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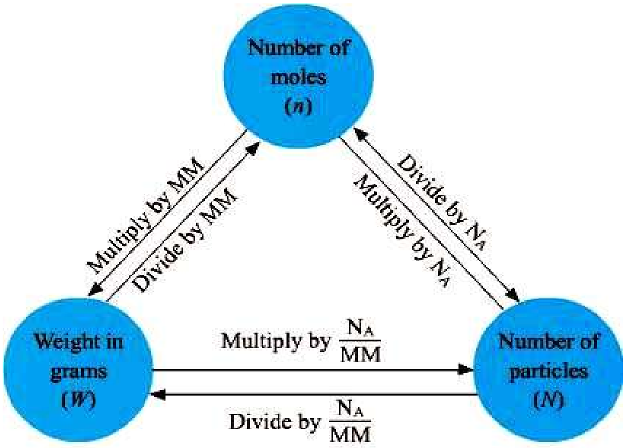
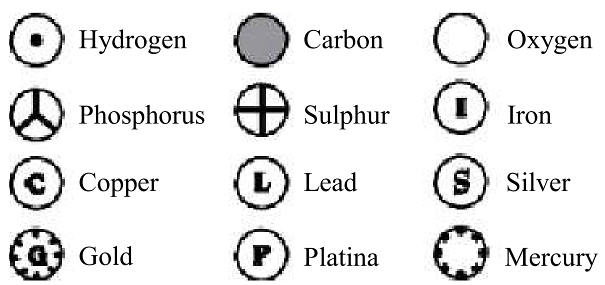
Atomic Foundations of Matter

Chapter Outline



MM = Molar mass (GAM or GMM)

$N_A = 6.023 \times 10^{23}$



Formula of sodium nitrate

Symbol/ Formula	Na	NO_3
Charge	1+	1–

Formula : $NaNO_3$

Formula of calcium hydroxide :

Symbol/ Formula	Ca	OH
Charge	2+	1–

Formula : $Ca(OH)_2$

INTRODUCTION

The concept that matter is composed of very small particles was given by Indian and Greek philosophers.

The idea of divisibility of matter was considered long back in India around 500 BC. An Indian philosopher Maharishi Kanad, postulated that if we go on dividing matter (padarth) we shall get smaller and smaller particles and ultimately a time will come when the particles obtained may be so small that they will not be further divided. He named these particles as 'Parmanu'.

Around the same era, ancient Greek philosophers – Democritus and Leucippus suggested that if we go on dividing matter, a stage will come when particles obtained will not further divided. The ultimate particles were considered as indivisible. These particles were called 'atomos' meaning indivisible. Later John Dalton gave the term 'atom' for 'atomos'

Note : In the neutral atom the total number of protons in the nucleus is equal to the total number of electrons revolving around the nucleus.

LAWS OF CHEMICAL COMBINATION

Chemistry is an experimental science and deals mainly with the reactions carried out time to time. In eighteenth century, chemists made several experiments and observed that all the chemical reactions always take place in accordance to certain laws. The experimental studies revealed the following laws.

(A) Law of Conservation of Mass (Lavoisier, 1798) : A french chemist Antoine L. Lavoisier (the father of chemistry) proposed a very significant law known as law of conservation of mass. The law can be stated as follows :

"The total mass of the products obtained during any physical or chemical change, is always equal to the total mass of reactants taken at the beginning of the change". The matter is neither created nor destroyed during any physical or chemical change. However, it may change from one form to another.

Illustration of law of conservation of mass :

(i) If 100 g of calcium carbonate ($CaCO_3$) is strongly heated, we get 56 g of calcium oxide (lime) and 44 g of carbon dioxide. The total mass of products (56 + 44 = 100 g) is exactly the same as the mass of calcium carbonate taken initially to carry out the reaction.

$$\underset{\substack{\text{Calciumcarbonate} \\ 100\text{g}}}{CaCO_3} \xrightarrow{\text{Heat}} \underbrace{\underset{\substack{\text{Calciumoxide(lime)} \\ 56\text{g}}}{CaO} + \underset{\substack{\text{Carbondioxide} \\ 44\text{g}}}{CO_2}}_{100\text{g}}$$

(ii) 12 g of carbon (C) consumes exactly 32 g of oxygen (O_2) during combustion and forms exactly 44 g of carbon dioxide. The total mass of reactants in this case (12 + 32 = 44 g) is exactly the same as the mass of the product i.e., (CO_2) obtained.

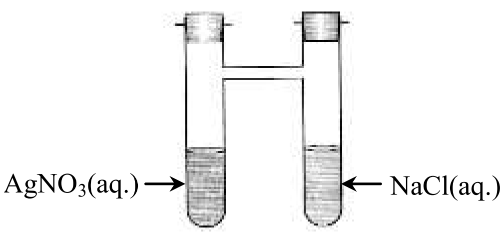
$$\underbrace{\underset{\substack{\text{Carbon} \\ 12\text{g}}}{C} + \underset{\substack{\text{Oxygen} \\ 32\text{g}}}{O_2}}_{44\text{g}} \longrightarrow \underset{\substack{\text{Carbondioxide} \\ 44\text{g}}}{CO_2}$$

Boost your knowledge

- **Experimental verification of the Law of conservation of mass :** The law was tested exhaustively by Heydweiller and Landolt (1901-1906) who performed to escape. It was noticed that there was hardly any change in the masses of the tube as a result of reaction.

$$\underset{\text{Silvernitrate}}{AgNO_3} + \underset{\text{Sodiumchloride}}{NaCl} \rightarrow \underset{\text{Silverchloride}}{AgCl\downarrow} + \underset{\text{Sodiumnitrate}}{NaNO_3}$$

- Let $AgNO_{3(aq.)}$ and $NaCl_{(aq.)}$ be filled in limbs of the H-tube, then tube is tilted to allow these reactants to react as : $AgNO_3 + NaCl \rightarrow AgCl + NaNO_3$. The mass of tube before and after the reaction comes out to be the same.



Ex.1 1.7 g of silver nitrate dissolved in 100 g of water is taken. 0.585 g of sodium chloride dissolved in 100 g of water is added to it. In chemical reaction 1.435 g of silver chloride and 0.85 g of sodium nitrate are formed. Justify that the data obey law of conservation of mass.

Sol. $\underset{\text{Silvernitrate}}{AgNO_3} + \underset{\text{Sodiumchloride}}{NaCl} \rightarrow \underset{\text{Silverchloride}}{AgCl\downarrow} + \underset{\text{Sodiumnitrate}}{NaNO_3}$

Total mass of reactants (initially) = mass of $AgNO_3$ + mass of NaCl

= 1.7 + 0.585 = 2.285 g

Total mass of products (finally) = mass of AgCl + mass of $NaNO_3$

= 1.435 + 0.85 = 2.285 g

Thus total mass before reaction = total mass after reaction = 2.285 g.

