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Chapter 3 Atoms and Molecules

Historical Background

- The idea of divisibility of matter was arose 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. Ultimately, a stage will come when we shall come across the smallest particles beyond which further division will not be possible. He named these particles **Parmanu.**
- Another Indian philosopher, Pakudha Katyayama, elaborated this doctrine and said that these particles normally exist in a combined form, which gives us various forms of matter.
- 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 cannot be divided further. Democritus called these indivisible particles atoms (meaning indivisible).
- All these ideas were based on philosophical considerations and much experimental work could not be done till the eighteenth century to validate these ideas.
- By the end of the eighteenth century, scientists recognized the difference between elements and compounds and they became interested in finding out how and why elements combine and what happens when they combine.
- Antoine L. Lavoisier laid the foundation of chemical sciences by establishing two important laws of chemical combination.

Laws of Chemical Combination

After much experimentations by Lavoisier and Joseph L. Proust, following two laws of chemical combination were established-

(1) Law of Conservation of Mass

This law was for the first time proposed by Lavoisier. According to this law, "The matter can neither be created nor be destroyed but it can be transformed from one form to another during the chemical reactions."

Thus, the total mass of products formed during a reaction is always equal to the total mass of reactants before the reaction.

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Mathematically,

Sum of the masses of products = Sum of the masses of reactants

- Is there a change in mass when a chemical change (chemical reaction) takes place ?

Activity 3.1

- Take one of the following sets, X and Y of chemicals-

X	Y
Copper sulphate 1.25 g	Sodium Carbonate 1.43 g
Barium chloride 1.22 g	Sodium sulphate 1.53 g
Lead nitrate 2.07 g	Sodium chloride 1.17 g

- Prepare separately a 5% solution of any one pair of substances listed under X and Y each in 10 mL 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 so that the solutions do not get mixed. Put a cork on the flask as shown in Fig.
- Weigh the flask with its contents carefully.
- Now tilt and swirl the flask, so that the solutions X and Y get mixed.
- Weigh again.
- What happens in the reaction flask ?
- Do you think that a chemical reaction has taken place ?
- Why should we put a cork on the mouth of the flask ?
- Does the mass of the flask and its contents change ?

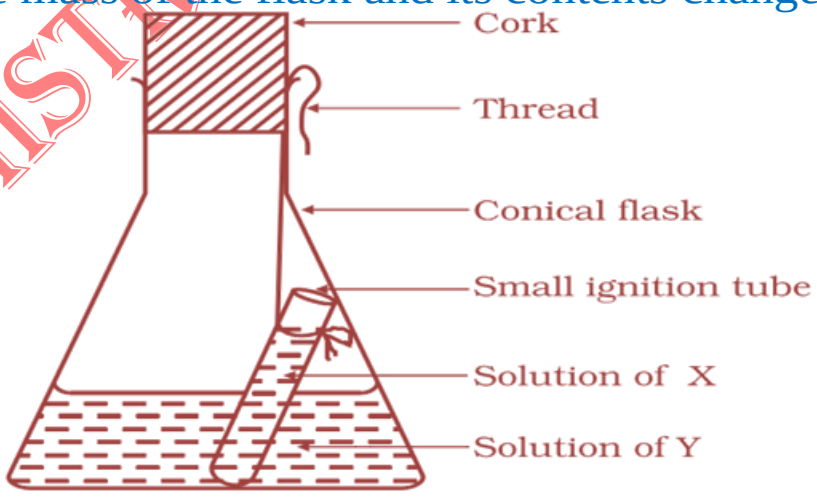


Fig.-Ignition tube (containing solution of X) dipped in a conical (flask containing solution of Y)

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(2) Law of Constant Proportions or Law of Definite Proportion

This law was for the first time proposed by Proust. According to this law-

"In a chemical substance the elements are always present in definite proportions by mass".

Thus, the chemical composition of a pure chemical compound is always fixed and it is independent of the source from which it has been obtained or the method from which it has been prepared.

For example, water can be obtained from a number of sources such as rivers, ponds, lakes, rain water etc. or it can be prepared by combination of hydrogen and oxygen. Here, the ratio hydrogen and oxygen by mass in pure water is always 2 : 16 i.e. 1 : 8 and it is independent of source and method of preparation.

Similarly in ammonia, nitrogen and hydrogen are always present in the ratio 14:3 by mass, whatever the method by which it is prepared or the source from which it is obtained.

