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ATOMS AND MOLECULES

01

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CHEMISTRY ATOMS AND MOLECULES

In the present chapter, we shall discuss the basis of the combination between the atoms resulting in the formation of compounds. We shall represent the element and compounds by chemical formulae respectively. In addition to these, we shall discuss the various ways in which the masses of the elements and compounds have been expressed.

LAWS OF CHEMICAL COMBINATION: —

1. Law of conservation of mass
2. Law of constant proportion
3. Law of multiple proportion.
3. Law of reciprocal proportion
4. Gay Loussac's law of combination

◈Law of conservation of mass (or Law of mass action): ---- {Father of chemistry – 'Antoine Lavoisier', 1774}

According this law, ***"During a physical or chemical change, the total mass of the products remains equal to the total mass of the reactants".*** or

"Matter can neither be created nor be destroyed in a chemical reaction".

or

"The mass can neither be created nor be destroyed in a chemical reaction".

☞Conclusion: -- There is neither increase nor decrease in the total mass of the matter during a physical or a chemical change.

- **Law of conservation of mass is also referred to as *Law of indestructibility of matter.***
- **The substance which combines together (or react) in a chemical reaction are known as 'Reactants'.**
- **The new substance formed as a result of chemical reaction is known as 'Product'.**
- **The reactants simply change their partners in chemical reaction**.

Example of Physical change: -- Take a piece of ice in a conical flask and weigh it. Leave the flask for some time, the ice will melt and will become water. The change of ice into water is a physical change. After some -time again weigh the flask. We will notice that there is no change in the two weights. Hence during the physical change, the total mass of the matter remains same.

$$\underset{\text{(solid)}}{\text{Ice}} \longrightarrow \underset{\text{(liquid)}}{\text{Water}}$$

Example of chemical change: -- When calcium carbonate is heated, a chemical reaction takes place to form calcium Oxide and carbon dioxide.

$$\underset{\text{Calcium Carbonate}}{CaCO_3} \xrightarrow{\text{Heat } (1000^0C)} \underset{\text{Calcium Oxide}}{CaO} + \underset{\text{Carbon dioxide}}{CO_2}$$

Mass of reactants = Mass of 'Ca' + Mass of 'C' + 3 × mass of O = 40 +12 + 3 × 16 = 100 g

Mass of Product = (Mass of Ca + Mass of O) + (Mass of C + 2 × Mass of O) = (40 +16) + (12 + 2 × 16) = 100g

Therefore, Total mass of reactants = total mass of products

◈ NUMERICAL BASED ON LAW OF CONSERVATION

1. **In a reaction ,4.0 g of sodium carbonate was reacted with10g of hydrochloric acid. The product was a mixture of 2.5 g of CO_2 and 11.5 g of sodium chloride solution .is this data in agreement with the law of conservation of mass?**

Solᵘ: - The chemical reaction leading to product is:

Sodium Carbonate + Hydrochloric Acid ⟶ Sodium Chloride solution +Carbon dioxide.

Mass of reactant s = (4.0 + 10.0) = 14.0g

Mass of products = (11.5 + 2.5) = 14.0g

Since the Reactants and products have the same mass as a result of the reaction. The data is in agreement with the law conservation of mass.

◙2. If 6.3 g of sodium bicarbonate are added to 15.0g of Ethanoic acid solution, the residue left is found to weigh 18.0g. What mass of CO_2 is released in the reaction?

Sol- The chemical reaction leading to products is:

Sodium bicarbonate + Ethanoic Acid ⟶ Sodium Ethanoate solution + Carbon dioxide.

(Residue) (Released)

Mass of reactant s = (6.3 + 15.0) = 21.3 g

Mass of products = Mass of residue + Mass of CO_2 = (18.0g + x)

A/Q, Law of mass action, Mass of reactant s = Mass of products

21.3 g = (18.0g + x)

∴ Mass of CO_2 released, x = 21.3g – 18.0g = 3.3 g.

◙3. **Calcium Carbonate decomposes, on heating, to form calcium oxide and CO_2. When 10g of calcium carbonate is deco--mposes completely, then 5.6 g of calcium oxide is formed. Calculate the mass of carbon dioxide formed. Which law of chemical combination will you use in solving this problem?** Solution?

Answer = 4.4g

◙ 4. **Copper sulphate reacts with sodium hydroxide to form blue precipitate of copper hydroxide and sodium Sulphate. In an experiment 15.95g of copper sulphate reacted with 8.0 g of sodium hydroxide to form 9.75 g 0f copper hydroxide and 14.0g of sodium sulphate. Show that this data verifies the law of conservation of mass. Solution: - ?**

◙5. **Potassium Chlorate decomposes, on heating, top form potassium chloride and oxygen. When 24.5g of potassium chlorate is decomposed completely, then 14.9 g of potassium chloride is formed. Calculate the mass of oxygen formed . which law of chemical combination have you used in solving this problem?**

Solution: -? **Answer = 9.6g**

◈ **LAW OF CONSTANT PROPORTION:-** (French chemist *JOSEPH PROUST*, 1799) **[Law of definite proportions]**

According to law of constant proportion: **"A pure chemical compound always contains the same element combined together in the same proportion by mass".**

or

"A chemical compound always consists of the same elements combined together in the same proportion by mass".

