For XAT , CMAT , MAT , IIFT Exam

ATOMS AND MOLECULES

- Antoine L. Lavoisier laid the foundation of chemical sciences by establishing two important laws of chemical combination.

LAW OF CONSERVATION OF MASS

Law of conservation of mass states that mass can neither be created nor destroyed in a chemical reaction.

LAW OF CONSTANT PROPORTIONS

This law was stated by **Proust** as "In a chemical substance the elements are always present in definite proportions by mass". This Law known as the Law of Definite Proportions or Law of definite proportions.

- British chemist John Dalton provided the basic theory about the nature of matter. Dalton picked up the idea of divisibility of matter, which was till then just a philosophy. He took the name 'atoms' as given by the Greeks and said that the smallest particles of matter are atoms. His theory was based on the laws of chemical combination. Dalton's atomic theory provided an explanation for the law of conservation of mass and the law of definite proportions.

According to Dalton's atomic theory

- All matter is made of very tiny particles called atoms, which participate in chemical reactions
- Atoms are indivisible particles, which cannot be created or destroyed in a chemical reaction
- Atoms of a given element are identical in mass and chemical properties.
- Atoms of different elements have different masses and chemical properties

ATOMS

- An atom is the smallest particle of an element that can take part in a chemical reaction
- Atomic radius is measured in nanometers.

$1/10^9$ m = 1 nm

1 m = 10^9 nm

- Hydrogen atom is smallest atom of all. Atomic radius of hydrogen atom is

  0.037×10^{-9}

Radii	**Example**
10^{-10}	Atom of hydrogen
10^{-9}	Molecule of water
10^{-8}	Molecule of hemoglobin
10^{-4}	Grain of sand
10^{-3}	Ant
10^{-1}	Apple

- Atoms of most elements are not able to exist independently. Atoms form molecules and ions. These molecules or ions aggregate in large numbers to form the matter that we can see, feel or touch.

ATOMIC MASS

- The most remarkable concept that Dalton's atomic theory proposed was that of the atomic mass. According to him, each element had a characteristic atomic mass.
- Atomic mass is defined as the mass of a single atom of a chemical element
- One atomic mass unit is a mass unit equal to exactly one-twelfth (1/12th) the mass of one atom of carbon-12. The relative atomic masses of all elements have been found with respect to an atom of carbon-12

ATOMIC MASS OF SOME ELEMENTS

Element	Atomic mass

Hydrogen	1
Carbon	12
Nitrogen	14
Oxygen	16
Sodium	23
Magnesium	24
Sulphur	32
Chlorine	35.5
Calcium	40

Avogadro constant

- The Avogadro constant 6.022×10^{23} is defined as the number of atoms in exactly 12 g of carbon-12.

MOLECULE

- A molecule is in general a group of two or more atoms that are chemically bonded together, that is, tightly held together by attractive forces. A molecule can be defined as the smallest particle of an element or a compound that is capable of an independent existence and shows all the properties of that substance. Atoms of the same element or of different elements can join together to form molecules.

MOLECULES OF ELEMENTS

- The molecules of an element are constituted by the same type of atoms. Molecules of many elements, such as argon (Ar), helium (He) etc. are made up of only one atom of that element. But this is not the case with most of the nonmetals. For example, a molecule of oxygen consists of two atoms of oxygen and hence it is known

as a diatomic molecule, O_2 . If 3 atoms of oxygen unite into a molecule, instead of the usual 2, we get ozone, O_3 . **The number of atoms constituting a molecule is known as its atomicity.**

Atomicity of some elements	
Argon	Monoatomic
Helium	Monoatomic
Oxygen	Diatomic
Hydrogen	Diatomic
Nitrogen	Diatomic
Chlorine	Diatomic
Phosphorus	Tetra-atomic
Sulphur	Poly-atomic

MOLECULES OF COMPOUNDS

- Atoms of different elements join together in definite proportions to form molecules of compounds

Molecules of some compounds	
Compound	Ratio by Mass
Water (H_2O)	1:8
Ammonia (NH_3)	14:3
Carbon dioxide (CO_2)	3:8

The ratio by number of atoms for water is H:O = 2:1.

ION

- Compounds composed of metals and nonmetals contain charged species. The charged species are known as ions. Ions may consist of a single charged atom or a group of atoms that have a net charge on them.
- An ion can be negatively or positively charged. A negatively charged ion is called an 'anion' and the positively charged ion, a 'cation'. Take, for example, sodium chloride (NaCl). Its constituent particles are positively charged sodium ions (Na^+) and negatively charged chloride ions (Cl^-).

MOLECULAR MASS

- The molecular mass of a substance is the sum of the atomic masses of all the atoms in a molecule of the substance. It is therefore the relative mass of a molecule expressed in atomic mass units (u).

THE STRUCTURE OF AN ATOM

- J.J. Thomson was the first one to propose a Model for the structure of an atom.
- Thomson proposed that:
  (i) An atom consists of a positively charged sphere and the electrons are embedded in it.
  (ii) The negative and positive charges are equal in magnitude. So, the atom as a whole is electrically neutral
- Rutherford's model of the atom proposed that a very tiny nucleus is present inside the atom and electrons revolve around this nucleus. The stability of the atom could not be explained by this model
- Neils Bohr's model of the atom was more successful. He proposed that electrons are distributed in different shells with discrete energy around the nucleus. If the atomic shells are complete, then the atom will be stable and less reactive.
- Electron was discovered by JJ Thomson
- Proton was discovered by Rutherford

J.J. Thomson (1856- 1940), a British physicist, was born in Cheetham Hill, a suburb of Manchester, on 18 December 1856. He was awarded the Nobel prize in Physics in 1906 for his work on the discovery of electrons. He directed the Cavendish Laboratory at Cambridge for 35 years and seven of his research assistants subsequently won Nobel prizes.