Dalton's atomic theory

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

According to Dalton's atomic theory, all matter, whether an element, a compound or a mixture is composed of small particles called atoms. The main postulates of this theory are as under-

- All matter is made of very tiny particles called atoms, which participate in chemical reactions.
- Atoms are indivisible particles, which cannot be created or destroyed in a chemical reaction.
- Atoms of a given element are identical in mass and chemical properties.
- Atoms of different elements have different masses and chemical properties.
- Atoms combine in the ratio of small whole numbers to form compounds.
- The relative number and kinds of atoms are constant in a given compound.

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Questions-

(1) In a reaction, 5.3 g of sodium carbonate reacted with 6 g of acetic acid. The products were 2.2 g of carbon dioxide, 0.9 g water and 8.2 g of sodium acetate. Show that these observations are in agreement with the law of conservation of mass.

Sodium carbonate + Acetic acid → Sodium acetate + Carbon dioxide + Water

(2) Hydrogen and oxygen combine in the ratio of 1:8 by mass to form water. What mass of oxygen gas would be required to react completely with 3 g of hydrogen gas ?

(3) Which postulate of Dalton's atomic theory is the result of the law of conservation of mass ?

(4) Which postulate of Dalton's atomic theory can explain the law of definite proportions.

What is an Atom ?

"The smallest particle of an element which takes part in a chemical reaction without being decomposed but usually does not exist in free state is called atom".

Atoms are the building blocks of all matter.

How big are atoms ?

Atoms are very small, they are smaller than anything that we can imagine or compare with. More than millions of atoms when stacked would make a layer barely as thick as this sheet of paper.

Atomic radius is measured in nanometers (nm).

$$1 \text{ nm} = \frac{1}{10^9} \text{ m}$$

or

$$1 \text{ m} = 10^9 \text{ nm}$$

Size of some Objects-

Radius of hydrogen atom = 10^{-10} m = 0.1 nm
Radius of water molecule = 10^{-9} m = 1 nm
Radius of haemoglobin molecule = 10^{-5} m
Radius of grain of sand = 10^{-4} m
Radius of an ant = 10^{-3} m
Radius of an apple = 10^{-1}

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Symbol of Different Elements

- Each element has a name and its unique chemical symbol.
- Dalton was the first scientist to use the symbols for different elements for their representation.
- Berzilius suggested that the symbols of elements should be made up of one or two letters of their names.
- In the beginning, the names of elements were derived from the name of the place, where they were found for the first time. For example, the name copper was taken from Cyprus. Some names were taken from specific colour of the element. For example, gold was taken from the English word meaning yellow.
- Now-a-days, IUPAC (International Union of Pure and Applied Chemistry) is an international scientific organisation which approves names of elements and their symbols.
- Most of the symbols are the first one or two letters of the English name of the elements. Here, first letter of a symbol is always written in capital letter (uppercase) and the second letter in small letter (lowercase). **For example,**
  (1) Hydrogen, H
  (2) Aluminium, Al and not AL
  (3) Cobalt, Co and not CO.
- Symbols of some elements are made up of the first letter of their name and a letter appeared later in the name. For example-
  (1) Chlorine, Cl
  (2) Zinc, Zn
- The symbol of some elements have been taken from their Latin, German or Greek names. For example, the symbol of iron is Fe which has been taken from its Latin name 'ferrum'. Similarly, the symbol of sodium is Na, taken from its Latin name 'natrium' and that of potassium is K taken from its Latin name 'kalium'.

The symbol of some most common elements are listed here-

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Name of Element	Latin Name	Symbol
Hydrogen	-	H
Helium	-	He
Carbon	-	C
Calcium	-	Ca
Chlorine	-	Cl
Magnesium	-	Mg
Sodium	Natrium	Na
Potassium	Kalium	K
Copper	Cuprum	Cu
Iron	Ferrum	Fe
Gold	Aurum	Au
Silver	Argentum	Ag
Mercury	Hydragyrum	Hg

Atomic Mass

Determination of the actual mass of an individual atom is a very difficult task. Hence, relative atomic masses of different elements have been determined using the laws of chemical combinations.

The relative atomic mass of an element is in fact, the average mass of the atom of that element, as compared to $1/12^{th}$ part of the mass of one atom of carbon-12 isotope. By definition,

"The number which represents how many times one atom of an element is heavier than $1/12^{th}$ part of one atom of C^{12} isotope is called atomic mass of the element."