This confirms the law of conservation of mass.

(B) Law of constant proportion or Law of Definite Proportion (Proust 1799):

A French chemist, Proust in 1799 proposed the law of constant proportion or Law of definite proportion. According to this law, "A chemical compound, no matter from which source it is obtained, always contains the same elements combined together in the definite proportion by mass".

For example, water (H_2O) is comprised of two elements hydrogen and oxygen in the ratio 1 : 8 by mass. Pure water obtained from any source, e.g., hand pump, well, river, spring, sea, rains or artificially prepared in the laboratory, always contain hydrogen and oxygen in the same fixed ratio 1 : 8 by mass.

Boost your knowledge

- **Experimental verification of law of constant proportion:** This law was verified experimentally by **Stas**. Stas obtained carbon dioxide (CO_2) from various sources, such as by burning carbon in oxygen ($C + O_2 \rightarrow CO_2$), by heating sodium bicarbonate ($2NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$) or by treating marble pieces with dilute hydrochloric acid ($CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$) etc. He noticed that CO_2 contains only two elements carbon and oxygen combining together in the ratio 3 : 8 (12 : 32) by mass.

Note : To solve numerical problems of law of constant proportion, calculate the percentage of constituents in each case and prove that they are the same.

Ex.2 The common salt can be obtained from two different sources. In one sample, the percentage of chlorine was found to be 60.75 %. In the second sample, 3.888 g of chlorine were present in 6.4 g of the salt. Show that these data are in accordance to the law of constant proportion.

Sol. The first sample of common salt contains 60.75 % chlorine.

$\because$ 6.4 g of salt contains chlorine = 3.888 g

$\therefore$ 100 g of salt will contain chlorine = $\frac{3.888 \times 100}{6.4} = 60.75$ g

Hence, the percentage of chlorine in second sample = 60.75 %

Since, both the samples of common salt contain the same percentage of chlorine; the given data are in accordance to the law of constant proportion.

DALTON'S ATOMIC THEORY (1808)

Keeping in view the laws of chemical combinations and the work of Greek philosophers, a meaningful atomic theory was finally proposed by John Dalton in 1808. The basic postulates of Dalton's theory are as follows :

(i) Each element is composed of extremely small particles called atoms.

(ii) All atoms of a given element are identical i.e., atoms of a particular element are alike in all aspects.

(iii) Atoms of different elements possess completely different properties and differ in all aspects.

(iv) Atoms are indestructible i.e., atoms are neither created nor destroyed in chemical reactions.

(v) Atoms of element take part in chemical reaction to form molecules.

(vi) In a given compound, the relative number and kind of atoms are constant.

(vii) Atom of same type of elements combine in different ratio to form more than one type of compounds.

Merits of Dalton's Atomic Theory :

(i) Dalton's theory provides us a conceptual picture of matter. Atoms are the basic building blocks of matter. They are the smallest units of an element that can combine with other elements in a chemical reaction. In compounds, the atoms of two or more elements combine in definite arrangement.

(ii) Dalton's theory embodies several simple laws of chemical combination that were known at that time. Postulate (iv) indicates for the law of conservation of mass. Postulate (vi) indicates for the law of definite proportion.

(iii) Dalton's theory also explains the law of multiple proportion. Postulate (vii) indicates for the law of multiple proportion.

(iv) It explains that what makes an element to differ from others.

Limitations of Dalton's Atomic Theory

(i) **Distinction between atoms and molecules :** According to Dalton, the smallest particle of an element as well as of compound was atom, however, he called 'compound atoms' to be smallest particle of compound. Later on Amedeo Avogadro used the term molecule for the 'compound atom' i.e., molecule is the smallest particle of compound.

(ii) It could not explain why do atoms combine to form a molecule.

(iii) It could not explain the nature of forces which hold the atoms and molecules in solid, liquid and gaseous state.

(iv) The theory fails to explain the existence of isotopes and isobars.

ATOMS

All the matter is made up of atoms. 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. 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’. Atomic radius is measured in ‘nanometres’. The symbol of a nanometre is nm.

Boost your knowledge

- 1 nanometre = $\frac{1}{10^9}$ metre or 1 nm = 10^{-9} m

Hydrogen atom is the smallest atom of all.

Atoms cannot be viewed by simple optical microscopes. However, through modern techniques such as scanning tunneling microscope it is possible to produce magnified images of surfaces of elements showing atoms.

SYMBOLS OF ELEMENTS

In order to represent the elements, instead of using full lengthy names, scientists use abbreviated names. These abbreviated names of the elements are known as symbols.

Thus, symbol may be defined as the abbreviation used for the name of an element.

Dalton’s symbols of elements :

Dalton was the first scientist to use the symbols to represent elements in a simple way.

Element	Dalton’s symbol
Hydrogen	⊙
Carbon	●
Oxygen	○
Phosphorus	☮
Sulphur	⊕
Platinum	Ⓟ
Iron	Ⓘ
Copper	Ⓒ
Silver	Ⓢ
Gold	Ⓖ
Lead	Ⓛ
Mercury	⊛

Dalton’s symbols for elements were difficult to draw and inconvenient to use. So, Dalton’s symbols are only of historical importance. They are not used at all.

Modern concept of symbols :

IUPAC (International Union of Pure and Applied Chemistry) approves names of elements. Berzelius introduced the concept of using letter(s) as symbols of elements. The symbol of elements are generally either the first letter or any other significant letter of the name of the elements.

The symbols of the following elements are the first letter of the name of that elements.

Element	Symbol
Hydrogen	H
Carbon	C
Nitrogen	N
Oxygen	O
Fluorine	F
Phosphorus	P
Sulphur	S
Iodine	I

Some symbols derived from the first two letters of the names of the elements.

Element	Symbol
Aluminium	Al
Barium	Ba
Lithium	Li
Beryllium	Be
Neon	Ne
Silicon	Si
Argon	Ar
Calcium	Ca
Nickel	Ni

Some symbols derived from the first and the third letters of the names of the elements

Element	Symbol
Arsenic	As
Magnesium	Mg
Chlorine	Cl
Chromium	Cr
Manganese	Mn
Zinc	Zn
Rubidium	Rb

Some symbols derived from the latin names of the elements are given below

Common name	Symbol source		Symbol
Hydrogen	Hydrogenium	(Latin)	H
Carbon	Carbonium	(Latin)	C
Nitrogen	Nitrogenium	(Latin)	N
Oxygen	Oxygenium	(Latin)	O
Sodium	Natrium	(Latin)	Na
Potassium	Kalium	(Latin)	K
Copper	Cuprum	(Latin)	Cu
Calcium	Calx	(Latin)	Ca
Chromium	Chrom	(Greek)	Cr
Krypton	Kryptos	(Greek)	Kr
Antimony	Stibium	(Latin)	Sb
Silicon	Silex	(Latin)	Si
Mercury	Hydragyrum	(Latin)	Hg
Iron	Ferrum	(Latin)	Fe
Gold	Aurum	(Latin)	Au
Silver	Argentum	(Latin)	Ag
Tin	Stannum	(Latin)	Sn
Lead	Plumbum	(Latin)	Pb

It is important to note that the first letter of every chemical symbol is capital letter but, if the symbol consists of two letters, the second letter is not capital letter.

