SSC-II Chemistry: Chapter Notes (FBISE, NBF 2025 book)

Built from the 13 book chapters (Units 1 to 13) and the FBISE 2025 and 2026 papers (2026 Sets B, D and M were read in full). Each chapter has: key definitions, equations and formulas, must-know points, and the past-paper questions with short model answers and worked numericals. Numericals use the atomic masses printed on the paper (H 1, C 12, N 14, O 16, Na 23, Mg 24, Al 27, S 32, Cl 35.5, K 39, Ca 40). Fe, Cu and Zn are not in that table, so the paper gives them in the question (Zn = Cu = 63.5).

Paper pattern

- Section A: 12 MCQs (20 minutes). Section B: 11 short parts of 3 marks each (33 marks), every part has an OR choice, marks split like 1+2, 2+1, 1.5+1.5 or 1x3. Section C: 4 long questions (20 marks), each with an OR, split like 2+2, 3+3, 1.5x4.
- Important: the 2026 papers (Sets B, D, M) follow the new NBF book (electrolysis, fuel cells, polymers, vitamins, amino acids, empirical formula). The 2025 paper still used the old syllabus (hardness of water, Solvay process, urea, Kc, Lewis acids, ozone). Those old topics are NOT in your NBF book, so they are left out here. Study the book chapters below.
- Every numerical on the 2026 papers is one of four types: empirical and molecular formula, molarity in mol/dm³ or g/dm³, limiting reactant with mass of product, or reacting mass of a gas.

Most repeated questions (appear in all of Sets B, D and M)

- Empirical formula from percentage composition, then molecular formula from molar mass (CH_2O with M = 60, 90 or 180 appears again and again).
- Molarity in mol/dm³ (or g/dm³) of a solution: 20 g NaOH, 10 g NaCl, 10 g Na_2CO_3, 9.8 g H_2SO_4 in 0.5 dm³, 0.25 mol KNO_3.
- Limiting reactant and mass of product (Zn with H_2SO_4, $CaCO_3$ with HCl, Na_2CO_3 with HCl).
- Classify SO_2, CO_2, CuO, CaO and Al_2O_3 as acidic, basic or amphoteric, with equations.
- Hydrogen-oxygen fuel cell: advantages over petrol engines, and the reactions at anode and cathode.
- Standard electrode potentials: which metal is more reactive (Zn or Al against Cu). Daniell cell diagram. Electroplating uses and chrome plating.
- Structural and displayed formula of propan-1-ol, butan-1-ol, butan-2-ol. Preparation of ethene (dehydration of an alcohol, dehydrohalogenation, or steam with ethene giving ethanol).
- Esterification (general word equation and an example). Complete combustion of methanol or ethanol.
- Fractional distillation: what it means, two fractions, uses, and how properties change bottom to top.
- Haber process (equation with conditions) and Contact process (catalyst, conditions).
- Vitamins A, C and D: two sources and one function (or deficiency disease). Amino acid general structure, dipeptide, protein.
- Polymers: monomer and polymer, addition against condensation, polyamide from a dicarboxylic acid and a diamine. Plastics: landfill and ocean problems.
- Why ionic compounds have high melting points. Metals with steam, oxygen, cold water and dilute acid. Role of kinetics in the food industry. Rate graph questions.

2026 Section A (MCQ) answers, Set B, for revision

- Reduction half-equation: $Ag^+ + e^- \rightarrow Ag$. Sublimation: solid to gas. Anode of an electrolytic cell: positively charged. Exothermic reaction rate increases with temperature. Soluble salt: sodium chloride. Soluble salt from acid and alkali: titration. Catalyst in Contact process: V_2O_5. Steeper slope: faster

reaction. Excess metal removed by filtration. 1 dm^3 = 1000 cm^3. C_2H_5OH + 2[O] with $KMnO_4/H_2SO_4$ gives CH_3COOH. Ethanol is blended with petrol.

Unit 1: History of Chemistry

Definitions

- Conservation of mass: in a chemical reaction the total mass of reactants equals the total mass of products (Lavoisier, 18th century).
- Scientific paradigm: a theoretical model, a set of ideas, methods and rules that guides research and explains nature. It is replaced when new evidence challenges it.
- Peer review: experts check experiments, data and conclusions before work is published, to make sure it is accurate and reliable.
- Repeatability: same result when the experiment is repeated under the same conditions, same tools, same place, same operator. Reproducibility: same or similar result under different conditions, equipment, methods or labs.
- Confidence interval: range showing how precise a measurement is (0.50 M with a 95% interval of 0.48 to 0.52 M means 95% sure the true value lies in that range). p-value: chance the result is random (0.01 means 1%). Standard deviation or standard error: spread of the data. Bayesian probability: updating confidence in an idea using new evidence. Uncertainty: how reliable a measurement is (0.250 ± 0.005 M).

Must-know points

- Phlogiston theory (1700s): burning materials release "phlogiston". Lavoisier proved combustion is a reaction with oxygen, which gave the modern ideas of oxidation and reduction.
- Atomic models: Thomson plum-pudding (1904), Rutherford nuclear model (1911, gold foil experiment, small dense positive nucleus), then Bohr (energy levels) and the quantum model.
- Mendeleev made the periodic table in 1869 by atomic mass and predicted undiscovered elements. The modern table uses atomic number and electron configuration, which explains periodicity.
- Methods of chemistry: conservation laws, observation and logic, controlled experiments (change one variable at a time), peer review, objectivity, skepticism.

Past-paper note

- No written question from this unit appeared in the 2026 papers. Expect it only as an MCQ. Likely short questions from the book exercise: state conservation of mass; define a paradigm with an example; differentiate repeatability and reproducibility; why skepticism matters.

Unit 2: Matter

Definitions

- Internal energy: kinetic energy (temperature) plus potential energy (particle positions and forces). During a change of state the temperature (kinetic energy) is constant and the potential energy changes.
- Evaporation: surface molecules gain enough kinetic energy to escape into the gas phase. It happens at any temperature below the boiling point, only at the surface, and cools the surroundings.
- Boiling: liquid turns to vapour throughout the liquid, with bubbles, at the fixed boiling point. Temperature stays constant while it boils.
- Sublimation: solid goes directly to gas without becoming liquid. Deposition: gas goes directly to solid.
- Diffusion: spreading and mixing of gas particles from high to low concentration by random motion.

- Boyle's law: at constant temperature, volume is inversely proportional to pressure (PV = constant, $P_1V_1 = P_2V_2$). Charles's law: at constant pressure, volume is directly proportional to absolute temperature (V/T = constant, T in kelvin). Avogadro's law: at constant T and P, volume is directly proportional to moles (V/n = constant). Graham's law: rate of diffusion is inversely proportional to the square root of molar mass.

Must-know points

- Melting, boiling and sublimation absorb energy (potential energy rises). Freezing, condensation and deposition release energy.
- Heating curve of a substance: A to B solid warming (kinetic energy rises), B to C melting (flat, latent heat of fusion), C to D liquid warming, D to E boiling (flat, latent heat of vaporization), E onward gas warming. A cooling curve is the same in reverse. The flat parts are where the energy changes potential energy only.
- Evaporation against boiling: evaporation is slow, at the surface, at any temperature below the boiling point. Boiling is fast and vigorous, throughout the liquid, at one fixed temperature, with bubbles.
- Pressure and boiling: higher external pressure raises the boiling point (pressure cooker cooks faster). Lower pressure (high altitude) lowers the boiling point, so water boils at a lower temperature on mountains. Lower pressure raises the rate of evaporation, higher pressure lowers it.
- Gas laws by kinetic theory: smaller volume means more wall collisions per second and more pressure (Boyle). Higher temperature means faster particles, so volume must rise to keep pressure constant (Charles). More particles need more volume at constant pressure (Avogadro).
- Diffusion: lighter gas diffuses faster, because at the same temperature all gases have the same average kinetic energy ($\frac{1}{2}mv^2$), so smaller m means larger v. Higher temperature raises the rate because particles move faster.
- Sublimation substances: dry ice (solid CO_2), camphor, naphthalene. Uses: solid air fresheners, dye-sublimation printing (T-shirts, mugs), freeze-drying of food.
- Diffusion in medicine: the diffusion rate decides how fast a drug reaches the blood and cells. A high concentration gradient and a liquid form act faster than a tablet. Controlled-release forms keep the effect steady.
- Why perfume on the palm feels cold, and why sweat cools us: the fastest molecules leave, taking energy from the surface, so the average kinetic energy left behind falls.

