Chemistry 6092/02 Paper 2, Oct/Nov 2026 (Questions 1–5)

Model answers aligned to **Chemistry Matters GCE 'O' Level Textbook, 3rd Edition (Marc Chang, Alistair Chew, John Sadler, Tan Yin Toon, Wong Heng-Vee, Woo Chang Hong; Marshall Cavendish Education, 2023; ISBN 978-981-4988-05-6)** · Page numbers are the printed page numbers of the book; 'PDF p.' is the page of the 460-page full PDF 'Chemistry Matters GCE O Level (3rd ed).pdf', counting from 1, which equals printed page + 12 throughout the numbered chapters. Printed numbers for pp. 416–417 (carbon cycle) are cropped off in the PDF; they are inferred from p. 418 and agree with the book's index (carbon cycle: 416–417). The Answer Key pages are printed pp. 427 (Chapter 3) and 437 (Chapter 22).

> This is the model answer sheet for Questions 1–5 of the real Chemistry 6092/02 Paper 2 (Oct/Nov 2026), aligned to Chemistry Matters (3rd ed.). Every textbook quotation is verbatim from the printed page (full defining sentences, paragraphs, list items and worked-example lines), and each mark point is worded as far as possible in the book's own scientific language. Cambridge has not released a mark scheme, so these are teacher-grade answers, not the official ones; where a mark could be split differently the accept notes say so.

Concepts not (fully) covered by the textbook

Parts by status: In the textbook **34** · Partly in the textbook **10** · NOT in the textbook **0** · Data skill (answered from the question) **0**

Part	Concept	Status	What to do
3(c)	Charge on a nucleus equals + (proton number)	Partly in the textbook	Teach with Table 3.1 (p. 47): the nucleus holds the protons (+1 each) and neutrons (0), so nuclear charge = +proton number; drill writing the sign (+35, not 35).
5(c)	Deducing the molecular formula (C_6H_{14}, an alkane) from an impossible empirical formula (C_3H_7) to decide saturation	Partly in the textbook	Add a short exercise: multiply an empirical formula by 1, 2, 3 and test each against C_nH_{2n+2} and C_nH_{2n}; link the result to the aqueous bromine test (p. 357).
6(b)	Counting bonds by type from displayed formulae (reactants C=C 1, C–H 4, O–H 2; product C–C 1, C–H 5, C–O 1, O–H 1)	Partly in the textbook	After the steam-addition equation on p. 349, have students draw ethene, steam and ethanol in full and tally the bonds by type; then link the tally to bond breaking and bond making (pp. 286, 291).
7(c)(i)	A reactive (copper) anode loses exactly the mass the cathode gains (5.0 g − 0.32 g = 4.68 g)	Partly in the textbook	With Figures 13.13 and 13.15 (pp. 230, 232) add the line 'the same number of electrons flows, so the mass lost at the anode equals the mass gained at the cathode' and set one numerical prediction like this.
8(c)	Overall equation for charging a rechargeable battery: the reverse of discharge, built by adding the two half-equations and cancelling Li^+ and e^-	Partly in the textbook	Add a short note to 13.4: charging is the discharge reactions reversed (an electrolytic process); practise adding two half-equations and cancelling ions and electrons, as on p. 228.
8(e)	Why Li^+ is smaller than most other metal ions (it has only one occupied electron shell)	Partly in the textbook	Teach explicitly that an ion is smaller than its atom when the outer shell is lost and that ion size follows the number of occupied shells (Li^+ 2; Na^+ 2, 8; K^+ 2, 8, 8); use pp. 53, 62, 247 and 249.
9(a)(i)	Products of complete combustion of a polymer made of C, H and O (carbon dioxide and water)	Partly in the textbook	Extend the rule 'complete combustion of a compound of C, H and O gives carbon dioxide and water' (pp. 348, 366) to plastics such as poly(ethene) and PAA, and contrast it with PVC giving hydrogen chloride (p. 396).

