Ratna Sagar

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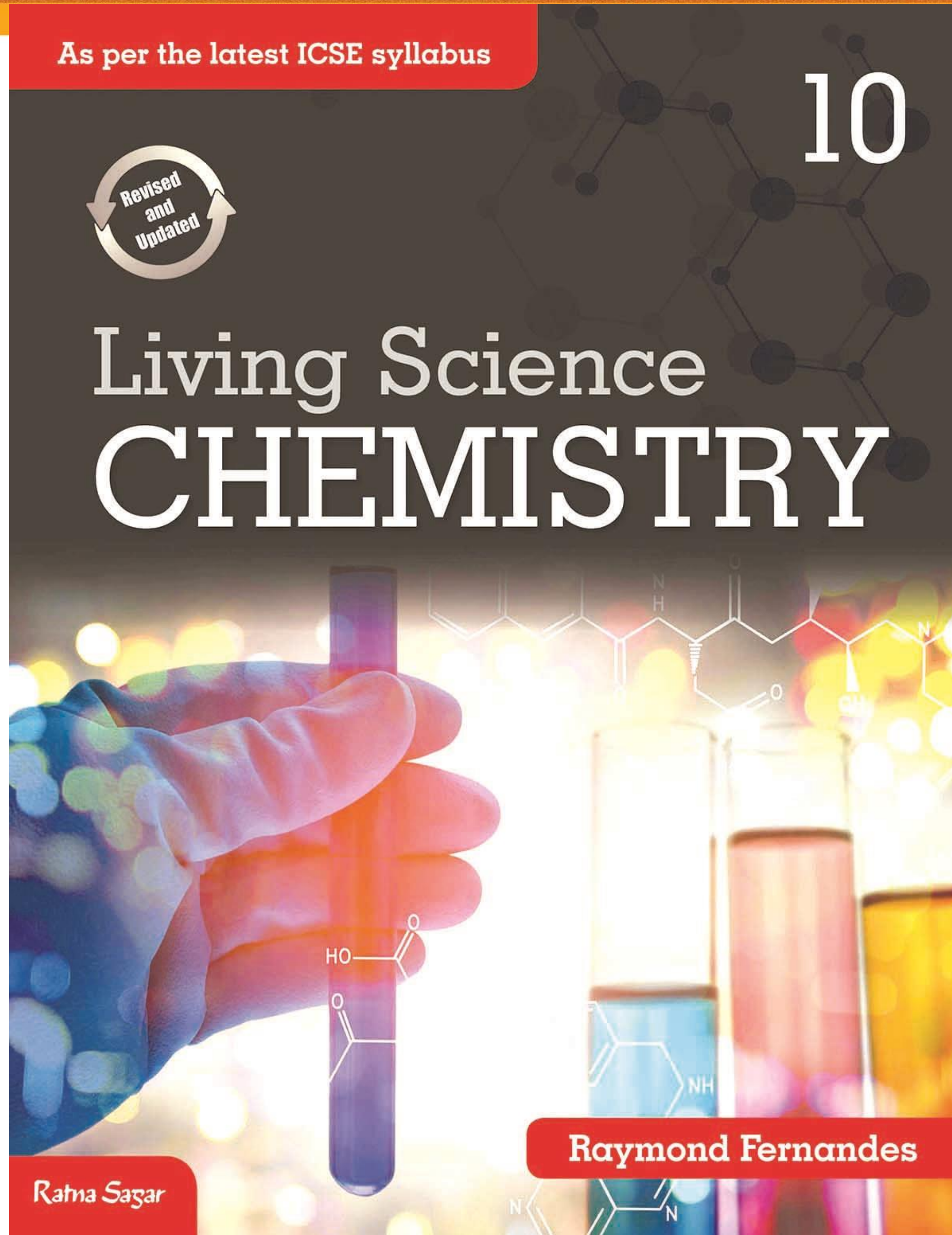
Education, Our Mission

ICSE
Living Science
Chemistry

Class 10

Chapter-5 Mole Concept and Stoichiometry



EDUCATION, OUR MISSION

LEARNING OBJECTIVES

Gas Laws

- ❖ Standard temperature and pressure

Gay-Lussac's Law of Combining Volumes

- ❖ Avogadro's Law

Relative Atomic Mass and Relative Molecular Mass

- ❖ Relative atomic mass and atomic mass
- ❖ Relative molecular mass and molecular mass
- ❖ Formula unit mass
- ❖ Gram molecular mass

Mole Concept

- ❖ Molar volume

Applications Avogadro's Law

Percentage Composition

Empirical and Molecular Formula

- ❖ Calculations based on chemical formula

What is Stoichiometry?

