How to use these solutions

- For each question, read the **Approach** line first, then close the solutions and try the question again before reading on.
- When you have the answer, read why each wrong option is wrong.
- Most MCQ errors come from three habits: reading the question too quickly and missing "not", "incorrect" or a detail; skipping a step in a calculation; and choosing an option that is true but does not answer the question.

Answer key

Q	1	2	3	4	5	6	7	8	9	10
Ans	A	D	C	A	B	A	C	C	C	A
Q	11	12	13	14	15	16	17	18	19	20
Ans	B	B	D	C	A	D	D	B	B	C
Q	21	22	23	24	25	26	27	28	29	30
Ans	B	C	A	C	D	C	D	B	A	B
Q	31	32	33	34	35	36	37	38	39	40
Ans	D	B	A	C	B	B	C	B	B	D

Q1. Answer: A

Topic: Salt preparation (insoluble base + acid)

Approach: Write the steps first: add excess solid CuO to the acid, filter off the excess, then crystallise the filtrate. Then look for the option that has apparatus for every step.

- **A is correct.** Measuring cylinder and beaker to react the acid with excess CuO; filter funnel and paper to remove the unreacted CuO; evaporating dish to crystallise $CuCl_2$ from the filtrate.
- B: no evaporating dish, so the salt cannot be recovered from the solution.
- C and D: no filtration step, so the excess solid CuO stays in the product. A burette and pipette are for titration, which is only used when both reactants are soluble.

Q2. Answer: D

Topic: Separation techniques

Approach: Take each separation in turn and ask what physical property differs. Rule out options as soon as one column is wrong.

- **D is correct.** 1: water is boiled off and condensed from the dissolved KCl, so **distillation**. 2: iodine sublimes and iron does not, so **sublimation**. 3: the water is evaporated to leave solid KCl, so **evaporation**. 4: ethanol and water are **miscible liquids** with different boiling points, so **fractional distillation**.
- A: only one liquid is being collected in 1, so fractional distillation is not needed. Crystallisation cannot separate iodine from iron.
- B: filtration cannot separate a dissolved solid (KCl) from water in 3.
- C: filtration cannot recover water from a solution in 1.

Q3. Answer: C

Topic: Chromatography

Approach: Distance travelled tells you solubility in the solvent. Then test each statement against what R_F and the start line mean.

- **C is correct.** X travels further up the paper than Y, so X is **more soluble** in the solvent.
- A: the solvent must be **below** the start line. If it were above Z, the spots would dissolve straight into the solvent in the beaker.
- B: R_F = distance moved by substance ÷ distance moved by solvent. It is a **ratio**, so it stays the same when the paper is longer.
- D: a locating agent is needed only for **colourless** substances, not always.

Q4. Answer: A

Topic: Diffusion and relative molecular mass

Approach: At the same temperature and pressure, gases diffuse at the same rate only if they have the same M_r. Work out every M_r before looking at the pairs.

gas	CO	N_2O	C_2H_4	C_3H_8	N_2
M_r	28	44	28	44	28

- Pair 1 is a match: N_2 and C_2H_4 are both 28.
- Pair 2 is a match: CO and N_2 are both 28.
- Pair 3 is a match: N_2O and C_3H_8 are both 44.
- Pair 4 is not a match: C_2H_4 is 28 but C_3H_8 is 44, so C_2H_4 diffuses **faster** (lower M_r, faster diffusion).
- **A is correct** (1, 2 and 3).

Q5. Answer: B

Topic: Atomic structure of ions

Approach: Tabulate protons, neutrons and electrons for each ion. Electrons = protons − charge.

ion	protons	neutrons	electrons
Fe^{2+}	26	56 − 26 = 30	24
Co^{3+}	27	59 − 27 = 32	24
Mn^{2+}	25	56 − 25 = 31	23

- **B is correct.** Only Fe^{2+} and Co^{3+} have 24 electrons.
- A: all three have different numbers of neutrons.
- C: all three are different elements, so they have different numbers of protons.
- D: Fe^{2+} and Mn^{2+} both have a nucleon number of 56, so they have the same relative mass.

Q6. Answer: A

Topic: Covalent bonding (lone pairs)

Approach: Draw each molecule and look for lone pairs. An atom with a lone pair has outer electrons that are not used in bonding.

