we possess of Dalton's use of symbols dates from September 1803 (see below) and it will be noticed that all the elements represented were either gaseous or the constituents of common gases. To each of the atoms represented symbolically Dalton attributed a definite weight. (These 'atomic weights' have been omitted from the Table, since our purpose in this chapter is to examine the symbols rather than the experimental results, which led to a progressive revision of these relative weights.) The character for carbon, a circle shaded black, was no doubt deliberately symbolic. The symbol for azote is identical with that previously used to denote nitre and it is just possible that the cross incorporated in the symbol for sulphur may be related to the lower half of the alchemical symbol for sulphur 🜍 . Five weeks later Dalton again wrote down some symbols in his note-books, this time giving an alternative symbol based on the use of initial letters.[79] It was probably

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[75] *Memoirs of the Literary and Philosophical Society of Manchester,* Second Series, *1* (1805), 284.

[76] Op. cit., vol. i, Part 1, Manchester, 1808, p. 145.

[77] Dalton, *On a new and easy method of analysing sugar,* Manchester, 1840, pp. 3–4.

[78] According to Dalton's friend William Henry (*Memoirs of . . . John Dalton,* London, 1854, p. 130).

[79] Dalton also made use of the symbol Ⓒ for lime in August 1804 (H. E. Roscoe and A. Harden, *A New View of the Origin of Dalton's Atomic Theory,* London, 1896, p. 64).

because Dalton was considering the use of initial letters that he reversed the symbols for oxygen and hydrogen, so that ○ now represented oxygen. Dalton next had occasion to draw up a list of symbols at the end of 1806 or early in 1807, for the purpose of illustrating the lectures he was to give in Scotland in April 1807. It will be noticed that the symbol for gold was unusually elaborate—it may have originally been intended to represent the sun, the letter G being afterwards added for clarity. In 1808 Dalton further extended his symbols for the elements and his symbol for mercury may well have been intended to suggest small globules of the metal. To avoid confusion with the symbol for gold, the latter was now denoted by the initial letter only. When in 1810 Dalton added zirconia to his list, he chose the wavy line (suggestive of the letter Z?) which he had formerly associated with magnesia, and he accordingly found another pattern to denote the latter.

Of the 36 'elements' represented in the 1810 list, exactly one half were denoted by a pattern rather than a letter and one has the impression that Dalton resorted to the use of letters only when the simple patterns were exhausted. This is confirmed by his original use of patterns rather than letters (September 1803, Spring 1807) and also by his preference for the use of a mixed system of patterns and letters rather than a consistent use of initial letters.

Dalton did not publish his symbols until 1808, but in the previous year Thomas Thomson gave a short account of the Atomic theory and the symbols in the third edition of his *System of Chemistry*. According to Thomson, Dalton showed him his table of symbols with the weight of atoms of 6 or 8 bodies in 1804,[80] but Thomson warned his readers that he could not vouch for the accuracy of the details of Dalton's scheme. Thomson frequently referred to Dalton's symbols,[81] although his representation of the atoms of carbon, sulphur and phosphorus differ from those of Dalton (see Table above). He also made the innovation of using the alchemical symbol for common salt to denote muriatic acid.[82] Thomson did not substantially alter his

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[80] *Annals of Philosophy*, 2 (1813), 445n.

[81] *System of Chemistry*, 3rd edn., Edinburgh, 1807, vol. 3, pp. 429-540. See especially p. 425n.

[82] Dalton held the curious view that muriatic acid was a compound of one atom of hydrogen and three atoms of oxygen (see Fig. 7).

Table showing the symbols used by Dalton up to the time of their standardization in 1808

DALTON 6 Sept. 1803 (A)	DALTON 12 Oct. 1803 (B)	or thus:	DALTON Spring 1807 (C)	DALTON 1808 (D)	(F) THOMSON 1807 (E)
○ Hydrogen	Ⓗ Hydrogen	⊙	⊙ Hydrogen	⊙ Hydrogen	⊙ Hydrogen
⊙ Oxygen	○ Oxygen	○	○ Oxygen	○ Oxygen	○ Oxygen
⦶ Azote	Ⓐ Azote	⦶	⦶ Azote	⦶ Azote	⦶ Azote
● Carbon	● Carbon	●	● Carbon	● Carbon	⊕ Carbon
⊕ Sulphur	Ⓢ Sulphur	⊕	⊕ Sulphur	⊕ Sulphur	⊜ Sulphur
	Phosphorus	Ⓨ	☮ Phosphorus	☮ Phosphorus	⦷ Phosphorus
			Ⓩ Magnesia	⊛ Magnesia	
				[Ⓩ Zircone] [g]	
			Ⓦ Lime	◎ Lime	
			☼ Gold	Ⓖ Gold	
				etc.	⊖ Muriatic Acid

(A) Roscoe and Harden, *New View of Dalton's Atomic Theory*, London, 1896, p. 26 and Plate 3.