Ex. Symbol for aluminum is Al not AL
Symbol for lead is Pb not PB

Boost your knowledge

- **Significance of the symbol of an element**
  - Symbol represents name of the element.
  - Symbol represents one atom of the element.
  - Symbol also represents one mole of atoms of the element. That is, symbol also represents 6.022×10^{23} atoms of the element.
  - Symbol represents a definite mass of the element. (equal to atomic mass expressed in grams)

ATOMIC MASS

Atoms of all the elements (except noble gases) are not able to exist independently. They combine with similar or different atomic species to form molecules or ions. These molecules or ions aggregate together in large numbers to form the matter which is around us.

Only a few elements, (noble gases) e.g., helium, neon, argon, krypton, xenon and radon are able to exist freely in atomic state i.e., these shows independent existence and exist as mono atomic gases in nature.

The atom of an element is so small that it cannot be weighed even with the help of the most sensitive balance known till now. Therefore the determination of mass of an atom by weighing is not feasible. Several indirect and advanced techniques have been used for the determination of absolute mass of atoms. The absolute atomic mass of an atom of hydrogen is 1 u or 1.67×10^{-24} g as well as absolute atomic masses of other atoms are also of the same order. Since the absolute atomic masses of all atoms are extremely small and are in the order of 10^{-24} g and therefore, it is very inconvenient to use mass of one atom in routine calculations. A new term relative atomic mass was therefore used. The relative atomic mass is its absolute mass compared to the absolute mass of an atom of a standard substance i.e. carbon, Thus,

$$\text{Relative atomic mass} = \frac{\text{Absolute mass of atom of the given substance}}{\text{Absolute mass of an atom of a standard substance}}$$

Direct determination of relative mass as defined above is again impossible as it will again require absolute masses of the atoms.

The relative atomic mass of an element is the number which tells how many times an atom of that element is heavier than an atom of hydrogen.

Boost your knowledge

- Most of the atomic masses determined with hydrogen as the standard were not whole numbers. Later on, O^{16} isotope of oxygen was taken as the reference substance and the relative atomic masses of most of the elements were calculated on its basis and found very close to whole numbers.
- In 1961, a new standard carbon-12, (C^{12}, the most stable isotope of carbon) was adopted by International Union of Chemistry to calculate the relative atomic masses of elements. The new scale adopted is called atomic mass unit scale.

Atomic Mass Unit Scale

On this scale, the relative atomic mass of an element is expressed in terms of atomic mass unit (abbreviated as amu or u). One atomic mass unit (1 amu or 1 u) is defined as the quantity of mass equal to $\frac{1}{12}$ th of the mass of an atom of carbon-12 (C^{12}, most stable isotope of carbon).

$$\text{Relative atomic mass of an element} = \frac{\text{Mass of an atom of the given element}}{\frac{1}{12} \times \text{Mass of an atom of } C^{12}}$$

$$1 \text{ u} = \frac{1}{12} \times \text{mass of an atom of C-12.}$$

Thus, the relative atomic mass of an element is the relative mass of an atom of that element as 1/12th of the mass of an atom of carbon-12.

On the basis of this definition, the relative atomic mass of hydrogen is found to be 1 u, while that of oxygen is 16 u.

Boost your knowledge

- Earlier, atomic mass unit was abbreviated as amu. But according to the latest IUPAC recommendation, it is now written as u which stands for unified mass. Also, 1 u = 1 Dalton = 1.66×10^{-24} g.

Atomic Masses of Some Common Elements
(On the atomic mass scale of C^{12} = 12 u)

Element	Symbol	Atomic mass (u)	Element	Symbol	Atomic Mass (u)
Hydrogen	H	1	Chlorine	Cl	35.5
Carbon	C	12	Potassium	K	39
Nitrogen	N	14	Calcium	Ca	40
Oxygen	O	16	Iron	Fe	56
Sodium	Na	23	Copper	Cu	63.5
Magnesium	Mg	24	Zinc	Zn	65
Aluminium	Al	27	Bromine	Br	80
Silicon	Si	28	Silver	Ag	108
Phosphorus	P	31	Iodine	I	127
Sulphur	S	32	Gold	Au	197

Gram-Atomic Mass

Gram-atomic mass or mass of one gram-atom (g-atom) of an element is the mass of Avogadro number or 6.02×10^{23} atoms of that element.

This may be understood as follow :

For example, the atomic mass of hydrogen is 1 u.

or 1 atom of hydrogen has mass = 1u = 1.66×10^{-24} g ($\because$ 1.66×10^{-24} g = 1u)

$\therefore$ 6.02×10^{23} atoms of hydrogen gas mass = $1 \times 1.66 \times 10^{-24} \times 6.023 \times 10^{23}$ g = 1 g

Thus, in short, GAM is the absolute atomic mass expressed in gram.

How do atoms exist ?

The atoms of only a few elements called noble gases (such as Helium, Neon, Argon, Krypton, Xenon and Radon) are chemically unreactive and exist in the free state (as single atoms). Atoms of most of the elements are chemically very reactive and do not exist in the free state (as single atoms).

Atoms usually exist in two ways.

(i) In the form of molecules and (ii) In the form of ions.

When atoms form molecules or ions, they become stable (because while doing so they acquire the stable electronic configuration like noble gases).

MOLECULES

According to Avogadro, molecule is the smallest unit of a substance (element or compound) which can exist independently.

It is important to know that the atoms of the same element or different elements can join together to form molecules. On this basis, molecules are of two types :

(1) Molecules of elements and (2) Molecules of compounds

Molecules of Elements :

Definition : The molecule which is made up of two or more atoms of the same element that are chemically bonded together is called molecule of an element.

Ex . H_2, N_2, O_2, Cl_2, O_3, P_4, S_8 etc. are the molecules of elements. Molecules of helium (He), neon (Ne), argon (Ar) etc. are made up of single atoms. These are chemically unreactive elements.

The number of atoms present in a single molecule of a substance is called atomicity of that molecule or substance. The molecules of elements composed of the same type of atoms are called homoatomic molecules. They may be monoatomic, diatomic, triatomic or polyatomic.