- **A is correct.** C forms four bonds and uses all four outer electrons. Each H forms one bond and uses its one electron.
- B: F in HF has **three lone pairs**.
- C: N in NH_3 has **one lone pair**.
- D: O in CH_3OH has **two lone pairs**.

Q7. Answer: C

Topic: Ionic lattice structure

Approach: In an ionic lattice, oppositely charged ions sit next to each other. Look along every edge of each cube for two ions of the same colour side by side.

- **C is correct.** Black and white ions alternate along every edge, so each Ca^{2+} ion is next to S^{2-} ions only.
- A, B and D: each has at least one edge where two ions of the same charge are next to each other. Like charges repel, so this arrangement is not stable.

Q8. Answer: C

Topic: Giant covalent and simple molecular structures

Approach: Check each statement for the one detail that is wrong: a number, or a particle type.

- **C is correct.** Poly(ethene) is made of molecules. Melting overcomes the **intermolecular forces** between the chains; the covalent bonds are not broken.
- A: each Si atom is bonded to **four** oxygen **atoms**. Silicon dioxide is covalent, so there are no oxide ions.
- B: each carbon atom in diamond is bonded to **four** other carbon atoms.
- D: graphite conducts because of **delocalised electrons** between the layers, not ions.

Q9. Answer: C

Topic: Writing formulae from ions

Approach: Get the charge on each ion first. NaSCN tells you thiocyanate is SCN^-; copper(II) is Cu^{2+}. Balance the charges.

- **C is correct.** One Cu^{2+} needs two SCN^- ions: $Cu(SCN)_2$.
- A and D: a 1 : 1 ratio would need Cu^+, which is copper(I).
- B: Cu_2SCN would need a thiocyanate ion with a 2− charge.

Q10. Answer: A

Topic: Moles and covalent bonding

Approach: Balance the equation to find moles of water, then count shared electrons per water molecule. Note "electrons", not "bonds".

- $C_3H_6 + 4.5O_2 \rightarrow 3CO_2 + 3H_2O$, so 0.5 mol propene gives 3 × 0.5 = 1.5 mol water.
- Each water molecule has two O-H single bonds, and each bond shares two electrons, so 4 shared electrons per molecule.
- **A is correct.** 1.5 × 4 = 6 mol of shared electrons = $6 \times 6 \times 10^{23} = 3.6 \times 10^{24}$.
- B: 2 mol, which uses 0.5 mol of water (the propene) instead of 1.5 mol.
- C: 3 mol, which counts the **bonds** and not the electrons.
- D: 1 mol, which makes both errors.

Q11. Answer: B

Topic: Moles and extraction of metals

Approach: Find moles of Fe_3O_4, then remember each formula unit contains **three** Fe atoms.

- $M_r(Fe_3O_4)$ = (3 × 56) + (4 × 16) = 232, so 116 g is 0.5 mol.
- **B is correct.** Moles of Fe = 3 × 0.5 = 1.5 mol; mass = 1.5 × 56 = 84 g.
- A: 1 mol of Fe, which fits neither the mole ratio nor the mass given.
- C: 2 mol of Fe, a wrong mole ratio.
- D: 3 mol of Fe, which forgets that only 0.5 mol of Fe_3O_4 is present.

Q12. Answer: B

Topic: Titration and formula of a salt

Approach: Find the mole ratio of hydroxide to acid. The ratio tells you how many OH^- the metal hydroxide has, and so the charge on M.

- Moles of hydroxide = 10 ÷ 1000 × 2.0 = 0.0200 mol. Moles of H_2SO_4 = 50 ÷ 1000 × 0.20 = 0.0100 mol.
- Ratio 2 : 1, so $2MOH + H_2SO_4 \rightarrow M_2SO_4 + 2H_2O$. M forms M^+ ions.
- **B is correct.** Two M^+ balance one SO_4^{2-}: M_2SO_4.
- A: MSO_4 would need M^{2+}, which reacts 1 : 1 with H_2SO_4.
- C: $M_2(SO_4)_3$ would need M^{3+}.
- D: $M(SO_4)_2$ would need M^{4+}.

Q13. Answer: D

Topic: Percentage purity

Approach: Build the calculation in four steps: moles of water, moles of NH_4NO_3 (use the 1 : 2 ratio), mass of NH_4NO_3, then divide by the mass of the impure sample.

