INTRODUCTION

Alongside the scientific work which gained him lectureships in physics at Lille (1887) and Rennes (1893), and the chair of physics at Bordeaux (1894, changed to chair of theoretical physics in 1895), Duhem began to publish articles on philosophical and historical topics related to his scientific interests in 1892. Many of these appeared in the Catholic journal *Revue des questions scientifiques*, and he was to draw on them in books published in the first years of the new century. English translations of all or part of these books have begun to appear in recent decades,[1] as well as a selection of articles, including some from *Revue des questions scientifiques* published during the 1890s (Duhem 1996). The present volume, which continues this work, focuses on issues related to chemistry, and contains translations of *Le mixte et la combinaison chimique* (1902) together with a number of related articles from *Revue des questions scientifiques* and other sources.

The question of chemical structure is taken up in one of the first of Duhem's *Revue des questions scientifiques* articles, "Atomic Notation and Atomistic Hypotheses" (1892b), where he retraces developments during the course of the 19th century from the establishment of the law of constant proportions by Proust around 1803. The greater part of this 1892 article is integrated either verbatim or with only minor linguistic changes into *Le mixte et la combinaison chimique* (henceforth *Mixture and Chemical Combination*), which elaborates the earlier account and adds chapters dealing with the pre-19th century history of the notion of mixture as well as more detailed interpretations and an assessment of what Duhem considered to be the way forward. A translation of this earlier article is therefore not included in the present selection. (The translation referred to under Duhem (1892b) in the list of references indicates the passages adapted in *Mixture and Chemical Combination*.)

It is difficult to conceive of modern chemistry without its notions of molecular structure. But this did not fall within the compass of the line of development Duhem advocated. He was critical of the atomic theory, both in the 1892 article and the 1902 book. It might help to put this into perspective by saying that it is only since the turn of the 20th century that the molecular nature of chemical substances has become a matter of universal consensus, and its general character is still a matter of dispute. The reductionist way in which the corpuscular doctrine is often interpreted has been vigorously criticised in recent philosophy of chemistry, and the

---

1 Duhem (1903), (1905-6), (1906), (1908), (1915), (1985).

standard chemist's conception is not without its critics.[2] Although Duhem seems to have been inordinately stubborn in ignoring pointers to corpuscular microstructure, there is something of value both in his critical attitude towards the naive way in which molecular conceptions have been introduced and in the way he developed his alternative approach.[3]

Duhem readily acknowledged that from Dalton's postulates, "it is easy to deduce the fundamental laws of chemistry" (1892b, p. 441). He did not dispute that it "agrees well with the primary laws and the primary notions of chemistry" (1892b, p. 443), but questioned whether it provides any explanation of them. He considers the elaborations in the form of ascribing atoms *atomicities*, added with a view to explaining aspects of chemical structure that came to light several decades into the 19th century, to be entirely gratuitous, and shows them to build on so many *ad hoc* devices as to render them completely devoid of explanatory value.

It might be thought, on the strength of his derogatory remarks on explanation in Ch. 1 of *Aim and Structure* (Duhem 1906), that Duhem should not think there is anything exceptional in a theory not providing any explanation of the phenomena with which it deals. A standard interpretation of this work has it that Duhem held the object of theory formation to be the classification of phenomena *as opposed to* the explanation of phenomena. Duhem's rhetorically excessive diatribes against explanation might better be seen, however, as directed specifically at the Cartesian tradition of seeking explanation by reduction to *a priori* principles, which in his view was continued long after Descartes' time in the form of insistence on explanations in terms of simple mechanical forces. This comes across clearly in his 1896 paper, "The Evolution of Physical Theory" (translated here as Essay 2), where he refers to the policy of searching for mechanical explanations upheld by the British school of physicists in the 19th century as "new Cartesianism" (1896, p. 492). (This continuity of tradition is not mentioned in *Aim and Structure*, presumably because it does not sit well with the nationalistic distinction between the "broad and shallow" mind of the British which he contrasted with the "deep and narrow" mind of the French—see Duhem 1906, Pt. I, Ch. IV.) Moreover, when presenting his own favoured theories and approaches, he has no qualms about making explanatory claims—something which is well illustrated by a number of passages in the works translated here. This would suggest that the charge that the

---

2 See, for example, van Brakel (1986), (1997) and (2000, Ch. 5) Scerri (1991), (1993) and (1994). The writings of R. G. Woolley raise some questions about the nature of modern conceptions of molecules; see, for example, Woolley (1978), (1988), (1991) and (1998). A useful review of recent discussion is Hendry (1998).

