ATOMIC STRUCTURE

OBJECTIVES

At the conclusion of this lesson the trainee will be able to:

1. Name the fundamental atomic particles and state their mass and electric charge.
2. Describe the Bohr model picture of the atom.
3. Understand and use the $^{A}_{Z}X$ notation for nuclides.
4. Define and describe isotopes.

ATOMIC STRUCTURE

For nearly 2500 years it has been believed that the vast array of substances which surround us are made of tiny particles called atoms. In the early nineteenth century John Dalton, an English Chemist, formalized this belief in his Atomic Theory which contains six basic points:

1. All matter is composed of particles called atoms;
2. These particles are far too small to be observed with the naked eye;
3. Different elements are made of atoms with different masses;
4. All atoms of the same element are identical;
5. Atoms combine in simple ratios to form new substances but the atoms themselves remain unchanged;
6. Atoms cannot be divided, created, or destroyed.

Much of this theory has proved correct. We now know that atoms are also made of more fundamental particles; the proton, the neutron and the electron.

FUNDAMENTAL PARTICLES

Proton

A proton is a very small particle. Its diameter is one hundred thousandth ($1/100,000 = 10^{-5}$) of the diameter of a hydrogen atom. A hydrogen atom's diameter is between one and two billionths of a meter (about 1.6×10^{-9}m).

The proton carries a single unit positive charge (+1e) and has a mass of about one mass unit (1u). This mass unit is very small; $1u = 1.66 \times 10^{-27}$kg. The proton mass is 1.0073u and most of the time we round this off to 1u.

Neutron

A neutron is a neutral (uncharged) particle the same size as the proton. It has a mass of 1.0087u, about 2.5 electron masses heavier than the proton. We generally approximate its mass as 1u.

Electron

An electron is the smallest of the three fundamental particles, having a mass of only 0.00054u, about 1/1840 of the mass of a nucleon. (Nucleon is a name for either of the two heavier fundamental particles).

The electron carries a unit negative charge (-1e). The unit charge is so small it takes a flow of 6.24 trillion charges a second to measure one microampere.

We shall now see how these fundamental particles are put together to form atoms.

STRUCTURE OF ATOMS

Niels Bohr, a Danish Physicist, received the Nobel Prize in 1922 for his theory about the structure of atoms. The picture which the Bohr model presents is of a positively charged nucleus, containing protons and neutrons, surrounded by negatively charged electrons in orbit. The atom, according to this model, looks like a very small solar system.

A neutral (i.e., uncharged) atom must have the same number of electrons in orbit as there are protons in the nucleus. The first three elements, hydrogen, helium and lithium are shown in Figure 1.1.