Past-paper note

- 2026 MCQ: in sublimation a substance changes from solid to gas. No long question from this unit in 2026. Likely short questions: why temperature stays constant during melting; evaporation against boiling; effect of external pressure on boiling point; effect of temperature and molar mass on diffusion.

Unit 3: Stoichiometry

Definitions

- Stoichiometry: study of the relative amounts of substances in a chemical reaction, from a balanced equation. Mole: atomic, molecular or formula mass in grams. Molar volume: 1 mole of any gas occupies 24 dm^3 at RTP (25 °C, 1 atm).
- Limiting reactant: the reactant completely used up, which gives the least product. Reactant in excess: the one left over.
- Theoretical yield: product calculated from the equation. Actual yield: product really obtained. Percentage yield is below 100% because of side reactions, reversible reactions and mechanical loss in filtering or crystallising.
- Empirical formula: simplest whole-number ratio of atoms. Molecular formula: actual number of atoms.
- Molarity: moles of solute per dm^3 of solution. Strength: grams of solute per dm^3 (or cm^3) of solution.

Formulas

- Moles = mass / molar mass. Gas at RTP: moles = volume (dm^3) / 24. Volume in dm^3 = cm^3 / 1000.
- Molarity (mol/dm^3) = moles of solute / volume (dm^3). Strength (g/dm^3) = molarity x molar mass. 1 g/dm^3 = 0.001 g/cm^3.
- Dilution: $M_1V_1 = M_2V_2$. Titration (acid and base, 1:1): $M_1V_1 = M_2V_2$ (use the mole ratio from the equation if it is not 1:1).
- % composition of an element = (mass of the element in 1 mole / molar mass) x 100. % yield = (actual / theoretical) x 100. % purity = (mass of pure compound / total mass of sample) x 100.
- Empirical formula steps: (1) moles of each element from mass or percentage (treat percentages as grams in 100 g); (2) divide by the smallest; (3) whole-number ratio gives the subscripts (if ratio has .5, multiply all by 2). Molecular formula: n = molar mass / empirical formula mass, then multiply all subscripts by n.

Past-paper questions with model answers

- Concentration in mol/dm^3 of 20 g NaOH in 1 dm^3 (2026 B): M = 40, moles = 20/40 = 0.5, so 0.5 mol/dm^3.
- 10 g NaCl in 1 dm^3 (B): M = 58.5, moles = 10/58.5 = 0.171, so 0.171 mol/dm^3.
- 10 g Na_2CO_3 in 1 dm^3 (M): M = 106, moles = 10/106 = 0.094, so 0.094 mol/dm^3.
- 9.8 g H_2SO_4 in 0.5 dm^3 (B): M = 98, moles = 9.8/98 = 0.1, molarity = 0.1/0.5 = 0.2 mol/dm^3.
- Concentration in g/dm^3 of 0.25 mol KNO_3 in 1 dm^3 (B): M = 39 + 14 + 48 = 101, mass = 0.25 x 101 = 25.25 g/dm^3.
- Empirical CH_2O, molar mass 180 (B and D): empirical mass = 30, n = 180/30 = 6, so $C_6H_{12}O_6$. For molar mass 60 (M): n = 2, so $C_2H_4O_2$.
- C 38.71%, H 9.68%, O 51.61%, molar mass 62 (B): moles C 3.226, H 9.68, O 3.226. Divide by 3.226 giving 1 : 3 : 1, so empirical formula CH_3O (mass 31). n = 62/31 = 2, so molecular formula $C_2H_6O_2$.
- C 40%, H 6.67%, O 53.33%, molar mass 90 (D): moles 3.33 : 6.67 : 3.33 = 1 : 2 : 1, so CH_2O (30). n = 3, so $C_3H_6O_3$.
- C 54.55%, H 9.09%, O 36.36%, molar mass 88 (M): moles 4.546 : 9.09 : 2.273 = 2 : 4 : 1, so C_2H_4O (44). n = 2, so $C_4H_8O_2$.
- 150 g Zn with 200 g dil. H_2SO_4 (B), $Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$ (the printed equation has an unbalanced $2ZnSO_4$, use the 1:1 balanced one): moles Zn = 150/63.5 = 2.36, moles H_2SO_4 = 200/98 = 2.04. H_2SO_4 gives fewer moles of H_2, so it is the limiting reactant. H_2 = 2.04 mol x 2 = 4.08 g.
- 68.1 g $CaCO_3$ with 51.6 g HCl (D), $CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$: moles $CaCO_3$ = 68.1/100 = 0.681; moles HCl = 51.6/36.5 = 1.414. HCl needed for 0.681 mol $CaCO_3$ is 1.362, which is less than 1.414, so $CaCO_3$ is the limiting reactant. $CaCl_2$ = 0.681 x 111 = 75.6 g.
- 159 g Na_2CO_3 with 73 g HCl (M), $Na_2CO_3 + 2HCl \rightarrow 2NaCl + CO_2 + H_2O$: moles Na_2CO_3 = 159/106 = 1.5; moles HCl = 73/36.5 = 2. 1.5 mol Na_2CO_3 would need 3 mol HCl, so HCl is the limiting reactant. NaCl = 2 mol x 58.5 = 117 g.
- 1.2 g Mg with excess HCl (M), $Mg + 2HCl \rightarrow MgCl_2 + H_2$: moles Mg = 1.2/24 = 0.05, so H_2 = 0.05 mol, mass = 0.05 x 2 = 0.1 g.

Other numericals from the book exercise (likely in future papers)

- 10.0 g NaCl in 500 cm^3: strength = 10/0.5 = 20 g/dm^3; molarity = (10/58.5)/0.5 = 0.34 mol/dm^3.
- 25.0 cm^3 of 0.10 M NaOH neutralises 20.0 cm^3 HCl: M(HCl) = (0.10 x 25.0)/20.0 = 0.125 mol/dm^3.
- Mass of NaCl for 250 cm^3 of 0.5 M: moles = 0.5 x 0.25 = 0.125; mass = 0.125 x 58.5 = 7.31 g. In g/dm^3 it is 0.5 x 58.5 = 29.25.
- Percentage yield example: theoretical 2.5 g, actual 1.85 g, yield = 1.85/2.5 x 100 = 74%.
- Dilution: to make 250 cm^3 of 0.1 M from 12 M HCl: V_1 = (0.1 x 250)/12 = 2.08 cm^3.
- Percentage composition of MgO: Mg = 24/40 = 60%, O = 16/40 = 40%.

Unit 4: Electrochemistry

Definitions

- Electrochemical cell: device converting chemical energy to electrical energy or the reverse. Electrolytic cell: electrical energy drives a non-spontaneous reaction. Galvanic (voltaic) cell: a spontaneous redox reaction produces electricity.
- Electrolyte: substance that conducts when molten or in solution and is chemically changed (NaCl, HCl, NaOH). Non-electrolyte: urea, glucose, sucrose, benzene.
- Electrolysis: decomposition of an ionic compound, molten or in solution, by passing an electric current.
- Oxidation: loss of electrons (at the anode). Reduction: gain of electrons (at the cathode). OIL RIG; oxidation always at the anode, reduction always at the cathode in both cell types.
- Electroplating: depositing a thin layer of one metal on another by electrolysis. Object = cathode, plating metal = anode, electrolyte contains ions of the plating metal.
- Electrode potential (E°): tendency of a metal to be oxidised or reduced in its salt solution, measured in volts against the standard hydrogen electrode. Electrochemical series: metals arranged by increasing reduction potential.
- Fuel cell: a galvanic cell using hydrogen and oxygen, giving water as the only chemical product. Battery: one galvanic cell or several joined in series.

