ATOMS AND MOLECULES

CBSE CLASS 9 SCIENCE • CHAPTER 3 • PREMIUM REVISION BOOKLET

1. Introduction

Everything in our universe is composed of foundational structural blocks known as **atoms** and **molecules**. Long before modern theory, ancient Indian philosopher Maharishi Kanad postulated that if we keep dividing matter (*Padarth*), we will eventually get the smallest possible particles, which he named **Parmanu**.

In modern chemistry, John Dalton provided the scientific scaffolding for this concept through his breakthrough Atomic Theory.

2. Laws of Chemical Combination

Chemical reactions occur under strict quantitative principles known as the Laws of Chemical Combination.

A. Law of Conservation of Mass

Formulated by Antoine Lavoisier, this law states: **Mass can neither be created nor destroyed in a chemical reaction.**

$$ ext{Total Mass of Reactants} = ext{Total Mass of Products}$$

Example: When Hydrogen gas reacts completely with Oxygen to form Water ($2 ext{H}_2 + ext{O}_2 ightarrow 2 ext{H}_2 ext{O}$), the collective atomic mass before the reaction precisely matches the molecular mass after the reaction.

B. Law of Constant Proportions

Formulated by Joseph Proust, this law states: **In a chemical substance, the elements are always present in definite proportions by mass.**

Example: Pure water ($ ext{H}_2 ext{O}$) obtained from any source—be it a river, laboratory, or rain—will always contain Hydrogen and Oxygen combined in a strict mass ratio of **$1:8$**. Similarly, Ammonia ($ ext{NH}_3$) always features Nitrogen and Hydrogen in a fixed mass ratio of **$14:3$**.

3. Dalton's Atomic Theory

Main Postulates of Dalton's Atomic Theory:

- All matter is composed of microscopic, indivisible particles called atoms.
- Atoms are indivisible structures that cannot be created or destroyed during chemical changes.
- Atoms of a given element are absolutely identical in mass and chemical properties.
- Atoms of different elements possess completely different masses and chemical properties.
- Atoms combine in simple, whole-number mathematical ratios ($ ext{e.g., } 1:1, 2:3$) to form stable compounds.
- The relative number and kinds of atoms are completely constant in a given compound.

4. What is an Atom?

An **atom** is the smallest defining unit of matter that retains all the unique chemical properties of its parent element and takes part directly in a chemical reaction.

- They are incredibly small; atomic radii are measured in nanometers ($1 ext{ nm} = 10^{-9} ext{ m}$).
- They cannot be observed with the naked eye.
- They exist in a highly reactive state for most elements, rarely existing independently in nature (except for Noble Gases like Helium and Neon).

5. Chemical Symbols of Elements

Modern chemical symbols are designated by IUPAC (International Union of Pure and Applied Chemistry). Many symbols are derived from the element's English name, while others originate directly from their classical Latin names:

Element	Symbol
Hydrogen	$ ext{H}$
Oxygen	$ ext{O}$
Nitrogen	$ ext{N}$
Carbon	$ ext{C}$
Calcium	$ ext{Ca}$

Element	Latin Name	Symbol
Sodium	Natrium	$ ext{Na}$
Potassium	Kalium	$ ext{K}$
Iron	Ferrum	$ ext{Fe}$
Copper	Cuprum	$ ext{Cu}$
Gold	Aurum	$ ext{Au}$

6. Atomic Mass Concepts

Since measuring the absolute weight of a single atom is impractical, scientists use a relative scale. The reference point is **Carbon-12 ($^{12} ext{C}$)**, where 1 **Atomic Mass Unit ($ ext{u}$)** is defined as exactly $ rac{1}{12}$th the mass of a single Carbon-12 atom.

Element	Atomic Mass ($ ext{u}$)
Hydrogen ($ ext{H}$)	$1 ext{ u}$
Carbon ($ ext{C}$)	$12 ext{ u}$
Nitrogen ($ ext{N}$)	$14 ext{ u}$

Element	Atomic Mass ($ ext{u}$)
Oxygen ($ ext{O}$)	$16 ext{ u}$
Sodium ($ ext{Na}$)	$23 ext{ u}$
Magnesium ($ ext{Mg}$)	$24 ext{ u}$

7. Molecules & Atomicity

A **molecule** is an electrically neutral cluster of two or more atoms chemically bonded together. It represents the smallest particle of an element or compound capable of completely independent existence while showcasing all the properties of that substance.

