Atomic Theory

Conceptual Origin of a Model of the Atom

The idea of the atom as an indivisible building block was proposed around 400 BCE by the Greek philosopher Democritus (460-370 BCE). Although his theory never gained wide acceptance in Greek thought, the word *atom* from the Greek *atomos*, meaning indivisible, is still used today. Democritus believed that all matter was made up of tiny, indestructible particles that could not be divided. According to Democritus, all atoms consisted of the same basic material and there was no limit to the types of atoms that existed. Democritus sought to explain the properties of substances in terms of the way the different types of atoms associated to form the macrostructure.

Dalton's "Billiard Ball" Model of the Atom

During the 18th century, Antoine Lavoisier studied the mass relationships between the reactants and products involved in a chemical reaction. He suggested that mass was conserved when elements reacted and formed compounds. Joseph Proust's (1754-1826) work in 1797 indicated that when elements combine and form compounds, they do so in definite proportions by mass.

In 1803, Dalton proposed an atomic theory to explain the mass relationships existing among the substances which take part in chemical reactions. According to Dalton, all substances are composed of small, hard, dense, indivisible particles of matter that resemble tiny billiard balls. He called these particles atoms. Dalton believed that each element consisted of a particular kind of atom, and he attributed the varying properties of the elements to the differences in their atoms. He further proposed that the most important physical difference in the atoms of the various elements was a difference in mass. Accordingly, he assigned separate mass values (atomic masses) to each of the known elements. They were relative masses based on an arbitrarily chosen atomic mass of 1 for hydrogen, the lightest element.

Dalton proposed that during the formation of chemical compounds, the atoms of elements unite in a definite numerical ratio. Thus, the composition by mass of a given compound is always the same. Dalton further postulated that the total number of atoms of each kind does not change as a result of a reaction. No atoms are gained or lost in a chemical change. This idea explains the conservation of matter noted by Lavoisier. Dalton's atomic theory is summarized by the following points:

1) All substances are composed of small, dense, indestructible particles called atoms.
2) Atoms of a give substance are identical in mass, size, and shape.
3) An atom is the smallest part of an element that enters into a chemical change.
4) Molecules of a compound are produced by the combination of the atoms of two or more different elements.

Some of the points of Dalton's original theory have been modified in accordance with more recent discoveries, but the particle nature of matter and the existence of atoms are now accepted by all scientists. Atoms are far too small to be observed directly. The best we can do is to develop a tentative mental picture of the concept. These mental pictures, called **models**, help scientists to understand and explain abstract concepts but have limitations and should not be taken literally.

Thompson's "Plum Pudding" Model of the Atom

Dalton's model was useful for explaining mass relationships in chemical reactions, but did not explain: (i) how or why atoms combined in certain ratios, (ii) the attractive forces existing between particles of matter, or (iii) the relationship between electricity and matter. A number of experiments in the 19th century suggested that atoms are divisible and contain electrically charged particles: electrons and protons. J. J. Thompson's (1856-1940) experiments that investigated the nature and characteristics of these charged particles led him to propose and improved model. He suggested that atoms consist of a solid bulk of positive charge with electrons dispersed throughout them. Thompson's concept became known as the "plum pudding" model of atoms.

Rutherford's Model of the Atom

Further experimentation by Ernest Rutherford (1871-1937) and his co-workers, in 1911, revealed that the positive charge (protons) and mass of atoms were concentrated in the centre (***nucleus***) of atoms. In this mode atoms are pictured as a tiny, dense, positively charged nucleus surrounded by electrons moving at inconceivably fast speeds at relatively great distances from the nucleus but still within an atom. X-rays, discovered by Wilhelm Roentgen (1845-1923) in 1895, were used by H. G. J. Moseley (1889-1915) to determine the positive charge on the nucleus of atoms. In a neutral atom, the nuclear charge, known as the ***atomic number***, also represents the number of electrons outside the nucleus. The ***neutron***, a nuclear particle, which contributed mass but no charge to the nucleus, was discovered in 1932 by James Chadwick, a British scientist.