Electrolytic cell facts

- Parts: vessel with electrolyte, two inert electrodes, battery. Electrons flow in the external wire from anode to cathode. Cations move to the cathode, anions to the anode.
- Rule for halide solutions: dilute solution gives oxygen at the anode; concentrated solution gives the halogen at the anode. Hydrogen is formed at the cathode in both cases. (In dilute NaCl, OH^- is discharged instead of Cl^- because of the concentration effect and the overpotential of chlorine.)
- Cathode: the less reactive ion (lower in the series) is reduced, so H^+ is reduced, not Na^+. Anode: halides are discharged before OH^- when the solution is concentrated.

Electrolysis reactions (half-equations)

- Molten NaCl (Down's cell, carbon anode, iron cathode): anode $2Cl^- \rightarrow Cl_2 + 2e^-$. Cathode $2Na^+ + 2e^- \rightarrow 2Na$. Gives sodium metal and chlorine.
- Molten lead(II) chloride (above 327 °C, Pt or graphite electrodes): anode $2Cl^- \rightarrow Cl_2 + 2e^-$. Cathode $Pb^{2+} + 2e^- \rightarrow Pb$. Lead collects at the bottom, chlorine at the anode. Chlorine forms at the anode because Cl^- is the only anion and is oxidised there.
- Concentrated aqueous NaCl (brine, inert electrodes): anode $2Cl^- \rightarrow Cl_2 + 2e^-$. Cathode $2H^+ + 2e^- \rightarrow H_2$. Solution left contains Na^+ and OH^-, which is NaOH. This is the industrial route to sodium hydroxide (Nelson cell).
- Dilute aqueous NaCl or dilute H_2SO_4 (Pt): cathode $4H^+ + 4e^- \rightarrow 2H_2$. Anode $4OH^- \rightarrow 2H_2O + O_2 + 4e^-$ (SO_4^{2-} stays unchanged). Products: hydrogen and oxygen.
- Copper(II) sulphate with platinum or graphite electrodes: cathode $Cu^{2+} + 2e^- \rightarrow Cu$. Anode $4OH^- \rightarrow 2H_2O + O_2 + 4e^-$. Blue colour fades.
- Copper(II) sulphate with copper electrodes: cathode $Cu^{2+} + 2e^- \rightarrow Cu$. Anode $Cu \rightarrow Cu^{2+} + 2e^-$. The anode dissolves and the cathode gains mass; the blue colour stays.
- Refining of copper: impure copper = anode, pure copper = cathode, $CuSO_4$ with a little H_2SO_4. Gold and silver fall to the bottom as anode mud. Copper obtained is 99.5% pure.
- Dilute KI: cathode H_2; anode O_2 (iodine only when concentrated). Molten NaBr: reddish-brown bromine at the anode, sodium at the cathode. Concentrated $CuCl_2$ with carbon: copper at the cathode, chlorine at the anode.

Electroplating

- Zinc plating of steel: Zn anode, steel cathode, electrolyte potassium zinc cyanide with a little sodium cyanide (cyanide is toxic, must not be dumped in rivers). Anode $Zn \rightarrow Zn^{2+} + 2e^-$, cathode $Zn^{2+} + 2e^- \rightarrow Zn$.
- Tin plating: tin anode, $SnSO_4$ electrolyte with a few drops of dilute H_2SO_4 (prevents hydrolysis). Tin is non-poisonous and stops corrosion, so food cans are tin plated (food acids would react with iron and form toxic substances).
- Chromium plating: steel is first plated with copper or nickel (chromium does not stick to steel), then chromium. Chromium anode, chromium sulphate electrolyte with dil. H_2SO_4. Anode $Cr \rightarrow Cr^{3+} + 3e^-$, cathode $Cr^{3+} + 3e^- \rightarrow Cr$. Used for car and bike parts.
- Applications to quote for "three uses": protection from corrosion, decoration and shine, hardness and wear resistance, recovering and refining metals.

Daniell (galvanic) cell

- Parts: zinc rod in 1 M $ZnSO_4$ (anode), copper rod in 1 M $CuSO_4$ (cathode), salt bridge (inverted U tube with KCl, completes the circuit and keeps neutrality), voltmeter and wires.
- Electrons flow from Zn through the wire to Cu. Anode (oxidation): $Zn \rightarrow Zn^{2+} + 2e^-$. Cathode (reduction): $Cu^{2+} + 2e^- \rightarrow Cu$. Overall: $Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$.
- For a diagram: label anode, cathode, salt bridge, voltmeter, electron flow arrow (Zn to Cu in the outer circuit), ions moving through the salt bridge.

Electrochemical series (use for "which metal is more reactive")

- The metal with the lower (more negative) reduction potential is more reactive: it loses electrons more easily and acts as the anode. Values: Na^+ −2.71, Al^{3+} −1.67, Zn^{2+} −0.76, Fe^{2+} −0.44, H^+ 0.00, Cu^{2+} +0.34, Ag^+ +0.80.

Hydrogen-oxygen fuel cell

- Porous carbon electrodes with platinum catalyst, hot aqueous KOH in the middle, H_2 at the anode, O_2 at the cathode. Anode: $2H_2 + 4OH^- \rightarrow 4H_2O + 4e^-$. Cathode: $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$. Net: $2H_2 + O_2 \rightarrow 2H_2O$. Gives about 0.9 V. Used in the American space programme (astronauts drink the water).
- Advantages over petrol engines: very efficient (chemical energy straight to electricity), only water vapour as product, no CO_2, NOx or SO_2 so no smog, no moving parts, long life with little maintenance, hydrogen can come from renewable sources, petrol is non-renewable.
- Disadvantages: hydrogen is flammable and explosive and hard to store and transport; making hydrogen by electrolysis of water is costly.

Past-paper questions with model answers

- Which of Zn (−0.76 V) and Cu (+0.34 V) is more reactive? (B). Zinc, because it has the lower reduction potential, so it loses electrons more easily. Same for Al (−1.67 V) against Cu (D).
- Three advantages of the hydrogen-oxygen fuel cell (B, D). Use the list above, pick three.
- Reactions at the electrodes of a hydrogen-oxygen fuel cell (M): write the anode, cathode and net reaction above.
- Which metal is commonly used for chrome plating, with anode and cathode reactions (M): chromium; anode $Cr \rightarrow Cr^{3+} + 3e^-$, cathode $Cr^{3+} + 3e^- \rightarrow Cr$.
- What is electroplating, two or three uses (B). Definition and uses above.
- Sketch a Daniell cell (M). Diagram points above.
- Sec C: electrolysis of dilute copper sulphate with copper electrodes, with equations (B). Anode $Cu \rightarrow Cu^{2+} + 2e^-$, cathode $Cu^{2+} + 2e^- \rightarrow Cu$, copper anode shrinks, cathode grows.
- Sec C: compare electrolysis of a halide in dilute and concentrated solutions (D). Dilute: oxygen at the anode (OH^- discharged), hydrogen at the cathode. Concentrated: halogen (e.g. Cl_2) at the anode, hydrogen

at the cathode. Give the half-equations for NaCl.
- Sec C: compare the fuel cell with petrol engines in four points (M). Pollution, efficiency, renewable fuel, moving parts, plus the disadvantages (storage, cost).

Unit 5: Reaction Kinetics

Definitions

- Rate of reaction: change in concentration of a reactant or product in a given time. Unit: mol dm^{-3} s^{-1}.
- Average rate: total change in concentration / total time. Rate at one moment: gradient of the tangent to the concentration-time curve.
- Collision theory: particles must collide with enough energy (at least the activation energy) and the correct orientation for a reaction.
- Activation energy: the minimum energy colliding particles need to react. Activated complex (transition state): the temporary high-energy state formed in an effective collision.
- Catalyst: speeds up a reaction without being used up, by giving an alternative pathway with lower activation energy. It does not change the overall energy change or the products, and cannot make an impossible reaction occur. In a reversible reaction it lowers the activation energy of both directions. Enzymes: biological catalysts (proteins), each works on one reaction.