(i) Monoatomic molecules : The molecules of noble gases like helium (He) , neon (Ne), argon (Ar), krypton (Kr), xenon (Xe) and radon (Rn) are composed of one atom only. Hence, they are monoatomic in nature and exist independently in monoatomic state.

(ii) Diatomic molecules : Diatomic molecules of most of the gases formed by non-metal atoms consists of two atoms of same element held strongly together by attractive forces e.g., a molecule of oxygen consists of two oxygen atoms and is represented as O_2. Examples of other diatomic molecules are nitrogen molecule (N_2), hydrogen molecule (H_2), chlorine molecule (Cl_2), fluorine molecule (F_2) etc.

In each of the above examples subscript 2 indicates that there are two atoms.

(iii) Triatomic molecules : Triatomaic molecules consists of three atoms of same element held tightly together by attractive forces e.g., a molecule of ozone consists of three atoms of oxygen and is represented as O_3.

(iv) Polyatomic molecules : The polyatomic molecules of some non-metals consist of more than three atoms and are referred as polyatomic molecules e.g., phosphorus molecules (P_4), sulphur molecule (S_8) etc.

The molecules of metals and some other elements, such as carbon (e.g. C-60) consist of a very large and indefinite number of atoms bonded together. Their structures are complicated.

Molecules of Compounds :

Definition : Molecules in which atoms of different elements are chemically bonded together are called molecules of compounds. Compounds in which atoms of different elements are chemically bonded together are called molecular or covalent compounds.

Water (H_2O), ammonia (NH_3), carbon dioxide (CO_2), methane (CH_4), hydrogen chloride (HCl), sulphuric acid (H_2SO_4) etc. are all molecules of compounds.

In all these compounds, atoms of different elements are chemically bonded together in the constant ratio by mass of elements.

Boost your knowledge

- **Heteroatomic molecules :** The molecules of compounds composed of two or more atoms of different elements linked together in definite proportions are called heteroatomic molecules.

  For example, a molecule of water is composed of two atoms of hydrogen (H) and one atom of oxygen (O) therefore, a molecule of water is represented as H_2O.

  The heteroatomic molecules of compounds can also be classified as diatomic (NO), triatomic (H_2O) and polyatomic (H_2O_2) depending upon the total number of atoms present in them.

Molecules of Some Compounds

Compound	Constituent Elements	Ratio by Mass	Formula of the Molecule	Atomicity
Hydrogen chloride	Hydrogen (H), Chlorine (Cl)	1: 35.5	HCl	2
Water	Hydrogen (H), Oxygen (O)	1 : 8	H_2O	3
Ammonia	Nitrogen (N), Hydrogen (H)	14 : 3	NH_3	4
Carbon monoxide	Carbon (C), Oxygen (O)	3 : 4	CO	2
Sulphur dioxide	Sulphur (S), Oxygen (O)	1 : 1	SO_2	3
Nitrous oxide	Nitrogen (N), Oxygen (O)	7 : 4	N_2O	3
Nitric oxide	Nitrogen (N), Oxygen (O)	7 : 8	NO	2

MOLECULAR MASS

As the term itself explains, molecular mass is the mass of one molecule of a substance. But like an atom, a molecule is so small that it is impossible to determine its absolute mass. Therefore its better to refer the relative molecular mass.

The relative molecular mass of a substance (molecule or compound) is the mass of a single molecule of that substance as compared to $\frac{1}{12}$ the mass of an atom of carbon-12 (C^{12}).

Thus relative Molecular mass = $\dfrac{\text{Actual mass of one molecule of the substance}}{\frac{1}{12} \times \text{Mass of an atom of } C^{12}}$

In other words, the relative molecular mass tells how many times one molecule of the given substance is heavier than $\frac{1}{12}$ the mass of an atom of C^{12}. The relative molecular mass is expressed in atomic mass units (amu or u).

Molecular mass of a substance can be obtained by adding up the atomic masses of all the atoms present in one molecule of it. For example,

Molecular mass of CO_2 = 1 × (atomic mass of C) + 2 × (atomic mass of O)

= (1 × 12) + (2 × 16) = 44 u

Similarly, the molecular mass of potassium sulphate (K_2SO_4) can be obtained as follows :

Molecular mass of K_2SO_4 = 2 × (atomic mass of K) + (atomic mass of S) + 4 × (atomic mass of O)

= (2 × 39) + 32 + (4 × 16) = 174 u.

Gram-Molecular Mass :

The gram molecular mass or molar mass of a substance (element or compound) is the mass of Avogadro number or 6.02×10^{23} molecules of that substance. It is expressed in g mol^{-1}.

This can be understand as -

For example, the molecular mass of one molecule of water is 18.0 u.

i.e. mass of 1 molecule of water = 18 u = $18 \times 1.66 \times 10^{-24}$ g

$\therefore$ mass of 6.02×10^{23} molecules of water = $18 \times 1.66 \times 10^{-24} \times 6.023 \times 10^{23}$ g = 18 g mol^{-1}

Boost your knowledge

- A numerical value of molecular mass and gram molecular mass is same. But their unit is different.

IONS

An ion is a positively or negatively charged atom (or group of atoms). An ion is formed by the loss or gain of electrons by an atom, so it contains an unequal number of electrons and protons.

Ex. Sodium ion (Na^+), magnesium ion (Mg^{2+}), chloride ion (Cl^-), and oxide ion (O^{2-}) etc.

Type of Ions :

I. On the basis of nature of charge :

There are two types of ions : cations and anions.

Cation

A positively charged ion is known as cation. A cation is formed by the loss of one or more electrons by an atom.

Ex. Sodium atom loses 1 electron to form a sodium ion, Na^+, which is cation :

$Na \xrightarrow{-1 \text{ electron}} Na^+$

Sodium atom	Sodium ion (cation)
Protons = 11 (+ charge)	Protons = 11 (+charge)
Electrons = 11 (– charge)	Electrons = 10 (–charge)
Overall charge = 0	Overall charge = 1+

Note : The ions of all the metal elements are cations.

E.g. A magnesium atom loses 2 electrons to form magnesium ion, so magnesium ion bears 2 units of positive charge and it is represented as Mg^{2+}

$Mg \longrightarrow Mg^{2+} + 2e^-$

E.g. An aluminium atom loses 3 electrons to form aluminium ion, so aluminium ion bears 3 units of positive charge and it is represented as Al^{3+}

$Al \longrightarrow Al^{3+} + 3e^-$

Anion

A negatively charged ion is known as anion. An anion is formed by the gain of one or more electrons by an atom.

Ex. A chlorine atom gains 1 electron to form a chloride ion, Cl^-, which is an anion.