➢ **This means that a particular compound may be formed or obtained from a number of different sources. In case it is pure then the ratio of different elements in all the samples of that compound will remain the same.**

Example: --[1] Water (H_2O) contains the elements hydrogen and oxygen. These are present in the ratio of 2 : 16 or 1:8 by mass. Now water may be obtained from number of sources such as rain water, river water, well water, tap water etc. It can also be made chemically combination of hydrogen and oxygen element under certain specified conditions. The law states that the ratio of mass of hydrogen and oxygen in all these samples of water will be the same i.e., 1 : 8

[2] Ratio of Carbon and oxygen in carbon dioxide (CO_2) -- $C : O_2 = 12 : 2 \times 16 = 12 : 32 = 3 : 8$

Numerical based on law of constant proportion: -

1. **Hydrogen and oxygen combines in the ratio of 1 : 8 by mass to form water .What mass of oxygen will be required to react completely with 4g hydrogen?**

Solution: -- According to available data,

1g of hydrogen gas requires = 8g of oxygen gas

∴ 4g of hydrogen gas requires = $8 \times 4 = 32$ g

2. **A 0.24 g sample of compound of oxygen and boron was found by analysis to contain 0.096 g of boron and 0.144 g of oxygen. Calculate the percentage of composition of the compound by mass.**

Solution: - Mass of the compound = 0.24 g

Mass of boron in the compound = 0.096 g

Mass of oxygen in the compound = 0.0144 g

∴ **Percentage of Boron =** $\frac{\text{Mass of oxygen.}}{\text{Mass of Compound}} \times 100\ \% = \frac{0.096}{0.24} \times 100\ \% = 40\%$

Percentage of Oxygen = $\frac{\text{Mass of Oxygen.}}{\text{Mass of Compound}} \times 100\ \% = \frac{0.144}{0.24} \times 100\% = 60\%$

3.The percentage of the three elements Calcium, Carbon and Oxygen in a given sample of Calcium Carbonate is given as

Calcium = 40 .0% ; Carbon = 12.0% ; Oxygen = 48.0% :If the law of constant proportion is ture ,

What weights of these element will be present 1.5 g of another sample of Calcium Carbonate?

Solution: -- Mass of calcium in 1.5 g of the sample = $\frac{40}{100} \times (1.5) = 0.6$ g

Mass of Carbon in 1.5 g of the sample = $\frac{12}{100} \times (1.5) = 0.18$ g

Mass of Oxygen = $\frac{48}{100} \times (1.5) = 0.72$ g

3. LAW OF MULTIPLE PROPORTION. ------

"When two elements combine to form two (or more than two) compounds, then the weight of one of these elements which combine with a fixed weight of the other element, bears a simple whole number ratio to one another".

Example: - Hydrogen and oxygen combine in two different ways to form water (H_2O) and hydrogen peroxide (H_2O_2).

Hydrogen [H_2] + Oxygen [O_2] → Water (H_2O)

→ Hydrogen peroxide (H_2O_2)

In these compounds, the ratio by weight of H_2 and O_2 is different. On studying the composition of these different compound obtained by same element; we get:

Ratio of Hydrogen and Oxygen in water = 2: 16 = 1 :8

Ratio of Hydrogen and Oxygen in H_2O_2 = 2: 32 = 1: 16

therefore, O (of water) : O (of hydrogen peroxide) = 8 : 16 = 1: 2

ATOMIC THEORY OF MATTER

The Word 'atom' means indivisible i.e., something which cannot be cut or divided. The theory that "all matter is made of very tiny invisible particle (atoms)" is called atomic theory of matter.

DALTON'S ATOMIC THEORY:-

In 1808, John Dalton gave his atomic theory of matter which was confirmed by experiment.

1. **All the matter is made up of very small particles. These small particles are called 'atom'.**
2. **Atoms are the ultimate particles of matter and cannot be further sub-divided into smaller particles.**
3. **Atoms can neither be created nor be destroyed in chemical reaction.**
4. **All atoms of a particular element are identical in all respects. This means that they have same mass , size and also same chemical properties.**
4. **Atoms of different elements have different masses, sizes, and also chemical properties.**
5. **Atoms are of various kind. There are as many kind s of atoms as are elements.**
7. **Chemical combination between two (or more) element s consist in the joining together of atoms of these element to form molecules of compounds.**
8. **Atoms of the same or different elements combine in simple whole number ratio to form molecules of a compound.**
9. **Atoms of the same element can combine in more than one ratio to form more than one compound.**
10. **The 'number' and 'kind' of atoms in a given compound is fixed.**

The postulate of Dalton's atomic theory that "the element consists of atoms and those atoms can neither be created nor be destroyed" can be used to explain the law of conservation of mass.

The postulate of Dalton's atomic theory that "the element consist of atoms having fixed mass , and the number and kind of atoms of each element in a given compound is fixed" can be used to explain the law of constant composition.

