CLASS 9 SCIENCE

Chapter 9 Notes

Atomic Foundations of Matter

Chapter focus

The chapter develops the laws of chemical combination, Dalton's atomic theory, molecules and chemical bonding, covalent and ionic compounds, writing and naming chemical formulae, properties of ionic and covalent compounds, molecular mass and formula unit mass.

1. Mass During Physical and Chemical Changes

- When common salt dissolves in water, the mass of the solution equals the total mass of the salt and water taken. Thus, mass remains practically unchanged during this physical change.
- Investigate whether the same principle applies during chemical reactions.
- When vinegar reacts with baking soda, carbon dioxide is produced. In an open arrangement the measured mass may appear to decrease because the gas escapes.
- When the reaction is carried out so that the gas remains trapped in an attached balloon, the final mass matches the initial mass.

2. Law of Conservation of Mass

Law

Matter can neither be created nor destroyed in a chemical reaction. Therefore, the total mass of reactants equals the total mass of products.

- The law was proposed by Antoine Lavoisier in 1789.
- Verify it using the vinegar-baking soda reaction and the reaction between sodium sulfate and barium chloride.
- Sodium sulfate + Barium chloride → Barium sulfate + Sodium chloride.
- A white precipitate of barium sulfate forms, while the total mass remains conserved.

Important experimental idea

If a gaseous product escapes from an open system, the measured mass of the remaining material may decrease. This does not mean that mass has been destroyed.

3. Numerical Use of Conservation of Mass

- To verify the law, calculate the total mass of all reactants and compare it with the total mass of all products.
- Example: 4.0 g calcium carbonate + 2.92 g hydrochloric acid gives products of masses 1.76 g, 0.72 g and 4.44 g.
- Reactants = 6.92 g; products = 6.92 g. Hence mass is conserved.
- If 12 g carbon produces 44 g carbon dioxide, then 2.4 g carbon produces 8.8 g carbon dioxide when oxygen is available in the required amount.

4. Law of Constant Proportions

Law
In a compound formed by two or more elements, the elements are always present in a fixed ratio by mass, irrespective of the source of the compound.

- This is also called the Law of Definite Proportions or Proust's Law.
- Joseph Proust established this law through careful experimental work.
- Purified water from any source contains hydrogen and oxygen in the mass ratio 1:8.
- Thus, 9 g of water contains 1 g hydrogen and 8 g oxygen.
- Sodium chloride contains sodium and chlorine in the mass ratio 23:35.5.

Compound versus mixture
A compound has a definite composition by mass, whereas the components of a mixture can be present in varying proportions.

5. Dalton's Atomic Theory

- The laws of conservation of mass and constant proportions formed the basis of Dalton's atomic theory.
- All matter is made of very tiny particles called atoms, which participate in chemical reactions.
- Atoms were proposed to be indivisible particles that cannot be created or destroyed in a chemical reaction.
- Atoms of a given element were proposed to be identical in mass and chemical properties.
- Atoms of different elements have different masses and chemical properties.
- Atoms combine in simple whole-number ratios to form compounds.
- The relative number and kinds of atoms remain constant in a given compound.
- During a chemical reaction, atoms rearrange rather than being created or destroyed.

6. Molecules and Chemical Bonds

Molecule
A molecule is an electrically neutral entity consisting of more than one atom, capable of independent existence and showing the properties of that substance.

- Atoms of the same element can combine to form molecules of that element, such as H_2.
- Atoms of different elements can combine to form molecules of compounds, such as HCl.
- Some elements such as helium exist as individual atoms because their electronic configuration is already stable.
- Atoms generally become more stable by sharing, losing or gaining valence electrons.
- The force that holds atoms together is called a chemical bond.
- The two main modes of bonding: sharing of electrons and transfer of electrons.

7. Covalent Bond - Sharing of Electrons

Covalent bond
The interaction that holds atoms together through shared electron pair(s) is called a covalent bond.

- Hydrogen: each H atom has one electron and shares one electron with another H atom. H—H contains one shared pair and is a single bond.
- Chlorine: each Cl atom has seven valence electrons and shares one electron. Cl—Cl is a single covalent bond.
- Oxygen: each O atom has six valence electrons and needs two more. Two oxygen atoms share two pairs of electrons. O=O is a double bond.
- Hydrogen chloride: H and Cl share one pair of electrons, giving H—Cl.
- Water: one oxygen atom shares electrons with two hydrogen atoms, forming H_2O.

8. Naming Covalent Compounds

- The first element retains its regular name; the name of the second element ends in -ide.
- Prefixes indicate the number of atoms: mono- (1), di- (2), tri- (3), tetra- (4), penta- (5), hexa- (6), etc.
- The prefix mono- is usually omitted for the first element.
- When a prefix ending in 'o' or 'a' is followed by an element name beginning with a vowel, the last vowel of the prefix is dropped, as in monoxide and pentoxide.