9(b)	Dot-and-cross diagram of a carboxylic acid (C=C, C=O and O–H in one molecule)	Partly in the textbook	After Worked Example 4C (p. 75), practise building dot-and-cross diagrams from valencies (C 4, O 2, H 1) for ethanoic acid and propenoic acid; check lone pairs on both oxygens.
10(b)	Deciding the state of a substance at a given temperature by comparing it with its melting and boiling points	Partly in the textbook	Add the rule 'below the melting point = solid; between melting and boiling point = liquid; above the boiling point = gas' (p. 28) and drill it with Table 5.3 and the ionic and giant covalent data (pp. 86–92).
11(c)	Group 1 compounds are colourless, so 'forms coloured compounds' shows an element is not Group 1	Partly in the textbook	Tell students explicitly that Group 1 compounds are white/colourless while transition metal compounds are coloured (p. 255), and pair it with the melting-point contrast (Table 14.4 against Table 14.8, p. 254).

Question 1 — Air pollution, the carbon cycle and global warming [8]

1(a)(i) **[2]**

State the names of two pollutant gases that cause acid rain.

- sulfur dioxide (SO_2) [1]
- nitrogen dioxide (NO_2) / nitrogen oxides (the book's own wording is 'sulfur dioxide and nitrogen oxides' and 'sulfur dioxide and nitrogen dioxide') [1]

Either order. Accept the formulae SO_2 and NO_2, 'NOx', and nitrogen monoxide / nitric oxide (NO) for the second mark. Reject carbon dioxide (it makes natural rain only slightly acidic and is not the pollutant behind acid rain), carbon monoxide, methane, ozone, and the elements 'sulfur' or 'nitrogen'. A bare 'sulfur oxide' is risky; the safe wording is sulfur dioxide and nitrogen dioxide.

Ch 22 Maintaining Air Quality › 22.2 What Are Air Pollutants? (Table 22.2, Harmful Effects column for sulfur dioxide and nitrogen oxides) › p. 409 (PDF p. 421)

"Sulfur dioxide causes breathing difficulties in humans and animals. Sulfur dioxide and nitrogen oxides react with oxygen in the air to form acidic compounds which dissolve in rain water, forming solutions of strong acids. This is called acid rain."

Ch 22 Maintaining Air Quality › 22.2 What Are Air Pollutants? (Acid Rain) › p. 410 (PDF p. 422)

"However, when rain combines with excessive amounts of sulfur dioxide and nitrogen dioxide produced by human activity, it can have a pH of around 4.0."

Ch 22 Maintaining Air Quality › Let's Map It (chapter summary map) › p. 425 (PDF p. 437)

"Acid rain (NO_2 and SO_2)"

Ch 22 Maintaining Air Quality › Let's Review (chapter review questions), Section B, question 2 › p. 426 (PDF p. 438)

"Two oxides of nitrogen are air pollutants. One is acidic and the other is neutral. (a) Name the two oxides. (b) Identify the oxide that is acidic and explain how it causes harm to the natural environment."

Ch 22 Maintaining Air Quality (Answer Key) › Let's Review (chapter review questions), Section B, answer 2 › p. 437 (PDF p. 449)

"(a) Nitric oxide and nitrogen dioxide (b) Nitrogen dioxide is acidic. It dissolves in rain to form acid rain which can kill plants and marine life."

In the textbook

LO: 12(e), 12(b)

1(a)(ii) **[1]**

Describe one harmful effect of acid rain.

- Any ONE, in the book's wording: acid rain kills plants and aquatic life; OR it corrodes buildings and structures made from limestone, marble and metals; OR it leaches essential nutrients like magnesium and calcium from the soil, which hampers the health and growth of trees; OR it lowers the pH of a lake or pond out of the survivable range, so the water body is less biodiverse; OR sulfur dioxide (one of the gases that cause it) causes breathing difficulties in humans and animals [1]

Syllabus 12(e)(ii) names respiration (breathing) and buildings, so those two are the likeliest mark-scheme points; plants and aquatic life are equally correct and are the book's first-named effects. The effect must be specific and harmful: 'pollution' or 'harms the environment' is too vague. Reject global warming and ozone-layer depletion (other pollutants' effects).