The postulate of Dalton's atomic theory that "Atoms of the same element can combine in more than one ratio to form more than one compound" can be used to explain the law of multiple proportion.

DRAWBACK OF DALTON'S ATOMIC THEORY:

1. **Dalton's atomic theory says that "all the atoms of the element have exactly the same mass".**
   However. it is now known that atoms of the same element can have slightly different mass
   EX: - {1} U-238 and U-235; {2} Cl-35 and Cl – 37 etc.

2. **Dalton's atomic theory says that "an atom cannot be further broken down.**
   However, it has been shown that atoms can be further divided into still simpler particles - Electron, proton & neutron

3. **Dalton's atomic theory said that "atoms of different elements have different masses".**
   However, it is now known that atoms of different elements can have same mass.
   EX: - Argon, Ar- 40 ----- Calcium, Ca – 40.

4. **There are different forms of the same element which have different properties.**
   Why should their properties be different?
   Dalton's atomic could not explains this.

5. **Dalton's atomic theory could not explain as to what is the difference in the atoms of various elements which cause them to have different properties.**

6. **Dalton's atomic theory said that "Atoms combine in a simple whole number ratio to form molecules".**
   However, in certain cases the ratio may not be simple. Ex: - In Sugar ($C_{12}H_{22}O_{11}$) – C: H :O = 12 : 22 :11

Dalton's Atomic theory and the Terms: Atoms, Elements & Compounds

A T O M S: - "According to Dalton's atomic theory, **"an atom is the smallest particle of an element that can take part in a chemical reaction".**

or

"An atom is the smallest particle of an element which may be may not have independent existence".

FACTS----------

- An atom maintains its identity in all physical and chemical change.
- Since there are 112 elements known and obviously there are 112 different types of atoms.
- Atoms of mast of the element 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. Ex: N_2, O_2, etc.
- The atoms of certain element such as Helium, Neon, Argon, Krypton etc are un reactive and have independent existence and exist in the free state.
- Atoms are building block of all the matter.

- **Atoms cannot be further subdivided in a chemical reaction.**

- **Atoms are extremely small in size. The size of an atoms is indicated by its radius which is called 'Atomic radius'. Atomic radius is measured in 'nanometres' (nm)**

  $1\ nm = 10^{-9}$

- **Hydrogen atom is the smallest atom of all. $0.037\ nm = 0.037 \times 10^{-9}\ m = 0.0000000000037\ m$.**

- **Atoms are so small that we cannot see them even under the most powerful optical microscope. The scanning tunnels microscope enables us to see atoms, though indirectly.**

Elements: – According to Dalton, "An element is a pure substance which is made up of only one kind of atom".

- There are 112 elements.

Symbol representing the atoms of the element: Once it was established that the matter is made of atoms of different elements, the next problem was their identification. Dalton suggested that each element must be identified by a short hand representation also called 'Symbol'. Thus

"Symbol is a short hand representation of the name of an element."

- **There are number of elements whose names begins with the same letter. EX: - Barium (Ba), Bromine (Br), etc all begins letter 'B. The symbol of such elements is represented by the first letter followed by some prominent letter form their English letter. The first letter is capital letter while the second letter is small.**

- **Some elements have both English as well as Latin / German names. For these elements, Symbol include first letter from the Latin /German names Expressed as capital along with some other prominent letter.**

Element:	Latin:	Symbol:
Silver	Argentum	Ag
Copper	Cuprum	Cu
Gold	Aurum	Au
Iron	Ferrum	Fe
Mercury	Hydrargyrum	Hg
Potassium	Kalium	K
Sodium	Natrium	Na
Lead	Plumbum	Pb
Antimony	Stibium	Sb
Tungsten	Wolfram	W

- **There are no hard and fast rules for framing the system of the elements**

- **The Symbols of some of the elements are given just to honour certain famous scientists. Ex: Einsteinium (Es), Nobelium (No), Curium (Cm)**

- **The development and researches in the field of chemistry are guided by a body known as *International Unit of Pure and applied Chemistry. {IUPAC}***

ATOMIC MASS: We know that the smallest portion of matter is atom. It is so small in size that it may not be possible to isolate a single atom and then weigh it. Moreover, the mass of the atom of an element is also extremely small.

For example, an atom of hydrogen has mass equal to 1.67×10^{-24} g (or 1.67×10^{-27}kg). It indicates that gram and kilogram is a very big unit to express the mass of an atom of a particular element. Moreover it is also very inconvenient to write such small masses.

