10th Class Chemistry Notes Punjab Board (PCTB) Full Book Notes

Complete chapter-wise notes with original practice questions

Based on the Punjab Curriculum and Textbook Board (PCTB) Chemistry book for Class 10
Punjab Boards of Intermediate and Secondary Education

13 chapters (book chapters 14–26) • Key concepts, definitions, equations and key terms
130 original MCQs • 65 short questions • 26 long questions
with an MCQ answer key at the end

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About These Notes

These notes follow the chapters of the Punjab Curriculum and Textbook Board (PCTB) Chemistry book prescribed for Class 10 by the Punjab Boards of Intermediate and Secondary Education. Each chapter contains concise study notes with key concepts, definitions, equations and key terms, followed by original practice questions: 10 multiple-choice questions, 5 short questions with answers and 2 long questions with answers. An MCQ answer key is given at the end of the book.

All questions in this book are original practice questions written for study and revision. They are not taken from any past paper and they are not a guess paper. Students should also study their textbook, work through its exercises and practise past papers issued by their board.

Paper Pattern (as commonly reported for Punjab boards)

The following pattern is reproduced from third-party sources (study-note and pairing-scheme websites) and is **not officially confirmed** from a PCTB, PECTAA or BISE document. Boards may change the pattern, so students should confirm it with their school or board before the examination.

Section	Marks
Multiple-choice questions (MCQs)	12
Short questions	30
Long questions	18
Theory paper total	**60**
Practical examination	15
Total (theory + practical)	**75**

Note on sources: the theory split (12 + 30 + 18 = 60) and the 15-mark practical (total 75) are the figures most sources agree on. One source lists the practical as 30 marks, which does not fit the 60-mark theory total, and another lists short 34 / long 16, which adds to 62 rather than 60; both are treated here as errors. Chapter-wise pairing schemes circulating online use the old 8-chapter numbering and do not match the current 13-chapter book, so no chapter-wise pairing is given in this book.

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Chapter 14 — States of Matter and Phase Changes

Matter exists in three common states: solid, liquid and gas. In a solid the particles are closely packed in a fixed arrangement and only vibrate about their mean positions, so a solid has a fixed shape and a fixed volume. In a liquid the particles are close together but can slide past one another, so a liquid has a fixed volume but takes the shape of its container. In a gas the particles are far apart and move freely in all directions, so a gas has neither a fixed shape nor a fixed volume.

Kinetic molecular theory. All matter is made of tiny particles that are always in motion. The energy of this motion is called kinetic energy, and it increases with temperature. The spaces between particles and the forces of attraction between them decide the state of a substance: strong forces and small spaces give a solid, weaker forces give a liquid, and almost no attraction gives a gas.

- **Diffusion:** the spreading of particles from a region of higher concentration to a region of lower concentration. Gases diffuse fastest, liquids more slowly, and solids hardly at all. Diffusion is faster at higher temperature because the particles move faster.
- **Evaporation:** the change of a liquid into vapour from its surface at any temperature. It cools the surface because the fastest-moving particles escape, taking energy with them.
- **Boiling:** rapid evaporation throughout the liquid at a fixed temperature, the boiling point, when the vapour pressure equals the outside pressure. Water boils at 100°C at sea level.
- **Melting and freezing:** a solid melts at its melting point and the liquid freezes at the same temperature. Ice melts at 0°C.
- **Sublimation:** the direct change of a solid into a gas without passing through the liquid state, shown by solid carbon dioxide (dry ice), iodine and camphor.
- **Vapour pressure:** the pressure exerted by the vapour of a liquid in a closed container. Liquids with weak attractions between particles evaporate easily and have a high vapour pressure.

Other states. At very high temperatures matter forms plasma, a state of charged particles found in the Sun, lightning and fluorescent tubes. At temperatures near absolute zero, a Bose–Einstein condensate can form. **Phase changes and energy:** melting, evaporation and sublimation absorb heat energy, while freezing, condensation and deposition release it. This is why sweating cools the body and why steam causes worse burns than boiling water.

> **Key terms:** kinetic energy — energy of moving particles; diffusion — spreading of particles from high to low concentration; vapour pressure — pressure of a vapour in equilibrium with its liquid; sublimation — solid changing directly to gas; boiling point — temperature at which vapour pressure equals atmospheric pressure.

Chapter 14 — States of Matter and Phase Changes: Practice Questions

Multiple-Choice Questions

1. Which state of matter has a fixed shape and a fixed volume?
(A) Liquid (B) Solid (C) Gas (D) Plasma

2. Particles of a gas move freely because:
(A) forces of attraction are almost absent (B) forces of attraction are very strong (C) particles are closely packed (D) temperature is very low

3. The spreading of particles from high to low concentration is called:
(A) evaporation (B) condensation (C) sublimation (D) diffusion

4. Evaporation takes place:
(A) only at the boiling point (B) only from the surface at any temperature (C) only in a closed container (D) only at 0°C

5. Water boils at sea level at:
(A) 90°C (B) 95°C (C) 100°C (D) 110°C

6. Which substance sublimes on heating?
(A) Sodium chloride (B) Camphor (C) Copper (D) Iron

7. Vapour pressure of a liquid increases when:
(A) temperature decreases (B) pressure increases (C) temperature increases (D) volume decreases

8. Ice melts at:
(A) 0°C (B) 10°C (C) 25°C (D) 100°C

9. Which state of matter is found in the Sun?
(A) Plasma (B) Solid (C) Liquid (D) Gas

10. Condensation is the change of:
(A) liquid to gas (B) gas to liquid (C) solid to gas (D) solid to liquid

Short Questions (with answers)

Q1. Define diffusion and give one daily-life example.
Answer: Diffusion is the spreading of particles from a region of higher concentration to a region of lower concentration. Example: the smell of perfume spreading through a room.

Q2. Why does a gas fill the whole container?
Answer: Gas particles are far apart, move freely in all directions and have almost no forces of attraction between them, so they spread out to fill all the available space.

Q3. Why does evaporation cause cooling?
Answer: The fastest-moving particles escape from the liquid surface, taking heat energy with them, so the average energy and temperature of the remaining liquid fall.

Q4. What is sublimation? Name two substances that sublime.
Answer: Sublimation is the direct change of a solid into a gas without becoming a liquid. Examples: solid carbon dioxide (dry ice) and camphor.

Q5. Distinguish between boiling and evaporation.
Answer: Evaporation occurs from the surface at any temperature and is slow; boiling occurs throughout the liquid at a fixed temperature (the boiling point) and is rapid.

Long Questions (with answers)

Q1. Explain the kinetic molecular theory and use it to describe the three states of matter.

Answer: The kinetic molecular theory states that all matter is made of tiny particles that are always moving, and that their kinetic energy rises with temperature. In a solid, strong forces of attraction hold particles in fixed positions and they only vibrate, giving a fixed shape and volume. In a liquid, the forces are weaker, so particles can slide past one another: the volume is fixed but the shape is not. In a gas, the forces are almost absent and particles move freely at high speed, so the gas has neither a fixed shape nor a fixed volume. The theory also explains diffusion, evaporation and the effect of heating on a substance.

Q2. Describe the phase changes of matter and explain which changes absorb heat and which release it.

Answer: The main phase changes are melting (solid to liquid), freezing (liquid to solid), evaporation and boiling (liquid to gas), condensation (gas to liquid), sublimation (solid to gas) and deposition (gas to solid). Melting, evaporation, boiling and sublimation absorb heat energy from the surroundings, because energy is needed to overcome the forces holding the particles together. Freezing, condensation and deposition release heat energy, because the particles lose energy as the forces of attraction pull them closer. This is why evaporation cools the skin and why steam, which releases extra heat on condensing, causes severe burns.

Chapter 15 — Stoichiometry

Stoichiometry is the study of the amounts of substances involved in a chemical reaction. It uses the balanced chemical equation to find how much reactant is needed and how much product is formed. A balanced equation shows the reacting ratio of moles, and one mole of any substance contains Avogadro's number of particles, 6.022×10^{23}.

The mole and molar mass. The molar mass of a substance is the mass of one mole of it, expressed in grams per mole (g/mol), and it is numerically equal to its relative atomic or molecular mass. For example, water H_2O has a molar mass of 18 g/mol, so 18 g of water is one mole. The number of moles is found by: moles = mass ÷ molar mass. The number of particles is: particles = moles × 6.022×10^{23}.

- **Empirical formula:** the simplest whole-number ratio of the atoms of each element in a compound, for example CH_2O for glucose.
- **Molecular formula:** the actual number of atoms of each element in one molecule, for example $C_6H_{12}O_6$ for glucose. Molecular formula = (empirical formula) × n, where n is a whole number.
- **Percentage composition:** the mass of each element in a compound expressed as a percentage of the total mass.
- **Limiting reagent:** the reactant that is used up first in a reaction and limits the amount of product formed. The other reactant is in excess.
- **Percentage yield:** (actual yield ÷ theoretical yield) × 100. The actual yield is usually less than the theoretical yield because of incomplete reactions and losses during separation.
- **Molar volume:** one mole of any gas occupies about 22.4 dm^3 at standard temperature and pressure (STP).

Working from an equation. To solve a stoichiometric problem: (1) write and balance the equation; (2) convert the given mass or volume into moles; (3) use the mole ratio from the equation to find the moles of the required substance; (4) convert moles back into mass or volume. Example: in $2H_2 + O_2 \rightarrow 2H_2O$, 2 moles of hydrogen react with 1 mole of oxygen to give 2 moles of water.

> **Key terms:** mole — the amount containing 6.022×10^{23} particles; Avogadro's number — 6.022×10^{23} per mole; limiting reagent — the reactant used up first; theoretical yield — the maximum product predicted by the equation; molar mass — mass of one mole in g/mol.