RUTHERFORD'S ATOMIC MODEL

According to this model:

1. The atom contains large empty space.
2. There is a positively charged mass at the centre of the atom, known as nucleus.
3. The size of the nucleus of an atom is very small compared to the size of an atom.
4. The electrons revolve around the nucleus in close circular paths called orbits.
5. An atom as a whole is electrically neutral, i.e., the number of protons and electrons in an atom are equal.

E. Rutherford (1871-1937) was born at Spring Grove on 30 August 1871. He was known as the 'Father' of nuclear physics. He is famous for his work on radioactivity and the discovery of the nucleus of an atom with the gold foil experiment. He got the Nobel prize in chemistry in 1908.

BOHR'S MODEL OF AN ATOM

- In order to overcome the objections raised against Rutherford's model of the atom, Neils Bohr put forward the following postulates about the model of an atom:
  1. Only certain special orbits known as discrete orbits of electrons, are allowed inside the atom.
  2. While revolving in discrete orbits the electrons do not radiate energy.
- These orbits or shells are called energy levels

Neils Bohr (1885-1962) was born in Copenhagen on 7 October 1885. He was appointed professor of physics at Copenhagen University in 1916. He got the Nobel prize for his work on the structure of atom in 1922. Among Professor Bohr's numerous writings, three appearing as books are:

(i) The Theory of Spectra and Atomic Constitution, (ii) Atomic Theory and, (iii) The Description of Nature.

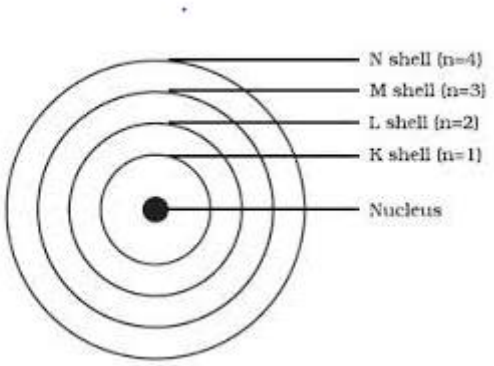
NEUTRONS

- J. Chadwick discovered the neutron
- Neutrons are present in the nucleus of all atoms, except hydrogen
- Mass of an atom equal to sum of the masses of protons and neutrons present in the nucleus

ELECTRONS DISTRIBUTED IN DIFFERENT ORBITS (SHELLS)

- Distribution of electrons into different orbits of an atom was suggested by Bohr and Bury.
- Maximum number of electrons present in a shell is given by the formula $2n^2$

  Where n=1,2,3,4,….
- These orbits or shells are represented by the letters K,L,M,N,…
- The maximum number of electrons that can be accommodated in the outermost orbit is 8.
- Electrons are not accommodated in a given shell, unless the inner shells are filled. That is, the shells are filled in a step-wise manner.



VALENCE ELECTRONS

- **Electrons** present in the outermost shell of an atom are known as the **valence electrons**
- The elements with same number of electrons in the valence shell show similar properties and those with different number of valence electrons show different chemical properties
- Elements, which have 1 or 2 or 3 valence electrons (except Hydrogen), are **metals**.
- Elements with 4 to 7 electrons in their valence shell are **non-metals**.

VALANCY

- Valency of an element is the combining capacity of the element with other elements and is equal to the number of electrons that take part in a **chemical reaction**
- Valency of the elements having valence electrons **1, 2, 3, 4 is 1, 2, 3, 4** respectively

- Valency of an element with **5, 6 and 7** valence electrons is **3, 2 and 1 (8–valence electrons)** respectively. Because 8 is the number of electrons required by an element to attain stable electronic configuration
- Elements having completely filled outermost shell show **Zero valency**

ATOMIC NUMBER

- Atomic number of an element is the same as the number of protons in the nucleus of its atom.

MASS NUMBER

- Mass number of an atom is equal to the number of protons and neutrons in a nucleus

ISOTOPES

- Two or more forms of an element having the same atomic number, but different mass number are called Isotopes ($_{17}Cl^{35}$, $_{17}Cl^{37}$).
- Many elements consist of a mixture of isotopes. Each isotope of an element is a pure substance. The chemical properties of isotopes are similar but their physical properties are different.
- **Applications**
    1. An isotope of uranium is used as a fuel in nuclear reactors.
    2. An isotope of cobalt is used in the treatment of cancer.
    3. An isotope of iodine is used in the treatment of goitre.

Isotopes of Hydrogen

- Hydrogen has three isotopes: protium, $_1H^1$, deuterium, $_1H^2$ or D and tritium, $_1H^3$ or T.
- These isotopes differ from one another in respect of the presence of neutrons. Ordinary hydrogen, protium, has no neutrons, deuterium (also known as heavy hydrogen) has one and tritium has two neutrons in the nucleus.
- In the year 1934, an American scientist, Harold C. Urey, got Nobel Prize for separating hydrogen isotope of mass number 2 by physical methods.
- Hydrogen is the first element in the periodic table

ISOBARS

- Atoms of different elements having the same mass number, but different atomic numbers are called Isobars ($_{18}Ar^{40}$, $_{20}Ca^{40}$).

ISOTONES

- Atoms of different elements having the same number of neutrons, but different atomic number and different mass number are called Isotones ($_{6}C^{13}$, $_{7}N^{14}$).