The term is generally used for referring to the calculation of quantities of substances involved in chemical reactions. These calculations are used during chemical analysis and during production of most commonly used chemicals.

Gas Laws

Gas law	Variables	Relationship	Equation
1. Boyle's law	Pressure, Volume	Volume $\propto \frac{1}{\text{Pressure}}$ (at constant temperature)	$P_1V_1 = P_2V_2$
2. Charle's law	Volume, Temperature	Volume $\propto$ Temperature (at constant pressure)	$\frac{V_1}{T_1} = \frac{V_2}{T_2}$
3. Gas equation (obtained on applying Boyle's and Charle's law)	Pressure, Volume, Temperature	When above two laws are combined together Pressure $\propto \frac{1}{\text{Volume}}$ $\propto$ Temperature	$\frac{PV}{T} = \text{K (constant)}$ $\Rightarrow \frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

Standard temperature and pressure (S.T.P.)

The volume of a gas changes with change in temperature and pressure. In order to compare the volume of gases, standard conditions of temperature and pressure are employed.

Standard temperature = 0 ° C or 273 K

Standard pressure = 10^5 Pa

Gay-Lussac’s Law of Combining Volumes

When gases react, they do so in volumes which bear a simple whole number ratio to one another and to the volume of the product if gaseous, provided all the volumes are measured at the same temperature and pressure.

Avogadro’s Law

Equal volumes of all gases at the same temperature and pressure contain the same number of molecules. Thus, if the temperature, pressure and volumes of two gases are the same, then, the two gases contain the same number of molecules regardless of their identity.

The usefulness of Avagadro’s law lies in the fact that it differentiates between an atom and a molecule.

An atom is the smallest particle of an element that participates in a chemical reaction and cannot have an independent existence.

A molecule is the smallest particle of an element or a compound that can have an independent existence.

Relative Atomic Mass and Relative Molecular Mass

Relative atomic mass and atomic mass

As hydrogen atoms are the lightest of all the atoms of elements, one atom of hydrogen was originally taken as the mass with which all other atoms would be compared and hence, the mass of an atom of hydrogen could be taken exactly as one unit.

According to hydrogen standard, original relative atomic mass =
Mass of one atom of the element / Mass of one atom of hydrogen

Relative atomic mass of an element = Mass of 1 atom of an element/
$1/16 \times$ mass of one atom of oxygen

Relative molecular mass and molecular mass

The relative molecular mass of an element or a compound is defined as the number of times one molecule of an element or a compound is heavier than 1/12 th of the mass of an atom of carbon-12.

Formula unit mass

For the substances containing ions, i.e. for ionic compounds, the term formula unit mass is used instead of molecular mass. The formula unit mass is the sum of the atomic masses of all the atoms present in a formula unit of compound

Gram atomic mass

The amount of an element whose mass in grams is numerically equal to its atomic mass is called gram atomic mass of that element. In other words, the atomic mass of an element expressed in grams is called its gram atomic mass. For example,

Atomic mass of oxygen = 16 u

So, Gram atomic mass of oxygen = 16 g

Gram molecular mass

The molecular mass of a substance expressed in grams is called its gram molecular mass. Molecular mass of oxygen, O_2 = 32 u

So, gram molecular mass of oxygen, O_2 = 32 g

Mole Concept

Atoms and molecules are expressed in terms of mole. The mole is the standard chemical unit used to measure the quantity of a substance in terms of number and mass.

One mole is the amount of a substance that contains as many particles or entities as there are atoms in exactly 12 g of the C-12 isotope. The mole is equal to 6.022×10^{23} particles (atoms, molecules or ions) of a substance.

1 mole of atoms = 6.022×10^{23} atoms

1 mole of molecules = 6.022×10^{23} molecules

This number of 6.022×10^{23}, which represents a mole, is known as **Avogadro number** (NA or L).

Mole of atoms: One mole of atoms of an element has a mass equal to the gram atomic mass of the element.

Mole of molecules: One mole of molecules of a substance has a mass equal to the gram molecular mass of the substance.

Molar Volume

The volume occupied by 1 mole of any gas at S.T.P. (i.e. at 273 K and 10^5 Pa) is called molar volume. This is equal to 22.4 L.

Note: Refer to **Table 5.2 for** Mole relationships for some gases.

Applications of Avogadro's Law

1. The law helped in initiating the crossover of statements involving **volumes of gases** to **molecules of gases**. "1 **volume** of hydrogen combines with 1 **volume** of chlorine to form 2 **volumes** of hydrogen chloride." This could now be referred to as 1 **molecule** of hydrogen combines with 1 **molecule** of chlorine to form 2 **molecules** of hydrogen chloride.