Chapter 15 — Stoichiometry: Practice Questions

Multiple-Choice Questions

1. One mole of any substance contains:

(A) 6.022×10^{23} particles (B) 6.022×10^{22} particles (C) 12 particles (D) 100 particles

2. The molar mass of water (H_2O) is:

(A) 10 g/mol (B) 16 g/mol (C) 18 g/mol (D) 20 g/mol

3. The empirical formula of glucose $C_6H_{12}O_6$ is:

(A) $C_6H_{12}O_6$ (B) CH_2O (C) $C_2H_4O_2$ (D) CHO

4. The reactant used up first in a reaction is called the:

(A) limiting reagent (B) excess reagent (C) catalyst (D) product

5. One mole of a gas at STP occupies about:

(A) 11.2 dm^3 (B) 22.4 dm^3 (C) 24 dm^3 (D) 44.8 dm^3

6. Percentage yield is calculated as:

(A) (theoretical ÷ actual) × 100 (B) (actual ÷ theoretical) × 100 (C) actual + theoretical (D) actual − theoretical

7. How many moles are in 36 g of water?

(A) 1 mol (B) 2 mol (C) 3 mol (D) 4 mol

8. The mole ratio in a balanced equation shows the ratio of:

(A) moles (B) masses (C) volumes only (D) temperatures

9. The molar mass of carbon dioxide (CO_2) is:

(A) 28 g/mol (B) 32 g/mol (C) 44 g/mol (D) 48 g/mol

10. Actual yield is usually less than theoretical yield because of:

(A) too much reactant (B) high temperature only (C) catalyst use (D) incomplete reaction and losses

Short Questions (with answers)

Q1. Define a mole and state Avogadro's number.

Answer: A mole is the amount of a substance that contains 6.022×10^{23} particles (atoms, molecules or ions). Avogadro's number is 6.022×10^{23} per mole.

Q2. What is molar mass? Give the molar mass of CO2.
Answer: Molar mass is the mass of one mole of a substance in grams per mole. The molar mass of carbon dioxide is 12 + (2 × 16) = 44 g/mol.

Q3. Distinguish between empirical and molecular formula.
Answer: The empirical formula is the simplest whole-number ratio of atoms in a compound, while the molecular formula gives the actual number of atoms of each element in one molecule.

Q4. What is a limiting reagent?
Answer: The limiting reagent is the reactant that is completely used up first in a chemical reaction; it decides the maximum amount of product that can form.

Q5. Why is the actual yield less than the theoretical yield?
Answer: Because reactions may not go to completion, side reactions may occur, and some product is lost during separation and purification.

Long Questions (with answers)

Q1. Explain how to use a balanced chemical equation to calculate the mass of a product formed, with a worked example.

Answer: First balance the equation, then convert the given mass of a reactant into moles using moles = mass ÷ molar mass. Next, use the mole ratio from the balanced equation to find the moles of the product. Finally, convert those moles into mass using mass = moles × molar mass. Example: $2H_2 + O_2 \rightarrow 2H_2O$. Four grams of hydrogen is 2 moles (4 ÷ 2). The equation shows 2 moles of hydrogen give 2 moles of water, so 2 moles of water form, with a mass of 2 × 18 = 36 g. The same steps work for volumes of gases using the molar volume of 22.4 dm^3 per mole at STP.

Q2. Define empirical and molecular formulae and explain how the molecular formula is found from the empirical formula.

Answer: The empirical formula is the simplest whole-number ratio of the atoms of each element in a compound, found from the percentage composition by converting each percentage to moles and dividing by the smallest value. The molecular formula is the actual number of atoms in one molecule. It is found by dividing the relative molecular mass of the compound by the mass of the empirical formula unit to get a whole number n, then multiplying the empirical formula by n. For example, glucose has the empirical formula CH_2O (mass 30) and a molecular mass of 180, so n = 180 ÷ 30 = 6, giving the molecular formula $C_6H_{12}O_6$.

Chapter 16 — Electrochemistry

Electrochemistry is the study of the relationship between chemical reactions and electricity. **Oxidation** is the loss of electrons, and **reduction** is the gain of electrons; the two always occur together in a redox reaction. The substance that loses electrons is the reducing agent, and the substance that gains electrons is the oxidising agent. Oxidation numbers help to track the transfer of electrons: oxidation is an increase in oxidation number and reduction is a decrease.

Electrochemical cells. A **galvanic (voltaic) cell** converts chemical energy into electrical energy by a spontaneous redox reaction, as in a simple Daniell cell where zinc gives electrons to copper ions. An **electrolytic cell** uses electrical energy from an outside source to drive a non-spontaneous reaction, as in the electrolysis of water or molten sodium chloride. In both kinds of cell, oxidation takes place at the anode and reduction at the cathode.

- **Electrolysis:** the decomposition of a compound by passing an electric current through its molten form or its solution. Ions move to the oppositely charged electrodes: cations to the cathode and anions to the anode.
- **Electrolysis of water:** water containing a little acid or alkali splits into hydrogen at the cathode and oxygen at the anode, in the volume ratio 2:1.
- **Standard electrode potential:** the voltage of a half-cell measured against the standard hydrogen electrode under standard conditions. A more positive value means a stronger tendency to gain electrons (to be reduced).
- **Electrochemical series:** metals arranged in order of their standard electrode potentials. Metals higher in the series lose electrons more easily and are more reactive; they can displace metals below them from their salts.
- **Electroplating:** coating one metal with a thin layer of another metal by electrolysis, to protect it from corrosion or to improve its appearance, for example chromium-plating steel or silver-plating cutlery.
- **Corrosion:** the slow destruction of a metal by air and water, especially the rusting of iron. Rusting needs both oxygen and water. It is prevented by painting, oiling, galvanising (coating with zinc) and cathodic protection.

Batteries. A dry cell (Leclanché cell) gives 1.5 V and is used in torches and remote controls. A lead-acid battery, used in cars, is rechargeable: it can be restored by passing a current through it in the opposite direction. Fuel cells convert the chemical energy of hydrogen and oxygen directly into electricity, producing only water.

> **Key terms:** oxidation — loss of electrons; reduction — gain of electrons; anode — electrode where oxidation occurs; cathode — electrode where reduction occurs; electrolysis — decomposition of a compound by an electric current; galvanising — coating iron with zinc to prevent rusting.

Chapter 16 — Electrochemistry: Practice Questions

Multiple-Choice Questions

1. Oxidation is defined as:

(A) gain of electrons (B) gain of protons (C) loss of electrons (D) loss of neutrons

2. In an electrochemical cell, reduction takes place at the:

(A) cathode (B) anode (C) salt bridge (D) battery

3. A galvanic cell converts:

(A) chemical energy into electrical energy (B) electrical energy into chemical energy (C) heat into light (D) light into electricity

4. During electrolysis of water, hydrogen is collected at the:

(A) anode (B) cathode (C) both electrodes (D) neither electrode

5. The volume ratio of hydrogen to oxygen from electrolysis of water is:

(A) 1:1 (B) 1:2 (C) 2:1 (D) 3:1

6. Which metal is used to galvanise iron?

(A) Copper (B) Aluminium (C) Tin (D) Zinc

7. Rusting of iron requires:

(A) oxygen only (B) water only (C) both oxygen and water (D) carbon dioxide only

8. In the electrochemical series, the most reactive metals are at the:

(A) top (B) bottom (C) middle (D) end

9. Electroplating is done to:

(A) remove metal (B) melt a metal (C) dissolve a metal (D) coat a metal with another metal

10. A dry cell produces a voltage of:

(A) 1.0 V (B) 1.5 V (C) 2.0 V (D) 12 V

Short Questions (with answers)

Q1. Define oxidation and reduction in terms of electrons.

Answer: Oxidation is the loss of electrons by an atom or ion, and reduction is the gain of electrons. They always occur together in a redox reaction.

Q2. What is an electrolytic cell?

Answer: An electrolytic cell is a cell in which electrical energy from an outside source is used to bring about a non-spontaneous chemical reaction, such as the electrolysis of water.

Q3. Why is zinc used to galvanise iron?

Answer: Zinc is more reactive than iron, so it corrodes in place of the iron. The zinc coating also keeps air and water away from the iron surface.

Q4. State the conditions needed for iron to rust.

Answer: Rusting needs both oxygen (from the air) and water. Iron does not rust in dry air or in water that contains no dissolved oxygen.

Q5. What is electroplating? Give one example.

Answer: Electroplating is coating one metal with a thin layer of another metal by electrolysis. Example: coating steel objects with chromium to protect them and give a shiny finish.

Long Questions (with answers)

Q1. Describe the construction and working of a simple galvanic cell and explain how it produces electricity.

Answer: A simple galvanic cell, such as the Daniell cell, has two half-cells: a zinc rod dipped in zinc

sulphate solution and a copper rod dipped in copper sulphate solution, connected by a salt bridge and an external wire. Zinc is more reactive, so it loses electrons (oxidation) at the anode: $Zn \rightarrow Zn^{2+} + 2e^{-}$. The electrons flow through the external wire to the copper electrode, where copper ions gain them (reduction) at the cathode: $Cu^{2+} + 2e^{-} \rightarrow Cu$. This flow of electrons through the wire is the electric current, and the salt bridge completes the circuit by allowing ions to move between the solutions. The chemical energy of the spontaneous redox reaction is thus converted into electrical energy.

Q2. What is electrolysis? Explain the electrolysis of water and state two uses of electrolysis.

Answer: Electrolysis is the decomposition of a compound by passing an electric current through it in its molten state or in solution. In the electrolysis of water, a little sulphuric acid is added to make the water conduct electricity. At the cathode, hydrogen ions gain electrons and hydrogen gas is released; at the anode, hydroxide ions lose electrons and oxygen gas is released. Hydrogen and oxygen are collected in the volume ratio 2:1, matching the formula H_2O. Uses of electrolysis include electroplating metals to protect them or improve their appearance, the extraction of reactive metals such as aluminium from their ores, and the purification of metals such as copper.

Chapter 17 — Reaction Kinetics

Reaction kinetics is the study of the rates of chemical reactions and the factors that affect them. The **rate of a reaction** is the change in the concentration of a reactant or a product per unit time. It is usually measured by following how quickly a reactant is used up or a product is formed, for example by measuring the volume of gas given off or the change in mass.

Collision theory. For a reaction to happen, the reacting particles must collide with enough energy and in the correct orientation. The minimum energy needed for a successful collision is called the **activation energy**. Most collisions do not lead to a reaction because the particles do not have enough energy or they hit each other in the wrong way. Raising the temperature increases the rate because more particles have energy equal to or greater than the activation energy.

- **Concentration:** increasing the concentration of a reactant increases the number of particles in a given volume, so collisions happen more often and the rate increases.
- **Temperature:** increasing the temperature makes particles move faster, so collisions are more frequent and more energetic; the rate usually roughly doubles for a 10°C rise.
- **Surface area:** a solid in smaller pieces (powder) has a larger surface area exposed to the other reactant, so the reaction is faster than with a large lump.
- **Catalyst:** a substance that speeds up a reaction without being used up itself. A catalyst provides an alternative pathway with a lower activation energy. Enzymes are biological catalysts.
- **Pressure:** for reactions involving gases, increasing the pressure crowds the particles together, increasing the collision frequency and the rate.
- **Light:** some reactions, such as the reaction of hydrogen with chlorine, are faster in bright light.