(B) Ibid., p. 45.

(C) Coward and Harden, *Memoirs of the Literary and Philosophical Society of Manchester*, 59 (1915), No. 12, 43 and Plate III.

(D) Dalton, *New System of Chemical Philosophy*, Part 1, 1808, Plate 4, opp. p. 219.

(E) Thomson, *System of Chemistry*, 3rd edn., Edinburgh, 1807, vol. iii, pp. 429ff.

(F) Thomson was one of several chemists who used symbols which, although not identical with those of Dalton, were based on the same principle. Another influential British author to do this was Fownes who illustrated the composition of the oxides and acids of nitrogen, taking ⊕ for nitrogen (*Manual*, 1st edn., London, 1844, p. 183).

(g) This symbol appears only in op. cit., Part 2, 1810 (see also Fig. 7).

account in the fourth edition of his *System of Chemistry* (1810) but in the fifth edition (1817) he gave only the very briefest account of Dalton's atomic symbols, although he now used Dalton's own symbol for carbon. In the sixth and seventh editions of his famous text-book (1820, 1831) Thomson made no use at all of Dalton's symbols. This was not, however, because he thought them valueless, since he expressed the contrary opinion in his *History of Chemistry*, where he gave due place to Dalton's theory and symbols:

> A bare inspection of the symbols and weights will make Mr Dalton's notions respecting the constitution of every body in the table evident to every reader . . . . It was this happy idea of representing the atoms and constitution of bodies by symbols that gave Mr Dalton's opinions so much clearness.[83]

Dalton's symbols were used more generally than may be thought, but they suffered from the same practical difficulty as the symbols of Hassenfratz and Adet, that they could only be incorporated into a printed text with some difficulty. The typographical obstacle was not so serious as in the case of the symbols of Hassenfratz and Adet, and the fact that it was overcome can be seen in books by Thomson[84], Turner[85] and Hume,[86] quite apart from reproductions of plates of symbols in the *Annals of Philosophy*[87] and also by William Higgins.[88] Dalton himself used his symbols in printed works covering a span of over thirty years. His first publication of them was in his *New System of Chemical Philosophy* (1808, 1810), each part of which contained plates of symbols at the end. When a second edition of the *New System* appeared in 1842, two years before Dalton's death, the symbols were again reproduced. In Dalton's paper *On the Phosphates and Arseniates*, which he published himself in 1840 after the Royal Society had refused to print it, there is another plate showing the compound symbols for three different phosphates and arsenates.

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[83] *History of Chemistry*, London, 1830, 31, vol. ii, p. 291.

[84] Op. cit., also *An attempt to establish the first principles of chemistry by experiment*, London, 1825, vol. i, pp. 10–11.

[85] E. Turner, *An introduction to the study of the laws of chemical combinations and the atomic theory*, Edinburgh, 1825, p. 35; *Elements of Chemistry*, 1st edn., Edinburgh, 1827, p. 132.

[86] G. L. Hume, *Chemical Attraction*, Cambridge, 1835, p. 118.

[87] *Annals of Philosophy*, ed. T. Thomson, 2 (1813), plate opp. p. 52.

[88] *Experiments and Observations on the Atomic Theory*, Dublin, 1814, p. 171.