Must-know points

- As a reaction proceeds, reactants fall and products rise, and the rate falls (curve gets flatter). A steep slope means a fast reaction. A flat line means the reaction has stopped (reactants used up or equilibrium reached).
- Factors with collision theory: higher concentration (more particles per unit volume, more collisions); higher pressure for gases (same reason); larger surface area of a solid (more exposed particles, powdered zinc reacts faster than a lump); higher temperature (faster particles, more frequent and more energetic collisions, more particles reach the activation energy, shown by the Maxwell-Boltzmann curve); catalyst (lower activation energy).
- Physical changes used to follow a rate: change in mass, formation of gas (in an open flask mass falls; in a closed vessel pressure rises), temperature change. Colour of the reactants is not used here.
- Fast reactions: acid-base neutralisation, explosions. Slow: fermentation, digestion, rusting.
- Role in the food industry: finds the best time to harvest and transport so produce reaches the market at its best taste, texture and nutrition; identifies what causes degradation in transport; helps slow spoilage by controlling temperature and humidity, so shelf life is longer; helps design storage and transport methods that keep nutritional value.

Past-paper questions with model answers

- Role of chemical kinetics in the food industry, any four aspects (D, Sec C 1.5 x 4): use the four bullets above, a sentence each.
- Rate of reaction meaning and how it is measured (B, Sec C): rate is change in concentration of a reactant or product per unit time. Measure by following the concentration of a product at regular times, or the volume or mass of gas given off, or the mass lost.
- Graph question, rate between 5 s and 20 s (B): rate = (concentration at 20 s − concentration at 5 s) / (20 − 5). Read both values from the graph and divide by 15 s. Unit mol dm^{-3} s^{-1}.
- Horizontal line at the end of the graph (B, M): the reaction has stopped (all the limiting reactant is used up, or equilibrium has been reached), so there is no further change in concentration.
- Two reactions A and B, which is faster (M): the one with the steeper line, shown by calculating rate = Δconcentration / Δtime for each from the graph; the larger value is the faster reaction.

Unit 6: Salts

Definitions

- Salt: ionic compound formed by electrostatic attraction between oppositely charged ions, the positive ions coming from a base and the negative ions from an acid ($HCl + NaOH \rightarrow NaCl + H_2O$).
- Lattice: a repeating three-dimensional arrangement of ions that maximises attraction and minimises repulsion.

Must-know points

- Ionic compounds are solids at room conditions with high melting and boiling points, because the strong electrostatic forces between the ions in the lattice need a lot of energy to break. (This is a repeated question: give two reasons: strong electrostatic attraction between oppositely charged ions, and the giant lattice.)
- Conductivity: solid salts do not conduct (ions fixed in the lattice). Molten and aqueous salts conduct because the ions are free to move and carry charge.
- Hard but brittle: a blow shifts the layers so like charges meet and repel, and the crystal splits.
- Solubility rules: all sodium, potassium and ammonium salts are soluble; all nitrates are soluble; chlorides are soluble except lead(II) chloride and silver chloride; carbonates are insoluble except sodium, potassium and ammonium; sulphates are soluble except lead, barium and calcium; hydroxides are insoluble except sodium, potassium, ammonium and (partly) calcium.
- Preparing a soluble salt:
    - Acid + alkali (titration), e.g. NaCl: pipette 25 cm^3 of acid, add indicator (phenolphthalein), add alkali from the burette to the end point, note the volume, then repeat WITHOUT indicator using that volume, evaporate to a saturated solution, cool, crystallise, filter.
    - Acid + excess metal, e.g. $ZnSO_4$: $Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$. Add excess zinc until bubbling stops, filter off the extra zinc, evaporate the filtrate, crystallise.
    - Acid + excess insoluble base, e.g. $CuSO_4$: $CuO + H_2SO_4 \rightarrow CuSO_4 + H_2O$. Add excess CuO, filter, evaporate, crystallise.
    - Acid + excess insoluble carbonate, e.g. $CaCl_2$: $CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$. Add excess $CaCO_3$ until effervescence stops, filter, evaporate, crystallise.

  The steps in every method: add excess solid, filter, evaporate to saturation, cool and crystallise, filter and dry.

Past-paper questions with model answers

- Why do ionic compounds have high melting points, two reasons (B, D, M): strong electrostatic forces between oppositely charged ions; the ions are held in a rigid giant lattice, so a large amount of energy is needed to separate them.
- What is the usual state of ionic compounds under normal conditions (B): solids (with a lattice structure).
- 2025 and 2026 MCQs: sodium chloride is soluble (silver chloride, lead chloride, calcium carbonate are not); a soluble salt from an acid and an alkali is made by titration; excess metal is removed by filtration.

Unit 7: Nitrogen, Sulphur and Metals

Definitions

- Photochemical smog: forms when sunlight reacts with nitrogen oxides (NO, NO_2) and unburned hydrocarbons. PAN (peroxyacetyl nitrate) is a stable component that travels long distances and releases

NOx and radicals again at higher temperature.
- Acid rain: rain with pH less than 5 (book definition), caused by SO_2 and NO_2.
- Oxides: binary compounds of an element with oxygen. Acidic oxide: oxide of a non-metal that forms an acid with water and reacts with bases (SO_2, CO_2). Basic oxide: oxide of a metal that reacts with acids to give salt and water (CuO, CaO, Na_2O). Amphoteric oxide: reacts with both acids and bases (Al_2O_3, ZnO).

PAN and acid rain

- PAN formation: (1) $2NO + O_2 \rightarrow 2NO_2$. (2) $NO_2 \rightarrow NO + O$ (UV light, photolysis). (3) $O + O_2 \rightarrow O_3$. (4) Unburned hydrocarbons (VOCs) react with O to give organic radicals RCO•. (5) $RCO\bullet + O_2 \rightarrow RCO_3\bullet$ (peroxyacyl radical). (6) $RCO_3\bullet + NO_2 \rightarrow$ PAN. Three reactions are enough for a 1x3 answer.
- Direct role of NOx in acid rain: $2NO + O_2 \rightarrow 2NO_2$ and $4NO_2 + 2H_2O + O_2 \rightarrow 4HNO_3$ (nitric acid).
- Catalytic role of NO_2 with SO_2: $SO_2 + NO_2 \rightarrow SO_3 + NO$; $SO_3 + H_2O \rightarrow H_2SO_4$; the NO is re-oxidised, $2NO + O_2 \rightarrow 2NO_2$, so a small amount of NO_2 converts a lot of SO_2 into sulphuric acid.

Haber process (ammonia)

- $N_2 + 3H_2 \rightleftharpoons 2NH_3$ (reversible, exothermic, volume decreases). Conditions: 450 °C, 200 atm (20 000 kPa), iron catalyst (Fe, with Mo as a promoter in the book). Hydrogen from methane (natural gas), nitrogen from air, ratio 1 : 3 by volume.
- Le Chatelier: high pressure favours ammonia because the volume falls; a low temperature favours yield but is too slow, so 450 °C with a catalyst is the compromise. Gases leaving contain about 10 to 12% ammonia; it is liquefied by cooling (refrigerated brine) and the unreacted N_2 and H_2 are recycled.

Contact process (sulphuric acid)

- SO_2 comes from burning sulphur ($S + O_2 \rightarrow SO_2$) or roasting sulphide ores; oxygen from air. Key step: $2SO_2 + O_2 \rightleftharpoons 2SO_3$ (reversible, exothermic). Conditions: 450 °C, 200 kPa (about 2 atm), vanadium(V) oxide catalyst (V_2O_5).
- SO_3 is absorbed in 98% H_2SO_4 to make oleum: $H_2SO_4 + SO_3 \rightarrow H_2S_2O_7$. Oleum diluted with water gives concentrated acid: $H_2S_2O_7 + H_2O \rightarrow 2H_2SO_4$. ($SO_3$ is not added to water directly because that gives a fog of acid.) Sulphuric acid is called the King of Chemicals (fertilisers, plastics, paints, explosives, textiles).
- Flow: burner or furnace, purification (coke filter), heat exchanger, catalytic converter, absorption tower, oleum tower, dilution.