Rate and equilibrium. A fast reaction is not the same as a complete reaction: many reactions reach a state of dynamic equilibrium where the forward and reverse reactions continue at equal rates. A catalyst speeds up both the forward and the reverse reaction equally, so it helps equilibrium to be reached sooner but does not change the position of equilibrium.

> **Key terms:** rate of reaction — change in concentration per unit time; activation energy — minimum energy needed for a successful collision; catalyst — a substance that speeds up a reaction without being used up; collision theory — reacting particles must collide with enough energy and correct orientation.

Chapter 17 — Reaction Kinetics: Practice Questions

Multiple-Choice Questions

1. The rate of a reaction is measured as:

(A) change in temperature per second (B) change in mass per mole (C) change in volume per gram (D) change in concentration per unit time

2. According to collision theory, reacting particles must collide with:

(A) any energy (B) no energy (C) very low speed (D) enough energy and correct orientation

3. Activation energy is the:

(A) minimum energy needed for a successful collision (B) energy released by a reaction (C) total energy of the reactants (D) energy of the products

4. Increasing the concentration of a reactant:

(A) decreases the rate (B) increases the rate (C) does not change the rate (D) stops the reaction

5. A catalyst works by:

(A) increasing the temperature (B) providing a pathway with lower activation energy (C) being used up in the reaction (D) decreasing the concentration

6. Powdered solid reacts faster than a lump because it has a:

(A) smaller mass (B) larger surface area (C) lower temperature (D) smaller volume

7. Raising the temperature increases the rate because:

(A) particles stop moving (B) the activation energy increases (C) more particles have energy above the activation energy (D) collisions stop

8. A catalyst is:

(A) not used up in the reaction (B) used up in the reaction (C) a product of the reaction (D) always a gas

9. Increasing the pressure of reacting gases:

(A) slows the reaction (B) has no effect (C) increases the collision frequency and the rate (D) removes the catalyst

10. Enzymes are:

(A) biological catalysts (B) inorganic catalysts (C) acids (D) salts

Short Questions (with answers)

Q1. Define the rate of a chemical reaction.

Answer: The rate of a reaction is the change in the concentration of a reactant or a product per unit time, for example moles per cubic decimetre per second.

Q2. What is activation energy?

Answer: Activation energy is the minimum energy that colliding particles must have for the collision to result in a chemical reaction.

Q3. How does a catalyst speed up a reaction?

Answer: A catalyst provides an alternative reaction pathway with a lower activation energy, so more collisions are successful, and it is not used up in the reaction.

Q4. Why does a powdered solid react faster than a large lump?

Answer: The powder has a much larger surface area exposed to the other reactant, so more collisions can take place at the same time.

Q5. Why does increasing temperature increase the reaction rate?

Answer: Particles move faster and collide more often, and a larger fraction of them have kinetic energy equal to or greater than the activation energy.

Long Questions (with answers)

Q1. State and explain the collision theory of reaction rates.

Answer: Collision theory states that for a chemical reaction to occur, the reacting particles must collide with each other with at least a certain minimum energy, called the activation energy, and in the correct orientation. Most collisions are unsuccessful because the particles do not have enough energy or they meet in the wrong orientation, so no bonds break and no new bonds form. Raising the temperature gives more particles enough energy to overcome the activation energy, and increasing the concentration or pressure increases how often collisions occur, so in both cases the rate of successful collisions and therefore the reaction rate increases. A catalyst increases the rate by providing a different pathway with a lower activation energy.

Q2. Describe four factors that affect the rate of a chemical reaction and explain each one.

Answer: (1) Concentration: a higher concentration means more particles in the same volume, so collisions are more frequent and the rate rises. (2) Temperature: higher temperature makes particles move faster, so collisions are more frequent and more energetic, and a larger fraction of particles exceed the activation energy. (3) Surface area: breaking a solid into smaller pieces increases the area exposed to the other reactant, so more collisions occur at once and the reaction is faster. (4) Catalyst: a catalyst lowers the activation energy by providing an alternative pathway, so more collisions succeed without the catalyst being used up. Pressure also matters for gases, since higher pressure crowds the particles together and increases the collision frequency.

Chapter 18 — Salts

A **salt** is a compound formed when the hydrogen ions of an acid are replaced, wholly or partly, by a metal ion or an ammonium ion. Common examples are sodium chloride (NaCl), copper sulphate ($CuSO_4$) and sodium carbonate (Na_2CO_3). Salts are usually crystalline solids with high melting points, and they conduct electricity when molten or dissolved in water because their ions are then free to move.

Types of salts. A **normal salt** is formed when all the replaceable hydrogen of an acid is replaced, for example NaCl from hydrochloric acid. An **acidic salt** still contains replaceable hydrogen, for example sodium hydrogensulphate ($NaHSO_4$). A **basic salt** contains hydroxide or oxide along with the salt, for example basic copper carbonate. A **double salt** contains two different cations, for example potash alum, and a **complex salt** contains a complex ion. Salts may also be hydrated, containing water of crystallisation, for example $CuSO_4.5H_2O$ (blue vitriol).

- **Preparation by neutralisation:** acid + base → salt + water, for example $HCl + NaOH \rightarrow NaCl + H_2O$.
- **Acid + metal:** acid + reactive metal → salt + hydrogen, for example $2HCl + Zn \rightarrow ZnCl_2 + H_2$.
- **Acid + carbonate:** acid + metal carbonate → salt + water + carbon dioxide, for example $2HCl + CaCO_3 \rightarrow CaCl_2 + H_2O + CO_2$.
- **Acid + metal oxide:** acid + metal oxide → salt + water.
- **Precipitation:** mixing two solutions to form an insoluble salt, for example $AgNO_3 + NaCl \rightarrow AgCl + NaNO_3$. The precipitate is filtered, washed and dried.
- **Solubility:** most sodium, potassium and ammonium salts are soluble; most carbonates are insoluble except those of sodium, potassium and ammonium; most sulphates are soluble except those of barium, lead and calcium.

Salt hydrolysis and pH. When a salt dissolves in water it may react with the water (hydrolysis). A salt of a strong acid and a strong base gives a neutral solution (pH 7), for example NaCl. A salt of a strong acid and a weak base gives an acidic solution, for example ammonium chloride. A salt of a weak acid and a strong base gives an alkaline solution, for example sodium carbonate. **Uses:** sodium chloride is used in food and in making chlorine and caustic soda; sodium carbonate (washing soda) is used in making glass and soap; calcium sulphate (plaster of Paris) is used for casts and moulds; copper sulphate is used as a fungicide.

> **Key terms:** salt — a compound formed when the hydrogen of an acid is replaced by a metal or ammonium ion; water of crystallisation — water molecules built into a salt crystal; hydrolysis — reaction of a salt with water; precipitation — formation of an insoluble solid from solution; neutralisation — acid reacting with a base to give salt and water.

Chapter 18 — Salts: Practice Questions

Multiple-Choice Questions

1. A salt is formed when the hydrogen of an acid is replaced by:
(A) a metal or ammonium ion (B) an acid (C) water (D) oxygen

2. Which of these is a normal salt?
(A) NaCl (B) $NaHSO_4$ (C) Basic copper carbonate (D) Potash alum

3. $CuSO_4.5H_2O$ is an example of a:
(A) anhydrous salt (B) acidic salt (C) hydrated salt (D) basic salt

4. Acid + base gives:
(A) salt + hydrogen (B) salt + carbon dioxide (C) salt + oxygen (D) salt + water

5. The reaction of hydrochloric acid with zinc gives:
(A) zinc oxide + water (B) zinc chloride + hydrogen (C) zinc carbonate (D) zinc hydroxide

6. Which salt solution is neutral?
(A) Sodium chloride (B) Ammonium chloride (C) Sodium carbonate (D) Sodium ethanoate

7. An insoluble salt is best prepared by:
(A) neutralisation (B) precipitation (C) evaporation only (D) filtration of an acid

8. Washing soda is:
(A) sodium chloride (B) sodium hydroxide (C) calcium carbonate (D) sodium carbonate

9. Plaster of Paris is made from:
(A) calcium carbonate (B) calcium sulphate (C) calcium chloride (D) calcium oxide

10. Which carbonate is soluble in water?
(A) Calcium carbonate (B) Barium carbonate (C) Sodium carbonate (D) Lead carbonate

Short Questions (with answers)

Q1. Define a salt and give two examples.
Answer: A salt is a compound formed when the hydrogen ions of an acid are replaced, wholly or partly, by a metal ion or an ammonium ion. Examples: sodium chloride (NaCl) and copper sulphate (CuSO4).

Q2. What is water of crystallisation? Give an example.
Answer: Water of crystallisation is the fixed number of water molecules built into the crystal of a hydrated salt. Example: CuSO4.5H2O contains five molecules of water per formula unit.

Q3. How is an insoluble salt prepared?
Answer: An insoluble salt is prepared by precipitation: two soluble solutions are mixed, the insoluble salt forms as a solid, and it is then filtered, washed and dried.

Q4. Why does a solution of sodium chloride remain neutral?
Answer: Sodium chloride is the salt of a strong acid (hydrochloric acid) and a strong base (sodium hydroxide), so it does not hydrolyse and its solution has pH 7.

Q5. Give two uses of sodium carbonate.
Answer: Sodium carbonate (washing soda) is used in making glass and soap, and as a water softener and cleaning agent.

Long Questions (with answers)

Q1. Describe the main types of salts with one example of each.
Answer: A normal salt is formed when all the replaceable hydrogen of an acid is replaced, for example sodium chloride (NaCl). An acidic salt still contains replaceable hydrogen, for example

sodium hydrogensulphate (NaHSO4). A basic salt contains hydroxide or oxide as well as the salt part, for example basic copper carbonate. A double salt contains two different cations in the same crystal, for example potash alum. A complex salt contains a complex ion, and a hydrated salt contains water of crystallisation, for example blue vitriol CuSO4.5H2O. Each type is named and identified by its composition, and the type decides properties such as the pH of its solution.

Q2. Explain four methods of preparing salts, giving a word or balanced equation for each.

