STRUCTURE OF THE ATOM

Atoms are basic building blocks of matter, and cannot be chemically subdivided by ordinary means. The word atom is derived from the Greek word atom which means indivisible. Atoms are composed of three type of particles: **protons**, **neutrons**, and **electron** referred as three sub-atomic particles. Protons and neutrons are responsible for most of the atomic mass and reside in the nucleus. They are held together rather closely in the center of the atom. Protons and neutrons are responsible for most of the atomic mass. Protons have a postive (+) charge, neutrons have no charge - they are neutral. Electrons reside in orbitals around the nucleus. They have a negative charge (-).

Particle	Charge	Mass (g)	Mass (amu)
Proton	+1	1.6727×10^{-24} g	1.007316
Neutron	0	1.6750×10^{-24} g	1.008701
Electron	-1	9.110×10^{-28} g	0.000549

The unit of mass used is the atomic mass unit (amu). This unit is much more convenient to use than grams for describing masses of atoms.

Atomic Mass Unit (amu)

Previously, the masses of protons and neutrons were expressed in kilogram (kg). In 1960, a new scale for mass was adopted, atomic mass scale (written as amu). One amu is 1/12 of the mass of ${}_{6}C^{12}$, the most abundant and the most stable isotope of carbon. It is always preferable to express the masses of atoms on the atomic mass scale because it is more suitable for the magnitude of atomic masses and is far more accurate, since atomic masses can be determined very accurately relative to the carbon atom ${}_{6}C^{12}$.

Since the mass of an atom is equal to its atomic weight divided by Avogadro number $6.02\ x\ 10^{23}$, we have:

$$1\ amu = \frac{1}{12}\left(\frac{atomic\ weight = 12}{avagadro\ number = \ 6.02\ x\ 10^{23}}\right) = \ 1.66\ x\ 10^{-24}\ g = \ 1.66\ x\ 10^{-27}\ kg$$

The atomic mass scale is also referred to as the isotropic mass scale and hence the mass of an atom in amu is its isotropic mass.

Exercise

Convert the mass of the following into amu.

i) Proton $(m_P = 1.672621777\ x\ 10^{-24}\ g)$

ii) Electron($m_e = 9.10938291 \: x \: 10^{-28} \: g$)

iii) Neutron $m_n = 1.674927351 \: x \: 10^{-24} \: g$)

Solution

$1 \: amu = \: 1.66 \: x \: 10^{-24} \: g$

$$m_P = \frac{1.672621777 \: x \: 10^{-24} \: g}{1.66 \: x \: 10^{-24} \: g} = 1.007825 \: amu$$

$$m_e = \frac{9.10938291 \: x \: 10^{-28} \: g}{1.66 \: x \: 10^{-24} \: g} = 5.487 \: x \: 10^{-4} \: amu$$

$$m_n = \frac{1.674927351 \: x \: 10^{-24} \: g}{1.66 \: x \: 10^{-24} \: g} = 1.008665 \: amu$$

It is the number of protons that determines the ***atomic number (A)***, e.g., H = 1. The number of protons in an element is constant (e.g., $H = 1$, $Ur = 92$) but neutron number may vary. ***Mass number (Z*** $= protons + neutrons$) may vary. The symbol form $^{Z}_{A}H$

Full chemical symbols

It is possible to calculate the number of each sub-atomic particle in an atom given its atomic number and its mass number. The full chemical symbol for an element shows its mass number at the top, and its atomic number at the bottom.

$$^{35}_{17}CL$$

The full symbol for a chlorine atom. This symbol tells you that the chlorine atom has 17 protons. It will also have 17 electrons, because the number of protons and electrons in an atom is the same. The symbol also tells you that the total number of protons and neutrons in the chlorine atom is 35. Note that you can work out the number of neutrons from the mass number and atomic number. In this example, it is 35 – 17 = 18 neutrons.

The same element may contain varying numbers of neutrons; these forms of an element are called isotopes. Example is oxygen which has atomic number of 8 can have 8, 9, or 10 neutrons. The table below shows the three carbon isotopes.

	protons	neutrons	mass number
carbon 12	6	6	12
carbon 13	6	7	13
carbon 14	6	8	14

The fact that they have varying numbers of neutrons makes no difference to the chemical reactions of the carbon atom.

Atoms have sizes on the order of $1 - 5 \: \dot{A}$ (1 angstrom= Å)

What holds an atom together?

The negatively charged electron is attracted to the positively charged nucleus by a Columbic attraction.

Strong nuclear force hold the protons and neutrons together in the nucleus.

ELEMENTS

They are fundamental substances, which cannot be broken down by chemical means. There are 92 elements that occur naturally. The elements hydrogen, carbon, nitrogen and oxygen are the elements that make up most living organisms. The modern arrangement of the elements is known as the Periodic Table of Elements and is arranged according to the ***atomic number*** of elements.

BOHR MODEL of the ATOM

Neils Bohr proposed the modern atom model. Bohr's model shows electrons circling the nucleus at different levels known as the orbitals much like planets circle the sun. Electrons move from one energy state to another but can only exist at definite energy level (orbit). He described atoms much like Rutherford but placed electrons in layers of orbits each with a specific energy and postulated that electrons jump up to higher energy orbits and when their energy dissipates they return to their orbits. The energy absorbed or released when electrons change states is in the form of electromagnetic radiation.

All atoms would like to attain electron configurations like noble gases. That is, have completed outer shells. Atoms can form stable electron configurations like noble gases by:

1. Losing electrons - Atoms that have 1, 2 or 3 electrons in their outer levels will tend to lose them.
2. Sharing electrons - Atoms that have 4 electrons in the outer most energy level will tend share electrons
3. Gaining electrons - Atoms that have 5, 6 or 7 electrons in their outer levels will tend to gain electrons from those atoms with 1, 2 or 3 electrons in their outer levels.

For a stable configuration, each atom must fill its outer energy level - that means eight electrons in the last shell (with the exception of He which has two electrons).

A mole is the amount of matter that has a mass in grams equal to the atomic mass in amu of the atoms. Thus, a mole of carbon has a mass of 12 grams. The number of atoms in a mole is called the Avogadro number, $N_{av} = 6.023 \times 10^{23}$. Note that

$N_{av} = 1$ gram/1 amu.

Calculating n, the number of atoms per cm^3 in a piece of material of density δ (g/cm^3).

$$n = N_{av} \times \delta / M$$

Where, M is the atomic mass in amu (grams per mol).

Thus, for graphite (carbon) with a density $\delta = 1.8$ g/cm^3, M =12, we get

6×10^{23} atoms/mol $\times$ 1.8 g/cm^3 / 12 g/mol) = 9×10^{22} Atoms/cm^3.