Topic: Symbols, Formulae, and Equations II

Subtopics Covered:

1. **Law of Constant Composition**
2. **Law of Multiple Proportions**
3. **Writing and Balancing Chemical Equations**

Lesson Objectives:

By the end of the lesson, students should be able to:

- State and explain the **Law of Constant Composition**.
- State and explain the **Law of Multiple Proportions**.
- Write and balance **chemical equations** properly.

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1. Law of Constant Composition (Law of Definite Proportions)

Statement:

"A chemical compound always contains the same elements combined in the same proportion by mass, regardless of its source or the method of preparation."

Explanation:

- The composition of a **pure compound** is **fixed**.
- The elements combine in **definite, fixed ratios**.

Examples:

Water (H_2O):

Element	**Mass of 1 mole**
Hydrogen	2g

Element	Mass of 1 mole
Oxygen	16g
Total	18g

Mass Ratio:

218:1618=1:8\frac{2}{18} : \frac{16}{18} = 1 : 8182:1816=1:8

So, water is always **1 part hydrogen** and **8 parts oxygen** by mass, no matter the source.

Carbon Dioxide (CO_2):

Element	Mass of 1 mole
Carbon	12g
Oxygen	32g
Total	44g

Mass Ratio:

1244:3244=3:8\frac{12}{44} : \frac{32}{44} = 3 : 84412:4432=3:8

Carbon dioxide is always **3 parts carbon** to **8 parts oxygen** by mass.

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2. Law of Multiple Proportions

Statement:

"When two elements combine to form more than one compound, the different masses of one element that combine with a fixed mass of the other are in simple whole-number ratios."

Explanation:

If **element A** combines with **element B** in different ways to form different compounds, the mass of B that combines with a fixed mass of A will be in **simple whole number ratios**.

Examples:

Carbon and Oxygen:

Compound	Formula	Mass of Carbon	Mass of Oxygen
Carbon monoxide	CO	12g	16g
Carbon dioxide	CO_2	12g	32g

Comparison:

Fix carbon at **12g**. Compare oxygen masses:

- In CO: 16g of oxygen
- In CO_2: 32g of oxygen

Ratio of oxygen = **16 : 32 = 1 : 2**

So, the oxygen masses are in a **simple whole-number ratio of 1:2**, confirming the law.

Another Example: Nitrogen Oxides

Compound	Formula	Mass of N (fixed)	Mass of O
Nitrous oxide	N_2O	28g	16g
Nitric oxide	NO	28g	32g
Nitrogen dioxide	NO_2	28g	64g

Ratio of Oxygen:

16 : 32 : 64 = **1 : 2 : 4**

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3. Writing and Balancing Chemical Equations

What is a Chemical Equation?

A **chemical equation** shows the **reactants** and **products** in a chemical reaction, using **symbols and formulae**.

Parts of a Chemical Equation:

Reactants	→	**Products**
Substances before reaction	Arrow (yields)	Substances after reaction

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Symbols Used in Equations:

Symbol	**Meaning**
+	"and" or "reacts with"
→	"produces" or "yields"
(s)	Solid
(l)	Liquid
(g)	Gas
(aq)	Aqueous solution (dissolved in water)

Steps to Balance Chemical Equations:

1. **Write the correct formulae** for all reactants and products.
2. **Count the number of atoms** of each element on both sides.
3. Use **coefficients (numbers in front)** to balance the atoms.
4. **Never change subscripts** (do not alter the formula).
5. Check your work by **recounting atoms**.

Examples of Balancing Equations:

Example 1: Combustion of Methane

Unbalanced:CH4+O2→CO2+H2O\text{Unbalanced:} \quad CH_4 + O_2 \rightarrow CO_2 + H_2OUnbalanced:CH4+O2→CO2+H2O

- Carbon: 1 (both sides)
- Hydrogen: 4 (left), 2 (right)
- Oxygen: 2 (left), 3 (right)

Balanced:

CH4+2O2→CO2+2H2OCH_4 + 2O_2 \rightarrow CO_2 + 2H_2OCH4+2O2→CO2+2H2O

- Carbon: 1
- Hydrogen: 4
- Oxygen: 4 (both sides)

Example 2: Reaction of Iron and Oxygen

Unbalanced:Fe+O2→Fe2O3\text{Unbalanced:} \quad Fe + O_2 \rightarrow Fe_2O_3Unbalanced:Fe+O2→Fe2O3

- Iron: 2 on right, so put **2 Fe** on left.
- Oxygen: 3 on right, 2 on left. Use LCM of 6.

Balanced:

4Fe+3O2→2Fe2O34Fe + 3O_2 \rightarrow 2Fe_2O_34Fe+3O2→2Fe2O3

Example 3: Neutralization Reaction

Unbalanced:NaOH+HCl→NaCl+H2O\text{Unbalanced:} \quad NaOH + HCl \rightarrow NaCl + H_2OUnbalanced:NaOH+HCl→NaCl+H2O

- All elements are already balanced.
- **Final equation:**

NaOH+HCl→NaCl+H2ONaOH + HCl \rightarrow NaCl + H_2ONaOH+HCl→NaCl+H2O

Additional Examples for Practice:

Reaction	Balanced Equation
Combustion of hydrogen	$2H_2 + O_2 \rightarrow 2H_2O$
Formation of ammonia	$N_2 + 3H_2 \rightarrow 2NH_3$
Decomposition of water	$2H_2O \rightarrow 2H_2 + O_2$
Reaction of sodium with chlorine	$2Na + Cl_2 \rightarrow 2NaCl$
Calcium carbonate decomposition	$CaCO_3 \rightarrow CaO + CO_2$

Summary of Key Points:

Concept	Meaning
Law of Constant Composition	A compound always has elements in a fixed ratio by mass.
Law of Multiple Proportions	Elements can combine in different ratios to form different compounds.
Chemical Equation	Symbolic representation of a chemical reaction.
Balancing Equations	Ensuring same number of atoms on both sides.

Conclusion

The **laws of composition** help explain how elements combine in nature.
Balanced chemical equations show how matter is conserved and reactions happen according to fixed rules.