Cl	$\xrightarrow{+1 \text{ electron}}$ Cl^-
Chlorine atom	Chloride ion (anion)
Protons = 17 (+ charge)	Protons = 17 (+ charge)
Electrons = 17 (– charge)	Electrons = 18 (– charge)
Overall charge = 0	Overall charge = 1–

Note : The ions of all the non-metal elements are anions

E.g. A oxygen atom gains 2 electrons to form oxide ion, so oxide ion bears 2 units of negative charge and it is represented as O^{2-}

$O + 2e^- \longrightarrow O^{2-}$

E.g. A nitrogen atom gains 3 electrons to form nitride ion, so nitride ion bears 3 units of negative charge and it is represented as N^{3-}

$N + 3e^- \longrightarrow N^{3-}$

Note : Size of a cation is always smaller and anion is always greater than that of the corresponding neutral atom.

II. On the basis of number of atoms :

There are two types of ions : monoatomic ions and polyatomic ions.

Monoatomic ions :

These ion which are formed from single atom are called simple ions.

Ex. Na^+, K^+, Ca^{2+}, O^{2-}, F^- etc.

Polyatomic ions :

Those ions which are formed from groups of joined atoms are called compound ions

Ex. NH_4^+, H_3O^+, OH^- etc.

FORMULA UNIT MASS

As we have read the sum of atomic masses of all the atoms present in the molecular formula of a substance is called its molecular mass.

In ionic compounds, there is no molecule or ionic compounds do not have any molecular formula. Say in sodium chloride, each sodium ion is surrounded by six Cl^- ions and each Cl^- is surrounded by six Na^+ ion. These forms an ionic lattice of sodium chloride in solid state. Therefore in all ionic compounds we use the term formula mass in place of molecular mass. For example, the chemical formula of aluminium chloride is $AlCl_3$ (an ionic compound) but it exists as a dimmer and its molecular formula is Al_2Cl_6 (a covalent compound).

Hence, The formula mass of aluminium chloride ($AlCl_3$) = $(1 \times 27) + (3 \times 35.5) = 133.5$ u

For ionic compounds, one mole represents 6.022×10^{23} formula units of the compound.

For example, one mole of sodium chloride (formula mass = 23 + 35.5 = 58.5) contains 6.022×10^{23} NaCl units.

Since each unit of NaCl contains one Na^+ and one Cl^-, it can be said that one mole of NaCl contains. One mole of potassium sulphate (K_2SO_4) contains.

$= 6.022 \times 10^{23}$ K_2SO_4 units

$= 2 \times 6.022 \times 10^{23}$ K^+ ions + 6.022×10^{23} SO_4^{2-} ions

CHEMICAL FORMULAE

The chemical formula of a compound or an element represents the composition of a molecule of the compound or an element, in terms of the symbols of elements and the number of atoms of each element present in one molecule of the compound or an element.

(a) Formulae of Elements:

The chemical formula of an element is a representation of the composition of its molecule in which symbol represents the element and subscript represents, how many atoms are present in one molecule.

e.g. One molecule of hydrogen element contains two atoms of hydrogen, therefore, the formula of hydrogen is H_2. It should, however, be noted that 2H represents two separate atoms of hydrogen , while H_2 represents one molecule of hydrogen.

(b) Formulae of Compounds:

The chemical formula of a compound is a representation of the composition of its molecule in which symbol represents, which elements are present and the subscript shows us how many atoms of each element are present in one molecule of a compound.

e.g. One molecule of carbon dioxide contains 1 atom of carbon and 2 atoms of oxygen. Hence, the formula of carbon dioxide is CO_2.

(i) In the chemical formula of a compound, the elements present are denoted by their symbols and the number of atoms of each element are denoted by writing their number as subscripts to the symbols of the respective elements.
e.g. Water is a compound whose one molecule is made up of 2 atoms of hydrogen and 1 atom of oxygen and hence, its chemical formula is H_2O.

(ii) While writing the formula of an ionic compound, the metal is written on the left hand side, while the non-metal is written on the right hand side.
e.g. Magnesium oxide is written as MgO , Sodium chloride is written as NaCl etc.
The name of the metal remains as such, but that of the non-metal is changed to have the ending 'ide'.

(iii) Molecular compounds, formed by the combination between two different non-metals, are written in such a way that the less electronegative element is written on the left hand side, while the more electronegative element is written on the right hand side. In naming molecular compounds, the name of the less electronegative non-metal is written as such but the name of the more electronegative element is changed to have the ending 'ide'.
e.g.H_2S is named as hydrogen sulphide and HCl is named as hydrogen chloride.

(iv) When there are more than one atoms of an element present in the formula of the compound, then the number of atoms are indicated by the use of appropriate prefixes (mono for 1, di for 2, tri for 3, tetra for 4 atoms etc. respectively) in the name of the compound.
e.g.CO is named as carbon monoxide, CO_2 is named as carbon dioxide and CCl_4 is named as carbon tetrachloride.

(v) The prefixes are needed in naming those binary compounds in which the two non-metals form more than one compounds (by having different number of atoms).
e.g. Two non-metals, nitrogen and oxygen, combine to form different compounds like nitrogen monoxide (NO), nitrogen dioxide (NO_2), dinitrogen trioxide (N_2O_3) etc.

(vi) If two non-metals form only one compound, then prefixes are not used in naming such compounds.
e.g. Hydrogen and sulphur combine to form only one compound H_2S. So, H_2S is named as hydrogen sulphide and not as hydrogen monosulphide or dihydrogen monosulphide.

Boost your knowledge

- The number ratio of atoms present in a molecule can be determined by dividing the ratio by mass with the respective atomic masses of the corresponding elements and finding the simplest ratio.

LIST OF COMMON ELECTROVALENT POSITIVE RADICALS

	Monovalent Electropositive			Bivalent Electropositive			Trivalent Electropositive			Tretravalent Electropositive	
1	Hydrogen	H^+	1	Magnesium	Mg^{2+}	1	Aluminium	Al^{3+}	1	Stannic [Tin(IV)]	Sn^{4+}
2	Ammonium	NH_4^+	2	Calcium	Ca^{2+}	2	Ferric [Iron(III)]	Fe^{3+}	2	Plumbic [lead(IV)]	Pb^{4+}
3	Sodium	Na^+	3	Zinc	Zn^{2+}	3	Chromium	Cr^{3+}			
4	Potassium	K^+	4	Plumbous [Lead(II)]	Pb^{2+}						
5	Cuprous [Copper(I)]	Cu^+	5	Cupric [Copper(II)]	Cu^{2+}						
6	Argentous [Silver(I)]	Ag^+	6	Argentic [Silver(II)]	Ag^{2+}						
7	Mercurous [Mercury(I)]	Hg^{1+}	7	Stannous [Tin(II)]	Sn^{2+}						
			8	Ferrous [Iron(II)]	Fe^{2+}						
			9	Mercuric [Mercury(II)]	Hg^{2+}						
			10	Barium	Ba^{2+}						

