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CHAPTER 3

ATOMS AND MOLECULES

All matter is made up of small particle called atoms and molecules. Different kinds of atoms and molecules have different properties.

Laws of Chemical Combination

laws of chemical combination were established after much experimentations by Lavoisier and Joseph L. Proust.

(i) Law of conservation of mass

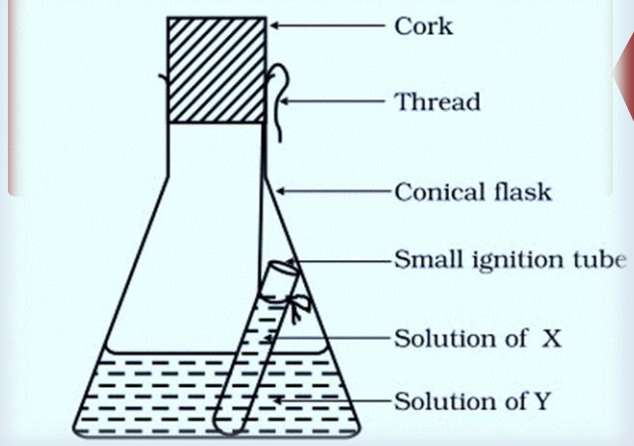
Law of conservation of mass states that mass can neither be created nor destroyed in a chemical reaction.
The substances which combine together react) in a chemical reaction are known as ' reactants ' whereas the new substances formed (or produced) as a result of chemical reaction are called ' products .
The law of conservation of mass means that in a chemical reaction, the total mass of products is equal to the total mass of reactants. There is no change in mass during a chemical reaction

Example
Take one of the following sets, X and Y of chemicals–

X	Y
barium chloride	sodium sulphate

• Prepare separately a 5% solution of any one pair of substances X and Y in water.
• Take a little amount of solution of Y in a conical flask and some solution of X in an ignition tube.

• Hang the ignition tube in the flask carefully; see that the solutions do not get mixed. Put a cork on the flask
Weigh the flask with its contents carefully.
• Now tilt and swirl the flask, so that the solutions X and Y get mixed.
• Weigh again
barium chloride solution reacts with sodium sulphate solution to form a white precipitate of barium sulphate , and sodium chloride solution . If we subtract the initial mass of the apparatus from this mass , we will get the mass of products . Suppose the mass of products is y , Now , if the mass of products (y) is equal to the mass of reactants (x) , then this experiment verifies the law of conservation of mass



(ii) LAW OF CONSTANT PROPORTIONS

law of constant proportions which is also known as the law of definite proportions. This law was stated by Proust as “In a chemical substance the elements are always present in definite proportions by mass”.

This law means that whatever be the source from which it is obtained (or the method by which it is prepared) , a pure chemical compound is always made up of the same elements in the same mass percentage

Example
In a compound such as water, the ratio of the mass of hydrogen to the mass of oxygen is always 1:8, whatever the source of water. Thus, if 9 g of water is decomposed, 1 g of hydrogen and 8 g of oxygen are always obtained.

Dalton's Atomic Theory

According to Dalton's atomic theory, all matter, whether an element, a compound or a mixture is composed of small particles called atoms. The postulates of this theory may be stated as follows:

(i) All matter is made of very tiny particles called atoms, which participate in chemical reactions.

(ii) Atoms are indivisible particles, which cannot be created or destroyed in a chemical reaction.

(iii) Atoms of a given element are identical in mass and chemical properties.

(iv) Atoms of different elements have different masses and chemical properties.

(v) Atoms combine in the ratio of small whole numbers to form compounds.

(vi) The relative number and kinds of atoms are constant in a given compound.

Atom

An atom is the smallest particle of an element that can take part in a chemical reaction.
Atoms of most of the elements are very reactive and do not exist in the free state (as single atoms) .
They exist in combination with the atoms of the same element or another element.

Atoms are very , very small in size.
The size of an atom is indicated by its radius which is called ' atomic radius ' (radius of atom) .
Atomic radius is measured in ' nanometers ' (which is a very , very small unit of measuring length) . The symbol of a nanometer is nm.
1 nanometer = $\frac{1}{10^9}$ **meters**

1nm = 10^9

WHAT ARE THE MODERN-DAY SYMBOLS OF ATOMS OF DIFFERENT ELEMENTS?

Dalton was the first scientist to use the symbols for elements in a very specific sense. When he used a symbol for an element he also meant a definite quantity of that element, that is, one atom of that element.

Now-a-days, IUPAC (International Union of Pure and Applied Chemistry) is an international scientific organization which approves names of elements, symbols and units.
Many of the symbols are the first one or two letters of the element's name in English. The first letter of a symbol is always written as a capital letter (uppercase) and the second letter as a small letter (lowercase).

ATOMIC MASS

The most remarkable concept that Dalton's atomic theory proposed was that of the atomic mass.
Atomic mass is the total of the masses of the electrons, neutrons, and protons in an atom, or in a group of atoms, the average mass.