Answer: (1) Neutralisation: an acid reacts with a base to give a salt and water, for example HCl + NaOH → NaCl + H2O. (2) Acid with a metal: a reactive metal displaces hydrogen, for example 2HCl + Zn → ZnCl2 + H2. (3) Acid with a carbonate: the products are a salt, water and carbon dioxide, for example 2HCl + CaCO3 → CaCl2 + H2O + CO2. (4) Precipitation: two soluble salts are mixed and an insoluble salt forms, for example AgNO3 + NaCl → AgCl + NaNO3; the precipitate is filtered, washed and dried. Soluble salts are usually obtained by crystallisation from the solution, while insoluble salts must be made by precipitation.

Chapter 19 — Nitrogen and Sulphur

Nitrogen makes up about 78% of the air by volume. It is a colourless, odourless gas that is very unreactive because its molecules contain a strong triple bond (N≡N). Its low reactivity makes it useful for providing an inert atmosphere, for example in food packaging and in electric bulbs. Nitrogen is essential for life: it is a part of proteins and nucleic acids, and plants obtain it from the soil as nitrates.

The nitrogen cycle. Nitrogen circulates between the air, the soil and living things. Nitrogen-fixing bacteria in the soil and in the root nodules of leguminous plants convert nitrogen gas into nitrates. Lightning also fixes some nitrogen. Plants absorb nitrates and build proteins; animals eat the plants; when plants and animals die, decomposers return nitrogen compounds to the soil, and denitrifying bacteria release nitrogen gas back into the air.

- **Ammonia (NH_3):** a colourless gas with a sharp smell, made by the Haber process: $N_2 + 3H_2 \rightleftharpoons 2NH_3$. The conditions are an iron catalyst, a temperature of about 450°C and a pressure of about 200 atm. Ammonia is used to make fertilisers, nitric acid and cleaning products.
- **Nitric acid (HNO_3):** made by the Ostwald process, in which ammonia is oxidised to nitrogen dioxide and the dioxide is dissolved in water. Nitric acid is a strong acid and a strong oxidising agent, used for fertilisers and explosives.
- **Oxides of nitrogen:** nitrogen monoxide (NO) and nitrogen dioxide (NO_2) are produced in car engines and power stations; they contribute to acid rain and to photochemical smog.
- **Sulphur:** a yellow, brittle solid found free in nature and in ores such as zinc blende and galena. It burns in air with a blue flame to give sulphur dioxide.
- **Sulphur dioxide (SO_2):** a colourless gas with a choking smell, produced by burning sulphur and fossil fuels. It dissolves in rain to form acid rain, which damages buildings, crops and lakes.
- **Sulphuric acid (H_2SO_4):** the most widely used industrial chemical, made by the Contact process: sulphur is burned to sulphur dioxide, the dioxide is oxidised to sulphur trioxide with a vanadium(V) oxide catalyst, and the trioxide is dissolved in concentrated acid to give oleum, which is diluted to sulphuric acid. It is used in fertilisers, detergents, batteries and the manufacture of many other chemicals.

Fertilisers. Nitrogen, phosphorus and potassium are the three main plant nutrients. Fertilisers such as urea and ammonium nitrate supply nitrogen, but overuse can wash nitrates into rivers and lakes, causing algal blooms that harm aquatic life.

> **Key terms:** Haber process — manufacture of ammonia from nitrogen and hydrogen; Ostwald process — manufacture of nitric acid from ammonia; Contact process — manufacture of sulphuric acid; nitrogen fixation — conversion of nitrogen gas into compounds plants can use; acid rain — rain made acidic by dissolved oxides of nitrogen and sulphur.

Chapter 19 — Nitrogen and Sulphur: Practice Questions

Multiple-Choice Questions

1. Nitrogen makes up about what percentage of air?
(A) 21% (B) 50% (C) 78% (D) 90%

2. Nitrogen gas is unreactive because its molecule has a:
(A) single bond (B) triple bond (C) double bond (D) ionic bond

3. Ammonia is manufactured by the:
(A) Contact process (B) Ostwald process (C) Haber process (D) electrolysis

4. The catalyst used in the Haber process is:
(A) vanadium(V) oxide (B) platinum (C) iron (D) nickel

5. Nitric acid is manufactured by the:
(A) Haber process (B) Contact process (C) Frasch process (D) Ostwald process

6. Sulphuric acid is manufactured by the:
(A) Haber process (B) Ostwald process (C) Solvay process (D) Contact process

7. The catalyst in the Contact process is:
(A) vanadium(V) oxide (B) iron (C) platinum (D) copper

8. Which gas is a major cause of acid rain?
(A) Oxygen (B) Sulphur dioxide (C) Nitrogen (D) Hydrogen

9. Nitrogen-fixing bacteria are found in the root nodules of:
(A) leguminous plants (B) wheat plants (C) rice plants (D) cotton plants

10. Sulphur burns in air with a:
(A) blue flame (B) yellow flame (C) red flame (D) colourless flame

Short Questions (with answers)

Q1. Why is nitrogen gas so unreactive?
Answer: Its molecules are held together by a very strong triple bond, which needs a large amount of energy to break, so nitrogen reacts only under extreme conditions.

Q2. Name the raw materials used in the Haber process.
Answer: Nitrogen (from the air) and hydrogen (usually from natural gas or water).

Q3. What is nitrogen fixation?
Answer: Nitrogen fixation is the conversion of nitrogen gas from the air into nitrogen compounds, such as nitrates, that plants can absorb and use.

Q4. How does sulphur dioxide cause acid rain?
Answer: Sulphur dioxide dissolves in rainwater and is oxidised to sulphuric acid, making the rain acidic enough to damage buildings, crops and lakes.

Q5. Give two uses of ammonia.
Answer: Ammonia is used to make nitrogenous fertilisers such as urea, and to make nitric acid and cleaning products.

Long Questions (with answers)

Q1. Describe the manufacture of ammonia by the Haber process, including the equation, conditions and uses.
Answer: Ammonia is made by the Haber process from nitrogen and hydrogen: $N_2 + 3H_2 \rightleftharpoons 2NH_3$. The nitrogen comes from the air and the hydrogen from natural gas. The reaction is carried out at a temperature of about 450°C and a pressure of about 200 atmospheres, using an iron catalyst. The

temperature is a compromise: a lower temperature would favour a higher yield (the forward reaction gives out heat) but would make the reaction too slow, while a higher pressure favours the yield but is expensive. The ammonia is removed by cooling, and the unreacted gases are recycled. Ammonia is used mainly to make fertilisers such as urea and ammonium nitrate, and also to make nitric acid and cleaning products.

Q2. Describe the manufacture of sulphuric acid by the Contact process and state its main uses.

Answer: Sulphuric acid is made by the Contact process in three stages. First, sulphur is burned in air to give sulphur dioxide: $S + O_2 \rightarrow SO_2$. Second, sulphur dioxide is oxidised to sulphur trioxide using oxygen and a vanadium(V) oxide catalyst at about 450°C: $2SO_2 + O_2 \rightleftharpoons 2SO_3$. Third, sulphur trioxide is not dissolved directly in water (the reaction is too violent); it is dissolved in concentrated sulphuric acid to form oleum ($H_2S_2O_7$), which is then carefully diluted with water to give sulphuric acid. Sulphuric acid is used to make fertilisers, detergents and paints, in car batteries, and in the manufacture of many other chemicals, which is why it is called the king of chemicals.

Chapter 20 — Water

Water is the most important compound for life. It covers about 71% of the Earth's surface, yet only a small fraction is fresh water suitable for drinking. A water molecule (H_2O) consists of two hydrogen atoms covalently bonded to one oxygen atom, with a bent shape. The bonds between water molecules are hydrogen bonds, which give water its unusual properties.

Properties of water. Pure water is a colourless, odourless liquid with a boiling point of 100°C and a melting point of 0°C. It is a very good solvent, which is why it is called the universal solvent: it dissolves many ionic compounds and polar substances. Water has a high specific heat capacity, so it warms up and cools down slowly, which helps to keep the climate mild near seas and lakes. Ice is less dense than liquid water, so it floats; this protects aquatic life in winter because the ice layer insulates the water below.

- **Hard water:** water that contains dissolved calcium and magnesium salts. It does not form a lather easily with soap and it leaves scale (fur) in kettles and boilers.
- **Temporary hardness:** caused by dissolved calcium and magnesium hydrogencarbonates. It is removed by boiling, which decomposes the hydrogencarbonates into insoluble carbonates.
- **Permanent hardness:** caused by dissolved calcium and magnesium sulphates or chlorides. It is not removed by boiling; it is removed by adding washing soda (sodium carbonate) or by ion-exchange resins.
- **Water purification:** dirty water is purified by filtration (to remove suspended solids), chlorination (to kill germs) and, in some plants, by aeration and sedimentation. Boiling also kills germs.
- **Water pollution:** sewage, industrial waste, fertilisers and pesticides pollute rivers and lakes. Polluted water spreads diseases such as cholera and typhoid, and excess fertiliser causes algal blooms that remove oxygen from the water.
- **Uses:** drinking, cooking, washing, agriculture (irrigation), industry (cooling and as a solvent), and producing hydroelectric power.

Saving water. Fresh water is a limited resource. It should be used carefully: fixing leaking taps, using drip irrigation, recycling waste water where possible, and keeping rivers and lakes free of waste. In Pakistan, water shortage is a serious issue, so conservation and proper storage matter for farms and cities alike.

> **Key terms:** hard water — water containing dissolved calcium and magnesium salts; temporary hardness — hardness removed by boiling; permanent hardness — hardness not removed by boiling; chlorination — adding chlorine to water to kill germs; universal solvent — a liquid that dissolves many substances.

Chapter 20 — Water: Practice Questions

Multiple-Choice Questions

1. Water covers about what fraction of the Earth's surface?
(A) 50% (B) 61% (C) 71% (D) 81%

2. The boiling point of pure water at sea level is:
(A) 90°C (B) 95°C (C) 100°C (D) 110°C

3. Water is called the universal solvent because it:
(A) dissolves many ionic and polar substances (B) dissolves everything (C) is found everywhere (D) has no taste

4. Ice floats on water because it is:
(A) heavier than water (B) hotter than water (C) saltier than water (D) less dense than water

5. Temporary hardness of water is caused by:
(A) calcium hydrogencarbonate (B) calcium sulphate (C) magnesium chloride (D) sodium chloride

6. Temporary hardness is removed by:
(A) filtration (B) boiling (C) adding salt (D) cooling

7. Permanent hardness is caused by dissolved:
(A) hydrogencarbonates (B) sodium salts (C) sulphates or chlorides of calcium and magnesium (D) potassium salts

8. Chlorination of water is done to:
(A) remove colour (B) kill germs (C) remove hardness (D) add taste

9. Which of these causes water pollution?
(A) Sewage and industrial waste (B) Rain (C) Sunlight (D) Wind

10. Hard water does not easily form a lather with:
(A) detergent (B) oil (C) soap (D) salt

Short Questions (with answers)

Q1. Why is water called the universal solvent?
Answer: Because it dissolves a very large number of ionic compounds and polar substances, more than any other common liquid.