LIST OF COMMON ELECTROVALENT NEGATIVE RADICALS

	Monovalent Electronegative			Bivalent Electronegative			Trivalent Electronegative			Tretravalent Electronegative	
1	Fluoride	F^-	1	Sulphate	SO_4^{2-}	1	Nitride	N^{3-}	1	Carbon	C^{4-}
2	Chloride	Cl^-	2	Sulphite	SO_3^{2-}	2	Phosphide	P^{3-}			
3	Bromide	Br^-	3	Sulphide	S^{2-}	3	Phosphite	PO_3^{3-}			
4	Iodide	I^-	4	Thiosulphate	$S_2O_3^{2-}$	4	Phosphate	PO_4^{3-}			
5	Hydride	H^-	5	Zincate	ZnO_2^{2-}						
6	Hydroxide	OH^-	6	Oxide	O^{2-}						
7	Nitrite	NO_2^-	7	Peroxide	O_2^{2-}						
8	Nitrate	NO_3^-	8	Dichromate	$Cr_2O_7^{2-}$						
9	Bicarbonate or Hydrogen carbonate	HCO_3^-	9	Carbonate	CO_3^{2-}						
10	Bisulphite or Hydreogen sulphite	HSO_3^-	10	Silicate	SiO_3^{2-}						
11	Bisulphide or Hydrogen sulphide	HS^-									
12	Bisulphate or Hydrogen sulphate	HSO_4^-									
13	Acetate	CH_3COO^-									

(c) Ion and method of writing the chemical formula of an ionic compound:

An ion is an atom or a group of atoms (of the same or different elements) that carries a positive or a negative charge and behaves like a single unit.

The species containing a single atom and carrying a positive or negative charge are called simple ions i.e., Na^+, Ca^{2+}, H^+, Cl^-, Br^- etc. The species containing a group of atoms and having a net charge on them are called polyatomic ions, i.e; NH_4^+, SO_4^{2-}, PO_4^{3-}, NO_3^- etc.

Positively charged ions are termed as cations, whereas the negatively charged ions are termed as anions.

The valency of an ion in usually equal to the number of charges present on it. Depending upon their valencies, ions are also referred to as monovalent (valency = 1), bivalent (valency = 2), trivalent (valency = 3) and tetravalent (valency = 4).

Note :

1. 2 + means two positive charges, i.e., + + e.g. Ca^{2+} ;

3 + means three positive charges, i.e., + + + e.g. Fe^{3+} ;

whereas 4 + indicates the presence of four positive charges (+ + + +) e.g. Sn^{4+}

Similarly 1 – means one negative charge i.e. –1 e.g. Cl^- and so on.

2. Roman number written in brackets represent the valency of the ion i.e. Fe^{2+} as Fe(II) in compounds.

Writing the formula of carbon dioxide as an example :

Following steps are used to write the formula of carbon dioxide -

- Carbon dioxide is a compound composed of two elements, carbon and oxygen. So, we first write their symbols C and O respectively.
- The valency of carbon is 4 and the valency of oxygen is 2. Now, these valencies are to be written under the corresponding symbols of elements.

Symbols : C O

Valencies : 4 2

- Now, the valencies of carbon and oxygen are to be exchanged. So, the subscript corresponding to C is 2 and that corresponding to O is 4. Hence, the formula of the compound becomes C_2O_4.
- But, the valencies 2 and 4 have a common factor 2. So, on dividing the whole formula by 2, we get the simplest formula CO_2. Thus, the formula of carbon dioxide is CO_2.

Ex. Write the formula of hydrogen sulphide.

Sol. Elements present in hydrogen sulphide are hydrogen and sulphur. Valency of hydrogen is 1 and that of sulphur is 2.

Symbol : H S   H S H_2S_1 or H_2S

Valency : 1 2   1 2   (Formula)

Crossover Valency

In the formula H_2S :

Valency of H is 1, atoms of H are 2.

Valency of S is 2, atom of S is 1.

Total valencies of H-atom = 1 × 2 = 2

Total valency of S-atom = 2 × 1 = 2

Since total valency of atoms of metals and non-metals comes out to be equal, the formula (H_2S) is correct of hydrogen sulphide.

Chemical formula of ionic compound :

The compounds which are made up of ions are known as ionic compounds. In an ionic compound, the positively charged ions (cations) and negatively charged ions (anions) are held together by the strong electrostatic forces of attraction. The forces which hold the ions together in an ionic compound are known as ionic bonds or electrovalent bonds. Since an ionic compound consists of an equal number of positive ions and negative ions, so the overall charge on an ionic compound is zero.

Ex. Sodium chloride (NaCl) is an ionic compound which is made up of equal number of positively charged sodium ions (Na^+) and negatively charged chloride ions (Cl^-).

Some ionic compound and their ions

S.No.	Name	Formula	Ions present
1	Sodium chloride	NaCl	Na^+ and Cl^-
2	Potassium chloride	KCl	K^+ and Cl^-
3	Ammonium chloride	NH_4Cl	NH_4^+ and Cl^-
4	Magnesium chloride	$MgCl_2$	Mg^{2+} and Cl^-
5	Calcium chloride	$CaCl_2$	Ca^{2+} and Cl^-
6	Magnesium oxide	MgO	Mg^{2+} and O^{2-}
7	Calcium oxide	CaO	Ca^{2+} and O^{2-}
8	Aluminium oxide	Al_2O_3	Al^{3+} and O^{2-}
9	Sodium hydroxide	NaOH	Na^+ and OH^-
10	Copper sulphate	$CuSO_4$	Cu^{2+} and SO_4^{2-}
11	Calcium nitrate	$Ca(NO_3)_2$	Ca^{2+} and NO_3^-

An ionic compound is electrically neutral and is usually formed by the combination of positive and negative ions in such a way that the positive charge of the cation is completely neutralized by the negative charge present on the anion. This fact should be kept in mind while writing the formula of a compound (say for example magnesium phosphate).

The method used to write the formula of a compound is called **Criss-cross method**. It is carried out in the following steps :

(i) Write the symbols of cation and anion side by side. Say for example magnesium oxide. The cation Mg^{2+} i.e., the ion having positive charge is written first i.e., O^{2-}. The anion (O^{2-}) is written after it.

(ii) Write the charge of each ion on the top of its symbol. While doing so, ignore the + and – sign i.e. Mg^2, O^2.

(iii) Divide the charges by their highest common factor (if any) to get a simple ratio.

(iv) Interchange the charge and write them on the lower right side of the symbols i.e. MgO. The number 1 does not need to be written. This is known as cris cross method.

(v) The formula of magnesium oxide MgO.

Let us consider another example of calcium nitride.