In 1961, IUPAC have accepted the atomic mass unit (**amu or U**) scale to be used for expressing atomic and molecular masses of elements and compounds respectively. In this **amu** scale, **the most stable isotope of carbon 12 $_6C$ (Mass number = 12) has been chosen as standard.**

"The atomic mass unit (amu or u) is defined as the quantity of mass equal 1/12th of the mass of atom of carbon – 12". **** 'u' --- unified mass**

$$\text{atomic mass unit (1 amu)} = \frac{\text{Mass of a Carbon -12 atom}}{12}$$

Absolute mass of a C-12 atom is 1.9924×10^{-23} g

$$\therefore \quad 1\text{amu} = \frac{1.9924 \times 10^{-23}\text{ g}}{12} = 1.66 \times 10^{-24}\text{ g} = 1.66 \times 10^{-27}\text{ kg}$$

(Mass of a hydrogen atom)

➢ **Relative atomic mass:** – **"The atomic mass of an element is the relative mass of its atom as compared with the mass of a carbon -12 atom taken as 12 units".**

- The atomic mass of an element indicates the number of times one atom the element is heavier than 1/12 of a carbon atom.
  Example: -- Atomic mass of Aluminium (Al) = 27 u, which indicates that one atom of Aluminium is 27 times heavier than 1/12 of carbon -12 atom.
- Conclusion: - The present standard for the atomic masses is carbon-12 atom which has assigned mass exactly 12 u.

ELEMENT'S	SYMBOL	RELATIVE ATOMIC MASS	
		EXACT VALUE	COMMON VALUE
Hydrogen	H	1.0079	1
Carbon	C	12.011	12.
Nitrogen	N	14.007	14
Oxygen	O	15.999	16
Sodium	Na	22.990	23
Magnesium	Mg	24.305	24
Chlorine	Cl	35.453	35.5
Calcium	Ca	40.078	40
Copper	Cu	63.546	63.5
Zinc	Zn	65.409	65.5
Bromine	Br	79.904	80
Silver	Ag	107.870	108
Iodine	I	126.900	127

** Common value is used in the numerical problems.

➢ **Gram atomic mass :-(for mole concept)**

"The atomic of an atom of an element expressed in grams which is numerically equal to the mass in amu, is called gram atomic mass".

Examples: - [1] Atomic mass of nitrogen (N) =14 u
Therefore, Gram atomic mass of nitrogen(N) = 14 g
[2] Atomic mass of Sulphur (S) = 32 u
Therefore, Gram atomic mass of Sulphur (S) = 32 g

Number of gram – atoms (Gram atomic mass) = $\frac{\text{Mass of the element in gram}}{\text{Atomic mass of the element}}$

For example: Mass of Calcium = 40 g
Atomic mass of calcium = 40
Therefore, Number of gram- atoms = $\frac{\text{Mass of Calcium in g}}{\text{Atomic mass of calcium}} = \frac{40}{40} = 1$

** The gram atomic mass of an element is also known as its gram – atom.

Significance of the symbol of an element: –

[1] Symbol represent name of the element.

[2] Symbol represents one atom of the element.

[3] Symbol also represents one mole atoms of the element i.e., symbol represents 6.023×10^{23} atoms of the element.

[4] Symbol represents a definite mass of the element (equal to atomic mass expressed in grams).

Existence of atoms: –

The atoms of only a few elements called noble gases (such as Helium, neon, Argon and krypton etc) are chemically un reactive and exist in the free state (as single atom). Atoms of most of the element are chemically very reactive and do not exist in the free state (as single atoms).

☞Atoms usually exist in two ways: -- [1] In the form of *molecules*
[2] In the form of *ions*.

MOLECULES: – "**A molecules is the smallest particle of a substance (element or compound) which can exist in the free state under normal condition and exhibit all the physical and Chemical properties of that substance".**

or

- ☞ A molecule is an electrically neutral group of two (or more) atoms chemically bonded together.
- ☞ A molecule may be defined as a group of two or more atoms (same or different) chemically bonded to each other and held tightly by strong forces of attractive forces.
- ☞ The forces which hold the atoms together in a molecule are called Covalent Bond.
- ☞ The properties of a substance (element or compound) are the properties of its molecules.
- ➢ Molecules can be formed either by the combination of atoms of the same element or of different elements. Depending on this, there are two types of *molecules of element* and *molecules of compounds*.

[A] Molecules of elements : [HOMOATOMIC MOLECULES] [Elementary molecules]

"The molecules of an element contain two (or more) similar atoms chemically combined together".

➢ Molecules of elements are formed by the combination of two more atoms of the same element.

Classification of Homoatomic molecules ------

{A} MONOATOMIC MOLECULES: -- A molecules containing one atom is called monoatomic.
Example: - He (Helium) , Ne(Neon), Ar(argon) etc

{B}**DIATOMIC MOLECULES**: -- **A** molecule containing two atoms is called diatomic molecule.
Example: -- H_2, N_2, O_2, Cl_2, etc.

{C} **TRIATOMIC MOLECULES**: -- A molecule containing three atoms is called triatomic molecule.
Example: - O_3 (ozone)

{D} **TETRA ATOMIC MOLECULES**: -- A molecule containing four atoms is called tetratomic molecule.
Example: -- P_4 (phosphorus)

{E} **POLYATOMIC MOLECULES:** --A molecule containing more than four atoms is called polyatomic molecule.
Example: -- S_8 (Sulphur)