Mathematically,

$$\textbf{Atomic Mass} = \frac{\textit{Mass of one atom of an element}}{\frac{1}{12}\times \textit{Mass of one atom of } C-12 \textit{ isotope}}$$

For example, atomic mass of oxygen is 16. It implies that, one atom of oxygen is 16 times heavier than $1/12^{th}$ part of one atom of C^{12} isotope. Similarly, atomic mass of chlorine is 35.5. It implies that, one atom of chlorine is 35.5 times heavier than $1/12^{th}$ part of one atom of C^{12} isotope.

Atomic masses of some important elements are listed here-

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Element	Symbol	Atomic Mass (u)	Element	Symbol	Atomic Mass (u)
Hydrogen	H	1.008	Calcium	Ca	40
Carbon	C	12	Chromium	Cr	52
Nitrogen	N	14	Manganese	Mn	55
Oxygen	O	16	Iron	Fe	56
Fluorine	F	19	Cobalt	Co	59
Sodium	Na	23	Nickel	Ni	58.5
Magnesium	Mg	24	Copper	Cu	63.5
Aluminium	Al	27	Zinc	Zn	65
Phosphorus	P	31	Bromine	Br	80
Sulphur	S	32	Silver	Ag	108
Chlorine	Cl	35.5	Tin	Sn	118.5
Potassium	K	39	Iodine	I	127

Gram Atomic Mass (GAM)

"The amount of an element in gram equal to its atomic mass is called Gram Atomic Mass (GAM) of the element."

For example, atomic mass of oxygen is 16u. Hence, its Gram Atomic Mass (GAM) will be 16 g. Similarly, atomic mass of chlorine is 35.5u. Hence, its Gram Atomic Mass (GAM) will be 35.5 g.

1GAM of all the elements contains 6.022×10^{23} atoms of the respective element. Hence, it is also called 1 Mole of the element.

The number of GAM (moles) in given amount of an element is obtained using following formula-

$$\text{No. of GAM (moles), } n = \frac{Mass\ of\ element\ (g)}{GAM\ of\ Element}$$

Development of Concept of Atomic Mass

The most remarkable concept that Dalton's atomic theory proposed was that of the atomic mass. According to him, each element had a characteristic atomic mass. The theory could explain the law of constant proportions so well that scientists were prompted to measure the atomic mass of an atom. Since determination of the actual mass of an individual atom was a very difficult task, relative atomic masses of different elements were determined using the laws of chemical combinations and the compounds formed.

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For example, it was observed experimentally that 3 g of carbon combines with 4 g of oxygen to form carbon monoxide (CO). Thus, carbon combines with 4/3 times its mass with oxygen to form carbon monoxide. Here, if mass of one carbon atom is taken as atomic mass unit (1 amu) [as per the latest IUPAC recommendations now it is called unified mass (u)] then atomic mass of carbon will be 1.0 u and that of oxygen will be 1.33 u. However, it is more convenient to take relative atomic masses of different elements as whole numbers or as near to a whole numbers as possible. Hence, scientists initially took 1/16 part of the mass of one atom of naturally occurring oxygen as the atomic mass unit. This was considered relevant due to following two reasons-

(1) Oxygen reacted with a large number of elements and formed compounds.

(2) This atomic mass unit gave atomic masses of most of the elements as whole numbers.

However, in 1961, carbon-12 isotope was chosen as the standard reference for determining the relative atomic masses of different elements. On this standard, one atomic mass unit (amu) or unified mass (u) is a mass unit equal to exactly one-twelth ($1/12^{th}$) part of the mass of one atom of carbon-12 isotope. The relative atomic masses of all the elements have been determined with respect to the one-twelth ($1/12^{th}$) part of the mass of one atom of carbon-12 isotope.

Thus, the relative atomic mass of an element can be defined as the average mass of the atom as compared to $1/12^{th}$ part of the mass of one atom of carbon-12 isotope.

Atomic Mass Unit (amu) or Unified mass (u)

"The mass of $1/12^{th}$ part of one atom of C^{12} isotope is called atomic mass unit (amu) or unified mass."

The value of 1 amu is found to be 1.66×10^{-24} g.

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.

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Questions

(1) Define the atomic mass unit.
(2) Why is it not possible to see an atom with naked eyes ?