Oxides with equations

- Acidic: $SO_2 + H_2O \rightarrow H_2SO_3$; $CO_2 + H_2O \rightarrow H_2CO_3$; $CO_2 + 2NaOH \rightarrow Na_2CO_3 + H_2O$ (reacts with a base).
- Basic: $CaO + H_2O \rightarrow Ca(OH)_2$; $CaO + 2HCl \rightarrow CaCl_2 + H_2O$; $CuO + H_2SO_4 \rightarrow CuSO_4 + H_2O$ (blue solution); $Na_2O + 2HCl \rightarrow 2NaCl + H_2O$.
- Amphoteric: $Al_2O_3 + 6HCl \rightarrow 2AlCl_3 + 3H_2O$ (acts as a base); $Al_2O_3 + 2NaOH + 3H_2O \rightarrow 2NaAl(OH)_4$ (acts as an acid, sodium aluminate). $ZnO + 2HCl \rightarrow ZnCl_2 + H_2O$; $ZnO + 2NaOH \rightarrow Na_2ZnO_2 + H_2O$ (sodium zincate).
- Metallic oxides are basic, non-metallic oxides are acidic, and oxides of metals near the dividing line are amphoteric.

Reactions of metals

- With dilute acid: metal + acid → salt + hydrogen ($Mg + 2HCl \rightarrow MgCl_2 + H_2$). K and Na are explosive; Mg, Zn and Fe react steadily; Cu, Ag and Au do not react.

- With cold water: metal + water → metal hydroxide + hydrogen ($2Na + 2H_2O \rightarrow 2NaOH + H_2$; $Ca + 2H_2O \rightarrow Ca(OH)_2 + H_2$). K, Na and Ca react vigorously; Mg very slowly; Zn and Fe not significantly.
- With steam: metal + steam → metal oxide + hydrogen ($Mg + H_2O \rightarrow MgO + H_2$; $3Fe + 4H_2O \rightarrow Fe_3O_4 + 4H_2$; $Zn + H_2O \rightarrow ZnO + H_2$). Copper does not react.
- With oxygen: metal + oxygen → metal oxide ($2Mg + O_2 \rightarrow 2MgO$; $4Na + O_2 \rightarrow 2Na_2O$; $4Al + 3O_2 \rightarrow 2Al_2O_3$). Mg and Al form a protective oxide layer. Copper oxidises slowly; gold and platinum do not react.
- Reactivity series: K > Na > Ca > Mg > Al > Zn > Fe > Pb > Cu > Ag > Au. Four groups: highly reactive (K, Na, Ca), moderately reactive (Mg, Al, Zn, Fe), less reactive (Pb, Cu, Ag), unreactive (Au, Pt). A metal that reacts with steam but not cold water sits in the moderate group (like Mg, Zn or Fe).

Past-paper questions with model answers

- Catalyst in the Contact process and its role (B, 1+2): V_2O_5 (vanadium(V) oxide); it speeds up the oxidation of SO_2 to SO_3 without being used up, by lowering the activation energy.
- Equation for conversion of SO_2 to SO_3 (B): $2SO_2 + O_2 \rightleftharpoons 2SO_3$. Optimum conditions (D, M): 450 °C, 200 kPa (2 atm), V_2O_5 catalyst.
- What is the Haber process, with its equation and conditions (D, M): industrial production of ammonia, $N_2 + 3H_2 \rightleftharpoons 2NH_3$, 450 °C, 200 atm, iron catalyst.
- How NOx forms PAN, with three reactions (B, 1x3): use steps 1 to 3 or 4 to 6 above.
- Type of compound formed when a metal reacts with oxygen, with an example (B, D): a metal oxide (basic oxide), e.g. $2Mg + O_2 \rightarrow 2MgO$.
- What happens when a reactive metal reacts with dilute acid (B), or with steam (M): salt + hydrogen; metal oxide + hydrogen, with an example equation each.
- Is CaO a basic oxide? Justify with an equation (B): yes, it reacts with acid to give salt and water, $CaO + 2HCl \rightarrow CaCl_2 + H_2O$ (or with water to form $Ca(OH)_2$). Is CO_2 an acidic oxide (D): yes, $CO_2 + H_2O \rightarrow H_2CO_3$ or $CO_2 + 2NaOH \rightarrow Na_2CO_3 + H_2O$. What are amphoteric oxides, two examples (M): oxides that react with both acids and bases, Al_2O_3 and ZnO.
- Sec C: classify SO_2, CuO and Al_2O_3 with balanced equations (B, D, M, every set): SO_2 acidic, CuO basic, Al_2O_3 amphoteric (equations above).
- Sec C: reactivity of metals with oxygen (Na, Al, Cu, Pt) (D): Na burns rapidly ($4Na + O_2 \rightarrow 2Na_2O$); Al forms a protective oxide layer ($4Al + 3O_2 \rightarrow 2Al_2O_3$); Cu oxidises slowly and only on heating ($2Cu + O_2 \rightarrow 2CuO$); Pt does not react.
- Sec C: reactions of metals with steam and oxygen (B), cold water and dilute acids (M): use the equations above.

Unit 8: Organic Chemistry

Definitions

- Organic chemistry: study of carbon compounds. Displayed formula: shows every atom and every bond as a line. Condensed (structural) formula: groups atoms, omits some bonds ($CH_3CH_2CH_3$). Functional group: the atom or group that decides a compound's class and reactions.
- IUPAC name = stem (number of carbons) + suffix (class). Stems: meth 1, eth 2, prop 3, but 4, pent 5, hex 6, hept 7, oct 8, non 9, dec 10.
- Alkane: -ane, all single C-C bonds, C_nH_{2n+2}. Alkene: -ene, at least one C=C, C_nH_{2n}. Alkyne: -yne, at least one C≡C, C_nH_{2n-2}. Alcohol: -ol, hydroxyl group -OH. Carboxylic acid: -oic acid, -COOH. Ester: RCOOR′ from an acid and an alcohol.

Must-know structures

- Methane CH_4; ethane CH_3CH_3; propane $CH_3CH_2CH_3$; butane $CH_3CH_2CH_2CH_3$.

- Ethene $CH_2=CH_2$; propene $CH_3CH=CH_2$; but-1-ene $CH_2=CHCH_2CH_3$; but-2-ene $CH_3CH=CHCH_3$. Ethyne $HC\equiv CH$; propyne $CH_3C\equiv CH$; but-1-yne $CH\equiv CCH_2CH_3$; but-2-yne $CH_3C\equiv CCH_3$.
- Methanol CH_3OH; ethanol CH_3CH_2OH; propan-1-ol $CH_3CH_2CH_2OH$; propan-2-ol $CH_3CH(OH)CH_3$; butan-1-ol $CH_3CH_2CH_2CH_2OH$; butan-2-ol $CH_3CH(OH)CH_2CH_3$. (Propan-1-ol and propan-2-ol have the same molecular formula C_3H_8O but different structures.)
- Methanoic acid $HCOOH$; ethanoic acid CH_3COOH; propanoic acid CH_3CH_2COOH; butanoic acid $CH_3CH_2CH_2COOH$. The -COOH carbon is always carbon number 1.
- Ester naming: the alkyl group from the alcohol first, then the acid name with -ic acid changed to -ate. CH_3COOCH_3 is methyl ethanoate; $CH_3CH_2COOCH_3$ is methyl propanoate. Ethanol + propanoic acid gives ethyl propanoate $CH_3CH_2COOCH_2CH_3$.