2. Modification of the Atomic Theory: The law modified the Atomic Theory by making a distinction between atoms and molecules.

3. Deduction of Gay-Lussac's law

4. Determining the atomicity of elementary gases: The atomicity of an element is the number of atoms present in a molecule of a gas.

5. Deriving the relationship between atomic weight and vapour density:
Vapour density (V.D.) = Mass of *V* mL of a substance in the gaseous state/ Mass of *V* mL of hydrogen under similar conditions

According to Avogadro's hypothesis, equal volumes of gases under similar condition should contain equal number of molecules.

Molecular weight of a gaseous substance = 2 $\times$ V.D. of a gaseous substance

6. Determining atomic weights

In 1858, Cannizzaro used Avogadro's law to calculate atomic and molecular weights. At S.T.P., 1 litre of H_2 weighs 0.0899 g and 1 litre of O_2 weighs 1.4290 g. By Avogadro's law, since their volumes are equal their number of molecules should also be equal and therefore 1 molecule of hydrogen will be 0.0899/ 1. 4290 times heavier than a molecule of oxygen.

7. Determining molecular formulae

To determine the molecular formula of ammonia, it was decomposed and the volumes of the gaseous products were determined.

8. Derivation of the mole concept

In general, a mole is that amount of a substance which contains as many entities (atoms, molecules, or ions) as there are atoms in 0.012 kg or 12 g of carbon-12.

Empirical and Molecular Formulae

Empirical Formula

The simplest formula of a substance which gives the relative number of atoms of each element present in a molecule of the substance is called **empirical formula**.

Empirical formula mass: The sum of the atomic masses of all the atoms present in the empirical formula is called the **empirical formula mass**.

Molecular formula

A symbolic representation of a molecule of a compound in terms of symbol and actual number of atoms of each element present in one molecule of the compound is called its **molecular formula**.

Molelecular formula = $n \times$ Empirical formula

where, n = Molecular mass / Empirical formula mass

Determination of molecular formula

To calculate the molecular formula, the relative molecular mass of the compound is required. This will be provided in the sum directly or in the form of the vapour density of the compound or in any other form that will lead to the calculation of the molecular mass.

Step 1: Calculate the empirical formula mass

Step 2: Calculate the molecular mass Molecular mass = 2 $\times$ Vapour density

Step 3: Multiplication factor n = Molecular mass / Empirical formula mass

Step 4: Molecular formula = (Empirical formula)n

Note: The value of n must be rounded off to nearest whole number.

Calculations Based on Chemical Equations

A chemical equation should represent a true chemical reaction and it should be a balanced equation, i.e. the number of atoms of each element on both the sides should be equal.

Information conveyed by a chemical equation

A chemical equation gives the following types of information:

1. **Qualitative information:** This gives the information regarding the

a. names of the reactants that take part in the reaction.

b. names of the products formed in the reaction.

2. **Quantitative information:** This gives the information regarding the

a. number of molecules or atoms of reactants and products.

b. number of moles of reactants and products.

c. volumes of gaseous reactants and products measured at S.T.P.

SUMMARY

1. **Gay-Lussac's law of combining volumes:** When gases react, they do so in volumes which bear a simple whole number ratio to one another and to the volume of the product if gaseous, provided all the volumes are measured at the same temperature and pressure.

2. **Avogadro's law:** Equal volumes of all gases at the same temperature and pressure contain the same number of molecules.

3. **Atomicity:** Atomicity is defined as the number of atoms in one molecule of an element.

4. **Vapour density:** It is the ratio of the mass of a certain volume of a gas or vapour to the mass of an equal volume of hydrogen; all measurements made under the same conditions of temperature and pressure.

5. **Relative atomic mass:** It is the ratio of the mass of an atom of an element to 1/12 th the mass of an atom of carbon-12.

6. Relative molecular mass: It is the ratio of the mass of one molecule of a substance to 1/12 th the mass of an atom of carbon-12.

7. Gram atomic mass: It is the relative atomic mass expressed in grams.

8. Gram molecular mass: It is the relative molecular mass expressed in grams.

9. Molar volume: It is the volume occupied by one mole of a gas at S.T.P.

10. Mole: One mole of an atom is the relative atomic mass of that atom expressed in grams. One mole of a molecule is the relative molecular weight of that element expressed in grams. In general, one mole is amount of a substance which contains as many entities (atoms, ions or molecules) as there atoms in 0.012 kg or 12 g of carbon-12.

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