What is a Molecule ?

In general, a molecule is a group of two or more atoms that are chemically bonded together i.e. tightly held together by attractive forces. By definition, "The smallest particle of an element or a compound that is capable of an independent existence and shows all the properties of respective substance is called the molecule". Atoms of the same element or of different elements can join together to form molecules.

Molecules of Elements

The molecules of an element are made up of the same type of atoms. Molecules of many elements, such as helium (He), Neon (Ne), argon (Ar) etc. are monoatomic i.e. they are made up of only one atom of the respective element. On the other hand, the molecules of most of the non- metals are diatomic or polyatomic in nature. For example, a molecule of oxygen (O_2) consists of two atoms of oxygen and therefore, it is a diatomic molecule. Similarly, a molecule of ozone (O_3) consists of three atoms of oxygen and therefore, it is a triatomic molecule.

The number of atoms constituting a molecule is known as the atomicity of the respective molecule. For example, atomicity of oxygen molecule (O_2) is 2 while, that of ozone molecule (O_3) is 3.

The atomicity of some elements are listed here-

Name of Element	Formula of Molecule	Atomicity
Helium	He	1 (Mono-atomic)
Neon	Ne	1 (Mono-atomic)
Argon	Ar	1 (Mono-atomic)
Sodium	Na	1 (Mono-atomic)
Iron	Fe	1 (Mono-atomic)
Oxygen	O_2	2 (Diatomic)
Nitrogen	N_2	2 (Diatomic)
Chlorine	Cl_2	2 (Diatomic)

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Ozone	O_3	3 (Tri-atomic)
Phosphorus	P_4	4 (Tetra-atomic)
Sulphur	S_8	8 (Octa-atomic)

Metals and some other elements, such as carbon, do not have a simple structure, but they are consisting of a very large and indefinite number of atoms bonded together.

Molecules of Compounds

Atoms of different elements join together in definite proportions to form the molecules of compounds . For example, a molecule of water (H_2O) consists of two atoms of hydrogen and one atom of oxygen and therefore, it is a triatomic molecule (atomicity = 3). Similarly, a molecule of sulphuric acid (H_2SO_4) consists of two atoms of hydrogen, one atom of sulphur and four atoms of oxygen and therefore, it is a hepta-atomic molecule (atomicity = 7).

Molecules of some most common compounds are listed here-

Compound	Combing Elements	Ratio by Mass
Water (H_2O)	Hydrogen and oxygen	2:16 or 1:8
Ammonia (NH_3)	Nitrogen and hydrogen	14:3
Carbon dioxide (CO_2)	Carbon and oxygen	12:32 or 3:8

What is an Ion ?

Compounds composed of metals and non-metals usually contain charged species called ions. An ion can be positively or negatively charged. The positively charged ions are called cations, while, the negatively charged ion are called anions. For example, sodium chloride (NaCl) consists of positively charged sodium ions (Na^+) and negatively charged chloride ions (Cl^-).

An ion can be monatomic (consisting of only one atom carrying a charge) such as H^+, Na^+, Ca^{2+}, Cl^-, Br^-, I^- etc. or polyatomic (consisting of a group of atoms carrying a net charge) such as carbonate ion (CO_3^{2-}), sulphate ion (SO_4^{2-}), nitrate ion (NO_3^-) etc.

Valency-

The number of charge present on an ion is called its valency. It represents the combining capacity of the ion.

Based on valency the ions can be categorized as monovalent, divalent, trivalent etc.