Q2. What is hard water?
Answer: Hard water is water that contains dissolved calcium and magnesium salts; it does not form a lather easily with soap and leaves scale in kettles.

Q3. How is temporary hardness removed?
Answer: By boiling, which decomposes the dissolved calcium and magnesium hydrogencarbonates into insoluble carbonates that settle out.

Q4. Why does ice float on water?
Answer: Ice is less dense than liquid water because its open crystal structure takes up more space, so it floats and insulates the water below.

Q5. Name two methods of purifying drinking water.
Answer: Filtration to remove suspended solids, and chlorination (or boiling) to kill germs.

Long Questions (with answers)

Q1. Explain the difference between temporary and permanent hardness of water, and describe how each is removed.
Answer: Hardness is caused by dissolved calcium and magnesium salts. Temporary hardness is

caused by dissolved calcium and magnesium hydrogencarbonates. It is called temporary because boiling removes it: the hydrogencarbonates decompose on heating into insoluble carbonates, which form a solid deposit and can be filtered off. Permanent hardness is caused by dissolved calcium and magnesium sulphates or chlorides, which do not decompose on boiling, so boiling has no effect. It is removed by adding washing soda (sodium carbonate), which reacts with the calcium and magnesium ions to form insoluble carbonates, or by passing the water through an ion-exchange resin that swaps calcium and magnesium ions for sodium ions. Soft water forms a lather easily with soap and does not leave scale in kettles and boilers.

Q2. Describe the properties of water that make it essential for life, and explain how water is purified for drinking.

Answer: Water is essential for life because it is an excellent solvent, carrying dissolved nutrients and waste in the bodies of living things; it has a high specific heat capacity, so it keeps body temperature and climate steady; and ice floats, so lakes do not freeze solid and aquatic life survives winter. Water for drinking is purified in stages: sedimentation and filtration remove suspended solids and dirt; chlorination kills disease-causing germs; and aeration improves taste. In homes, boiling also kills germs. Clean water prevents diseases such as cholera and typhoid, so protecting rivers and lakes from sewage and industrial waste is essential.

Chapter 21 — Organic Chemistry

Organic chemistry is the study of the compounds of carbon, especially compounds of carbon with hydrogen. Carbon is special because it can form strong covalent bonds with itself, a property called **catenation**, so it can build long chains, branched chains and rings. Millions of organic compounds exist, and they include fuels, plastics, medicines, food and the molecules of life.

Why carbon is different. A carbon atom has four electrons in its outer shell, so it forms four covalent bonds (tetravalency). Carbon bonds to hydrogen, oxygen, nitrogen, halogens and other carbon atoms. The strength of the carbon–carbon bond and the ability to form single, double and triple bonds give organic chemistry its huge variety.

- **Hydrocarbons:** organic compounds containing only carbon and hydrogen, for example methane (CH_4) and ethane (C_2H_6).
- **Homologous series:** a family of compounds with the same functional group and a general formula, whose members differ from the next by a $–CH_2–$ group. Members show a steady change in physical properties such as boiling point.
- **Functional group:** the atom or group of atoms that gives a family of compounds its characteristic chemical properties, for example –OH in alcohols and –COOH in carboxylic acids.
- **Alkanes:** saturated hydrocarbons with single bonds only, general formula C_nH_{2n+2}.
- **Alkenes:** unsaturated hydrocarbons with one double bond, general formula C_nH_{2n}.
- **Alkynes:** unsaturated hydrocarbons with one triple bond, general formula C_nH_{2n-2}.
- **Isomerism:** compounds with the same molecular formula but different structures and different properties, for example butane and methylpropane (both C_4H_{10}).
- **Sources:** the main sources of organic compounds are petroleum (crude oil), natural gas and coal. Crude oil is separated into fractions by fractional distillation.

Organic vs inorganic. Organic compounds are usually covalent, have low melting and boiling points, are often insoluble in water but soluble in organic solvents, and burn to give carbon dioxide and water. Inorganic compounds are often ionic, with high melting points, and many dissolve in water. **Uses:** organic compounds are used as fuels, solvents, plastics, medicines, dyes, soaps and fertilisers.

> **Key terms:** catenation — the ability of carbon atoms to bond to each other in chains and rings; homologous series — a family of compounds with the same functional group; functional group — the group that decides a compound's chemical behaviour; isomerism — same molecular formula, different structure; tetravalency — carbon forming four covalent bonds.

Chapter 21 — Organic Chemistry: Practice Questions

Multiple-Choice Questions

1. Organic chemistry is the study of compounds of:

(A) oxygen (B) nitrogen (C) iron (D) carbon

2. The ability of carbon to form chains with itself is called:

(A) catenation (B) isomerism (C) polymerisation (D) ionisation

3. How many covalent bonds does a carbon atom form?

(A) Four (B) Two (C) Three (D) Five

4. A homologous series is a family of compounds with the same:

(A) molecular mass (B) functional group (C) number of atoms (D) boiling point

5. The general formula of alkanes is:

(A) C_nH_{2n} (B) C_nH_{2n+2} (C) C_nH_{2n-2} (D) C_nH_{2n+1}

6. Alkenes contain:

(A) only single bonds (B) one double bond (C) one triple bond (D) ionic bonds

7. Compounds with the same molecular formula but different structures are called:

(A) isotopes (B) isomers (C) polymers (D) monomers

8. The functional group –OH belongs to:

(A) alcohols (B) carboxylic acids (C) alkanes (D) alkenes

9. The main source of organic compounds is:

(A) sea water (B) sand (C) petroleum (D) limestone

10. Butane and methylpropane are examples of:

(A) isotopes (B) polymers (C) isomers (D) alloys

Short Questions (with answers)

Q1. Define organic chemistry.

Answer: Organic chemistry is the study of the compounds of carbon, especially compounds of carbon with hydrogen and their derivatives.

Q2. What is catenation?

Answer: Catenation is the ability of carbon atoms to form strong covalent bonds with each other, building long chains, branched chains and rings.

Q3. What is a functional group? Give one example.

Answer: A functional group is the atom or group of atoms in a molecule that gives the compound its characteristic chemical properties. Example: –OH in alcohols.

Q4. What is a homologous series?

Answer: A homologous series is a family of organic compounds with the same functional group and general formula, whose members differ from the next by a –CH2– group.

Q5. Give two differences between organic and inorganic compounds.

Answer: Organic compounds are usually covalent with low melting points and burn easily; inorganic compounds are often ionic with high melting points and many dissolve in water.

Long Questions (with answers)

Q1. Explain why carbon forms such a large number of compounds.

Answer: Carbon forms millions of compounds for three main reasons. First, it is tetravalent, forming four strong covalent bonds. Second, it shows catenation: carbon atoms bond strongly to each other, forming long straight chains, branched chains and rings of almost any length. Third, carbon forms

single, double and triple bonds, and it bonds with many other elements such as hydrogen, oxygen, nitrogen and halogens, giving many different functional groups. Each functional group gives a new family of compounds with its own properties, and isomerism multiplies the number further, since the same atoms can be arranged in different structures. This variety makes carbon the basis of fuels, plastics, medicines and the molecules of life.

Q2. Define a homologous series and a functional group, and illustrate them with the alkane family.

Answer: A functional group is the atom or group of atoms that decides the characteristic chemical properties of a family of compounds, for example –OH in alcohols and –COOH in carboxylic acids. A homologous series is a family of compounds that share the same functional group and the same general formula, with each member differing from the next by a –CH2– group. The alkanes are a homologous series with the general formula CnH2n+2 and only single bonds: methane (CH4), ethane (C2H6), propane (C3H8) and butane (C4H10). They show similar chemical properties, such as burning in air, while their physical properties, like boiling point, increase gradually with molecular size. Alkenes (CnH2n) and alkynes (CnH2n−2) are other homologous series.

Chapter 22 — Hydrocarbons

Hydrocarbons are organic compounds containing only carbon and hydrogen. They are the main components of petroleum and natural gas. There are three main families: alkanes (saturated, single bonds), alkenes (unsaturated, one double bond) and alkynes (unsaturated, one triple bond). Saturated compounds contain only single bonds; unsaturated compounds contain at least one double or triple bond.

Alkanes. General formula C_nH_{2n+2}. The first members are methane (CH_4), ethane (C_2H_6), propane (C_3H_8) and butane (C_4H_{10}). Alkanes are unreactive because their single bonds are strong; their main reactions are combustion and substitution. Methane burns in air: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$. In sunlight, methane reacts with chlorine by substitution, replacing hydrogen atoms one at a time. Alkanes are used as fuels (natural gas, petrol, LPG) and as raw materials for other chemicals.

- **Alkenes:** general formula C_nH_{2n}. Ethene (C_2H_4) is the simplest alkene. Alkenes are reactive because of their double bond and undergo addition reactions: hydrogenation (adding hydrogen to give an alkane), addition of halogens (bromine water is decolourised, a test for unsaturation) and addition of water (to give an alcohol).
- **Alkynes:** general formula C_nH_{2n-2}. Ethyne (acetylene, C_2H_2) is the simplest alkyne. It burns with a very hot flame and is used in oxy-acetylene welding.
- **Test for unsaturation:** bromine water (brown) is decolourised by alkenes and alkynes but not by alkanes; alkaline potassium permanganate (purple) is also decolourised by unsaturated hydrocarbons.
- **Cracking:** the breaking of large alkane molecules into smaller alkenes and alkanes by heat and a catalyst. It is used to make petrol and ethene from larger fractions of crude oil.
- **Fractional distillation of crude oil:** crude oil is heated and its vapours rise up a fractionating column, condensing at different levels. The fractions, in order of increasing boiling point, are refinery gas, petrol, kerosene, diesel, fuel oil and bitumen.
- **Uses:** methane is a fuel and the raw material for hydrogen; ethene is used to make polythene and ethanol; ethyne is used for welding; LPG (propane and butane) is used as a cooking fuel.

Fuels and the environment. Burning hydrocarbons gives energy but also produces carbon dioxide, which contributes to global warming. Incomplete combustion produces carbon monoxide, a poisonous gas, and soot. Cleaner fuels and complete combustion reduce these harmful effects.