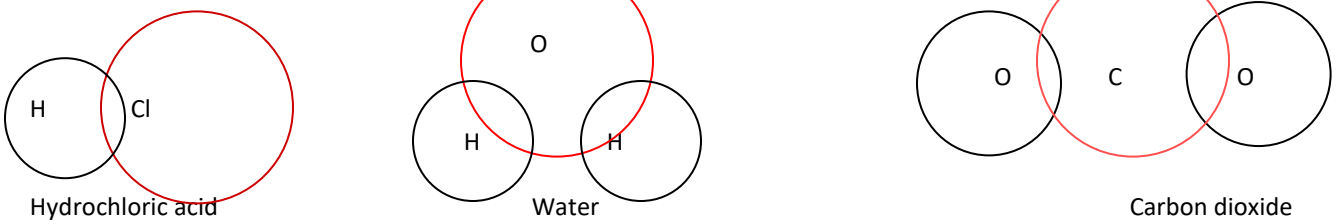
Hydrogen molecule | nitrogen molecule | Chlorine molecule | Oxygen molecule

[B] **Molecules of Compound: [HETEROATOMIC MOLECULES] [Compound molecules]—**
"Heteroatomic molecules are the molecules which are made up of two or more different compounds".

- In the molecules of compounds, the atoms of different elements are combined or bonded together by chemical bonds. These are present in definite proportion by mass according to law of constant composition.

- **Classification of Heteroatomic molecules:** The heteroatomic molecules can be classified as diatomic , triatomic, tetratomic and polyatomic.

[1] Diatomic molecules: -- HCl, NaCl, CO etc
[2] Triatomic molecules: -- CO_2, H_2O, SO_2 etc.
[3] Tetratomic molecules: -- H_2O_2, NH_3 etc
[4] Polyatomic molecules: -- H_2SO_4, Ca SO_4, $C_6H_{12}O_6$, etc



Hydrochloric acid | Water | Carbon dioxide

Atomicity: -- "***The no. of atoms in a molecule of an element or a compound is called Atomicity".***
Examples: - Atomicity of Sulphur in H_2SO_4 = 2
" " Oxygen " " = 4
" " Oxygen in O_2 = 2

IONS: "An *atom or group of atoms having positive or negative charge is called ion*"

Types of ions:
[1] CATIONS: "A positively charged ion is called cation". Ex: -- Na^+, Mg^{+2}, Fe^{+2} etc
[2] ANION: - "A negatively charged ion is called anion". Ex: - Cl^{-1}, O^{+2} etc.

** In addition to these ions, there are **POLYATOMIC** ions. They contain in them group of atoms with some charge on them. Ex: - Carbonate ions $(CO_3)^{-2}$, Sulphate $(SO_4)^{2-}$, etc

.

Chemical formula: ---

We know that atoms of elements combine to form a molecule. We represent the atoms with the help of symbols. In the same way, the molecules can also be represented by the symbols of the constituent atoms. This is known as the chemical formula of the molecules. Thus,

"A chemical formula represents the composition of a molecule of the substance in the form of the symbol of the elements present in the molecule". or

"A chemical formula is the representation of a molecule in terms of the symbols of the constituting atoms".

or

"The chemical formula of an element or compound is a statement of the composition of its molecule in which symbol tells us the element and the subscript tell us how many atoms are present in one molecule".

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

Ex: - {1} One molecule of oxygen element contains two atoms of oxygen; therefore, the formula of oxygen is O_2.
{2} A molecule of water contain 2 H- atoms and 1 O- atoms of oxygen, therefore, the formula of water is H_2O.

- Significance of a formula: A chemical formula of a substance conveys the following information------

[1] Formula represents the name of the substance. Ex: - H_2O represent water.
[2] It represents one molecule of the substance. Ex: H_2O represent one molecule of water.
[3] It also represent one mole of the substance, i.e., it corresponds to 6.023×10^{23} molecules of the substance.
EX: H_2O represents one mole (i.e., 6.023×10^{23} molecules) of water.
[4] It gives the various atoms present in a molecule.
[5] It gives the no. of atoms of each element present in one molecule. Ex: - H_2O tells us that water contain 2 H atoms and 1 oxygen atom.
[6] It represents the definite mass of the molecule known as molecular mass. Ex: - H_2O represent 18 g of water.
[7] It tells us that 18 parts by weight of water contains 2 parts by weight of hydrogen and 16 parts by weight of oxygen.

Molecular mass: "The relative mass of a molecule of a compound (or element) as compared with the mass of ^{12}C atoms taken as 12, is called molecular mass".

- It means that, molecular mass expresses as to how many times a molecule of a substance is heavier than 1/12 of mass of an atom of carbon.

Ex; - CO_2 is 44 times heavier than 1/12 of the mass of a carbon atom, therefore, molecular mass = 44 amu

- Calculation of molecular mass:

The molecular mass is equal to sum of the atomic masses of all the atoms present in one molecule of the substance.
Ex: - Molecular mass of H_2SO_4 = mass of 2 H atoms + mass of 1 sulphur atom + mass of 4 oxygen atom.
$= 2 \times 1 + 1 \times 32 + 4 \times 16 = 2 + 32 + 64 = 98$ amu.