Some of the most common ions along with their valencies are listed here-

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Valency	Cations	Anions
Monovalent	H^+ (Hydrogen ion)	H^- (Hydride ion)
	Na^+ (Sodium ion)	Cl^- (Chloride ion)
	K^+ (Potassium ion)	Br^- (Bromide ion)
	NH_4^+ (Ammonium ion)	I^- (Iodide ion)
	Ag^+ (Silver ion)	F^- (Fluoride ion)
	Cu^+ [Cuprous or copper (I) ion]	CN^- (Cyanide ion)
	Hg^+ [Mercurous or Mercury (I) ion]	NO_2^- (Nitrite ion)
		NO_3^- (Nitrate ion)
		HCO_3^- (Hydrogen carbonate ion)
		OH^- (Hydroxide ion)
Divalent	Mg^{2+} (Magnicium ion)	CO_3^{2-} (Carbonate ion)
	Ca^{2+} (Calcium ion)	SO_3^{2-} (Sulphite ion)
	Ba^{2+} (Barium ion)	SO_4^{2-} (Sulphate ion)
	Cu^{2+} [Cupric or copper (II) ion]	S^{2-} (Sulphide ion)
	Fe^{2+} [Ferrous or Iron (II) ion]	$C_2O_4^{2-}$ (Oxalate ion)
	Co^{2+} (Cobalt ion)	O^{2-} (Oxide ion)
	Ni^{2+} (Nickel ion)	
	Zn^{2+} (Zinc ion)	
	Sn^{2+} [Stanous or Tin (II) ion]	
	Hg^{2+} [Mercuric or Mercury (II) ion]	
	Pb^{2+} [Plumbus or Lead (II) ion]	
	Sn^{2+} [Stannous or Tin (II) ion]	
Trivalent	Al^{3+} (Aluminium ion)	PO_4^{3-} (Phosphate ion)
	Cr^{3+} (Chromium ion)	N^{3-} (Nitride ion)
	Fe^{3+} [Ferric or Iron (III) ion]	
Tetravalent	Sn^{4+} [Stannic or Tin (IV) ion]	
	Pb^{4+} [Plumbic or Lead (IV) ion]	

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- Some elements show more than one valencies. Here, Roman numeral written in parentheses shows their valency.

Writing Chemical Formulae

The chemical formula of a compound is a symbolic representation of its composition. It can be written easily using the symbols and combining capacity of the atoms or ions.

Rules of writing a chemical formula of compounds

(1) The valencies or charges on the ion must balance.

(2) When a compound consists of a metal and a non-metal, the name or symbol of the metal is written first and those of nonmetal is written later. For example, sodium chloride (NaCl), calcium oxide (CaO), iron sulphide (FeS), copper oxide (CuO) etc. Here, sodium, calcium, iron and copper are metals and therefore, they are written on the left while, chlorine, oxygen, sulphur are non- metals and therefore, they are written on the right.

(3) For compounds containing polyatomic ions, the number of ions present in the compound is indicated by enclosing the formula of ion in a bracket and writing the number of ions outside the bracket. For example, $Mg(OH)_2$. However, if the number of polyatomic ion is only one, the bracket is not required. For example, NaOH.

Finding the Formulae of Simple Compounds

The simplest compounds, which are made up of only two different elements or only two types of ions are called binary compounds.

In order to get chemical formulae of a binary compounds, first we write the constituent elements or ions and their respective valencies and then we crossover the valencies of the constituent atoms or ions. **For Example,**

(1) For hydrogen chloride

Symbol	**H**	**Cl**
Valency	**1**	**1**
Formula	**HCl**	

(2) For calcium chloride

Symbol	**Ca**	**Cl**
Valency	**2**	**1**
Formula	**$CaCl_2$**	

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(3) For hydrogen sulphide

Symbol H S

Valency 1 2

Formula H_2S

(4) For calcium oxide

Symbol Ca O

Valency 2 2

Formula Ca_2O_2 or CaO

(5) For Aluminium oxide

Symbol Al O

Valency 3 2

Formula Al_2O_3

Same method is applied to get the formula of ionic compounds. For example,

(1) For Magnesium chloride

Symbol Mg^{2+} Cl^-

Valency 2 1

Formula $MgCl_2$

(2) For Sodium carbonate

Symbol Na^+ CO_3^{2-}

Valency 1 2

Formula Na_2CO_3

(3) For calcium sulphate

Symbol Ca SO_4^{2-}

Valency 2 2

Formula $Ca_2(SO_4)_2$ or $CaSO_4$

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(4) For Calcium phosphate

Symbol	**Ca**	**PO_4^{3-}**
Valency	**2**	**3**
Formula	**$Ca_3(PO_4)_2$**	

(5) For Ammonium sulphate

Symbol	**NH_4^+**	**SO_4^{2-}**
Valency	**1**	**2**
Formula	**$(NH_4)_2SO_4$**	

It is clear that, if the cation and anion have same valencies, then they combine in ratio of 1:1 to give the formula of the compound. For example, NaCl, CaO, $CaCO_3$, $BaSO_4$ etc. On the other hand, if the cation and anion have have different valencies, then cross multiplication of their valencies is carried out to get the formula of the compound. For example, **Al_2O_3, Na2CO3, K_2SO_4, $(NH_4)_2SO_4$, $Ca_3(PO_4)_2$ etc.**

In formula of the compounds, the charges on cations and anions are not expressed.