> **Key terms:** saturated hydrocarbon — contains only single bonds; unsaturated hydrocarbon — contains a double or triple bond; addition reaction — atoms add across a double bond; substitution reaction — one atom replaces another; cracking — breaking large molecules into smaller ones; fractional distillation — separating liquids by their boiling points.

Chapter 22 — Hydrocarbons: Practice Questions

Multiple-Choice Questions

1. Hydrocarbons contain only:

(A) carbon and oxygen (B) carbon and hydrogen (C) hydrogen and oxygen (D) carbon and nitrogen

2. The general formula of alkenes is:

(A) C_nH_{2n+2} (B) C_nH_{2n} (C) C_nH_{2n-2} (D) C_nH_n

3. Methane burns in air to give:

(A) carbon monoxide only (B) carbon dioxide and water (C) carbon and hydrogen (D) oxygen and water

4. Bromine water is decolourised by:

(A) alkanes only (B) water (C) carbon dioxide (D) alkenes and alkynes

5. The simplest alkene is:

(A) methane (B) ethene (C) ethyne (D) propane

6. Ethyne (acetylene) is used for:

(A) oxy-acetylene welding (B) cooking only (C) making soap (D) making glass

7. Cracking is the process of:

(A) breaking large molecules into smaller ones (B) joining small molecules (C) dissolving oil in water (D) burning oil completely

8. LPG mainly consists of:

(A) propane and butane (B) methane and ethane (C) hydrogen and oxygen (D) ethene and ethyne

9. Incomplete combustion of hydrocarbons produces:

(A) oxygen (B) nitrogen (C) water only (D) carbon monoxide and soot

10. Which fraction of crude oil has the lowest boiling point?

(A) Diesel (B) Kerosene (C) Petrol (D) Bitumen

Short Questions (with answers)

Q1. Define a hydrocarbon and name its three main families.

Answer: A hydrocarbon is an organic compound containing only carbon and hydrogen. The three main families are alkanes (single bonds), alkenes (one double bond) and alkynes (one triple bond).

Q2. How can alkenes be distinguished from alkanes?

Answer: Alkenes decolourise bromine water (brown to colourless) and alkaline potassium permanganate, while alkanes do not, because alkenes are unsaturated and undergo addition reactions.

Q3. What is cracking? Why is it useful?

Answer: Cracking is the breaking of large alkane molecules into smaller alkenes and alkanes using heat and a catalyst. It is useful for making petrol and ethene from heavier oil fractions.

Q4. Write the equation for the complete combustion of methane.

Answer: $CH4 + 2O2 \rightarrow CO2 + 2H2O$.

Q5. Why is carbon monoxide dangerous?

Answer: Carbon monoxide is a poisonous gas formed by incomplete combustion; it binds to haemoglobin in the blood more strongly than oxygen, preventing oxygen from reaching the body.

Long Questions (with answers)

Q1. Compare alkanes, alkenes and alkynes in terms of bonding, general formula and chemical reactivity.

Answer: Alkanes are saturated hydrocarbons with only single bonds and the general formula

CnH2n+2, for example methane and ethane. Their bonds are strong, so they are relatively unreactive; their main reactions are combustion and substitution with halogens in sunlight. Alkenes are unsaturated, containing one carbon–carbon double bond, with the general formula CnH2n, for example ethene. The double bond makes them reactive, and they undergo addition reactions such as hydrogenation, addition of bromine and addition of water. Alkynes are unsaturated with one triple bond and the general formula CnH2n−2, for example ethyne (acetylene). They are also reactive and undergo addition reactions; ethyne burns with a very hot flame and is used in welding. Alkenes and alkynes decolourise bromine water, but alkanes do not.

Q2. Describe how crude oil is separated by fractional distillation and name the main fractions and their uses.

Answer: Crude oil is a mixture of hydrocarbons, so it is separated by fractional distillation. The oil is heated until it vaporises, and the vapours rise up a tall fractionating column, which is hot at the bottom and cooler at the top. Each fraction condenses at the level where the temperature matches its boiling point. The fractions, in order of increasing boiling point, are: refinery gas (fuel and chemicals), petrol (fuel for cars), kerosene (aircraft fuel and heating), diesel (fuel for trucks and trains), fuel oil (fuel for ships and power stations) and bitumen (road surfacing). Larger molecules left over are cracked into smaller, more useful molecules such as petrol and ethene.

Chapter 23 — Monohydroxy Alkanes or Alcohols

Alcohols are organic compounds containing the hydroxyl functional group (–OH) attached to a carbon atom. The simplest alcohols are methanol (CH_3OH) and ethanol (C_2H_5OH). Alcohols form a homologous series with the general formula $C_nH_{2n+1}OH$. **Monohydroxy alkanes** are alcohols with only one –OH group per molecule.

Preparation. Ethanol is made in two main ways: (1) **fermentation** of sugars by yeast, for example glucose → ethanol + carbon dioxide ($C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$); (2) **hydration of ethene**, in which steam is added to ethene with a phosphoric acid catalyst at high temperature and pressure. Methanol is made from carbon monoxide and hydrogen (synthesis gas). Fermentation gives dilute ethanol, which is concentrated by distillation.

- **Physical properties:** methanol and ethanol are colourless liquids with a characteristic smell. They are soluble in water because the –OH group forms hydrogen bonds with water. Their boiling points are higher than those of alkanes of similar size, again because of hydrogen bonding. Ethanol boils at 78°C.
- **Combustion:** alcohols burn in air with a clean blue flame to give carbon dioxide and water, for example $C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$. Ethanol is used as a fuel and fuel additive.
- **Reaction with sodium:** alcohols react with sodium to give a sodium alkoxide and hydrogen gas, for example $2C_2H_5OH + 2Na \rightarrow 2C_2H_5ONa + H_2$.
- **Oxidation:** ethanol is oxidised to ethanoic acid by acidified potassium dichromate (orange to green), or by air in the presence of certain bacteria, which is how vinegar is made.
- **Dehydration:** heating ethanol with concentrated sulphuric acid at about 170°C removes water and gives ethene.
- **Denatured alcohol:** ethanol mixed with methanol and other poisonous substances so that it cannot be drunk; it is used as a solvent and fuel.

Uses and dangers. Ethanol is used as a solvent, in medicines and perfumes, as a fuel, and in alcoholic drinks. Methanol is highly poisonous: drinking it can cause blindness and death, so it must never be used as a drink. Alcoholic drinks harm health, damage the liver and impair judgement; in Pakistan their sale and use are restricted by law.

> **Key terms:** hydroxyl group — the –OH functional group of alcohols; fermentation — breakdown of sugars by yeast to give ethanol and carbon dioxide; denatured alcohol — ethanol made undrinkable by adding poisonous substances; dehydration — removal of water from a compound.

Chapter 23 — Monohydroxy Alkanes or Alcohols: Practice Questions

Multiple-Choice Questions

1. The functional group of alcohols is:

(A) –COOH (B) –CHO (C) $–NH_2$ (D) –OH

2. The general formula of monohydroxy alkanes is:

(A) C_nH_{2n+2} (B) $C_nH_{2n+1}OH$ (C) C_nH_{2n} (D) C_nH_{2n-2}

3. Ethanol is made by fermentation of:

(A) starch only (B) sugars by yeast (C) petroleum directly (D) salt water

4. The boiling point of ethanol is about:

(A) 58°C (B) 68°C (C) 78°C (D) 98°C

5. Ethanol reacts with sodium to give:

(A) oxygen and water (B) carbon dioxide (C) ethene (D) hydrogen gas and sodium ethoxide

6. Oxidation of ethanol gives:

(A) methanol (B) ethene (C) ethanoic acid (D) carbon monoxide

7. Heating ethanol with concentrated sulphuric acid at 170°C gives:

(A) methanol (B) ethene (C) ethanoic acid (D) ethane

8. Denatured alcohol is ethanol mixed with:

(A) methanol and poisonous substances (B) water only (C) sugar (D) salt

9. Methanol is dangerous because it is:

(A) flammable only (B) highly poisonous and can cause blindness (C) radioactive (D) corrosive to glass

10. Ethanol burns in air with a:

(A) clean blue flame (B) smoky yellow flame (C) red flame (D) no flame

Short Questions (with answers)

Q1. What is a monohydroxy alkane? Give one example.
Answer: A monohydroxy alkane is an alcohol containing only one hydroxyl (–OH) group per molecule. Example: ethanol (C2H5OH).

Q2. Write the equation for the fermentation of glucose.
Answer: C6H12O6 → 2C2H5OH + 2CO2, carried out by yeast enzymes.

Q3. Why are alcohols soluble in water?
Answer: The –OH group forms hydrogen bonds with water molecules, so small alcohols dissolve readily in water.

Q4. What is denatured alcohol and why is it made?
Answer: Denatured alcohol is ethanol mixed with methanol and other poisonous substances so it cannot be drunk; it is used as a solvent and fuel.

Q5. How is ethene obtained from ethanol?
Answer: By dehydration: heating ethanol with concentrated sulphuric acid at about 170°C removes a molecule of water and gives ethene.

Long Questions (with answers)

Q1. Describe the preparation of ethanol by fermentation and by hydration of ethene, and compare the two methods.
Answer: Ethanol is prepared by fermentation: sugars such as glucose are broken down by enzymes in yeast, giving ethanol and carbon dioxide: C6H12O6 → 2C2H5OH + 2CO2. Fermentation is carried out at about 30°C, and the yeast is killed when the alcohol concentration reaches about 15%, so the

product is dilute and must be concentrated by distillation. Ethanol is also made by the hydration of ethene: steam is added across the double bond of ethene using a phosphoric acid catalyst at high temperature and pressure, giving pure ethanol directly. Fermentation uses renewable raw materials such as sugar cane and grains, while hydration uses ethene from petroleum, a non-renewable resource, but gives a purer product in one step.

Q2. Describe the chemical properties of ethanol: combustion, reaction with sodium, oxidation and dehydration.

Answer: Ethanol burns in air with a clean blue flame to give carbon dioxide and water: $C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$, so it is used as a fuel. With sodium it reacts steadily to give sodium ethoxide and hydrogen gas: $2C_2H_5OH + 2Na \rightarrow 2C_2H_5ONa + H_2$. Ethanol is oxidised to ethanoic acid by acidified potassium dichromate, which changes colour from orange to green; the same oxidation by bacteria in air produces vinegar. On heating with concentrated sulphuric acid at about 170°C, ethanol is dehydrated — a molecule of water is removed — to give ethene. These reactions all involve the hydroxyl group or the carbon chain, and they show that ethanol is a versatile starting material in the chemical industry.