- Moles of H_2O = 28 ÷ 18. Moles of NH_4NO_3 = 28 ÷ 18 × ½ = 28 ÷ 36.
- Mass of NH_4NO_3 = 28 ÷ 36 × 80, where 80 is $M_r(NH_4NO_3)$.
- **D is correct.** Percentage purity = (28 ÷ 36) × (80 ÷ 90) × 100.
- A: misses the 1 : 2 mole ratio (uses 28 ÷ 18).
- B and C: 90 ÷ 80 is upside down. Divide the pure mass (80 per mole) by the sample mass (90 g). C also misses the mole ratio.

Q14. Answer: C

Topic: Acids and pH

Approach: pH depends on the concentration of H^+ ions, not on how much acid was dissolved.

- **C is correct.** A dilute strong acid and a more concentrated weak acid can give the same H^+ concentration, and so the same pH.
- A: pH measures the concentration of **H^+ ions**, not of the acid.
- B: H^+ ions **gain** electrons to form hydrogen: $2H^+ + 2e^- \rightarrow H_2$.
- D: universal indicator turns red, orange or yellow in acid. Blue means alkaline.

Q15. Answer: A

Topic: Identifying gases (ammonia)

Approach: Damp universal indicator turning blue means an **alkaline gas**. The only alkaline gas in the syllabus is ammonia. Which pair gives off ammonia?

- **A is correct.** An alkali heated with an ammonium salt gives off ammonia: ammonium chloride + barium hydroxide → salt + water + NH_3.
- B: neutralisation gives salt and water only; no gas.
- C: no reaction occurs.
- D: gives carbon dioxide, an **acidic** gas, which turns the paper red or orange.

Q16. Answer: D

Topic: Choosing a salt preparation method

Approach: Check each option on three points: is it safe, does the reaction happen, and will the product be pure.

- **D is correct.** Ag*Cl* is insoluble. Mixing aqueous silver nitrate with dilute H*Cl* precipitates it, and it is filtered, washed and dried.
- A: potassium reacts **explosively** with acid, so it is not safe.
- B: $CaSO_4$ is insoluble. It coats the calcium oxide, the reaction stops, and the product is mixed with unreacted CaO.
- C: copper is below hydrogen in the reactivity series, so it does **not react** with dilute sulfuric acid.

Q17. Answer: D

Topic: Salt preparation methods

Approach: Sort the salts by solubility first. Insoluble salts need precipitation. Soluble salts of sodium, potassium and ammonium need titration. Other soluble salts use excess metal or insoluble carbonate.

- **D is correct.** Zinc chloride: zinc + H*Cl*. Ammonium sulfate: titration of aqueous ammonia with H_2SO_4. Iron nitrate: insoluble iron carbonate + nitric acid. Lead sulfate: insoluble, so precipitation.
- A: lead sulfate is insoluble, so it coats the metal and stops metal + acid. Zinc chloride is soluble, so it cannot be precipitated.
- B: zinc chloride needs no titration, because excess zinc can be filtered off. Sodium carbonate is soluble, so the excess cannot be filtered off; sodium sulfate needs titration.
- C: lead sulfate is insoluble, so it cannot be made from carbonate + acid. Sodium sulfate is soluble, so it cannot be precipitated.

Q18. Answer: B

Topic: Haber process

Approach: The question asks for the statement that is **not** correct. Recall what a catalyst changes and what it does not.

- **B is correct.** The iron catalyst increases the **rate** of reaction. It does not change the percentage yield.
- A: true. $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$.
- C: true. Cracking of oil is a source of hydrogen.
- D: true. The reaction is **reversible**, so some ammonia breaks down to nitrogen and hydrogen, and the yield is below 100%.

Q19. Answer: B

Topic: Precipitation and colours

Approach: Name the colour of each reactant solution and each product before reading the options. $NaI(aq) + AgNO_3(aq) \rightarrow NaNO_3(aq) + AgI(s)$.

- **B is correct.** Both reactant solutions are colourless. Silver iodide is a **yellow** precipitate, and sodium nitrate solution is colourless.
- A: a white precipitate would be silver chloride, not silver iodide.
- C and D: sodium iodide solution is colourless, not yellow.