Mass of an atomic particle is called the atomic mass.

in 1961 for a universally accepted atomic mass unit, carbon-12 isotope was chosen as the standard reference for measuring atomic masses. One atomic mass unit is a mass unit equal to exactly one-twelfth (1/12th) the mass of one atom of carbon-12.

Atomic mass of carbon 12 atom is 1.9926 × 10^{-23}gm
If we divide this mass by 12 we get the absolute mass of atomic unit (u)

Means 1(u) = 1.6605 × 10^{-24}gm

HOW DO ATOMS EXIST?

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

Molecule

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.

or

molecule is an electrically neutral group of two (or more) atoms chemically bonded together . The forces which hold the atoms together in a molecule are called covalent bonds. Thus, a combination of atoms is called a molecule .

MOLECULES OF ELEMENTS

The molecules of an element are constituted by the same type of atoms.

The molecule of an element contains two (or more) similar atoms chemically combined together .

Example,

a molecule of hydrogen element contains 2 hydrogen atoms combined together , and it is written as H_2 .

Hydrogen gas consists of H_2 molecules and not of single atoms H.

Hydrogen molecule (H_2) is a diatomic molecule because it contains 2 atoms per molecule .

MOLECULES OF COMPOUNDS

The molecule of a compound contains two (or more) different types of atoms chemically combined together .

Example
hydrogen chloride is a compound . The molecule of hydrogen chloride (HCl) contains two different types of atoms : hydrogen atom (H) and chlorine atom .

Water is a compound . A molecule of water (H_2O) is made up of two different types of atoms : hydrogen atoms (H) and oxygen atom (O)

WHAT IS AN 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'.

Writing Chemical Formulae

Chemical Formulae A chemical formula represents the composition of a molecule of the substance in terms of the symbols of the elements present in the molecule.

A chemical formula is also known as a molecular formula. The formula can be of an element or of a compound.

<u>The rules that you have to follow while writing a chemical formula are as follows:</u>

• the valencies or charges on the ion must balance.

• when a compound consists of a metal and a non-metal, the name or symbol of the metal is written first. For example: calcium oxide (CaO), sodium chloride (NaCl), iron sulphide (FeS), copper oxide (CuO) etc., where oxygen, chlorine, sulphur are non-metals and are written on the right, whereas calcium, sodium, iron and copper are metals, and are written on the left.

• in compounds formed with polyatomic ions, the ion is enclosed in a bracket before writing the number to indicate the ratio. In case the number of polyatomic ion is one, the bracket is not required. For example, NaOH

FORMULAE OF SIMPLE COMPOUNDS

The simplest compounds, which are made up of two different elements are called binary compounds. While

writing the chemical formulae for compounds, we write the constituent elements and their valencies. Then we must crossover the valencies of the combining atoms.

Molecular Mass and Mole Concept

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.

The molecular mass of a substance is the relative mass of its molecule as compared with the mass of a carbon - 12 atom taken as 12 units. The molecular mass of a substance indicates the number of times one molecule of the substance is heavier than ($\frac{1}{12}$) of a carbon - 12 atom .

Example
the molecular mass of hydrogen is 2 , which means that a molecule of hydrogen is 2 times heavier than of a carbon - 12 atom . The molecular mass is expressed in atomic mass units (u) .

FORMULA UNIT MASS

The formula unit mass of a substance is a sum of the atomic masses of all atoms in a formula unit of a compound.
Formula unit mass is calculated in the same manner as we calculate the molecular mass.
The only difference is that we use the word formula unit for those substances whose constituent particles are ions.

Example
sodium chloride as, has a formula unit NaCl. Its formula unit mass can be calculated as–
1 × 23 + 1 × 35.5 = 58.5 u

MOLE CONCEPT

One mole of any species (atoms, molecules, ions or particles) is that quantity in number having a mass equal to its atomic or molecular mass in grams.

The number of particles (atoms, molecules or ions) present in 1 mole of any substance is fixed, with a value of 6.022 × 1023.
This is an experimentally obtained value. This number is called the Avogadro Constant or Avogadro Number (represented by N_0), named in honour of the Italian scientist, Amedeo Avogadro.
1 mole (of anything) = 6.022 × 1023 in number,
as, 1 dozen = 12 nos.
1 gross = 144 nos.

The mass of 1 mole of a substance is equal to its relative atomic or molecular mass in grams. The atomic mass of an element gives us the mass of one atom of that element in atomic mass units (u).
To get the mass of 1 mole of atom of that element, that is, molar mass, we have to take the same numerical value but change the units from 'u' to 'g'.
Molar mass of atoms is also known as gram atomic mass.

To find the gram molecular mass or molar mass of a molecule, we keep the numerical value the same as the

molecular mass, but simply change units as above from u to g.

Example
we have already calculated, molecular mass of water (H2O) is 18 u. From here we understand that 18 u water has only 1 molecule of water, 18 g water has 1 mole molecules of water, that is, 6.022 × 10^{23} molecules of water.