Chapter 24 — Carboxylic Acids

Carboxylic acids are organic compounds containing the carboxyl functional group (–COOH). The simplest carboxylic acids are methanoic acid (formic acid, HCOOH) and ethanoic acid (acetic acid, CH_3COOH). They form a homologous series with the general formula $C_nH_{2n+1}COOH$. Ethanoic acid is the acid in vinegar, which is a dilute (about 5%) solution of ethanoic acid in water.

Preparation. Ethanoic acid is made by the oxidation of ethanol, using acidified potassium dichromate or oxygen in the presence of bacteria (the process that turns wine into vinegar). It is also made industrially by the carbonylation of methanol (reacting methanol with carbon monoxide). Carboxylic acids can also be made by oxidising primary alcohols and aldehydes.

- **Physical properties:** ethanoic acid is a colourless liquid with a sharp, vinegar-like smell. It is soluble in water because the –COOH group forms hydrogen bonds with water. Pure ethanoic acid freezes at 17°C into ice-like crystals, so it is called glacial acetic acid. Its boiling point (118°C) is higher than that of ethanol because of stronger hydrogen bonding.
- **Acidic properties:** carboxylic acids are weak acids: they partly ionise in water to give hydrogen ions, for example $CH_3COOH \rightleftharpoons CH_3COO^- + H^+$. They turn blue litmus red and react with metals, bases and carbonates like other acids, but more slowly than strong acids.
- **Reaction with metals:** $2CH_3COOH + Zn \rightarrow (CH_3COO)_2Zn + H_2$.
- **Reaction with carbonates:** $2CH_3COOH + Na_2CO_3 \rightarrow 2CH_3COONa + H_2O + CO_2$.
- **Esterification:** a carboxylic acid reacts with an alcohol, in the presence of concentrated sulphuric acid, to give an ester and water: $CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$. Esters have sweet, fruity smells and are used in perfumes and flavourings.
- **Uses:** ethanoic acid is used in vinegar, in making dyes, plastics and medicines, and as a solvent. Methanoic acid is used in leather tanning and in rubber processing.

Soaps. When a carboxylic acid such as stearic acid reacts with sodium hydroxide, it forms a salt called a soap (sodium stearate). Soaps clean because one end of the soap molecule dissolves in water and the other end dissolves in grease, so dirt and grease are lifted off surfaces and washed away.

> **Key terms:** carboxyl group — the –COOH functional group; esterification — reaction of a carboxylic acid with an alcohol to give an ester; ester — a sweet-smelling compound formed from an acid and an alcohol; glacial acetic acid — pure ethanoic acid; weak acid — an acid that partly ionises in water.

Chapter 24 — Carboxylic Acids: Practice Questions

Multiple-Choice Questions

1. The functional group of carboxylic acids is:
(A) –COOH (B) –OH (C) –CHO (D) –CO–

2. Ethanoic acid is commonly known as:
(A) formic acid (B) citric acid (C) oxalic acid (D) acetic acid

3. Vinegar is a dilute solution of:
(A) ethanoic acid (B) methanoic acid (C) sulphuric acid (D) hydrochloric acid

4. Carboxylic acids are:
(A) weak acids (B) strong acids (C) bases (D) neutral

5. Pure ethanoic acid is called glacial acetic acid because it:
(A) is very cold (B) freezes into ice-like crystals at 17°C (C) is made from ice (D) contains water

6. Ethanoic acid reacts with ethanol to give:
(A) a salt (B) an ester and water (C) a ketone (D) an alkane

7. The catalyst used in esterification is:
(A) dilute hydrochloric acid (B) concentrated sulphuric acid (C) sodium hydroxide (D) iron

8. Esters are known for their:
(A) bitter taste (B) sour taste (C) black colour (D) sweet fruity smell

9. Ethanoic acid reacts with sodium carbonate to give:
(A) hydrogen only (B) sodium chloride (C) sodium ethanoate, water and carbon dioxide (D) ethene

10. Soaps are salts of:
(A) mineral acids (B) alcohols (C) long-chain carboxylic acids (D) alkanes

Short Questions (with answers)

Q1. What is the carboxyl group? Give the formula of ethanoic acid.
Answer: The carboxyl group is –COOH, the functional group of carboxylic acids. Ethanoic acid is CH3COOH.

Q2. Why are carboxylic acids weak acids?
Answer: Because they only partly ionise in water, releasing a small proportion of their hydrogen ions.

Q3. What is esterification? Give one example.
Answer: Esterification is the reaction of a carboxylic acid with an alcohol, in the presence of concentrated sulphuric acid, to give an ester and water. Example: ethanoic acid + ethanol → ethyl ethanoate + water.

Q4. Why is pure ethanoic acid called glacial acetic acid?
Answer: Because it freezes at 17°C into colourless, ice-like crystals.

Q5. Give two uses of ethanoic acid.
Answer: It is used in vinegar (as a food preservative and flavouring) and in making dyes, plastics, medicines and solvents.

Long Questions (with answers)

Q1. Describe the properties and reactions of ethanoic acid as a typical carboxylic acid.
Answer: Ethanoic acid (CH3COOH) is a colourless liquid with a sharp vinegar smell, soluble in water because its –COOH group forms hydrogen bonds. It is a weak acid, partly ionising in water to give hydrogen ions, so it turns blue litmus red but reacts more slowly than strong acids. With reactive metals it gives a salt and hydrogen, for example with zinc it forms zinc ethanoate and hydrogen. With

bases it gives a salt and water, and with carbonates it gives a salt, water and carbon dioxide, for example with sodium carbonate it gives sodium ethanoate, water and carbon dioxide. With an alcohol in the presence of concentrated sulphuric acid it undergoes esterification to give a sweet-smelling ester and water. Pure ethanoic acid freezes at 17°C into ice-like crystals and is called glacial acetic acid.

Q2. What is esterification? Explain the reaction, its conditions and the uses of esters.

Answer: Esterification is the reaction between a carboxylic acid and an alcohol, in the presence of concentrated sulphuric acid as a catalyst, to form an ester and water. For example, ethanoic acid reacts with ethanol to give ethyl ethanoate and water: $CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$. The reaction is reversible, and the concentrated sulphuric acid acts as both a catalyst and a dehydrating agent that removes water and pushes the reaction forward. Esters have pleasant, sweet and fruity smells, so they are used in perfumes, cosmetics and food flavourings, and as solvents. The reverse reaction, hydrolysis of an ester with an alkali, is used to make soaps from fats and oils.

Chapter 25 — Biochemistry

Biochemistry is the study of the chemical processes and substances that occur in living organisms. The main classes of biochemicals are carbohydrates, proteins, lipids (fats and oils), nucleic acids, enzymes and vitamins. All of them are built from a small number of elements, mainly carbon, hydrogen, oxygen and nitrogen.

Carbohydrates. Carbohydrates are compounds of carbon, hydrogen and oxygen, with the general formula $C_x(H_2O)_y$. **Monosaccharides** are simple sugars such as glucose and fructose. **Disaccharides** are formed from two monosaccharides, for example sucrose (table sugar) and lactose (milk sugar). **Polysaccharides** are long chains of sugar units: starch is the storage carbohydrate in plants, glycogen is the storage carbohydrate in animals, and cellulose forms plant cell walls. Carbohydrates are the main source of energy in the diet; glucose is broken down in respiration to release energy.

- **Proteins:** large molecules made of amino acids joined by peptide bonds. There are 20 different amino acids, and the sequence decides the protein's shape and function. Proteins build and repair body tissues, make enzymes and hormones, and carry oxygen (haemoglobin). Heating or strong acid changes a protein's shape (denaturation), as when an egg white sets on cooking.
- **Lipids:** fats and oils, made of fatty acids and glycerol. They store energy, insulate the body and form cell membranes. Saturated fats (from animals) have only single bonds; unsaturated fats (from plants) contain double bonds. Excess fat in the diet is linked to heart disease.
- **Enzymes:** biological catalysts made of protein. Each enzyme works on one specific substance (its substrate) and works best at a particular temperature and pH. For example, amylase in saliva breaks down starch into sugars, and pepsin in the stomach digests proteins.
- **Vitamins:** organic compounds needed in small amounts for health. Vitamin C prevents scurvy, vitamin D is needed for strong bones, and vitamin A is needed for good eyesight. Lack of a vitamin causes a deficiency disease.
- **Nucleic acids:** DNA and RNA store and carry genetic information. DNA is made of two strands in a double helix, built from nucleotides containing a sugar, a phosphate and a nitrogenous base.
- **Minerals:** iron is needed to make haemoglobin, calcium for bones and teeth, and iodine for the thyroid gland.

Food tests. Starch is tested with iodine solution, which turns blue-black. Reducing sugars are tested with Benedict's solution, which changes from blue to brick red on heating. Proteins are tested with the Biuret test, which gives a purple colour. Fats are tested with the emulsion test: shaking with ethanol and water gives a milky white emulsion.

> **Key terms:** monosaccharide — a simple sugar such as glucose; polysaccharide — a long chain of sugar units; amino acid — the building block of proteins; enzyme — a biological catalyst made of protein; denaturation — loss of a protein's shape by heat or acid; substrate — the substance an enzyme acts on.

Chapter 25 — Biochemistry: Practice Questions

Multiple-Choice Questions

1. Biochemistry is the study of chemical processes in:
(A) rocks (B) living organisms (C) the atmosphere (D) metals

2. The general formula of carbohydrates is:
(A) $C_x(H_2O)_y$ (B) C_nH_{2n+2} (C) C_nH_{2n} (D) $C_xH_yO_zN$

3. Glucose is an example of a:
(A) disaccharide (B) monosaccharide (C) polysaccharide (D) protein

4. The storage carbohydrate in plants is:
(A) starch (B) glycogen (C) cellulose (D) sucrose

5. Proteins are made of:
(A) fatty acids (B) sugars (C) nucleotides (D) amino acids

6. Enzymes are made of:
(A) carbohydrate (B) fat (C) protein (D) mineral

7. Amylase in saliva breaks down:
(A) protein (B) starch (C) fat (D) vitamins

8. Lack of vitamin C causes:
(A) rickets (B) night blindness (C) anaemia (D) scurvy

9. DNA stores:
(A) genetic information (B) energy (C) oxygen (D) water

10. Starch is tested with:
(A) Benedict's solution (B) Biuret reagent (C) iodine solution (D) ethanol

Short Questions (with answers)

Q1. Define biochemistry.
Answer: Biochemistry is the study of the chemical substances and processes that occur in living organisms.

