John Dalton (1766-1844): The Father of the Chemical Atomic Theory

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Before delving into Dalton, I want to draw a difference between physical and chemical atomism.

The path that Dalton took to the chemical atomic theory is complex. As Leonard K. Nash points out, there are three more-or-less contemporary descriptions of how Dalton developed his ideas. This includes Dalton's own words on the subject. Add to this the several theories advanced over the years by historians and there is a lot to read, study and ponder about. And then, it turns out that the three contemporary descriptions are mutually contradictory and none are consistent with information available elsewhere.

The ChemTeam believes that the most satisfactory answer to Dalton's path to the chemical atomic theory was by way of his studies on vapor pressure, gas solubility and gas mixtures. I intend to develop this topic in the future.

John Dalton wrote his first table of atomic weights in his notebook dated September 1803. In 1830, in a paper read to the Manchester Literary and Philosophical Society, he said:

"A series of Essays read before this society and afterwards published in the 5th Vol. of their Memoirs gradually led me to the consideration of ultimate particles or atoms & their combinations. Under the date of Sept 3d, 1803, I find in my notebook 'Observations on the ultimate particles of bodies and their combinations,' in which the atomic symbols I still use [were] introduced. On the 23rd of October the same year I read my Essay on the absorption of Gases [by Water] at the conclusion of which a series of atomic [weights] was given for 21 simple and compound elements . . . ."

It was not until 1805 that the above essay was published and it was not until 1808 that Dalton himself discussed his methods for atomic weight determination. He published his theories on the atmosphere and gas behavior in a book titled A New System of Chemical Philosophy. Only in the last few pages (Chapter III) did he discuss his atomic theory.

Modern scholarship has identified four basic ideas in Dalton's chemical atomic theory.

1) chemical elements are made of atoms
2) the atoms of an element are identical in their masses
3) atoms of different elements have different masses
4) atoms only combine in small, whole number ratios such as 1:1, 1:2, 2:3 and so on.

1) elements are made of atoms
Elements are made up of minute, discrete, indivisible, and indestructible particles called atoms. These atoms maintain their identity through all physical and chemical changes. This, of course, is not a new idea to Dalton. This basic idea goes back to the Greeks. However, please keep in mind that atoms, as such, were not part of the chemical mainstream in the early 1800's.

Dalton's idea of an element is what we believe today - an element is a chemical substance that cannot be
decomposed further by chemical means (i.e. heat, electricity, reacting with another chemical). This definition traces to Lavoisier.

Daltonian atoms are usually taught as being similar to featureless billiard balls. In truth, Dalton never ruled out the possibility of subatomic structure. He just knew that the state of the art in the early 1800's did not allow the physical structure of an atom to be probed.

2) the atoms of an element are identical in their masses
Atoms of the same element have the same properties, such as weight. Atoms of different elements have different properties, including a different weight. The idea that all atoms of a given chemical element weigh the same is known today to be incorrect, but in 1803 the concept of isotopes was just over 100 years in the future.

Also, the concept of chemical combination in 1803 was much, much different than what Dalton was proposing. Although Dalton was well-known at the time, the most authoritative chemist of the period was Claude Louis Berthollet and his ideas were phrased thus:

"Berthollet has shown also, that every body, how weak soever its affinity for another maybe, is capable of abstracting part of that other from a third, how strong soever the affinity of that third is, provded it be applied in sufficient quantity."

Even many years later, Berthollet resisted the idea of the atom: that elements combine in small, whole number ratios that are fixed. Even into the late 1800's, there were French chemists who used their authority to punish lesser colleagues and students who publically supported the chemical atomic theory.

Incidently, please do not think that Berthollet was a total loser. On the contrary. He was the first, in 1798, to observe a reversible reaction and ideas like the ones expressed in the above quote worked perfectly well for chemical substances reacting, just not for determining atomic weights. Some of the negative reaction to his anti-atom stance seems to have spilled over into unjustly ignoring his other work. Consequently, it was not until the mid-1860's that chemical equilibrium began to be explored in depth.

3) atoms of different elements have different masses
Although this idea is implicit in Dalton's theory, it is not original with him. Once again, the Greeks, developed this general idea. This idea was even discussed in chemical textbooks of Dalton's time, so the idea was "in the air," so to speak.

However, here is where we meet the original contribution of Dalton. Arnold W. Thackray says (his original is in italics):

"The particular development of Dalton, which distinguishes his chemical atomic theory from earlier work, was his devising of an effective system to obtain these relative particle weights from currently available chemical data. . . ."

In other words, while it was claimed atoms of different elements had different weights, no one could figure out what the different weight values were. Dalton was the first to do so.

So, exactly how did he determine atomic weights? I intend to develop this topic in the future.
4) atoms combine in small, whole number ratios
Chemical combination between two or more atoms occur in simple, numerical ratios (i.e., 1 to 1, 1 to 2; 2 to 3; etc.).

This point gives immediate explanation to the Law of Definite Proportions, announced by Joseph Louis Proust in 1797.

During his research, Dalton discovered the Law of Multiple Proportions, another law which is easily explained by his atomic theory.

Dalton discovered this law while studying some of the oxides of nitrogen. I will defer discussion of this work to a future time. The law, in modern terminology, is:

   Atoms of the same element can unite in more than one ratio with another element to form more than one compound.

A fifth idea implicit in Dalton's theory, but usually not discussed is this: atoms can be neither created nor destroyed. An element's atoms do not change into other element's atoms by chemical reactions. For example, nitrogen and oxygen atoms stay as themselves even when combined. They can be recovered by decomposing the substance. As Dalton says:

"We might as well attempt to introduce a new planet into the solar system, or to annihilate one already in existence, as to create or destroy a particle of hydrogen. All the changes we can produce, consist in separating particles that are in a state of cohesion or combination, and joining those that were previously at a distance."

As with most of Dalton's theory, this idea is not original to Dalton. It is Lavoisier who is responsible for the Law of Conservation of Mass in chemical reactions.

Finally, a few Dalton factoids to close:

1) In "A New System of Chemical Philosophy," he proposed standard symbols for the elements. He was the first to do so.
2) He was the first to identify color-blindness. He, himself, suffered from red-green color-blindness. Still today, "daltonism" is often used to name this problem.
3) The unit for atomic weight was called a "dalton" for many years. In modern times, you most often hear it used in biochemical circles, as in "The atomic weight of that protein is 35,000 daltons."

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