Problems: ---

[1] Calculate the molecular mass of the following: [I]Chloroform [$CHCl_3$]; [ii] Nitric acid [HNO_3]; [iii] Chlorine [Cl_2]
[iv] ethene [C_2H_4]; [v] Ammonia [NH_3]; [vi] Ethanol [C_2H_5OH]; [vii] CH_3COOH [Acetic acid]
[viii] CS_2 [Carbon disulphide].

——: MOLE CONCEPT: - - - - - -

- We know that atomic masses, molecular masses are just number. They are relative masses and do not have any unit like gram or kilogram. But there is some relationship between the masses of substance and the no. of atoms or molecules.

- In chemistry, scientist link the mass of an element or compound to the number of atoms or molecules present in them. This is done through the 'MOLE'. (*Mole is a link between the mass of atoms (or molecules) and the number of of atoms (molecules)*.

- Scientist count atoms and molecules by weighing them. It has been found by performing experiments that if we weigh an element equal to its atomic mass in grams, then it contains 6.023×10^{23} atoms of the element.

◈ Gram atomic mass: -----

"Gram atomic mass is the no. of grams of the element equal to its atomic mass".

or

"The amount of a substance whose mass in gram in grams is equal to its atomic mass is called gram atomic mass of that substance".

or

"Atomic mass expressed in gram is the gram atomic mass".

** Gram atomic mass is also known as *'one gram atom'*.

** To write the gram atomic mass of a substance, we write its atomic mass and then add the word- 'Gram' or its symbol 'g'.

Example—Atomic mass of sodium = 23 amu

therefore, its Gram atomic mass = 23 g

Illustration: -The gram atomic mass of carbon is 12g. The mass of one atom of carbon has been calculated as 1.9924×10^{-23}g

The number of carbon atoms in 12 g of carbon can be calculated as:

$$\text{No. of carbon atoms} = \frac{\text{Gram atomic mass of carbon}}{\text{mass of one carbon atom}} = \frac{12\text{ g.}}{1.9924 \times 10^{-23}\text{g}} = 6.023 \times 10^{23}$$

** **Conclusion:** -- [1] Gram atomic mass of an element contains 6.023×10^{23} atoms.

[2] Mass of 1 mole atoms of any element is equal to its gram atomic mass

i.e., 1 mole atoms of an element = gram atomic mass of element

** It must be remembered that 1 gram atomic mass is not equal to the mass of a single atom . One gram atomic mass is equal to the mass of 1 mole [6.023×10^{23}] of atoms.

i.e., Mass of 6.023×10^{23} atoms. = 1-gram atomic mass

∴ $$\text{Mass of 1 atom} = \frac{\text{1 gram atomic mass}}{6.023 \times 10^{23}}$$

ELEMENT	MASS	CONTAINS
CARBON	12 g (1 g atomic mass of C)	6.023×10^{23} 'C' atoms (or 1 mole 'C' atoms)
IRON	55. 85 g (1 g atomic mass of Fe)	6.023×10^{23} 'Fe' atoms (or 1 mole 'Fe' atoms)
Oxygen	16 g (1 g atomic mass of O)	6.023×10^{23} 'O' atoms (or 1 mole 'O' atoms)

➢ Gram molecular mass: – "The molecular mass of the substance expressed in gram which is numerically equal to the molecular mass in it, is called gram molecular mass".

or

"Gram molecular mass is the no. of grams of the compound equal to its molecular mass".

or

"The amount of a substance whose mass in gram is numerically equal to its molecular mass, is called gram molecular mass of that substance".

** Molecular mass of a substance expressed in gram is called 'gram molecular mass'.

** To write the gram molecular mass of a substance, we write its molecular mass and then add the word- 'gram 'or 'g'.

Example: - Gram molecular mass of Ammonia (NH_3) =17 amu

Therefore, its gram molecular mass = 17 g

** Gram molecular mass of a substance is also called '*One gram molecule*

Illustration: -- The gram molecular mass of Oxygen (O_2) is 32 g. The mass of one molecule is 5.313×10^{-23}g. The no. of oxygen atoms in 32 g of oxygen can be calculated as:

$$\text{No. of oxygen molecules} = \frac{\text{Gram molecular mass of oxygen}}{\text{Mass of one oxygen molecule}} = \frac{32\ g}{5.313 \times 10^{-23} g} = 6.023 \times 10^{23}$$

- The mass of 6.023×10^{23} molecules of a substance is equal to its gram molecular mass.
- The no. of molecules presents in 1-gram molecular mass of any substance is equal to 6.023×10^{23} molecules.
- Mass of 6.023×10^{23} molecules = Gram molecular mass

$$\therefore \quad \text{Mass of 1 molecule} = \frac{\text{Gram molecular mass}}{6.023 \times 10^{23}}$$

MOLE MOLE MOLE MOLE MOLE MOLE

Necessity of mole concept: --We know that the atoms and molecules of any substance are very small in size. This is quite evident from the fact that 12 g of carbon contains 6.023×10^{23} atoms of carbon. This means that it may not be possible to count these atoms individually. However, they can be collectively be represented as one mole. This is convenient method to represent different particles. For example: -