(i) Writing the symbols of cation and anion Ca^{2+}, N^{3-}

(ii) Writing the charge of ions : $\overset{2}{Ca}\ \overset{3}{N}$

(iii) Interchange their charge : $Ca^{2}\ N^{3}$

(iv) Thus, the formula of calcium nitride is Ca_3N_2.

NAMING COMPOUNDS FROM THEIR FORMULAE

(a) Naming Simple Compounds Formed by a Metal and a Non-metal :

The name of a simple compound formed by a metal and a non-metal (or group of non-metals) can easily by written by identifying cation and anion in its formula. The name of the compound is obtained by first writing the name of the metal cation followed by the name of the non metal anion.

Formula	Name
NaCl	Sodium chloride
KCl	Potassium chloride
$MgCl_2$	Magnesium chloride
$CaCl_2$	Calcium chloride
MgO	Magnesium oxide
CaO	Calcium oxide
Al_2O_3	Aluminium oxide

Note : The valency of an element is always a whole number. Some elements exhibit more than one valency, i.e., they have variable valency. Generally, the Latin / Greek name for the element is modified to end in 'ous' for the lower valency and to end in 'ic' for the higher valency. The table below lists some elements that exhibit variable valencies.

Element	Symbol	Valency	Ions	Nomenclature
Copper	Cu	1 2	Cu^{1+} Cu^{2+}	Copper [I] or Cuprous Copper [II] or Cupric
Silver	Ag	1 2	Ag^{1+} Ag^{2+}	Silver [I] or Argentous Silver [II] or Argentic
Mercury	Hg	1 2	Hg^{1+} Hg^{2+}	Mercury [I] or Mercurous Mercury [II] or Mercuric
Iron	Fe	2 3	Fe^{2+} Fe^{3+}	Iron [II] or Ferrous Iron [III] or Ferric
Tin	Sn	2 4	Sn^{2+} Sn^{4+}	Tin [II] or Stannous Tin [IV] or Stannic
Lead	Pb	2 4	Pb^{2+} Pb^{4+}	Lead [II] or Plumbous Lead [IV] or Plumbic

Boost your knowledge

- In case of the metal forming the compound is capable of showing variable valencies, the valency of the metal is written in roman numerals in paranethessis after the name of the metal. This representation is called **stock notation**. For example :

Naming Simple Compounds from Their formulae

Formula	Name
CuCl	Copper (I) chloride or Cuprous chloride
$CuCl_2$	Copper (II) chloride or Cupric chloride
$FeCl_2$	Ferrum (II) chloride or Ferrous chloride
$FeCl_3$	Ferrum (III) chloride or Ferric chloride

(b) Naming Compounds formed by Two non-metals :

Compounds formed by two non-metals are named by writing first non-metal and then other using the suffixes di, tri, tetra, penta etc. before the name of the non-metals if they appear with more than one atom. The name of more electronegative non-metal comes in last. For example.

Formula	Name
CO_2	Caron dioxide
NO_2	Nitrogen dioxide
OF_2	Oxygen difluoride
PCl_3	Phosphorus trichloride
CCl_4	Carbon tetrachloride
PCl_5	Phosphorus pentachloride
N_2O_5	Dinitrogen pentoxide

MOLE CONCEPT

Mole is a Latin word which means 'heap' or 'pile'. Scientist Wilhelm Ostwald used the term mole to represent a collection of a large number of particles (atoms and molecules) of chemical substances. It was accepted as a unit of quantity in 1967.

The mass of any species, which contains 6.022×10^{23} atoms (or molecules or ions) is known as one mole of that species. It is abbreviated as mole or mol. Just like a pair or a dozen or a gross, mole simply represents a collection of a definite number of particles. A pair represents two species, a dozen represents a collection of 12 object, whereas a gross is a collection of 144 objects. Similarly, one mole represents a collection of 6.022×10^{23} particles.

The term mole now-a-days has been widely used for any species and may be defined as follows :

A mole is the number of any species which contains as many as elementary entities (atoms, molecules, ions, neutrons, protons, electrons, protons etc. or any species even rupee etc.) as there are atoms in 12 g of C^{12}, i.e., as equal to Avogadro's number, 6.022×10^{23}.

When we talk of a mole, we mean the entity that it represents, is equal to 6.022×10^{23} entities of that species.

Avogadro's Number or Avogadro's Constant (N or N_0 or N_A):

It has been found experimentally that one g-atom of any element contains as many atoms as are present in one g-atom of carbon-12 i.e., in 12 g of C^{12}. Also, one gram-molecule of any compound is also found to contain the same number of molecule. In other words, the number of atoms present in one g-atom of any element is the same as the number of molecules present in one gram-molecule of any compound and in equal to the number of atoms present in 12 g of C-12. Avogadro named this significant number as Avogadro's Constant or simply Avogadro's Number. It is represented by N or N_0 or N_A and is defined as follows :

Avogadro's number or Avogadro's constant is the number of atoms present in 12 g of C^{12} isotope of carbon.

The value of Avogadro's number is 6.022×10^{23}.

Avogadro's number (N_0)

= Number of atoms present in one g-atom of any substance.

= Number of molecules present in one gram-molecule of any compound.

= Number of ions present in one gram-ion of any ionic substance.

For example, the g-atomic mass (one g-atom) of hydrogen is 1 g while the gram-molecular mass or molar mass of dihydrogen (one gram-molecule) is 2 g of dihydrogen contains 6.022×10^{23} molecules of H_2 or 1.204×10^{24} atoms of H. Similarly, the g-atomic mass of nitrogen is 14 g while its gram-molecular mass of (N_2) is 28 g. Thus 14 g of nitrogen contain 6.022×10^{23} atoms while 28 g of dinitrogen contain 6.022×10^{23} molecules or 1.204×10^{24} atoms of N.

One mole (in general) = 6.022×10^{23} particles

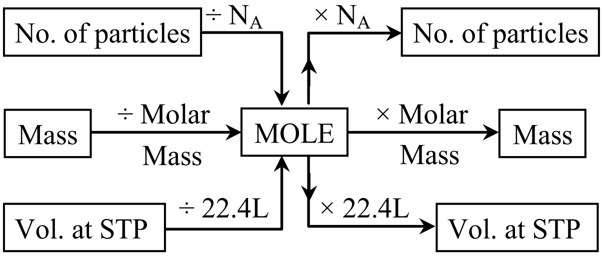
One mole of atoms = 6.022×10^{23} atoms

One mole of compound = 6.022×10^{23} molecules

One mole of ions = 6.022×10^{23} ions

One mole of electron = 6.022×10^{23} electrons.