Formula	Name
CO	Carbon monoxide
CO_2	Carbon dioxide
CS_2	Carbon disulfide
PCl_3	Phosphorus trichloride
SF_6	Sulfur hexafluoride
N_2O_4	Dinitrogen tetroxide
N_2O_5	Dinitrogen pentoxide
H_2S	Hydrogen sulfide
H_2O	Water (common name)
NH_3	Ammonia (common name)

9. Ionic Bond - Transfer of Electrons

- Atoms with fewer than four valence electrons generally tend to donate electrons to reach a stable configuration; atoms with more than four often gain or share electrons.
- Sodium (2, 8, 1) loses one electron and forms Na^+, a positively charged ion or cation.
- Chlorine (2, 8, 7) gains one electron and forms Cl^-, a negatively charged ion or anion.
- Cations and anions are collectively called ions.

Ionic bond
The electrostatic force of attraction between oppositely charged ions that holds them together is called an ionic bond.

- Na^+ and Cl^- attract each other to form sodium chloride, NaCl.
- Ionic compounds generally form three-dimensional crystals rather than separate molecules.
- In sodium chloride, ions occur in a regular repeating crystal structure; each Na^+ is surrounded by six Cl^- ions and each Cl^- by six Na^+ ions.

10. Naming Ionic Compounds

- The name of the cation is written first, followed by the name of the anion.
- Names of simple anions usually end in -ide.
- Ionic compounds are typically formed when metals combine with non-metals.
- Ions formed from two or more atoms are called polyatomic ions; their names generally do not end in -ide.

Common ion	**Formula**	**Valency**
Sodium	Na^+	1
Potassium	K^+	1
Calcium	Ca^{2+}	2
Magnesium	Mg^{2+}	2
Aluminium	Al^{3+}	3
Ferrous	Fe^{2+}	2
Ferric	Fe^{3+}	3
Cuprous	Cu^+	1
Cupric	Cu^{2+}	2
Chloride	Cl^-	1
Oxide	O^{2-}	2
Sulfide	S^{2-}	2
Polyatomic ion	**Formula**	**Valency**
Hydroxide	OH^-	1
Nitrate	NO_3^-	1
Hydrogencarbonate	HCO_3^-	1
Carbonate	CO_3^{2-}	2
Sulfate	SO_4^{2-}	2
Ammonium	NH_4^+	1

11. Writing Chemical Formulae

Covalent Compounds

- Write the symbols of the constituent elements.
- Write their valencies.
- Cross over the valencies and write them as subscripts.
- A subscript 1 is not written.

Compound	Valencies used	Formula
Hydrogen chloride	H = 1, Cl = 1	HCl
Hydrogen sulfide	H = 1, S = 2	H_2S
Carbon tetrachloride	C = 4, Cl = 1	CCl_4

Ionic Compounds

- Write the cation first and the anion second.
- Use the charges/valencies to obtain the simplest electrically neutral ratio.
- When more than one identical polyatomic ion is needed, place the polyatomic ion in brackets and write the required subscript outside.

Compound	Ions	Formula
Sodium chloride	Na^+, Cl^-	NaCl
Magnesium chloride	Mg^{2+}, Cl^-	$MgCl_2$
Magnesium hydroxide	Mg^{2+}, OH^-	$Mg(OH)_2$
Aluminium hydroxide	Al^{3+}, OH^-	$Al(OH)_3$
Aluminium sulfate	Al^{3+}, $SO_4{}^{2-}$	$Al_2(SO_4)_3$

Bracket rule
Aluminium hydroxide is $Al(OH)_3$, not $AlOH_3$. Brackets are used when two or more polyatomic ions of the same type occur in a formula.

12. Properties of Ionic and Covalent Compounds

Property	Ionic compounds	Covalent compounds
Typical solubility	Generally soluble in water; generally insoluble in kerosene and petrol	Many are insoluble in water and dissolve in kerosene/petrol; exceptions such as sugar can dissolve in water
Electrical conductivity - solid	Do not conduct because ions are fixed	Generally do not conduct
Electrical conductivity - aqueous	Conduct when dissolved in water because ions can move	Generally do not conduct because they do not provide mobile ions
Melting and boiling points	Generally high due to strong inter-ionic attraction	Usually lower than ionic compounds

- The activity compares camphor, sodium chloride, copper sulfate, sugar and naphthalene.
- Sodium chloride and copper sulfate illustrate ionic compounds; camphor, sugar and naphthalene illustrate covalent compounds.
- Ionic compounds can conduct in the molten state because ions become free to move.

13. Molecular Mass of Covalent Compounds

Definition
Molecular mass is the total mass of a molecule obtained by adding the atomic masses of all atoms present in it.

- Water, H_2O: $(1 \times 2) + (16 \times 1) = 18$ u.
- Carbon dioxide, CO_2: $(12 \times 1) + (16 \times 2) = 44$ u.
- For any covalent molecule, multiply each element's atomic mass by the number of its atoms and add the results.

14. Formula Unit Mass of Ionic Compounds

Formula unit
In an ionic compound, the simplest whole-number ratio of ions is called a formula unit. Ionic compounds do not exist as separate molecules in their crystal.