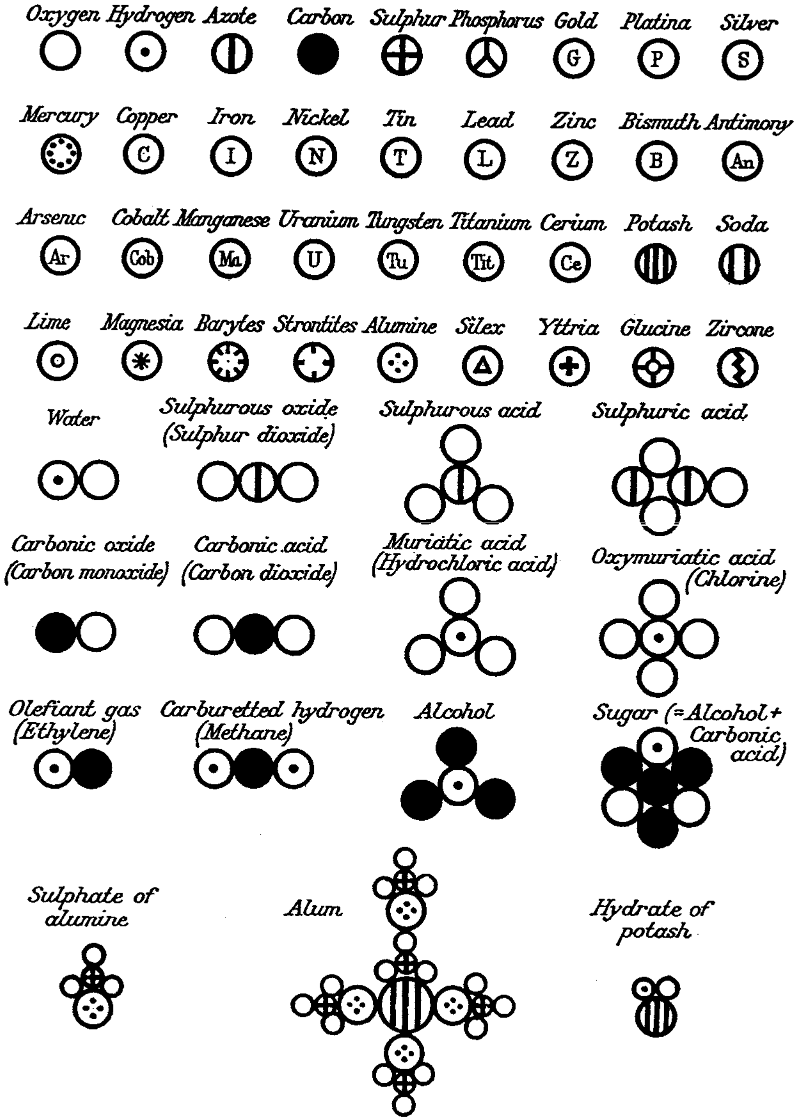

Fig. 7. Dalton's Symbols (from *New System of Chemical Philosophy*, 1810).

It has been shown,[89] however, that Dalton made greater use of his symbols in lectures on the atomic theory than in his pub-

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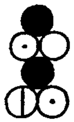
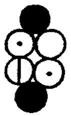
[89] W. Gee, H. F. Coward and A. Harden, 'John Dalton's Lectures and Lecture Illustration's, *Memoirs of the Manchester Literary and Philosophical Society*, 59 (1915) No. 12, 1–66.

lished works or even in his laboratory note-books. Quite apart from two tables of atomic weights and symbols, an important source for a study of Dalton's ideas has deen a collection of over thirty sheets representing the composition of 'compound atoms' of the most diverse inorganic and organic compounds. A famous lecture given by Dalton was in October 1835, when he lectured at the Manchester Mechanics Institution. The subject was the atomic theory and the audience was issued with a lithographed sheet of atomic symbols.[90] This sheet contains examples of compounds containing from two to ten atoms and an interesting feature is the representation of chlorine by 

Dalton was familiar with the Berzelian system of denoting the elements by letters, but he never used this system and indeed opposed it on the grounds that Berzelius neglected what Dalton called the 'allocation', i.e. the arrangement of the atoms.[91] This was one advantage possessed by Dalton's symbols—anyone using them thoughtfully could not help but consider the relative position of the atoms. Dalton was able to use this advantage to the full in organic chemistry and he expressed clearly by means of his symbols the concept of isomerism. In one of his lecture sheets[92] we find:


Albumen


Gelatin

These two compounds were considered to contain the same number of 'ultimate atoms' of the same kind, but differing in arrangement. It will be noticed that the group  is common to both these substances and this 'vegetable atom'[93] is found in Dalton's formulae for such different substances as citric acid, sugar and wood. It has been remarked that this concept of the radical marks an intermediate stage between Lavoisier's idea and later theories of compound radicals.

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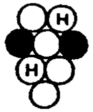
[90] A facsimile is bound at the end of Henry's *Memoirs of . . . John Dalton*, London, 1854.

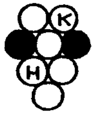
[91] Ibid., p. 124. See also *Report of the British Association for the Advancement of Science, 1835*, p. 207.

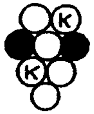
[92] Sheet 23 (reverse) (Gee, Coward and Harden, loc. cit. Plate VII).

[93] Dalton's own expression (*Note Books*, iv, 56, cited by Coward and Harden, p. 57; see also p. 42).