Q2. Give one example each of a monosaccharide, a disaccharide and a polysaccharide.
Answer: Monosaccharide: glucose. Disaccharide: sucrose (table sugar). Polysaccharide: starch.

Q3. What are enzymes? Give one example.
Answer: Enzymes are biological catalysts made of protein; each one speeds up a specific reaction in the body. Example: amylase breaks down starch into sugars.

Q4. Why is iron important in the diet?
Answer: Iron is needed to make haemoglobin in red blood cells, which carries oxygen around the body; lack of iron causes anaemia.

Q5. How is starch tested in the laboratory?
Answer: By adding iodine solution, which turns blue-black in the presence of starch.

Long Questions (with answers)

Q1. Describe the three main classes of food — carbohydrates, proteins and lipids — and state the function of each.
Answer: Carbohydrates are compounds of carbon, hydrogen and oxygen. Simple sugars such as glucose are monosaccharides; sucrose and lactose are disaccharides; starch, glycogen and cellulose are polysaccharides. Carbohydrates are the body's main source of energy, released when glucose is broken down in respiration. Proteins are large molecules made of amino acids joined by peptide

bonds. They build and repair tissues, form enzymes and hormones, and carry oxygen as haemoglobin. Lipids are fats and oils made of fatty acids and glycerol. They store energy, provide insulation, and form cell membranes. Saturated fats come mainly from animals and unsaturated fats from plants. A balanced diet must contain all three in the right proportions, along with vitamins, minerals, water and fibre.

Q2. What are enzymes? Explain how they work and the factors that affect their activity.

Answer: Enzymes are biological catalysts made of protein. Each enzyme has an active site with a shape that fits only its own substrate, so each enzyme works on one specific reaction — for example, amylase breaks down starch and pepsin digests proteins. Enzymes work by lowering the activation energy of a reaction, so reactions in the body happen fast enough at body temperature. Their activity is affected by temperature: it increases up to an optimum (about 37°C in the human body) and then falls sharply as the enzyme is denatured by heat. pH also matters: each enzyme has an optimum pH, and strong acids or alkalis denature it. Enzymes are not used up in the reaction, so a small amount can catalyse many reactions.

Chapter 26 — Polymers

A **polymer** is a large molecule made by joining many small repeating units, called **monomers**, in a long chain. The process of joining monomers is called **polymerisation**. Natural polymers include starch, cellulose, proteins and natural rubber. Synthetic polymers include polythene, PVC, nylon and polyester. Polymers are used for almost everything in modern life, from packaging and clothing to pipes and medicines.

Addition polymerisation. In addition polymerisation, many unsaturated monomer molecules join together by addition across their double bonds, with no other product formed. For example, ethene polymerises to polythene (polyethylene): $n(CH_2{=}CH_2) \rightarrow -(CH_2{-}CH_2)_n-$. Other addition polymers are polyvinyl chloride (PVC) from chloroethene, polystyrene from styrene, and polypropene from propene. Addition polymers are usually made from a single type of monomer.

- **Condensation polymerisation:** monomers join together with the loss of a small molecule, usually water. The monomers must have two functional groups each. Nylon is a condensation polymer made from a diamine and a dicarboxylic acid; polyester (terylene) is made from a diol and a dicarboxylic acid.
- **Nylon:** a strong, light, elastic fibre used for clothing, ropes, parachutes and fishing nets.
- **Polyester:** used for clothing, bottles and films; it resists creasing and is easy to wash and dry.
- **Polythene:** a light, flexible, waterproof plastic used for bags, bottles and packaging.
- **PVC:** a tough plastic used for pipes, window frames, cables and flooring.
- **Thermoplastics and thermosets:** thermoplastics (such as polythene and PVC) soften on heating and can be reshaped; thermosetting plastics (such as Bakelite) set hard on heating and cannot be reshaped.
- **Natural rubber:** a polymer of isoprene obtained from rubber trees. Vulcanisation, heating rubber with sulphur, makes it stronger and more elastic, and it is used for tyres.

Plastics and the environment. Most synthetic polymers do not break down (they are non-biodegradable), so plastic waste builds up in landfills and in rivers and seas, harming wildlife. The problem is reduced by the three Rs: reduce the use of plastic, reuse plastic items, and recycle plastic waste into new products. Biodegradable plastics, which break down naturally, are being developed as an alternative.

> **Key terms:** polymer — a large molecule made of many repeating units; monomer — the small molecule that joins to form a polymer; addition polymerisation — monomers joining across double bonds with no by-product; condensation polymerisation — monomers joining with loss of a small molecule such as water; thermoplastic — a plastic that softens on heating.

Chapter 26 — Polymers: Practice Questions

Multiple-Choice Questions

1. A polymer is made of many repeating units called:
(A) isotopes (B) isomers (C) monomers (D) alloys

2. Polythene is made from:
(A) ethane (B) ethene (C) ethyne (D) ethanol

3. Addition polymerisation involves:
(A) addition across double bonds (B) loss of water (C) loss of carbon dioxide (D) breaking of chains

4. Nylon is an example of a:
(A) addition polymer (B) condensation polymer (C) natural polymer (D) metal

5. PVC is made from:
(A) chloroethene (B) ethene (C) propene (D) styrene

6. Which plastic can be reshaped on heating?
(A) Bakelite (B) Thermosetting plastic (C) Rubber (D) Thermoplastic such as polythene

7. Vulcanisation of rubber uses:
(A) sulphur (B) oxygen (C) chlorine (D) nitrogen

8. Natural rubber is obtained from:
(A) petroleum (B) coal (C) rubber trees (D) sand

9. Polyester is used for:
(A) making glass (B) clothing and bottles (C) making steel (D) making cement

10. Plastic waste is a problem because most plastics are:
(A) biodegradable (B) soluble in water (C) magnetic (D) non-biodegradable

Short Questions (with answers)

Q1. Define a polymer and a monomer.
Answer: A polymer is a large molecule made by joining many small repeating units together. A monomer is the small molecule that joins with others to form the polymer.

Q2. Give two examples of natural polymers and two of synthetic polymers.
Answer: Natural: starch and cellulose (or protein, natural rubber). Synthetic: polythene and nylon (or PVC, polyester).

Q3. What is addition polymerisation?
Answer: Addition polymerisation is the joining of many unsaturated monomer molecules across their double bonds to form a polymer, with no other product formed.

Q4. What is condensation polymerisation?
Answer: Condensation polymerisation is the joining of monomers with two functional groups each, with the loss of a small molecule such as water at each join.

Q5. Why is plastic waste an environmental problem?
Answer: Most synthetic plastics are non-biodegradable, so they do not rot away; they pile up in landfills and pollute rivers and seas, harming wildlife.

Long Questions (with answers)

Q1. Explain addition polymerisation and condensation polymerisation, giving an example of each.
Answer: In addition polymerisation, many molecules of an unsaturated monomer join together by addition across their carbon–carbon double bonds, and no other substance is produced. The classic example is ethene polymerising to polythene: n(CH2=CH2) → –(CH2–CH2)n–. PVC from

chloroethene and polystyrene from styrene are other examples. In condensation polymerisation, monomers with two functional groups join together and a small molecule, usually water, is lost at each join. Nylon is made this way from a diamine and a dicarboxylic acid, and polyester is made from a diol and a dicarboxylic acid. Addition polymers are usually made from one kind of monomer, while condensation polymers are made from two kinds, and the two types have different properties and uses.

Q2. Describe the properties and uses of three synthetic polymers, and discuss the environmental problem of plastic waste.

Answer: Polythene is light, flexible and waterproof, and is used for bags, bottles and packaging. PVC is tough and weather-resistant, and is used for pipes, window frames and cable insulation. Nylon is strong, light and elastic, and is used for clothing, ropes and fishing nets. Polyester resists creasing and is used for clothing and drink bottles. The environmental problem is that most of these polymers are non-biodegradable: they do not rot, so discarded plastic accumulates in landfills, rivers and seas, where it harms birds and sea animals. The problem is reduced by reducing plastic use, reusing items, and recycling waste plastic into new products; biodegradable plastics are also being developed. Thermoplastics such as polythene can be melted and reshaped, which helps recycling, while thermosetting plastics such as Bakelite cannot.

MCQ Answer Key

Answers to all 130 multiple-choice questions, chapter by chapter.

Chapter 14 — States of Matter and Phase Changes

1. B **2.** A **3.** D **4.** B **5.** C **6.** B **7.** C **8.** A **9.** A **10.** B

Chapter 15 — Stoichiometry

1. A **2.** C **3.** B **4.** A **5.** B **6.** B **7.** B **8.** A **9.** C **10.** D

Chapter 16 — Electrochemistry

1. C **2.** A **3.** A **4.** B **5.** C **6.** D **7.** C **8.** A **9.** D **10.** B

Chapter 17 — Reaction Kinetics

1. D **2.** D **3.** A **4.** B **5.** B **6.** B **7.** C **8.** A **9.** C **10.** A

Chapter 18 — Salts

1. A **2.** A **3.** C **4.** D **5.** B **6.** A **7.** B **8.** D **9.** B **10.** C

Chapter 19 — Nitrogen and Sulphur

1. C **2.** B **3.** C **4.** C **5.** D **6.** D **7.** A **8.** B **9.** A **10.** A

Chapter 20 — Water

1. C **2.** C **3.** A **4.** D **5.** A **6.** B **7.** C **8.** B **9.** A **10.** C

Chapter 21 — Organic Chemistry

1. D **2.** A **3.** A **4.** B **5.** B **6.** B **7.** B **8.** A **9.** C **10.** C

Chapter 22 — Hydrocarbons

1. B **2.** B **3.** B **4.** D **5.** B **6.** A **7.** A **8.** A **9.** D **10.** C

Chapter 23 — Monohydroxy Alkanes or Alcohols

1. D **2.** B **3.** B **4.** C **5.** D **6.** C **7.** B **8.** A **9.** B **10.** A

Chapter 24 — Carboxylic Acids

1. A **2.** D **3.** A **4.** A **5.** B **6.** B **7.** B **8.** D **9.** C **10.** C

Chapter 25 — Biochemistry

1. B **2.** A **3.** B **4.** A **5.** D **6.** C **7.** B **8.** D **9.** A **10.** C

Chapter 26 — Polymers

1. C **2.** B **3.** A **4.** B **5.** A **6.** D **7.** A **8.** C **9.** B **10.** D

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