3 Truesdell (1984) places Duhem in a tradition of rigorously developing the foundations of thermodynamics which is an active field of research today; see also Pradas (1991). Prigogine has always acknowledged Duhem as the first to appreciate the importance of Clausius' notion of non-compensated heat in the development of the thermodynamics of irreversible processes for which he has himself become famous. See Kondepundi and Prigogine (1998, p. 87 and *passim*), and Brouzeng (1987, pp. 121-34), (1991).

atomic theory lacks explanatory value is a negative criticism directed specifically against that particular theory.

But if Duhem rejected atomism as the basis of understanding chemical structure, what does he offer in its place? The reference to notation in the title of the 1892 article might suggest a mere form of words without substantial referential content—in a word, instrumentalism.[4] Whether an interpretation along these lines is borne out by a consideration of all the threads in Duhem's argument is a question which merits further attention, however. The precise role assigned to convention is crucial here. Dalton's atomism was not received by his contemporaries as the uncontroversial assumption demanded by the laws of constant and multiple proportions that it is usually presented as being in school chemistry today. Wollaston thought Dalton had no grounds whatsoever for claiming as he did that his assumption about water, to the effect that its formula is HO, is "very probable"; it is a convention for which the question of correctness does not arise beyond a certain point (it would be wrong to include a symbol for sulphur in the formula for water, for example). There were, in fact, no grounds for assigning a compound a particular compositional formula, as opposed to any other featuring the same elements, until Cannizzaro published his method in 1858. Despite this, the term "conventionalist" has come to be associated specifically with those who, like Wollaston, recognised the limitations of what they could reasonably claim to know and sought to articulate their claims accordingly. It by no means follows that conventionalists declined to make any truth claim simply because they shrank from making the particular kind of truth claims Dalton advocated. The issue is far more delicate.

Duhem is rather clear about exactly what is involved in the conventional aspect of compositional formulas. This accords with the great stress laid on articulating the precise meaning of scientific claims in his general philosophy, which is much concerned with the representation afforded by a physical theory as a result of a correspondence between a concept and a physical magnitude. A simple illustration is provided by the "correspondence between the concept of warmth and the algebraic magnitude that we call the temperature. ... [B]y virtue of the correspondence established between these two ideas, the one becomes the *symbol* of the other" (Duhem 1992a, p. 143; 1996, pp. 3-4). In general,

> The physical concept which we are concerned to represent possesses a certain number of fundamental properties. The magnitude intended to symbolise it should present a certain number of essential features for representing these properties. But every magnitude that introduces these features can be taken as a symbol of the physical concept that concerns us. (Duhem 1892a, p. 144; 1996, p. 4)

Temperature, as he goes on to point out, introduces the characteristics that equally warm bodies have the same temperature and a greater value of temperature is

4 As Ariew and Barker put it in their Introduction, "Duhem's rejection of atomism was based on his instrumentalism (or fictionalism)" (Duhem 1996, p. xi).

assigned to a warmer body, and "every magnitude which introduces these two characteristics can be taken as *temperature*" (loc. cit.).

A discussion in a paper on the foundations of thermodynamics published in the same year (1892c, pp. 284-9) makes it quite clear that Duhem's intention was not to offer a strict empiricist interpretation of the relations of being as warm as and being warmer than, as required by the instrumentalism that some of the logical positivists were to espouse. The import of the warmth relations not only extends far beyond what is discernible by the senses; it even contradicts them. They apply to temperatures far above and below the range of human experience. And within this range, the senses inform us about surface regions with a certain extension for a certain duration, whereas the warmth relations apply to subregions of these regions for indefinitely shorter and longer intervals, to say nothing of the interiors of bodies. Moreover, wooden and metal bodies judged from the circumstances to be at equilibrium are counted as equally warm, despite our experiences to the contrary when we touch them. What Duhem had in mind was something other than an operational interpretation of these relations.

