

1.5: Evidence for Atoms

It is important to note that from the time that the first ideas of atoms arose, and for thousands of years thereafter, there was not one shred of evidence for the particulate nature of matter or the physical existence of atoms. The idea of atoms was purely a product of imagination, and while there was vigorous debate about the nature of matter, this debate could not be settled scientifically until there was objective empirical evidence one way or another.

So the question arises, how did scientists in the nineteenth century eventually produce clear evidence for the existence of atoms? We have already said atoms are much too small to be seen by any direct method. So what would lead scientists to the unavoidable conclusion that matter is composed of discrete atoms? It is often the case that a huge intuitive leap must be made to explain the results of scientific observations. For example, the story about Isaac Newton (1643–1727) and the falling apple captures this truism, namely the remarkable assumption that the movement of Earth around the Sun, the trajectory of a cannon ball, and the falling of an apple to Earth are all due to a common underlying factor, the force of gravity, which acts at a distance and obeys an inverse square relationship, $\frac{1}{r^2}$ where r is the distance between two objects. This seems like a pretty weird and rather over-blown speculation; how does this “action at a distance” between two objects work? Yet, followed scientifically, it appeared to be very powerful and remarkably accurate. The point is that Newton was able to make sense of the data, something that is in no way trivial. It requires a capacity for deep, original, and complex thought. That said, it was not until Albert Einstein (1874-1955) proposed his general theory of relativity in 1915 that there was a coherent, mechanistic explanation for gravitational forces.

The first scientific theory of atomic structure was proposed by John Dalton (1766–1844), a self-taught Quaker^[11] living in Manchester, England.^[12] In 1805 Dalton published his atomic theory to explain the observed law of multiple, or definite, proportions, which stated briefly is “when elements combine, they do so in the ratio of small whole numbers”, we will return to this idea later on, in much greater detail.^[13] Rather surprisingly, Dalton never really explained what led him to propose his atomic theory, although he certainly used it to explain existing rules about how different elements combine. Among these rules was the observation that the total matter present in a system does not change during a chemical reaction, although a reaction might lead to a change from a solid to a gas or vice versa. Dalton’s atomic theory (1805) had a number of important components:

- Elements are composed of small indivisible, indestructible particles called atoms.
- All atoms of an element are identical and have the same mass and properties.
- Atoms of a given element are different from atoms of other elements.
- Compounds are formed by combinations of atoms of two or more elements.
- Chemical reactions are due to the rearrangements of atoms, and atoms (matter) are neither created nor destroyed during a reaction.

Based on these tenets he was able to explain many of the observations that had been made, by himself and others, about how matter behaves and reacts. More modern atomic theories have made some modifications, for example to include the existence of atomic isotopes, that is, atoms with different numbers of neutrons, but the same number of protons and electrons, and the conversion of energy into matter and vice versa, but Dalton’s core ideas remain valid.

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Questions to Answer

- In what ways is Dalton’s atomic theory different from the ideas of the Greek philosophers?
- Which tenets of Dalton’s theory still hold up today?
- Design an experiment to investigate whether there is a change in mass when water changes phase. What data would you collect? How would you analyze it?

Questions to Ponder

- How did Dalton conclude that there were no half-atoms?
- Which parts of Dalton’s theory were unfounded speculation and which parts were based on direct observation?

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