Q.1-Write the formulae of following compounds-

(1) Sodium oxide
(2) Aluminium chloride
(3) Sodium suphide
(4) Magnesium hydroxide
(5) Barium chloride
(6) Sodium phosphate

Q.2- Write the name of following compounds-

(1) $CaCl_2$
(2) **$Al_2(SO_4)_3$**
(3) **$Ca_3(PO_4)_2$**
(4) $BaSO_4$
(5) $NaNO_3$
(6) Fe_2O_3

Q.3-What is meant by the term chemical formula ?

Q.4- How many atoms are present in-

(i)H_2S molecule (ii) PO_4^{3-} ion

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Molecular Mass

"The number which represents how many times one molecule of a substance is heavier than $1/12^{th}$ part of one atom of C^{12} isotope is called molecular mass of the substance."

Mathematically,

$$\text{Molecular mass} = \frac{Mass\ of\ one\ molecule\ of\ the\ substance}{\frac{1}{12}\times Mass\ of\ one\ atom\ of\ C{-}12\ isotope}$$

For example, Molecular mass of oxygen is 32u. It implies that, one molecule of oxygen is 32 times heavier than $1/12^{th}$ part of one atom of C^{12} isotope. Similarly, Molecular mass of chlorine is 71u. It implies that, one molecule of chlorine is 71 times heavier than $1/12^{th}$ part of one atom of C^{12} isotope.

Molecular mass of the compounds is obtained by adding the atomic masses of the atoms present in the molecule of respective compound. For example,

Mol. mass of $CaCO_3$ = 1× At. Mass of Ca + 1 × At. Mass of C+ 3 × (At. Mass of O)

= 40 + 12 + 3×16 = 100 u

Mol. mass of H_2SO_4 = 2×(At. Mass of H) + At. Mass of S+ 4× (At. Mass of O)

= 2×1+32+4×16 = 98 u

Gram Molecular Mass (GMM)

"The amount of a substance in gram equal to its Molecular mass is called Gram Molecular Mass (GMM) of the substance."

For example, molecular mass of oxygen is 32 u. Hence, its Gram Molecular mass (GMM) will be 32 g. In the same way, molecular mass of H_2SO_4 is 98 u. Hence, its Gram Molecular mass (GMM) will be 98 gram.

1GMM of all the substances contains 6.022×10^{23} molecules of the respective substance. Hence, it is also called 1 Mole of the substance.

The number of GMM (moles) in given amount of a substance is obtained using following formula-

$$\text{No. of GMM (moles), n} = \frac{Mass\ of\ substance\ (g)}{GMM\ of\ Substance}$$

Formula Unit Mass

The formula unit mass of a compound is the sum of the atomic masses of all atoms present in a formula unit of the compound. Formula unit mass is calculated in the same manner as we calculate the molecular mass, but it is used for ionic compounds where, the constituent particles are ions.

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For example, for sodium chloride (NaCl),
Formula unit mass = 1 × 23 + 1 × 35.5 = 58.5 u

Ques. Calculate the formula unit mass of $CaCl_2$.

Sol. Formula unit mass of $CaCl_2$ = GAM of Ca + (2 × GAM of Cl)
= 40 + 2 × 35.5
= 40 + 71
= **111 u**

Mole Concept

'Mole' is a counting unit, which is used in counting atoms, ions, molecules and subatomic particles like electrons, protons, neutrons etc. By definition-

"The amount of a substance which contains as number of particles as number of carbon atoms present in 12g of C^{12} isotope is called 1 mole of the substance."

Experimentally, it has been found that 12g of C^{12} isotope contains 6.022×10^{23} carbon atoms. Hence, 'mole' can also be defined as under-

"The amount of a substance which contains 6.022×10^{23} particles irrespective of its nature is called 1 mole of the substance."

Thus,

1 Mole = 6.022×10^{23} particles

For example,

1 Mole H atoms = 6.022×10^{23} H atoms
1 Mole H_2 molecules = 6.022×10^{23} H_2 Molecules
1 Mole H^+ ions = 6.022×10^{23} H^+ Ions
1 Mole electrons = 6.022×10^{23} Electrons
1 Mole protons = 6.022×10^{23} Protons

1GAM of all the elements contains 6.022×10^{23} atoms of the respective element. Hence, it is also called 1 Mole of the element.