If several magnitudes, as he says, represent the same concept of temperature, their differences cannot be significant. Thus, it would be incorrect to say that by heating a body from 10°C to 20°C its temperature is doubled; for although 20 is twice 10, 10°C is the same as 50°F, and 20°C the same as 68°F, but 68 is not twice 50. It is a mistake to conclude that features of the numbers used to represent a concept necessarily reflect a feature of that concept. Duhem points out that "we do not understand what statements such as ... body A is seventeen times warmer than body B or is three times less warm than body B" (1892a, p. 142; 1996, p. 3). Duhem knew that properties of numbers used to represent qualities may well not represent, or may misrepresent, properties of the qualities themselves, and was wary of drawing conclusions from properties of the number system. The modern theory of measurement, whose founding fathers were only just beginning to write on the subject as Duhem was writing on chemical structure,[5] clarifies the degree of arbitrariness Duhem was talking about in terms of scale types. A scale type is characterised by the kind of transformations of scale that are considered to preserve the physical features of the underlying concept. Empirical temperature is measured by a type of scale called an interval scale, which can be interconverted to an equally acceptable scale by a linear transformation, like that used in converting degrees Celsius to degrees Fahrenheit, and any features not preserved by the transformation are purely conventional aspects of a particular scale without physical significance.

---

5 Helmholtz (1887) and Hölder (1901). The contemporary development of measurement theory took off with the critique of Hölder's account in Suppes (1951). For a historical review, see Diez (1997). Miller (1971, p. 229) makes the point that "Duhem's axiomatic outlook which characterised this discussion of the first law [of thermodynamics] was indeed pioneering for physics and to some extent anticipated the major axiomatic research in mathematics." Duhem's views on the import of measurable concepts were distinctly modern.

Conventionalism is, however, usually understood to involve a far more radical position than the mere recognition of certain conventional aspects of scientific descriptions such as those involved in scales of measurement. It is usually taken to involve an instrumentalist stand, allowing for no substantial theoretical truth, and correspondingly no ontological commitment in Quine's sense, i.e. no reference of items designated by the predicates of the theory. Ariew and Barker, in their Introduction to Duhem (1996), seem to regard Duhem as a conventionalist in this sense when they describe him as holding the view that "Theoretical propositions are not true or false but 'convenient' or 'inconvenient'" (p. xi). The question is whether Duhem is correctly interpreted as a conventionalist in this sense, as distinct from merely acknowledging that laws accepted as true delimit the import of physical concepts only up to a certain degree as with any measurable property. It seems pretty clear that the care with which Duhem does specify the conventional element in his treatment of formulas leaves no room for charges of conventionalism, and is comparable with what he says about temperature.

A critic who charges the atomist with overlooking elements of convention and declines to embrace the truth claims of the atomist may, nevertheless, want to make claims about what is true, then. He might adopt the view that matter is ultimately continuous, although it seems divisible into discrete portions on a sufficiently large scale. Again, he might prefer to keep an open mind regarding the ultimate nature of matter, aware that the application of mathematical analysis incurs postulates—such as those going beyond infinite divisibility (denseness of the rational numbers)—whose literal physical interpretation may be difficult to justify. Mathematical analysis was not called upon in the development of the notion of chemical formulas that ensued once limitations of compositional formulas came to light and which Duhem discusses. It remained, nevertheless, an issue for him since, as he makes clear in the final two chapters of *Mixture and Chemical Combination*, he saw the way forward in chemistry as building on the links with physics established in the newly emerging field of physical chemistry, and in particular, with thermodynamics which is couched in the language of mathematical analysis.

In this connection, it is interesting to note what he says about the consequences of trying to follow the path of viewing matter as discrete on the microscopic level.

> we are entirely free to represent a body, which our senses perceive as continuous, either by a continuous distribution of matter in a certain space, or by a discontinuous collection of very small atoms.
>
> The latter mode of representation has been adopted by many theoreticians of physics. Poisson, in particular, employed it is systematic fashion because he believed he saw there the expression of the real constitution of bodies. Without wishing here to examine all the objections which confront this way of dealing with Physics, there is at least one that we can draw attention to now. The formulas to which it immediately leads always involve extensive sums of a very large number of disjoint, very small masses in very close proximity. To render these formulas manageable in Analysis and, at the same time, to extract from them results which can be translated into experimental language, it is necessary to replace these sums, by means of a calculus

http://www.springer.com/978-1-4020-0232-8

Mixture and Chemical Combination
And Related Essays
Duhem, P.
2002, XXX, 322 p., Hardcover
ISBN: 978-1-4020-0232-8