Q20. Answer: C

Topic: Qualitative analysis

Approach: Use each branch for one ion. The sodium hydroxide branch identifies the cation; the lead(II) nitrate branch identifies the anion.

- **C is correct.** A white precipitate that dissolves in excess NaOH(aq) means Zn^{2+} or Al^{3+}. A white precipitate with acidified lead(II) nitrate means Cl^- (lead(II) chloride). Zinc chloride fits both.
- A: Al^{3+} fits, but nitrate ions give no precipitate with lead(II) nitrate.
- B: Na^+ gives no precipitate with NaOH(aq).
- D: calcium sulfate does not dissolve in water to give a solution, and calcium hydroxide does not dissolve in excess NaOH(aq).

Q21. Answer: B

Topic: Redox and oxidation states

Approach: Work out the oxidation state of each element that changes. Disproportionation needs the **same element** to go both up and down.

- **B is correct.** Br goes from 0 in Br_2 to −1 in NaBr (reduced) and to +1 in NaOBr (oxidised).
- A: Cu is oxidised (0 to +2) but N is reduced (+5 to +4). Two different elements.
- C: S is oxidised (+4 to +6) and O in H_2O_2 is reduced (−1 to −2). Two different elements.
- D: Cu is oxidised (0 to +2) and S is reduced (+6 to +4). Two different elements.

Q22. Answer: C

Topic: Electrolysis of molten compounds

Approach: Opposite charges attract. Cations go to the cathode and are reduced; anions go to the anode and are oxidised.

- **C is correct.** At the cathode: $K^+(l) + e^- \rightarrow K(l)$. Gaining electrons is reduction.
- A: Cl^- ions move to the **positive** electrode.
- B: Cl^- ions **lose** electrons, so they are oxidised: $2Cl^-(l) \rightarrow Cl_2(g) + 2e^-$.
- D: K^+ ions move to the **negative** electrode.

Q23. Answer: A

Topic: Electrolysis of aqueous solutions

Approach: X is joined to the positive terminal, so X is the anode and Y is the cathode. Then apply the selective discharge rules at each electrode.

- **A is correct.** At anode X, the **high concentration** of I^- means iodide is discharged over OH^-: $2I^- \rightarrow I_2 + 2e^-$. At cathode Y, M is less reactive than L, so M^{2+} is discharged: $M^{2+} + 2e^- \rightarrow M$.
- B: oxygen would need OH^- to be discharged, but I^- is concentrated. L is the more reactive metal, so its ions stay in solution.
- C and D: these put the cathode products at X and the anode product at Y, the wrong way round.

Q24. Answer: C

Topic: Electrolysis in series

Approach: The two cells are in **series**, so the same current, and the same number of electrons, flows through both. What can make the mass deposited different?

- **C is correct.** Q and S are both cathodes where metal is deposited. With the same electrons passing, a different mass means a different metal, with a different A_r or charge. So the cations must differ.
- A: in a series circuit the current is the same in both cells.
- B: nothing in the data tells you about the anions.
- D: platinum is inert, so neither P nor R loses mass.

Q25. Answer: D

Topic: Simple cells (electrochemical cells)

Approach: In a simple cell, the more reactive metal loses electrons. Electrons flow to the less reactive metal, where hydrogen is released. So Y must be the **less reactive** metal.

- **D is correct.** Iron is more reactive than copper. Iron dissolves at X; electrons flow to copper at Y, where hydrogen bubbles off.
- A and B: zinc is more reactive than both copper and iron. Zinc would dissolve, and the bubbles would form at X.
- C: iron is more reactive than silver, so again the bubbles would form at X.

Q26. Answer: C

Topic: Periodic Table trends

Approach: Test each property across Period 3 (Na to Cl) before looking at the options.

- Property 2 increases: outer shell electrons go from 1 to 7.
- Property 4 increases: elements change from metal to non-metal.
- Property 1 does not increase steadily: +1, +2, +3, then −3, −2, −1.
- Property 3 does not increase: all elements in a period have the **same** number of inner shell electrons.
- **C is correct** (2 and 4).

Q27. Answer: D

Topic: Group trends (Groups 1 and 17)

Approach: Identify the elements from the proton numbers first: P = Na, Q = K, R = Br, S = I.