How to draw a displayed formula (marks come from this)

- Write the carbon chain, number it from the end that gives the smaller number to the functional group or double bond, place the double bond or OH on the numbered carbon, then add hydrogens so each carbon has four bonds, and draw every C-H and O-H bond as a line. For an alcohol draw the O-H bond too.
- Example butan-1-ol displayed: H3C-H2C-H2C-H2C-OH written with every bond (four carbons in a row, each with its hydrogens, OH on carbon 1). Example butan-2-ol: the OH sits on the second carbon of the four.

Past-paper questions with model answers

- Draw the structural and displayed formula of propan-1-ol (B), butan-1-ol (D), butan-2-ol (M, D). Use the structures above, and show all the bonds in the displayed one.
- 2025 MCQ: which is a straight-chain hydrocarbon; functional group in carboxylic acids is -COOH.
- Name the functional groups of ethanol and ethanal (2025): -OH (hydroxyl) in ethanol; -CHO (aldehyde) in ethanal.

Unit 9: Hydrocarbons

Definitions

- Hydrocarbon: compound of carbon and hydrogen only. Saturated: only single C-C bonds (alkanes). Unsaturated: has a C=C double bond (alkenes) or C≡C triple bond (alkynes). Alkenes are unsaturated because they can still add atoms across the double bond.
- Cracking: breaking large alkanes into smaller, more useful alkanes and alkenes. Thermal cracking: high temperature (about 450 to 750 °C) and high pressure. Catalytic cracking: about 550 °C with a zeolite catalyst, which gives more C5 to C10 hydrocarbons. Reasons: supply of petrol demand is larger than the supply from distillation; smaller hydrocarbons are more volatile, burn well and make better fuels; alkenes are raw material for plastics and chemicals.
- Elimination reaction: a small molecule (H_2O or HX) is removed from adjacent carbons, giving a double bond. Dehydration: loss of water. Dehydrohalogenation: loss of hydrogen halide.
- Fossil fuels: coal, natural gas, petroleum (non-renewable, from remains of ancient organisms). Natural gas is mainly methane. Petroleum (crude oil) is a thick dark mixture of hydrocarbons; the name comes from Latin petra (rock) and oleum (oil).

Preparation of alkenes

- Cracking: $C_{10}H_{22} \rightarrow C_8H_{18} + C_2H_4$ (decane gives octane and ethene).
- Dehydration of alcohols (any of three routes): $CH_3CH_2OH \rightarrow CH_2=CH_2 + H_2O$ using conc. H_2SO_4 at 170 °C, or passing vapour over heated alumina (Al_2O_3) at 340 to 450 °C, or phosphoric acid. Propan-1-ol or

propan-2-ol similarly gives propene.
- Dehydrohalogenation: heat a halogenoalkane with alcoholic KOH: $CH_3CH_2Br + KOH \rightarrow CH_2{=}CH_2 + KBr + H_2O$. Bromopropane (1- or 2-) gives propene: $CH_3CH_2CH_2Br + KOH \rightarrow CH_3CH{=}CH_2 + KBr + H_2O$.

Reactions of alkenes (addition reactions)

- Bromine or bromine water: $C_2H_4 + Br_2 \rightarrow CH_2Br\text{-}CH_2Br$ (1,2-dibromoethane). Orange-brown bromine water turns colourless. This is the test for unsaturation (alkenes and alkynes). Alkanes give no reaction (stays orange-brown).
- Cold dilute alkaline $KMnO_4$ (Baeyer's test): purple colour is discharged and a brown MnO_2 precipitate forms. $3C_2H_4 + 2KMnO_4 + 4H_2O \rightarrow 3CH_2OH\text{-}CH_2OH + 2MnO_2 + 2KOH$. Ethene is oxidised to ethane-1,2-diol (ethylene glycol, antifreeze). Alkanes do not react.
- Hydrogenation: $C_2H_4 + H_2 \rightarrow C_2H_6$ with finely divided nickel at 200 to 300 °C and high pressure (Pt or Pd at room temperature). Propene gives propane.
- Hydration: $C_2H_4 + H_2O$ (steam) $\rightarrow C_2H_5OH$ using phosphoric acid catalyst. Propene gives propanol.
- Polymerisation of ethene gives polythene (Unit 12).

Ethyne (alkyne)

- $HC{\equiv}CH$, triple bond. Test with bromine: $C_2H_2 + 2Br_2 \rightarrow CHBr_2\text{-}CHBr_2$ (tetrabromoethane), so bromine water is decolourised.
- Uses: welding and cutting (oxy-acetylene flame at about 3200 °C, the hottest of the fuel gases) and artificial ripening of fruit. Ripening: a packet of calcium carbide in the crate gives ethyne with moisture, $CaC_2 + 2H_2O \rightarrow C_2H_2 + Ca(OH)_2$. Health risk: harmful chemicals, breathing problems.
- Distinguishing propane and propene, or hexane and hexene: add bromine water (or alkaline $KMnO_4$); the alkene decolourises it, the alkane does not.

Fractional distillation of petroleum

- Crude oil is heated to about 400 °C in a furnace and the vapour rises up a fractionating tower that is hotter at the bottom and cooler at the top. Each fraction condenses where the temperature matches its boiling point range. Compounds with the highest boiling points condense near the bottom. The method works because the components have different boiling points.
- Fractions (top to bottom) with carbon numbers and uses: LPG or refinery gas (C1 to C4, below 20 °C), cooking and heating; petrol or gasoline (C5 to C10, 35 to 70 °C), motor fuel; naphtha (C8 to C12), chemical feedstock for plastics and drugs; kerosene (C10 to C16), jet fuel and heating; diesel or gas oil (C14 to C20), diesel engines; lubricating oil (C20 to C50), lubricants, waxes and polishes; fuel oil (C50 to C70), power stations, ships and home heating; bitumen (above C70), roads and roofing.
- From bottom to top: chain length decreases, boiling point decreases, viscosity decreases, volatility increases, flammability increases, and the colour gets lighter. Reason: longer chains have stronger intermolecular forces.

Past-paper questions with model answers

- What are fossil fuels? Name three (B 1.5+1.5, D). Natural fuels formed from the remains of ancient organisms over millions of years, non-renewable: coal, natural gas, petroleum.
- What is petroleum, why must it be separated (B 1+2): a mixture of hydrocarbons (crude oil). It must be separated because the crude mixture is not directly useful, and each fraction has its own use and boiling range.
- What is fractional distillation, two fractions (B, D, M 2+1): separation of crude oil into fractions by boiling point difference; for example petrol (car fuel) and kerosene (jet fuel).
- State the observation when an unsaturated hydrocarbon reacts with aqueous bromine (B): the reddish-brown colour disappears (colourless), because bromine adds across the double bond. How can a double

bond be identified (D): bromine water test, or alkaline $KMnO_4$ turns from purple to colourless with brown MnO_2.
- $KMnO_4$ test with balanced equation (M): Baeyer's test above.
- Preparation of ethene from bromoethane and ethanol (B), of propene from bromopropane and propan-1-ol (D), dehydration of ethanol and dehydrohalogenation of chloroethane (M): use the equations above (alcoholic KOH; conc. H_2SO_4 or alumina).
- Ethene prepared by steam: $C_2H_4 + H_2O \rightarrow C_2H_5OH$, phosphoric acid catalyst (B OR). The 2025 paper asked hydrogenation of ethene ($C_2H_4 + H_2 \rightarrow C_2H_6$ with nickel).
- Sec C: four petroleum fractions with uses (B, 1x4); how properties change from bottom to top, chain length and boiling point (M).
- Sec C: uses of ethyne (D): (a) artificial ripening with calcium carbide and water, $CaC_2 + 2H_2O \rightarrow C_2H_2 + Ca(OH)_2$; (b) welding, because the oxy-acetylene flame reaches about 3200 °C.