The number of moles (GAM) in given amount of an element is obtained using following formula-

$$\text{No. of GAM (moles), n} = \frac{Mass\ of\ element\ (g)}{GAM\ of\ Element}$$

1GMM of all the substances contains 6.022×10^{23} molecules of the substance. Hence, it is also called 1 Mole of the substance.

The number of moles (GMM) in given amount of a substance is obtained using following formula -

$$\text{No. of GMM (moles), n} = \frac{Mass\ of\ substance\ (g)}{GMM\ of\ Substance}$$

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Avogadro's Number

"The number particles present in 1 mole of a substance is called Avogadro's number."

Experimentally, it has been found that 1 mole of all the substance contains 6.022×10^{23} particles irrespective of their nature. Hence, Avogadro's number,

$$N_0 = 6.022\times10^{23}$$

Atomic Mass Unit (amu) or Unified Mass (u)

"The mass of $1/12^{th}$ part of one atom of C^{12} isotope is called atomic mass unit (amu) or unified mass (u)."

$\because$ Gram Atomic Mass of C^{12} isotope = 12g

$\therefore$ Mass of 6.023×10^{23} atoms of C^{12} = 12g

$\therefore$ Mass of one atom of $C^{12} = \frac{12}{6.022\times10^{-23}}$ g

$\therefore$ Mass of $1/12^{th}$ part of one atom of C^{12} isotope $= \frac{1}{12}\times\frac{12}{6.022\times10^{-23}}$ g

$= \frac{1}{6.022\times10^{-23}}$ g

$= 1.66\times 10^{-24}$ g

Thus, $1\ u = 1.66\times 10^{-24}$g

It is clear that, atomic mass unit or unified mass is numerically equal to the reciprocal of Avogadro's number (N_0)

Numericals

Q.1. Calculate the no. of GAM (moles) in 2.3 g of sodium.

Sol – Here, No. of moles, $n = \frac{Mass\ of\ element\ (g)}{GAM\ of\ Element}$

$= \frac{2.3\ g}{23\ g}$

$= 0.1$ moles

Q.2. Find the total no of sodium atom in 2.3 g of sodium.

Sol- Here, No. of moles, $n = \frac{Mass\ of\ element\ (g)}{GAM\ of\ Element}$

$= \frac{2.3\ g}{23\ g}$

$= 0.1$ moles

$\therefore$ No. of Sodium atoms, $N = n \times No$

$= 0.1 \times 6.022 \times10^{23}$

$= 6.022 \times 10^{22}$ atoms

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Q.3. Find the no. of atoms in 9 g of aluminium.

Sol. Here, No. of moles, $n = \frac{Mass\ of\ element\ (g)}{GAM\ of\ Element}$

$= \frac{9\ g}{27\ g}$

$= 0.33$ moles.

$\therefore$ No. of atoms, $N = n \times 6.022 \times 10^{23}$

$= 0.33 \times 6.022 \times 10^{23}$

$= 2.0073 \times 10^{23}$ atoms

Q.4. Find the total no. of moles of HCl molecules in 3.65 g of HCl.

Sol- Here, No. of GMM (moles), $n = \frac{Mass\ of\ substance\ (g)}{GMM\ of\ Substance}$

$= \frac{3.65\ g}{36.5\ g}$

$= 0.1$ moles

Q.5. Find the total no. of molecules of HCl in 3.65g of HCl.

Sol- Here, No. of GMM (moles), $n = \frac{Mass\ of\ substance\ (g)}{GMM\ of\ Substance}$

$= \frac{3.55\ g}{35.5\ g}$

$= 0.1$ moles

$\therefore$ No. of molecules, $N = n \times No$

$= 0.1 \times 6.022 \times 10^{23}$

$= 6.022 \times 10^{22}$ molecules

Q.6. Find the total no. of H_2SO_4 molecules in 49 g of H_2SO_4.

Sol. Here, No. of GMM (moles), $n = \frac{Mass\ of\ substance\ (g)}{GMM\ of\ Substance}$

$= \frac{49\ g}{98\ g}$

$= 0.5$ moles

$\therefore$ No. of molecules, $N = n \times No$

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

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

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