ACTIVITY 4– ARE ATOMS INDIVISIBLE?

Background Information

Dalton's atomic theory was the result of fine work indeed, but it begs the question; what are atoms made of? How do atoms of the various elements differ? Dalton could not answer this.

Scientists had observed that like charges repelled each other and that when an electric charge moved through a magnetic field it was deflected. These observations were explained in a general theory developed by James Maxwell (a British physicist) in 1873, known as Maxwell's equation. With these equations and Faraday's work with electric fields, the understanding of the atom would change very rapidly in the next 20 years.

The Electron

Many feel that Faraday's experiments were the basis to the understanding that electricity consists of individual negative charges.

However, in the late 1890s an English physicist named J.J. Thomson showed that the atoms of any element can be made to emit tiny negatively charged particles. He studied these electrical discharges in partially evacuated tubes called **cathode-ray tubes**. The tubes must be under vacuum because when the tube is filled with air there are few ions present, and furthermore, any charged particles formed at the electrode are unable to push through the air molecules; therefore electricity will not flow.

When an electric charge is passed through a gas at a reduced pressure, we note a characteristic color. A common example of this phenomenon that we are familiar with is the neon tube.

If we continue to reduce the pressure of the gas in the discharge tube, we find that the characteristic color disappears but the glass walls start to fluoresce (**fluorescence** is light emission by a phosphor when it is struck by energetic radiation). This then led to the question, what is the nature of these mysterious, invisible carriers of electricity that were called cathode rays? Some scientists believed that they were a form of electromagnetic radiation, and some thought they were particles of matter. When the beam of current was allowed to travel through a slit that was connected to the negative terminal (the cathode) in Thomson's cathode-ray tube, it was found that the end of the tube would fluoresce and that the beam would continue traveling in a straight direction toward the positive terminal (the anode). When he brought a magnet near the tube he noted that the fluorescing beam would be deflected. Thomson correctly concluded that the cathode rays consist of negatively charged particles. The name **electron** was given to these units of negative charge. Cathode rays are beams of electrons.

J.J. Thomson is given credit for finding the charge/mass ratio and the charge of the electron was finally found through Millikan's oil-drop experiment. The charge was determined to be -1.6×10^{-19} C (the SI unit of electric charge, a coulomb (C) is defined as 1 amp–sec). The mass of an electron was calculated to be 9.11×10^{-28} g.

The Atomic Nucleus
(Rutherford's Nuclear Model of the Atom)
It was obvious to Thomson that atoms could not be made solely of electrons. Since matter is electrically neutral, there had to be some positively charged species to balance the negatively charged electrons. Moreover, if electrons have such an extremely small mass, what accounts for an atom's much higher mass? The atomic model Thomson proposed was that of a spherically shaped atom with a diffused arrangement of positive charge. Electrons were somehow imbedded in this sphere. This model came to be known as the **plum-pudding model**.

Once the French discovered radioactivity in the late 1800s, scientists began experimenting with the emission of particles from atoms of certain elements. In 1911, Ernest Rutherford (who was born in New Zealand) used one of these particles in his famous **"gold foil" experiment**. Rutherford knew that **alpha (α) particles**, which are given off by radioactive elements such as radon, polonium, and radium, are massive in size compared to the size of electrons (about 7500 times larger). The positive electrical charge on α particles is twice the magnitude, but opposite in sign to the charge on an electron. His work with this radiation indicated that when these particles travel through air, some of the particles were deflected by something in the air. With the plum-pudding model in mind, Rutherford bombarded thin gold foil with α particles. Surrounding the foil was a detector with a coating of zinc sulfide, which would produce tiny flashes wherever it was hit by an α particle. He assumed that the α particles would act like tiny, dense, positively charged missiles that would pierce the gold atoms. The results were startling. Most of the α particles passed straight through the foil, but some of them were deflected at great angles. Some of the particles were even reflected backwards. Rutherford calculated that the atom is mostly space occupied by electrons and its mass is concentrated in a tiny core that he called the **nucleus**. Most of the α particles encountered empty space as they flew through the foil. When a positively charged α particle had chanced to come close to the positive center of the atom, deflection was seen. The reflected α particles were a result of one of them making a head-on hit on the positive center. Rutherford proposed that positive particles lay within the nucleus (he called these particles **protons**) and he accurately calculated the magnitude of the nuclear charge. We say that a proton has a relative charge of +1 and an electron has a relative charge of –1.

The atomic number (Z) on the periodic table represents the number of protons for each element. If the atom is neutral, it has the same number of electrons as protons.