Unit 10: Hydroxy Compounds (Alcohols)

Definitions

- Alcohol: organic compound with a hydroxyl group -OH on a saturated carbon.
- Fermentation: enzymes in yeast turn aqueous glucose into ethanol and carbon dioxide at 25 to 35 °C in the absence of oxygen: $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$. It gives 10 to 15% ethanol (more kills the yeast). Fractional distillation raises it to 96% (rectified spirit); the last 4% water cannot be removed by distillation, so a dehydrating agent such as conc. H_2SO_4 is used to get 100% ethanol.
- Hydration of ethene: $C_2H_4 + H_2O \rightleftharpoons C_2H_5OH$ with steam at 300 °C and 6 atm (book value) using phosphoric acid catalyst. About 4% converts per pass, the ethene is recycled until about 96% is converted. (The book states 6 atm, 6000 kPa; learn it as the book gives it.)
- Gasohol: petrol blended with 10 to 20% ethanol.

Fermentation against hydration (table, often asked as "one advantage and one disadvantage")

- Raw material: fermentation uses glucose from plants (renewable); hydration uses ethene from crude oil (non-renewable).
- Process: fermentation is a batch process (slow, all reactants left for days); hydration is continuous (fast, efficient).
- Product: fermentation gives impure, dilute ethanol that needs further distillation; hydration gives pure ethanol.
- Energy: fermentation needs a moderate temperature and low energy; hydration needs high temperature and pressure, so more energy.

Combustion and uses

- Complete combustion: alcohol + oxygen → carbon dioxide + water + heat. $2CH_3OH + 3O_2 \rightarrow 2CO_2 + 4H_2O$. $C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$.
- Fuel: ethanol is renewable, has a higher octane number than petrol, reduces carbon monoxide and smog-forming emissions, gives about two-thirds of petrol's energy per litre. Methanol has low energy content, so it reduces driving range. Disadvantage of alcohol fuels: absorb water from air (hygroscopic) and can corrode engine parts. Corn-based ethanol cuts greenhouse gas emissions by about 40 to 50%.
- Pharmaceuticals: solvents (herbal extracts, homoeopathy), antiseptic and disinfectant (swabs before injections, kill bacteria, viruses and fungi), isopropanol for sterilising equipment, help drugs pass through the skin.
- Cosmetics: deodorants, perfumes, lotions, toners; antibacterial and keep ingredients mixed.

- Daily life: solvents in paints, inks and cleaners; hand sanitisers and surface disinfectants (important in COVID-19).

Past-paper questions with model answers

- Write the equation for complete combustion of methanol or ethanol and name the products (D, M, 2+1): equation above; products carbon dioxide and water.
- Equation for fermentation of glucose (M OR): $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$ (yeast, 25 to 35 °C, no oxygen).
- Complete balanced equation for addition of steam to ethene to give ethanol (B): $C_2H_4 + H_2O \rightarrow C_2H_5OH$, phosphoric acid, 300 °C, 6 atm.
- One advantage and one disadvantage of fermentation compared with catalytic hydration of ethene (D): advantage, uses renewable raw material and low energy; disadvantage, slow batch process giving impure, dilute ethanol.
- Any two uses of alcohols in daily life (M): fuel (gasohol), solvent, disinfectant and sanitiser, cosmetics and perfumes.

Unit 11: Carboxylic Compounds

Definitions

- Carboxylic acid: compound containing the carboxyl group -COOH, general formula RCOOH. Weaker acid than mineral acids but still gives H^+ in water. Carbonyl compounds contain C=O.
- Ester: sweet-smelling compound from an acid and an alcohol, general formula RCOOR′, containing the -COO- group. Esterification: carboxylic acid + alcohol ⇌ ester + water with conc. H_2SO_4 as catalyst (a condensation reaction, since a small molecule, water, is lost).

Formation of ethanoic acid

- Chemical oxidation: ethanol is oxidised by acidified aqueous potassium manganate(VII) (or potassium dichromate). $CH_3CH_2OH + [O] \rightarrow CH_3CHO$ (ethanal) $+ H_2O$, then $CH_3CHO + [O] \rightarrow CH_3COOH$. Overall $CH_3CH_2OH + 2[O] \rightarrow CH_3COOH + H_2O$. Fast, but needs a strong oxidising agent. The purple permanganate is decolourised. $KMnO_4$ is the oxidising agent.
- Bacterial oxidation: acetobacter bacteria (enzymes) oxidise ethanol in air (aerobic) to ethanoic acid, giving vinegar (4 to 8% acetic acid, about 5% commonly). Slow, but uses renewable resources and is environmentally friendly.

Reactions of ethanoic acid

- With a base: $CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$ (sodium ethanoate, salt and water).
- With a carbonate: $2CH_3COOH + Na_2CO_3 \rightarrow 2CH_3COONa + H_2O + CO_2$ (effervescence). With a bicarbonate: $CH_3COOH + NaHCO_3 \rightarrow CH_3COONa + H_2O + CO_2$. CO_2 turns limewater milky.
- With an active metal: $2CH_3COOH + 2Na \rightarrow 2CH_3COONa + H_2$ (also Mg, Ca, K). Propanoic acid with sodium gives sodium propanoate and hydrogen. Methanoic acid with $NaHCO_3$ gives sodium methanoate, water and CO_2.
- With an alcohol (esterification): $CH_3COOH + CH_3OH \rightleftharpoons CH_3COOCH_3 + H_2O$ (methyl ethanoate); $CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$ (ethyl ethanoate); $HCOOH + CH_3CH_2CH_2OH$ gives propyl methanoate.

Uses

- Acids: methanoic acid in textile industry; ethanoic acid for plastics, esters and aspirin; vinegar for pickles and salad; sodium salts of fatty acids for soap and detergents; citric acid and benzoic acid (sodium benzoate) as food preservatives; tartaric acid in baking powder; ascorbic acid is vitamin C; solvents; perfumes and food essences.
- Esters: flavouring and fragrance (isopentyl acetate banana, octyl acetate orange, ethyl butyrate pineapple, methyl butyrate apple, isobutyl formate raspberry), solvents for dyes, glues, inks and nail polish remover, car paints and varnishes, polyesters for bottles and clothing fibres, cosmetics (soften and smooth skin), aspirin (an ester) as fever reducer and painkiller.

Past-paper questions with model answers

- What is esterification? Give an example having a balanced equation (B, 1x3 and 2026 M, 1+2): reaction of a carboxylic acid with an alcohol in the presence of conc. H_2SO_4 giving an ester and water. Example $CH_3COOH + CH_3OH \rightleftharpoons CH_3COOCH_3 + H_2O$.
- Balanced chemical reaction between ethanoic acid and methanol, name the products (D, 1+2): same as above; methyl ethanoate and water.
- General word equation for esterification with an example (M): carboxylic acid + alcohol → ester + water.
- 2026 Section A MCQ: $C_2H_5OH + 2[O]$ with $KMnO_4/H_2SO_4$ gives CH_3COOH. 2025: functional group in carboxylic acids is -COOH; vinegar turns blue litmus red.

Unit 12: Polymers

Definitions

- Polymer: a large molecule built from many small repeating units called monomers joined by covalent bonds. Polymerisation: joining of many monomers.
- Addition polymerisation: monomers with a C=C double bond join without losing any molecule; the double bond opens and becomes a single bond. Condensation polymerisation: monomers with two functional groups join and a small molecule (usually water) is lost at each link.
- Plastics: synthetic materials made from organic polymers (Greek plastikos, mouldable).

Addition polymers (repeat unit = the monomer with the double bond turned to a single bond)

- Ethene $CH_2=CH_2$ gives polyethene, repeat unit $-CH_2-CH_2-$ (made at high temperature and pressure). Propene gives polypropene. Chloroethene (vinyl chloride) gives polyvinylchloride (PVC). To deduce the monomer from a polymer, change the single bond in the backbone back to a double bond.