Formula unit mass
The sum of the atomic masses of all atoms present in one formula unit is called the formula unit mass.

- Sodium oxide, Na_2O: $(23 \times 2) + 16 = 62$ u.
- Calcium nitrate, $Ca(NO_3)_2$: $40 + 2(14 + 3 \times 16) = 164$ u.

15. Important Distinctions

Pair	Key difference
Physical vs chemical change	Physical change does not create a new substance; a chemical change forms new substance(s). Mass remains conserved in both.
Atom vs molecule	An atom is a basic particle of an element; a molecule contains more than one atom and can exist independently.
Cation vs anion	Cation is positively charged after loss of electron(s); anion is negatively charged after gain of electron(s).
Covalent vs ionic bond	Covalent bond involves sharing of electrons; ionic bond results from electron transfer and attraction between opposite ions.
Molecular mass vs formula unit mass	Molecular mass is used for molecules of covalent compounds; formula unit mass is used for ionic compounds.

16. Important Formulae and Rules

Concept	Rule
Conservation of mass	Total mass of reactants = Total mass of products
Constant proportions	Elements in a compound occur in a fixed ratio by mass
Covalent formula	Use constituent symbols and valencies; cross over valencies as subscripts
Ionic formula	Choose the simplest ratio of ions that makes total positive and negative charge equal
Molecular mass	Sum of atomic masses of all atoms in one molecule
Formula unit mass	Sum of atomic masses of all atoms in one formula unit

17. Quick Solved Examples

Example 1 - Conservation of mass
If 20 g hydrogen reacts completely with 160 g oxygen, the mass of water formed is 20 + 160 = 180 g, provided these are the reacting amounts stated.

Example 2 - Constant proportions
CO contains carbon and oxygen in the mass ratio 3:4. If carbon = 9 g, oxygen required = (4/3) × 9 = 12 g.

Example 3 - Molecular mass
HNO_3 = 1 + 14 + (3 × 16) = 63 u.

Example 4 - Formula unit mass
KCl = 39 + 35.5 = 74.5 u.

Example 5 - Formula from ions
Mg^{2+} needs two Cl^- ions for electrical neutrality, so magnesium chloride is $MgCl_2$.

18. Key Terms

Term	Meaning
Law of Conservation of Mass	Mass is neither created nor destroyed in a chemical reaction.
Law of Constant Proportions	A compound contains its elements in a fixed mass ratio.
Postulate	A fundamental assumption accepted as a basis for developing further ideas.
Molecule	Electrically neutral entity of more than one atom capable of independent existence.
Chemical bond	Force holding atoms together.
Covalent bond	Bond formed by sharing electron pair(s).
Ion	Electrically charged species.
Cation	Positively charged ion.
Anion	Negatively charged ion.
Ionic bond	Electrostatic attraction between oppositely charged ions.
Polyatomic ion	Ion made of atoms of two or more elements.
Molecular mass	Sum of atomic masses in a molecule.
Formula unit	Simplest whole-number ratio of ions in an ionic compound.
Formula unit mass	Sum of atomic masses in a formula unit.

19. Exam-Oriented Self-Check Questions

1. State and explain the Law of Conservation of Mass with an experimental example.
2. Why can an open chemical reaction appear to show a loss of mass when a gas is produced?
3. State the Law of Constant Proportions. Explain it using water.
4. Why does the Law of Constant Proportions apply to compounds but not mixtures?
5. Write the main postulates of Dalton's Atomic Theory.
6. Define molecule and chemical bond.
7. Explain the formation of H_2, Cl_2 and O_2 by sharing of electrons.
8. What is a covalent bond? Distinguish between single and double covalent bonds.
9. Explain the formation of HCl and H_2O.
10. State the rules used to name covalent compounds.
11. Explain the formation of Na^+ and Cl^- ions and hence the ionic bond in NaCl.
12. Define cation, anion and polyatomic ion.
13. Write the formulae of magnesium chloride, aluminium hydroxide and aluminium sulfate.
14. Compare the solubility and electrical conductivity of ionic and covalent compounds.
15. Why does solid sodium chloride not conduct electricity, while its aqueous solution does?
16. Why does sugar solution generally not conduct electricity even though sugar dissolves in water?
17. Define molecular mass and calculate the molecular mass of CO_2.
18. Define formula unit mass and calculate the formula unit mass of Na_2O.
19. Differentiate between molecular mass and formula unit mass.
20. Explain why ionic compounds generally have high melting and boiling points.

One-Minute Chapter Summary

Quick revision

Mass is conserved during physical and chemical changes; in a chemical reaction, the total mass of reactants equals that of products. Compounds contain elements in fixed mass ratios. Dalton used such observations to develop atomic theory. Atoms combine to become more stable and are held by chemical bonds. Sharing of electrons produces covalent bonds, while transfer of electrons produces cations and anions that are held by ionic bonds. Chemical formulae show the constituent elements and their ratios. Ionic and covalent compounds differ in solubility, conductivity and melting/boiling behaviour. Molecular mass is used for covalent molecules, whereas formula unit mass is used for ionic compounds.

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