No. of oxygen atoms in 3 moles = $(3 \times N_o) = 3 \times 6.023 \times 10^{23} = 1.81 \times 10^{24}$ atoms

||y, the number of carbon and oxygen atoms in 1 mole of carbon dioxide (CO2) =

Avogadro's no. of carbon atoms (N_o) + Avogadro's no. of oxygen atoms (N_o)

$= (6.023 \times 10^{23} + 2 \times 6.023 \times 10^{23})$ atoms

$= 1.81 \times 10^{24}$ atoms

"A group of 6.023×10^{23} particles (atoms, ions, or molecules) of a substance is called a mole of that substance".

or

"A mole is defined as the amount of substance which contains the same number (i.e., atoms, ions, molecules etc) as the number of carbon atoms present in 12 g (1 mole) of ^{12}C isotope of carbon".

or

"A mole of a substance is that amount of the substance which contain 6.023×10^{23} particles (atoms or molecules) of the substance".

- The no. of atoms of an element presents in one – gram atom of it or the no. of molecules of substance present in one-gram molecule of it, is called AVOGADROS'S NUMBER (= 6.023×10^{23})

- It is represented by (N_o) OR (N_A).

- One mole of substance represents 6.023×10^{23} particles (ions, atoms, or molecule).

Examples: -- [1] 1 mole of oxygen atom = 6.023×10^{23} O atoms

[2] 1 mole of oxygen molecule = 6.023×10^{23} O_2 molecules.

[3] 1 mole of Na ion = 6.023×10^{23} sodium ions.

** 1 mole of oxygen molecule = 6.023×10^{23} O_2 molecules.

$= 2 \times 6.023 \times 10^{23}$ O atoms.

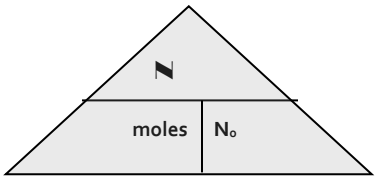
- A mole represents----------

[1] A definite number of atoms or molecules of a substance i.e., it represent 6.023×10^{23} atoms or molecules.

[2] Definite amount of the substance i.e., it represents the amount of a substance equal to its atomic mass or atomic mass or gram molecular mass.

◈ **Expressing number of particles in term of moles**: Number of particles of any substance (element or compound) are related to the no. of moles by the relation-------

$$\text{Number of moles} = \frac{\text{Given no. of particles [N]}}{\text{Avogadro's no. of particle [N}_o\text{]}}$$

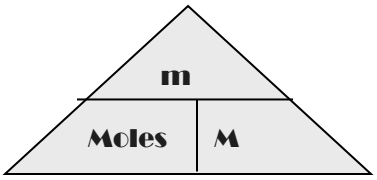


** In using the term mole, it is essential to specify the kind of particles involved. For example, one mole of hydrogen atom contain 6.023×10^{23} atoms of hydrogen. But one mole of hydrogen molecule (H_2) contains 6.023×10^{23} molecule of hydrogen.

► Expressing **mass of a substance in term of moles**:

For elements :-- $\text{Number of moles} = \frac{\text{Given mass [m]}}{\text{Gram atomic mass [M]}}$

For compounds: $\text{Number of moles} = \frac{\text{Given mass [m]}}{\text{Gram molecular mass [M]}}$



ILLUSTRATIVE EXAMPLES

[1] **Calculate the no. of moles in the following (i) 52 g of He (ii) 46 g of Na (iii) 60g of Ca . Given gram atomic mass of He = 4g ; Na = 23 g ; Ca = 40 g.**

Sol^{n}: - [i] 52 g of Helium,

$$\text{Number of moles} = \frac{\text{Mass of He in grams}}{\text{Gram atomic mass}} = \frac{m}{M} = \frac{5\ 2\ g}{4g} = 13 \text{ mol}$$

[Ans: (ii) 2 mol (iii) 1.5 mol]

[2] **Calculate the mass of the following: (i) 0.5 mole of O_2 gas (ii) 0.5 mole of O atoms (iii) 3.011×10^{23} atoms of O (iv) 6.023×10^{23} molecules of O_2. Given: Gram atomic mass of O = 16g & Gram molecular mass of O_2 = 32 g.**

Sol^{n}: - [i] 0.5 mole of O_2 gas,

$$\text{Number of moles} = \frac{\text{Mass of } O_2 \text{ in grams}}{\text{Gram molecular mass}} = \frac{m}{M}$$

Mass of O_2 in grams (m) = No. of mole × Gram molecular mass (M)

$= 0.5 \times (32g) = 16$ g.

[ii] 3.011×10^{23} atoms of Oxygen [O] ,

STEP I— Calculation of no. of gram atoms of Oxygen --------

$$\text{No. of gram atoms} = \text{No. of atoms of Oxygen} = \frac{N}{N_o} = \frac{3.011 \times 10^{23}}{6.023 \times 10^{23}} = 0.5 \text{ gram atoms.}$$

STEP II --- Calculation of mass of Oxygen [O] atoms - - - - - -

Mass of Oxygen atoms = Gram atomic mass of Oxygen × no. of gram atoms of Oxygen

$= 16 \times 0.5 = 8$ g

[Ans: {ii} 8g {iv}32 g]

[3] **What is the mass of 4 mole of Aluminium atoms? Given: Atomic mass of Al = 27 u.**

Sol^{n}: - Since atomic mass of Al = 27 u

therefore, gram atomic mass of Al = 1 mole of Al atoms has a mass of 27 g

Now, 1 mole of aluminium atoms = 27g

4 mole of Al atoms = 27×4 g = 108 g.