Other chemists too made good use of the advantages of Dalton's symbols. Thomson used them to explain how it was possible for acetic and succinic acids to have apparently the same number of the same atoms and yet be different substances, because the atoms were differently arranged.[94] Even Gerhardt in 1844 found it useful to use symbols similar to those of Dalton to explain the relationship between oxalic acid and its salts.[95] He represented oxalic acid, the acid salt and the neutral salt of potassium respectively as follows:







It has been suggested by a younger contemporary of Dalton,[96] that by the use of his symbols Dalton familiarized men of science with the way in which chemical combination took place and thus paved a surer way for the reception of the Atomic Theory. Other chemists besides Dalton used these symbols to explain chemical reactions. The French chemist, A. M. Gaudin, explained the combination of hydrogen with oxygen, with chlorine and with nitrogen on the assumption that each of these gases was composed of diatomic 'compound atoms'.[97] He explained the changes in volume in each of these three reactions by drawing boxes to represent a unit volume and Daltonian symbols to represent the atoms of the gases. For oxygen and hydrogen he used exactly the same symbols as Dalton, but he denoted nitrogen by ⊖ and chlorine by ⊗

Symbols similar to those of Dalton were used to illustrate the structural formulae of similar compounds.[98] In organic chemistry A. W. Hofmann used the same type of symbols to explain certain cases of substitution[99] and the graphic formulae used by Kekulé[100] were really a compromise between Daltonian and Berzelian symbolism. It is certainly true that organic

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[94] *History of Chemistry*, London, 1830, 31, vol. ii, pp. 304–5. Thomson's argument was, however, based on a false premiss, since the respective formulae of these acids are $C_2H_4O_2$ and $C_4H_6O_4$.

[95] *Précis de chimie organique*, Paris, 1844, 45, vol. i, p. 13.

[96] C. Daubeny, *An introduction to the atomic theory*, 2nd edn., Oxford, 1850, p. 99.

[97] *Annales de Chimie et de Physique*, 52 (1833), 113–33.

[98] Daubeny, op. cit., pp. 202–3.

[99] According to W. Henry, op. cit., pp. 126–7.

[100] See p. 334.

chemists were forced to accept Dalton's view of the importance of the relative position of atoms in a compound, and it might well be said that modern chemistry has adopted Berzelius' symbols but uses them in the manner advocated by Dalton. There is a slight irony in the fact that even Berzelius, whose symbols were preferred to those of Dalton, made use of Daltonian symbols in at least one publication. He represented the compound Fe_3O_4 by a cluster of circles, ○ denoting oxygen and ⊕ iron.[101] He numbered each atom and remarked how it was possible for particular atoms of iron to be replaced by atoms of another metal.

An interesting postscript bearing on the value of Dalton's symbols is contained in a German obituary notice printed in 1844.[102] The author claimed that Dalton's symbols had the advantage over those of Berzelius, in that they were even more international since, for the most part, they did not depend on initial letters in any one language. Thus the formula $\oplus\bigcirc^{3}$ could be recognized the whole world over as representing sulphuric acid.[103]

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[101] Berzelius, *Jahresbericht*, *15* (1835), p. 249.

[102] A German translation of Dalton's *New System* by Wolf had appeared in Berlin in 1812, 14.

[103] i.e., the anhydride of sulphuric acid (Du Menil. *Archiv der Pharmacie*, *90* (1844), 324).

CHAPTER FOUR

The Symbols of Berzelius

The Early Use of Abbreviations

The essence of the system of symbols used by Berzelius was simply the use of the initial letters of the Latin names of the elements; when these letters were joined with a plus sign, or were merely adjacent, they denoted the formula of a compound. Before describing the details of Berzelius' scheme and its reception by other chemists, it is proposed to consider to what extent abbreviations had been used in chemistry before Berzelius.

A large proportion of the symbols found in the Greek alchemical manuscripts were either themselves abbreviations or were derived from abbreviations, as Zuretti has clearly shown. In the western alchemical tradition, abbreviations were not quite so common, if we exclude the manuscript abbreviations which were not confined to alchemy. In the *Practica*[104] and the *De Secretis Naturae*,[105] attributed to Raymond Lull, they were used in a mystical way rather arbitrarily. There is no agreement between the meaning assigned to the letters in the former and the latter work respectively:

A *significat Deum*	A *significat Chaos*
B *significat Mercurium*	B *significat Materia*
C *significat Salus Petrum*	C *significat Forma*
D *significat Vitriolum*	D *significat Coelum*
etc.	etc.

To add to the confusion in the latter work, each letter was given two distinct meanings, and Thorndike[106] has noted that the alphabets vary somewhat in different manuscripts. Lull's alphabets and others equally mystical would not be worth mentioning,

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[104] *Th. Ch.*, iv, folding plate opp. p. 156

[105] Op. cit., Cologne, 1567.

[106] *A History of Magic and Experimental Science*, New York, 1923–41, vol. iv, pp. 41–2.