- **D is correct.** Oxidising power of the halogens decreases down Group 17, so bromine is a stronger oxidising agent than iodine.
- A: reactivity increases down Group 1, so potassium (Q) is more reactive than sodium (P).
- B: sodium and bromine form sodium bromide, an **ionic** compound.
- C: two non-metals form a **simple molecular** compound, not a giant structure.

Q28. Answer: B

Topic: Extraction of metals

Approach: Place each metal in the reactivity series. Very unreactive metals occur native; metals below carbon are reduced by carbon; metals above carbon need electrolysis.

- **B is correct.** Silver is unreactive and occurs as the metal. Iron and zinc are below carbon. Magnesium and sodium are above carbon, so they need electrolysis.
- A: magnesium is too reactive to occur as the metal.
- C: sodium is above carbon, so carbon cannot reduce its compounds.
- D: magnesium does not occur as the metal, and potassium cannot be reduced by carbon.

Q29. Answer: A

Topic: Energy profiles and activation energy

Approach: Sketch the energy profile. Endothermic in reverse means exothermic forward, so the reactants sit 196 kJ/mol above the products.

- E_a(reverse) is measured from the products up to the peak. E_a(forward) is measured from the reactants, which are 196 kJ/mol higher.
- **A is correct.** E_a(forward) = 271 − 196 = 75 kJ/mol.
- B: 121 does not come from any correct use of the profile.
- C: 196 kJ/mol is the enthalpy change, not an activation energy.
- D: 271 kJ/mol is the activation energy of the **reverse** reaction.

Q30. Answer: B

Topic: Bond energies and enthalpy change

Approach: Two facts settle this: bond breaking takes in energy, bond forming releases energy. A negative ΔH means more is released than taken in.

- **B is correct.** ΔH is negative, so the reaction is exothermic: energy released in forming bonds is **greater** than energy taken in to break bonds.
- A: this describes an endothermic reaction.
- C and D: both have the energy directions reversed. Forming bonds releases energy; breaking bonds takes it in.

Q31. Answer: D

Topic: Rates of reaction (mass-loss graph)

Approach: Compare the initial gradient (rate) and the final mass loss (amount of hydrogen). The mass falls because H_2 escapes. Moles of Zn = 1.0 ÷ 65 = 0.015 mol; moles of acid = 0.025 mol, so zinc is limiting.

- **D is correct.** In both experiments the mass is still falling between 10 s and 20 s, so acid is still being used up. Its concentration at 20 s is lower than at 10 s.
- A: experiment 1 is the **slower** one. A catalyst would also not change the final mass.
- B: experiment 2 loses **more** mass, so more hydrogen is made. With zinc limiting, experiment 2 used more zinc.
- C: experiment 1 has the less steep initial gradient, so it is slower, not hotter. Temperature would also not change the final mass.

Q32. Answer: B

Topic: Rates of reaction (volume-time graph)

Approach: Work out two things: which experiment is faster (concentration) and whether the final volumes are the same (moles of the limiting reactant, HC*l*).

- Moles of HC*l*: experiment 1 = 50 ÷ 1000 × 0.20 = 0.010 mol; experiment 2 = 20 ÷ 1000 × 0.50 = 0.010 mol. $CaCO_3$ is in excess, so both give the **same final volume**.
- **B is correct.** Experiment 2 uses more concentrated acid, so its curve is steeper at the start, and both curves level off at the same volume.
- A and C: experiment 1 is shown as ending with more gas. C also makes experiment 1 faster.
- D: experiment 2 is shown as ending with more gas.

Q33. Answer: A

Topic: Fractional distillation of crude oil

Approach: The bottom of the column is the hottest part, so only the largest molecules condense and leave there. Then list the properties of large hydrocarbon molecules.

- **A is correct.** Bottom fractions have large molecules, which are the **least flammable**.
- B: large molecules are the **most** viscous.
- C: bottom fractions have the **highest** relative molecular mass.
- D: bottom fractions have the **highest** boiling points. Low boiling points leave at the top.