Condensation polymers

- Polyamide (nylon-6,6): dicarboxylic acid (adipic acid $HOOC-(CH_2)_4-COOH$) + diamine (hexamethylenediamine $H_2N-(CH_2)_6-NH_2$), amide linkage -CONH- (peptide bond), water released. Used in clothing, carpets, ropes that do not rot, toothbrushes; strong, elastic, resists abrasion.
- Polyester (PET): dicarboxylic acid (terephthalic acid) + diol (ethylene glycol, ethane-1,2-diol), ester linkage -COO-, water released. Used for clothing, curtains, bed linen, rope, tyre cords, drink bottles; strong, flexible, quick drying, keeps colour and shape.
- General equation: n $HOOC-R-COOH$ + n $H_2N-R'-NH_2$ → $[-OC-R-CO-NH-R'-NH-]_n$ + 2n H_2O (approximately; one water per link).
- PET recycling: acid hydrolysis with H_2SO_4 or HCl at 200 to 250 °C breaks the ester bonds back into terephthalic acid and ethylene glycol, which can be re-polymerised. This saves raw material and reduces plastic waste.

Addition against condensation (give two points)

- Monomer: addition uses unsaturated monomers with C=C; condensation uses monomers with two functional groups (-COOH and -OH or $-NH_2$).
- By-product: addition gives none; condensation releases a small molecule such as water.
- Examples: addition gives polyethene, PVC, polypropene; condensation gives nylon and PET (polyamides and polyesters). Repeat unit: in addition it equals the monomer; in condensation it contains parts of two different monomers.

Plastics and the environment

- Properties that affect disposal: durable (last hundreds or thousands of years), lightweight (carried by wind and water), contain additives that leach out, limited recyclability.
- Landfill: takes up a lot of space and resists compaction; leaches chemicals into soil and groundwater; breaks into microplastics.
- Oceans: about 8 million tons enter the ocean every year; gather into garbage patches; animals eat or are entangled by plastic and die; microplastics enter the food chain and reach humans.
- Burning: releases toxic gases (dioxins, furans), CO_2 and methane, causes air pollution and respiratory disease; leftover ash is toxic.

Past-paper questions with model answers

- What is a polymer? Give two examples (B 3 marks); what is meant by monomer (B, 2+1), define monomer and polymer (D, M): monomer = small repeating unit; polymer = large molecule built from many monomers; examples polyethene, PVC, nylon, PET.
- Sec C: describe the formation of a polyamide from a dicarboxylic acid and a diamine with a general equation and the type of linkage (B, 2+2): see condensation polymer above; linkage is the amide (peptide) bond -CONH-.
- Sec C: two differences between addition and condensation polymerisation (D): use the points above.
- Sec C: environmental challenges of plastic, landfill disposal and ocean accumulation (M, 2+2): use the points above.

Unit 13: Biochemistry

Definitions

- Amino acid: organic compound with an amine group ($-NH_2$) and a carboxylic group (-COOH) on the same carbon, plus a variable side chain R. General structure H_2N-CH(R)-COOH. Label the amino group and the carboxyl group.
- Protein: natural polyamide (polymer of amino acids) joined by peptide bonds (-CO-NH-). Two amino acids make a dipeptide, with loss of one water: the $-NH_2$ of one reacts with the -COOH of the other.
- Dipeptide general structure: H_2N-CH(R_1)-CO-NH-CH(R_2)-COOH, with the peptide bond -CO-NH- in the middle.
- Lipids: insoluble in water, soluble in organic solvents (ether, hexane); simple lipids (fats and oils) are esters of fatty acids with glycerol (glycerides). Main function: long-term energy storage, plus insulation, cell membranes and absorbing fat-soluble vitamins. Triglyceride = glycerol + 3 fatty acids + loss of 3 water.
- Carbohydrates: general formula $C_x(H_2O)_y$, made by plants in photosynthesis. Glucose is a monosaccharide, starch and cellulose are polymers of glucose. Main function: supply energy.
- Nucleic acids (DNA and RNA): long-chain molecules that store and pass on genetic information from one generation to the next and direct the making of proteins.

- Vitamins: organic compounds needed in small amounts for metabolism, growth and immunity, which must come from food. Fat-soluble: A, D, E, K (stored in fat and liver). Water-soluble: B complex and C (not stored, lost in urine, so needed regularly).

Vitamins: sources and functions (high value for 1x3 answers)

- Vitamin A: carrots, sweet potatoes, spinach, kale, liver, eggs, dairy. Function: vision, immunity, skin health.
- Vitamin B complex: whole grains, meat, fish, eggs, milk, legumes, leafy greens. Function: energy production, red blood cells, nervous system.
- Vitamin C: oranges, strawberries, kiwi, bell peppers, broccoli, tomatoes. Function: immune system, antioxidant, collagen formation. Deficiency disease: scurvy (this name is not in the book text, it is general knowledge, so state it with confidence only if your teacher has covered it).
- Vitamin D: sunlight on skin, fatty fish (salmon, mackerel), fortified milk, egg yolk. Function: calcium absorption and healthy bones. Deficiency: rickets (general knowledge, not in the book text).
- Vitamin E: nuts, seeds, spinach, vegetable oils. Function: antioxidant. Vitamin K: leafy greens, broccoli. Function: blood clotting and bone health.

Applications and genetics

- Blood tests: measure ions, enzymes, sugars, lipids and proteins to check kidney, liver and other organ function. Pregnancy test: detects the hormone hCG (human chorionic gonadotropin) in urine or blood. Cancer screening: finds early signs in people without symptoms. Parental genetic screening: finds the chance of a child having a serious genetic disorder; also used to determine parentage.
- Gene: unit of DNA on a chromosome that controls a trait and is passed from parent to child.
- Genetic engineering: modifying an organism's DNA in the lab by adding, removing or repairing genes (vaccines, drugs). Gene therapy: inserting a healthy copy of a defective gene into a patient's cells to treat or prevent disease; it targets faulty cells, not all DNA.
- Cloning: producing a genetically identical copy. Three types: reproductive (identical organisms), therapeutic (embryonic stem cells for medical research and treating spinal injury, diabetes, Parkinson's), gene cloning (copying specific genes or DNA segments).

Past-paper questions with model answers

- Two sources of vitamin A (B), vitamin D (B, M), vitamin C (M) and state one function or deficiency disease (1x3): use the list above.
- How do amino acids join to form a protein, with an equation (B, 3 marks): amino group of one reacts with the carboxyl group of another, losing water to form a peptide bond (-CO-NH-); $H_2N\text{-}CHR\text{-}COOH + H_2N\text{-}CHR'\text{-}COOH \rightarrow H_2N\text{-}CHR\text{-}CO\text{-}NH\text{-}CHR'\text{-}COOH + H_2O$; thousands of units give a protein.
- Draw the general structure of an amino acid and label the main functional groups (B, D); draw the general structure of a dipeptide from two amino acids (M).
- 2025 paper (old syllabus): the bonds holding amino acids together in proteins are peptide bonds; a tripeptide with its two peptide bonds marked.

Where the old 2025 syllabus differs (not in the NBF book)

- 2025 also asked: Law of Mass Action and Kc, self-ionisation and Kw of water, Lewis acids and bases, hardness of water (temporary and permanent), Solvay process, urea manufacture, ozone layer, troposphere against stratosphere, mono- and disaccharides, aquatic life in cold weather. These do not appear in your NBF book and the 2026 papers did not ask them. If your teacher still covers any of them, they are outside these notes.

Last-minute checklist

- Practise the four numerical types until they take under four minutes each: empirical and molecular formula, molarity, limiting reactant with a mass of product, mole to gas volume (24 dm^3).
- Memorise the equations: Haber, Contact, esterification, fermentation, combustion of CH_3OH and C_2H_5OH, ethene preparation (dehydration and dehydrohalogenation), Baeyer's test, hydrogenation, hydration, Daniell and electrolysis half-equations, fuel cell.
- Know one example equation each for amphoteric Al_2O_3, acidic SO_2 and CO_2, basic CuO and CaO.
- Be able to draw: propan-1-ol, butan-1-ol, butan-2-ol, an amino acid, a dipeptide, a Daniell cell, and the fractionating tower.