> **Ch 22 Maintaining Air Quality › 22.2 What Are Air Pollutants? (Table 22.2, Harmful Effects column) › p. 409 (PDF p. 421)**
> *"Acid rain kills plants and aquatic life. It also corrodes buildings and structures made from limestone, marble and metals."*

> **Ch 22 Maintaining Air Quality › 22.2 What Are Air Pollutants? (Acid Rain) › p. 410 (PDF p. 422)**
> *"Frequent exposure to acid rain can have devastating effects on forests and water bodies. Acid rain leaches essentials nutrients like magnesium and calcium from the soil, which hampers the health and growth of trees (Figure 22.5). Acid rain can also lower the pH of soil below what many plant species can tolerate, killing them."*

> **Ch 22 Maintaining Air Quality › 22.2 What Are Air Pollutants? (Acid Rain) › p. 410 (PDF p. 422)**
> *"Aquatic organisms are also very susceptible to pH changes. Over time, the addition of acidic rainwater to a water body like a lake or a pond can cause the pH to drop out of the survivable range."*

In the textbook

LO: 12(e)

1(b)(i) **[2]**

State two processes that add carbon dioxide to the atmosphere.

- Any TWO of the three processes the book names: respiration [1]; combustion [1]; decomposition [1]
- in the book's wording: living organisms gain the energy for life processes by breaking down glucose back into carbon dioxide and water, which are released into the atmosphere (respiration); carbon dioxide is a product of combustion; aerobic decomposition occurring in the presence of oxygen releases carbon dioxide into the atmosphere

Syllabus 12(g)(i) names combustion and respiration, so those two are the likeliest scheme answers. Accept examples of combustion (burning petrol, coal, natural gas, wood; power stations; vehicles; forest fires), and volcanic eruptions or heating of limestone. 'Breathing' is weaker than 'respiration'. 'Deforestation / clearing of forests' is risky: the book (p. 420 and Table 22.3) does call it a large contributor to carbon dioxide emissions, but it is not one of the carbon cycle's three named processes and it works partly by removing a sink, so the official scheme may not credit it unless the burning of forests is stated. Reject photosynthesis and 'ocean uptake' (these remove CO_2). The book's own review question (p. 426, Section B, question 4(c)) asks for exactly this and its key accepts 'Respiration / decomposition / combustion (Any two)'.

> **Ch 22 Maintaining Air Quality › 22.4 What Is the Carbon Cycle? (The Carbon Cycle, Respiration) › p. 416 (PDF p. 428)**
> *"Living organisms gain the energy for life processes by breaking down glucose back into carbon dioxide and water, which are released into the atmosphere."*

> **Ch 22 Maintaining Air Quality › 22.4 What Is the Carbon Cycle? (Combustion) › p. 417 (PDF p. 429)**
> *"Most fossil fuels contain mainly methane. They are burnt in the presence of oxygen to generate energy. Carbon dioxide is a product of combustion."*

> **Ch 22 Maintaining Air Quality › 22.4 What Is the Carbon Cycle? (Decomposition) › p. 417 (PDF p. 429)**
> *"Dead organisms are broken down into simpler compounds by decomposers. Aerobic decomposition occurring in the presence of oxygen releases carbon dioxide into the atmosphere."*

Ch 22 Maintaining Air Quality › 22.5 What Are Global Warming and Climate Change? (after the greenhouse-effect discussion) › p. 420 (PDF p. 432)

"The combustion of fossil fuels in factories, power plants and vehicles is a major contributor of atmospheric carbon dioxide. In 2019, these sources produced 36.7 billion tonnes of carbon dioxide, or about 4700 kg per human on Earth. The clearing of forests for agriculture is also a large contributor to carbon dioxide emissions. It has the added effect of reducing the number of plants available to absorb and retain carbon."

Ch 22 Maintaining Air Quality › Let's Map It (chapter summary map) › p. 425 (PDF p. 437)

"Production of CO_2 • Respiration • Decomposition • Combustion"

Ch 22 Maintaining Air Quality (Answer Key) › Let's Review (chapter review questions), Section B, answer 4(c) › p. 437 (PDF p. 449)

"(c) Respiration / decomposition / combustion (Any two)"

In the textbook

LO: 12(g)

1(b)(ii) **[1]**

State one process that removes carbon dioxide from the atmosphere.

- photosynthesis: plants take in carbon dioxide and water to make glucose and oxygen in the presence of sunlight [1]
- (the book's second removal process, also acceptable: ocean uptake, oceans and other large bodies of water absorb carbon dioxide)

Accept 'plants taking in carbon dioxide to make glucose', and dissolving of carbon dioxide in the oceans / ocean uptake (the book's key accepts either: 'Photosynthesis / ocean uptake (Any one)'; the syllabus names only photosynthesis). Reject respiration and combustion. 'Planting trees' names an action, not a process; photosynthesis is the process wanted.