Atomicity: The total number of constituent atoms present within one single molecule of an element.

Classification	Definition	Examples with Formulae
Monoatomic	Consists of a single isolated atom.	Helium ($ ext{He}$), Argon ($ ext{Ar}$)
Diatomic	Composed of exactly two bonded atoms.	Hydrogen ($ ext{H}_2$), Oxygen ($ ext{O}_2$), Nitrogen ($ ext{N}_2$)
Triatomic	Composed of three atoms.	Ozone ($ ext{O}_3$)
Polyatomic	Contains more than three bonded atoms.	Phosphorus ($ ext{P}_4$), Sulfur ($ ext{S}_8$)

8. Ions: Charged Entities

Compounds made of metals and non-metals contain charged species known as **ions**. Ions are formed when stable atoms lose or gain valence electrons.

- **Cations (+):** Positively charged ions formed when atoms lose electrons (e.g., $ ext{Na}^+$, $ ext{K}^+$, $ ext{Ca}^{2+}$, $ ext{Al}^{3+}$).
- **Anions (-):** Negatively charged ions formed when atoms gain electrons (e.g., $ ext{Cl}^-$, $ ext{O}^{2-}$, $ ext{S}^{2-}$, $ ext{N}^{3-}$).

9. Valency & Criss-Cross Rules for Writing Chemical Formulae

The combining capacity of an element is called its **valency**. When writing a chemical formula, follow these fundamental rules:

1. Write the symbol of the electropositive element (metal/cation) first, followed by the electronegative element (non-metal/anion).
2. Write the valency or net ionic charge directly beneath each corresponding symbol.
3. Cross over (criss-cross) the valencies to determine the subscript numbers for each element. Simplify ratios if necessary.

Step-by-Step Formula Derivation Examples

Sodium Chloride:
Symbols: $ ext{Na} \quad ext{Cl}$
Valencies: $+1 \quad -1$
Criss-cross gives: **$ ext{NaCl}$**

Calcium Oxide:
Symbols: $ ext{Ca} \quad ext{O}$
Valencies: $+2 \quad -2$
Ratio reduces $2:2 ightarrow 1:1$: **$ ext{CaO}$**

Magnesium Chloride:
Symbols: $ ext{Mg} \quad ext{Cl}$
Valencies: $+2 \quad -1$
Criss-cross gives: **$ ext{MgCl}_2$**

Aluminium Oxide:
Symbols: $ ext{Al} \quad ext{O}$
Valencies: $+3 \quad -2$
Criss-cross gives: **$ ext{Al}_2 ext{O}_3$**

10. Calculation of Molecular Mass & Formula Unit Mass

- **Molecular Mass:** The sum of the individual atomic masses of all atoms present in a molecule. Used for molecular compounds.
- **Formula Unit Mass:** Evaluated in the exact same mathematical manner, but specifically used for ionic compounds where discrete molecules do not exist.

Sample Math Calculation 1: Water ($ ext{H}_2 ext{O}$) $$ ext{Molecular Mass} = (2 imes ext{Mass of H}) + (1 imes ext{Mass of O})$$ $$ ext{Molecular Mass} = (2 imes 1 ext{ u}) + (1 imes 16 ext{ u}) = 2 ext{ u} + 16 ext{ u} = 18 ext{ u}$$

Sample Math Calculation 2: Carbon Dioxide ($ ext{CO}_2$) $$ ext{Molecular Mass} = (1 imes 12 ext{ u}) + (2 imes 16 ext{ u}) = 12 ext{ u} + 32 ext{ u} = 44 ext{ u}$$

Sample Math Calculation 3: Sodium Chloride ($ ext{NaCl}$) Formula Unit Mass $$ ext{Formula Unit Mass} = 23 ext{ u} \ (ext{Na}) + 35.5 ext{ u} \ (ext{Cl}) = 58.5 ext{ u}$$

11. Core Summary & High-Yield Keyword Index

Summary: Matter consists of atoms that combine in fixed whole-number mass ratios to form molecules or ions, satisfying the Laws of Chemical Combinations. Valency allows us to determine formulas through the criss-cross method, and molecular weights can be calculated directly using carbon-12 relative atomic mass units.

Core Keywords for High-Scoring Answers:

`Law of Conservation of Mass` `Constant Proportions` `Dalton Postulates` `Carbon-12 Reference` `Atomicity` `Polyatomic Ions` `Valency Cross-Over` `Formula Unit Mass`