Basic formulae of mole concept :



Ex.1 Calculate the mass of the following :

(i) 0.5 mole of N_2 gas

(ii) 0.5 mole of N-atoms

(iii) 3.011×10^{23} number of N-atoms

(iv) 6.022×10^{23} number of N_2 molecules

Sol. (i) Mass in gram (m) = Moles (n) × Molar mass (M) = 0.5 × 28 = 14 g

(ii) Mass in gram (m) = Moles (n) × Atomic mass (M) = 0.5 × 14 = 7g

(iii) $\text{Moles} = \dfrac{\text{Number of particles}}{\text{Avogadro's number}} = \dfrac{3.01 \times 10^{23}}{6.022 \times 10^{23}} = 0.5$

Mass in grams (m) = Moles (n) × Atomic mass (M) = 0.5 × 14 = 7g

Second Method : Molar mass of N-atom is 14 gram.

$\because$ 6.022×10^{23} atoms of N weigh = 14 gram

$\therefore$ 3.011×10^{23} atoms of N weigh

$= \dfrac{14 \times 3.011 \times 10^{23}}{6.022 \times 10^{23}} = 7$ gram

(iv) $\text{Moles (n)} = \dfrac{\text{Number of particles}}{6.022 \times 10^{23}} = \dfrac{6.022 \times 10^{23}}{6.022 \times 10^{23}} = 1$

$\because$ Molar mass of N_2 = 28 gram

$\therefore$ Mass in gram (m) = Moles (n) × Molar mass (M) = 1 × 28 = 28 g

Second Method : Mass of 6.022×10^{23} particles is equal to molar mass. Therefore, mass of 6.022×10^{23} moles of N_2 is equal to 28 gram.

Ex.2 Calculate the number of moles, molecules, number of H-atoms, number of S-atoms and number of O-atoms in 49 gram H_2SO_4.

Sol. In such questions, number of moles are calculated first. Moles on multiplication with 6.022×10^{23} give the number of molecules. Then see how many atoms of the given element are present in one molecule of the compound ? Then calculate the number of atoms.

Mass of H_2SO_4 (m) = 49 gram, Molar mass of H_2SO_4(M) = 98 gram.

$\text{Moles of } H_2SO_4 = \dfrac{\text{Mass in gram (m)}}{\text{Molar mass (M)}} = \dfrac{49}{98} = 0.5$

Number of molecules of H_2SO_4 = Moles × 6.022×10^{23}

$= 0.5 \times 6.022 \times 10^{23}$

$= 3.011 \times 10^{23}$

Now one molecules of H_2SO_4 contains :

Two H-atom, One S-atom, Four O-atoms

Number of H-atoms = 2 × number of molecules of H_2SO_4

$= 2 \times 3.011 \times 10^{23} = 6.022 \times 10^{23}$

Number of S-atoms = 1 × Number of molecules of H_2SO_4

$= 1 \times 3.011 \times 10^{23} = 3.011 \times 10^{23}$

Number of O-atoms = 4 × Number of molecules of H_2SO_4

$= 4 \times 3.011 \times 10^{23} = 12.044 \times 10^{23}$

Ex.3 Calculate the number of aluminium ions present in 0.051 g of aluminum oxide (Al_2O_3). Given that Al = 27u. O = 16 u.

Sol. Calculate moles, molecules and then aluminium ions.

Molar mass of $Al_2O_3 = (2 \times 27) + (3 \times 16) = 102$ g

Moles of $Al_2O_3 = \frac{\text{Mass in gram}}{\text{Molar mass}} = \frac{0.051}{102} = 0.0005$

Molecules of Al_2O_3 = Moles $\times 6.022 \times 10^{23} = 0.0005 \times 6.022 \times 10^{23} = 3.011 \times 10^{20}$

Now one molecules of Al_2O_3 contains 2 aluminium ions.

$\therefore$ Number of aluminum ions = 2 × molecules of Al_2O_3

$= 2 \times 3.011 \times 10^{20} = 6.022 \times 10^{20}$

If we are asked to calculate the number of oxide ions.

then one molecule of Al_2O_3 contains three O^{2-} ions.

Number of oxide ions $= 3 \times 3.011 \times 10^{20} = 9.033 \times 10^{20}$

Ex.4 Calculate the mass of 60 mL of chlorine at S.T.P. (Atomic mass of Cl = 35.5 u)

Sol. Molecular mass of chlorine (Cl_2) = 35.5 × 2 = 71 u

Molar mass of Cl_2 = 71 g mol^{-1}

1 mole of chlorine = 71 g = 22.4 L at S.T.P.

Therefore,

$\because$ Mass of 22400 mL Cl_2 at S.T.P. = 71 g

$\therefore$ Mass of 60 mL of Cl_2 at S.T.P. $= \frac{71}{22400} \times 60 = 0.19$ g

Ex.5 Calculate in 196 g of sulphuric acid (H_2SO_4)

(i) the number of mole

(ii) the number of molecules

(iii) the total number of atoms, and

(iv) the number of oxygen atoms in the sample

(Given : Atomic mass of H = 1, S = 32, O = 16)

Sol. (i) Molecular mass of $H_2SO_4 = (1 \times 2) + 32 + (16 \times 4) = 98$ u

1 mole of H_2SO_4 = molar mass of H_2SO_4 = 98 g mol^{-1}

$\because$ 98 g of H_2SO_4 = 1 mole

$\therefore$ 196 g of $H_2SO_4 = \frac{196}{98} = 2$ mol

(ii) $\because$ moles of H_2SO_4 = 2 mol

$\therefore$ number of molecules of $H_2SO_4 = 2 \times 6.022 \times 10^{23} = 12.044 \times 10^{23}$

(iii) 1 molecule of H_2SO_4 contains 2 atoms of H, 1 atom of S and 4 atoms of oxygen.

$\therefore$ Total number of atoms in 1 molecule of H_2SO_4 = 2 + 1 + 4 = 7

Therefore, total number of atoms present in 196 g (containing 1.2044×10^{24} molecules of H_2SO_4)

$= 1.2044 \times 10^{24} \times 7 = 8.4308 \times 10^{24}$

(iv) 1 molecule of H_2SO_4 contains 4 atoms of oxygen.

$\therefore$ Number of oxygen atoms in 196 g or 1.2044×10^{24} molecules of $H_2SO_4 = 1.2044 \times 10^{24} \times 4$

$= 4.8176 \times 10^{24}$

Ex.6 Calculate the number of mole and number of molecules in 4.4 g of CO_2.

Sol. The molecules mass of $CO_2 = 12 + (2 \times 16) = 44$u.

Hence, the molar mass of CO_2 = 44 g

$\because$ Number of mole $= \frac{\text{Mass in grams}}{\text{molar mass}}$

$\therefore$ Number of mole contained in 4.4 g of $CO_2 = \frac{4.4}{44} = 0.10$

$\because$ One mole of CO_2 has 6.022×10^{23} molecules.

$\therefore$ Number of molecules in 0.10 mole of $CO_2 = 0.10 \times 6.022 \times 10^{23} = 6.022 \times 10^{22}$ g