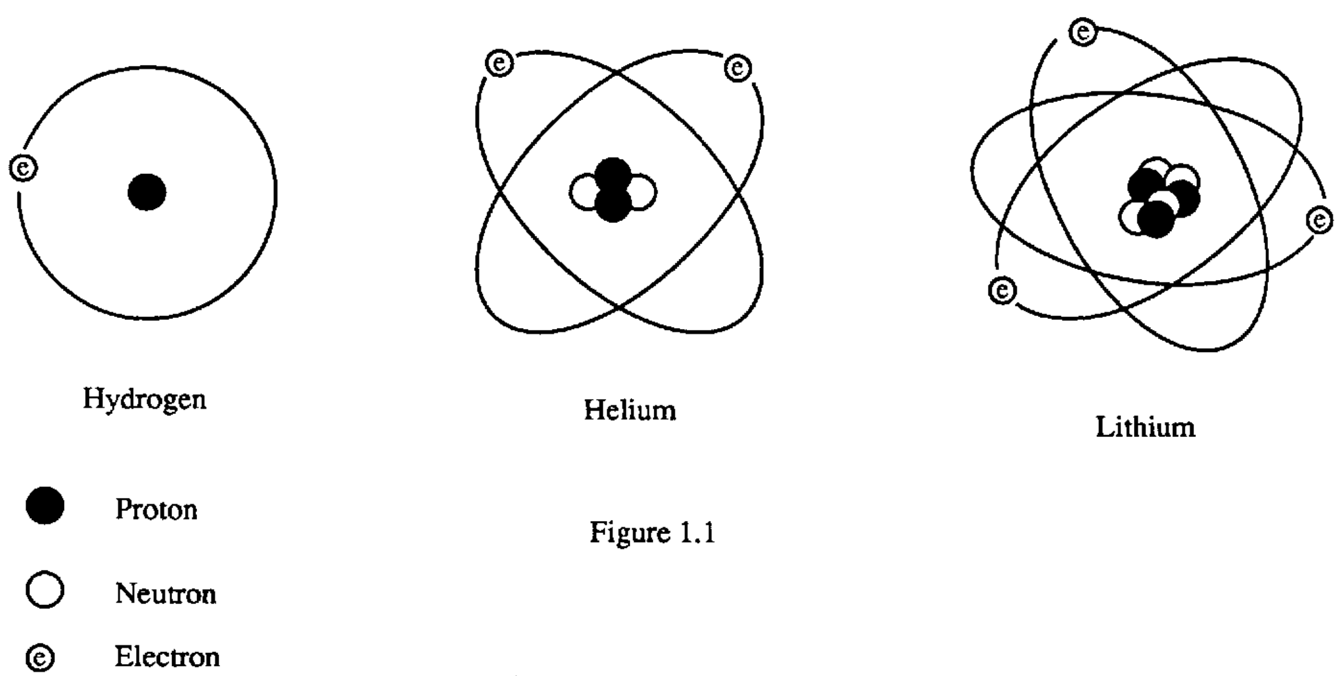

Figure 1.1

Over 110 elements are known, each having a characteristic number of protons in the nucleus. Ninety of these elements exist naturally in the world around us and most of these (81) are made of stable atoms. Unstable atoms (i.e., radioactive atoms) also occur naturally, and the "manmade" atoms are unstable.

ATOMIC NOTATION

Each element can be identified and represented by its chemical symbol, its atomic number (number of protons), and its atomic mass number (equal to the number of nucleons) as follows:

$^{A}_{Z}X$ Where: Z = Atomic Number
X = Chemical Symbol
A = Atomic Mass Number

For example, the three elements of Figure 1.1 are:

Hydrogen $^{1}_{1}H$ (1 proton)

Helium $^{4}_{2}He$ (2 protons, 2 neutrons)

Lithium $^{7}_{3}Li$ (3 protons, 4 neutrons)

Since the number of protons uniquely determines the chemical symbol we often write these in a simpler way; for example, $^{4}_{2}He$ becomes He-4 or helium-4.

When the numbers of nucleons in the nucleus of an atom are shown (i.e., both Z and A) then the atom is sometimes called a nuclide.

ISOTOPES

The lithium atom in Figure 1.1 has 3 protons and 4 neutrons in its nucleus. Only 92.5% of naturally occurring lithium atoms are like this. The other 7.5% of lithium atoms have three protons and three neutrons. We call these different kinds of lithium isotopes of lithium. Isotopes of an element are atoms which have the same number of protons with a varying number of neutrons. All isotopes of a given element have similar chemical and physical properties but show very large variations in nuclear properties.

The isotopes of two elements (hydrogen and uranium) are of particular significance in this course. Hydrogen has three isotopes shown in Figure 1.2. The first two occur naturally, although deuterium is only 0.015% abundant (about one atom in every 7000). Unfortunately we need deuterium in the form of heavy water (D_2O) to make the CANDU reactor work. This requires an expensive separation process (discussed in detail in another course). The third isotope, tritium, is produced in our reactors; it is radioactive and can be a serious health hazard.

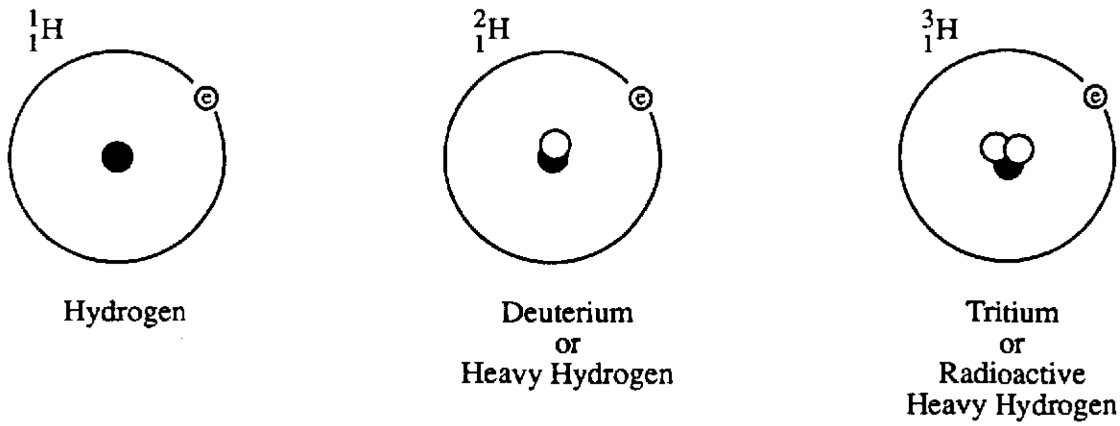

Figure 1.2

Uranium used for CANDU fuel has two isotopes, $^{238}_{92}U$ and $^{235}_{92}U$. U-235 is 0.7% abundant and will fission (split, releasing energy) when struck by a low energy (slow speed) neutron. It is said to be fissile. U-235 is the only naturally occurring fissile material. U-238 is 99.3% abundant and is not fissile. Nevertheless, it strongly affects the behavior of nuclear fuel, as we will see later.

ASSIGNMENT

1. List the mass, charge, and location of each of the fundamental particles.

2. Define an isotope.

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