[4] **Calculate the number of atoms in 0.2 mole of sodium (Na).**

Sol^{n}: - 1 mole of sodium atoms = 6.023×10^{23}

therefore, 0.2 mole of sodium atoms = $6.023 \times 10^{23} \times 0.2$ atoms

$= 12.044 \times 10^{22}$.

[5] ***Calculate the number of molecules of sulphur (S_8) present in 8 g of solid sulphur.***

Sol^{n}: - Gram molecular mass of sulphur (S_8) = 8 × Gram atomic mass of sulphur = 8 × 32 g = 256 g

No. of S_8 molecules in 256 g of sulphur = 6.023×10^{23}

No. of S_8 molecules in 1 g of sulphur = $\frac{6.023 \times 10^{23}}{256}$

No. of S_8 molecules in 1 g of sulphur = $\frac{6.023 \times 10^{23}}{256} \times 8 = 1.88 \times 10^{22}$ molecules.

[6] ***Calculate the number of iron atoms in a piece of iron weighing 2.8g.(Given : atomic mass of iron = 56 u)***

Sol^{n}: - 1 mole of iron = Gram atomic mass of iron = 56 g

We know that 1 mole of iron element contains 6.023×10^{23} atoms of iron.

Now, 56 g of iron contains = 6.023×10^{23} atoms

1g of iron contains = $\frac{6.023 \times 10^{23}}{56}$ atoms

2.8 g of iron contains = $\frac{6.023 \times 10^{23}}{56} \times 2.8$ atoms = 3.011×10^{23} atoms

[7] ***An atom of oxygen has a mass of 2.65×10^{-23} g. How many atoms of oxygen are there in 32 g of oxygen gas?***

Sol^{n}: - number of Oxygen atoms = $\frac{\text{Mass of oxygen gas}}{\text{Mass of 1 atom of oxygen}} = \frac{32}{2.65 \times 10^{-23}} = 12.08 \times 10^{23}$

[8] ***If one mole of carbon atoms weighs 12 g , what is mass in gram of 1 atom of carbon?***

Sol^{n}: - Since 1 mole carbon atom weighs 12g

therefore, 6.023×10^{23} atoms of carbon have mass = 12g

1 atom of carbon have mass = $\frac{12 \text{ g}}{6.023 \times 10^{23}} = 1.99 \times 10^{-23}$

[9] ***Which has a greater number of atoms: 100 g of sodium or 100 g of iron?***

Sol^{n}:- (I) Number of moles of sodium = $\frac{\text{Given mass.}}{\text{Gram atomic mass}} = \frac{100}{23} = 4.34$

(II) Number of moles of sodium = $\frac{\text{Given mass.}}{\text{Gram atomic mass}} = \frac{100}{56} = 1.78$

Since 100 g of sodium contains 4.34 moles and 100g of iron contains 1.78 moles, therefore 100g of sodium contains more atoms than 100 g of iron.

[10] ***The mass of a single atom of an element 'X' is 2.65×10^{-23} g. What is its atomic mass? What would this element be?***

Sol^{n}: - The atomic mass of an element is numerically equal to the mass of 1 mole of its atom. Since 1 mole of atoms is 6.023×10^{23} atoms, so it means that the atomic mass of an element is numerically equal to the mass of its 6.023×10^{23} atoms.

Now, 1 atom of element X has mass = 2.65×10^{-23} ***g***

therefore, 6.023×10^{23} atoms of element X has mass = 2.65×10^{-23} ***g*** × 6.023×10^{23}

= 15.96 g ≈ 16 g

The atomic mass of the element X is 16 u. The element of atomic mass 16 u is oxygen.

[11] ***Calculate the number of aluminium ions in 0.102 g of aluminium oxide (Al_2O_3).***

Sol^{n}: - Step 1: -- Calculation of no. of moles in 0.012 g of Al_2O_3 :--

Calculation of no. of moles of Al_2O_3 = 2 × Gram atomic mass of Al + 3 × Gram atomic mass of O

= 2 × 27 + 3 × 16

= 54 + 48 = 102 g

Now, 102 g of Al_2O_3 = 1 mole

therefore, 0.102 g of Al_2O_3 = $\frac{0.102}{102}$ = 0.001 mol

Step II: -- Calculation of no. of Al ions in 0.001 mole of Al_2O_3:--

1 mole of Al_2O_3 contains Al atoms = 2 × No

0.001 mole of Al_2O_3 contains Al atoms = 2 × 0.001 × No

= 2 × 0.001 × 6.023×10^{23}

= 1.204×10^{21} atoms

No. of aluminium ion (Al^{3+}) present is the same as the no. of Al atoms, therefore,

No. of aluminium ion (Al^{3+}) = 1.204×10^{21}