Q34. Answer: C

Topic: Cracking

Approach: Try each ratio and check that both carbon and hydrogen atoms balance with $C_{12}H_{26}$.

option	C atoms	H atoms
A (1 : 1 : 1)	2 + 3 + 3 = 8	4 + 8 + 6 = 18
B (1 : 1 : 3)	2 + 3 + 9 = 14	4 + 8 + 18 = 30
C (3 : 1 : 1)	6 + 3 + 3 = 12	12 + 8 + 6 = 26
D (1 : 3 : 1)	2 + 9 + 3 = 14	4 + 24 + 6 = 34

- **C is correct.** $C_{12}H_{26} \rightarrow 3C_2H_4 + C_3H_8 + C_3H_6$. Only C balances 12 C and 26 H.
- A, B and D: the atom counts do not match $C_{12}H_{26}$.

Q35. Answer: B

Topic: Isomers and substitution

Approach: The molecule is methylpropane, $CH(CH_3)_3$. The three CH_3 groups are equivalent. The central C has only one H, so it can take at most one C*l*. List the distinct places the two C*l* atoms can go.

- Both C*l* on the same CH_3 group: $(CH_3)_2CH\text{-}CHCl_2$.
- One C*l* on the central C and one on a CH_3: $(CH_3)_2CCl\text{-}CH_2Cl$.
- One C*l* on each of two CH_3 groups: $ClCH_2\text{-}CH(CH_3)\text{-}CH_2Cl$.
- **B is correct.** There are 3 isomers. Two C*l* on the central C is impossible, and any other arrangement is one of these three drawn differently.
- A: misses one of the three. C and D: count the same structure more than once.

Q36. Answer: B

Topic: Esterification

Approach: Count H in each reactant, then subtract the H atoms that leave in the water molecule.

- Acid $C_xH_yCO_2H$ has y + 1 H. Alcohol $C_nH_{2n+1}OH$ has 2n + 2 H. Total = y + 2n + 3.
- Water (H_2O) is removed: the OH from the acid and the H from the alcohol, taking 2 H.
- **B is correct.** y + 2n + 3 − 2 = y + 2n + 1.
- A: forgets to remove the water.
- C: removes only one H.
- D: removes three H.

Q37. Answer: C

Topic: Functional groups (alkene and alcohol)

Approach: Spot the functional groups first: a C=C double bond, an -OH group, and alkane-like C-H parts. Then test each statement against them.

- Statement 1 is true: the saturated C-H parts undergo **substitution** with chlorine in UV light, as alkanes do.
- Statement 2 is true: the C=C bond (and the -OH group) is oxidised by acidified potassium manganate(VII), which turns from purple to colourless.
- Statement 4 is true: the C=C bond allows **addition polymerisation**, and an addition polymer has the same empirical formula as its monomer.
- Statement 3 is false: an alcohol is not acidic, so it does not react with sodium hydroxide to form a salt.
- **C is correct** (1, 2 and 4).

Q38. Answer: B

Topic: Organic reaction pathways

Approach: Work backwards from the salt. $(CH_3CH_2CH_2CO_2)_2Mg$ contains butanoate, so the acid is butanoic acid, the alcohol is butan-1-ol, and the alkene has **four carbons**.

- **B is correct.** But-1-ene, $CH_3CH_2CH{=}CH_2$, has four carbons with the C=C at the end of the chain, so hydration gives butan-1-ol, which oxidises to butanoic acid.
- A: propene has only three carbon atoms.
- C: but-2-ene has the C=C in the middle of the chain, so the -OH ends up on the second carbon, not the end one.
- D: pent-1-ene has five carbon atoms.

Q39. Answer: B

Topic: Polymers

Approach: Classify each polymer by linkage first. Nylon has **amide** linkages, so it is a condensation polymer. Poly(ethene) is made from ethene by addition.

- **B is correct.** Nylon is a condensation polymer and is used as a fibre, for example in sleeping bags.
- A: nylon is not an addition polymer.
- C: poly(ethene) is an addition polymer, but its use in this set is cling film, not sleeping bags.
- D: poly(ethene) is not a condensation polymer.

Q40. Answer: D

Topic: Air pollution and acid rain

Approach: Acid rain comes from **acidic oxides** of non-metals dissolving in rainwater. Check each gas: is it acidic?

- **D is correct.** SO_2 and NO_2 are both acidic oxides that dissolve in rainwater to form acids.
- A and C: CO is a **neutral** oxide and does not form acid rain.
- B: CH_4 is not an oxide; it contributes to global warming, not acid rain.