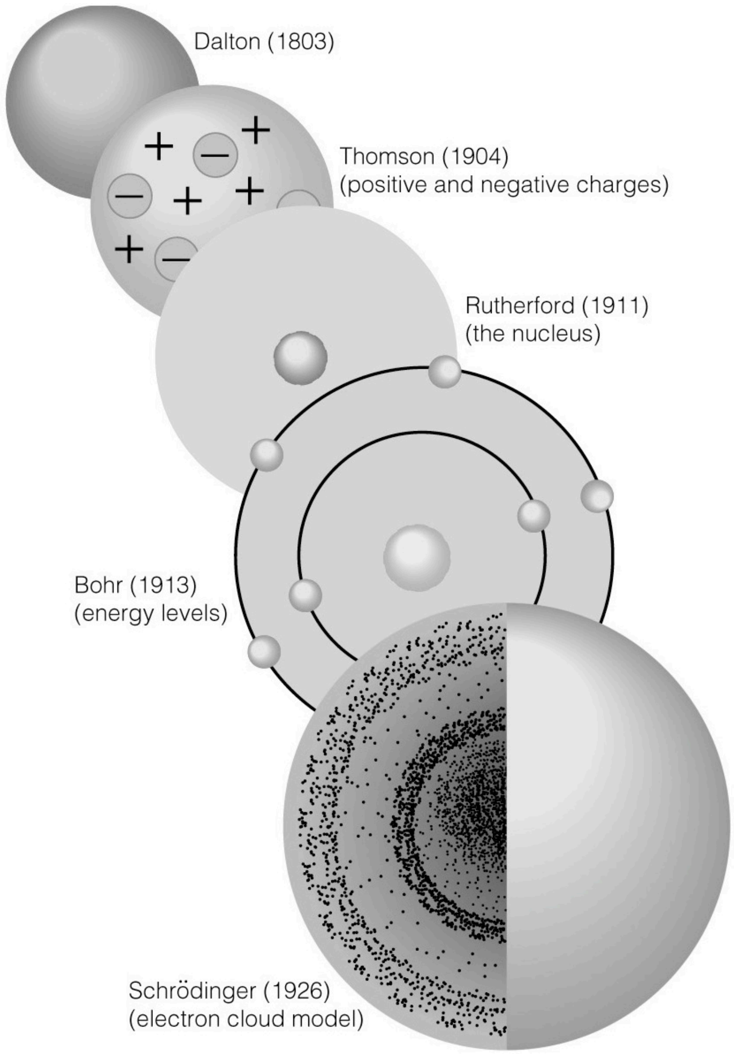
Bohr's "Solar System" Model of the Atom

In 1913, Niels Bohr (1885-1962) used Rutherford's concept of the nucleus, concepts from Max Planck's (1858-1947) quantum theory and other experimental data to develop his well-known "satellite" or "solar system" model of atoms. In Bohr's model, the electrons are arranged in ***definite energy levels*** (shells) and follow a prescribed orbit around the nucleus.

The Wave-Mechanical (Electron Cloud) Model of the Atom

During the 1920's, the discovery of the wavelike properties of electrons led to the wave-mechanical model of atoms in which atoms are conceived to be a positively charged nucleus surrounded by pulsating electron waves. In this model, the electrons are associated with definite energy levels but they do not follow a prescribed trajectory. Instead, they are described in terms of the probability of being found in certain regions of space about the nucleus. These regions of space are called ***orbitals***. The wave-mechanical model of atoms is widely used at present to explain the behaviour of atomic and molecular systems.

The evolution of the atomic model from Dalton's simple "billiard ball atoms" to the highly mathematical, abstract, and sophisticated wave-mechanical model illustrates the importance of experimental investigation. As new evidence accumulates, theories and models must be modified accordingly. It should be noted however that no matter how refined a model of atoms becomes, it can never depict a true atomic system.



Discussion

1) What limitations in Dalton's model of the atom resulted in Thompson's model of the atom?

2) Can you find two more examples where a limitation in an early model led to a better model being proposed?

3) Is the Wave Mechanical (Electron Cloud) model the perfect, final model of the atom?

4) In what sense is scientific knowledge tentative? In what sense is it durable?