Ch 22 Maintaining Air Quality › 22.4 What Is the Carbon Cycle? (The Carbon Cycle, Photosynthesis) › p. 416 (PDF p. 428)

"Plants take in carbon dioxide and water to make glucose and oxygen in the presence of sunlight."

Ch 22 Maintaining Air Quality › 22.4 What Is the Carbon Cycle? (The Carbon Cycle, Ocean uptake) › p. 416 (PDF p. 428)

"Oceans and other large bodies of water absorb carbon dioxide. Some marine plants use the dissolved gas to photosynthesize. It is also converted to carbonic acid and calcium carbonate that make up the shells of marine organisms and accumulate on the seabed when they die."

Ch 22 Maintaining Air Quality › 22.4 What Is the Carbon Cycle? › p. 417 (PDF p. 429)

"The carbon cycle describes a set of processes that regulates the amount of carbon dioxide in the atmosphere."

Ch 22 Maintaining Air Quality › Let's Map It (chapter summary map) › p. 425 (PDF p. 437)

"Removal of CO_2 • Photosynthesis • Ocean uptake"

Ch 22 Maintaining Air Quality (Answer Key) › Let's Review (chapter review questions), Section B, answer 4(b) › p. 437 (PDF p. 449)

"(b) Photosynthesis / ocean uptake (Any one)"

In the textbook

LO: 12(g)

1(c) **[2]**

Describe two potential effects of global warming.

- Any TWO independent effects, one mark each, in the book's wording:
- glaciers and polar ice caps melt and shrink; sea levels would rise and permanently flood coastal areas [1]

- extreme weather phenomena like typhoons and tornadoes will become stronger and occur more frequently [1]
- also in the book: changes in rainfall patterns (lush areas receive too little rain and turn into deserts, other areas flood more often; fertile land becomes barren, causing food shortages); heat waves become more common; coral reefs bleach and die as oceans warm; acidified waters dissolve the shells of crustaceans

Syllabus 12(h) names 'more extreme weather events and melting of polar ice', so these are the likeliest scheme answers (and the book's own answer to its review question 3(c) is 'extreme weather conditions and melting of polar ice caps'). 'Rising sea level' caused by melting ice is probably the same effect as 'melting polar ice', so choose two independent effects. Reject 'temperature of the Earth rises' (that is global warming itself), ozone-layer depletion, acid rain, and 'more pollution'.

Ch 22 Maintaining Air Quality › 22.5 What Are Global Warming and Climate Change? › p. 418 (PDF p. 430)

"Global warming has major implications for human civilisation. It is predicted that extreme weather phenomena like typhoons and tornadoes will become stronger and occur more frequently. Parts of the world that are currently fertile will quickly become arid and barren. Island nations like Singapore are also likely to face challenges related to sea levels rising from melting polar ice sheets and the thermal expansion of ocean water."

Ch 22 Maintaining Air Quality › 22.5 What Are Global Warming and Climate Change? (Climate Change and Other Consequences, Change in Rainfall Patterns) › p. 421 (PDF p. 433)

"Shifting wind patterns can lead to changes in rainfall patterns. Lush areas might begin to receive too little rain and turn into deserts while other areas may receive too much rain and flood more often than before (Figure 22.19). Fertile land would become barren and will no longer be able to produce food, potentially causing food shortages."

Ch 22 Maintaining Air Quality › 22.5 What Are Global Warming and Climate Change? (Heat Waves) › p. 421 (PDF p. 433)

"Heat waves would also become more common. Some parts of the world would even become too hot for humans to live in."

Ch 22 Maintaining Air Quality › 22.5 What Are Global Warming and Climate Change? (Tropical Storms) › p. 422 (PDF p. 434)

"The warmer the ocean, the stronger these storms become. There has been a notable increase in their strength and frequency since the 1980s."

Ch 22 Maintaining Air Quality › 22.5 What Are Global Warming and Climate Change? (Glacial Retreat and the Melting of Polar Ice Caps) › p. 423 (PDF p. 435)

"Increases in average global temperatures have caused glaciers and polar ice caps to melt and shrink."

Ch 22 Maintaining Air Quality › 22.5 What Are Global Warming and Climate Change? (Glacial Retreat and the Melting of Polar Ice Caps) › p. 424 (PDF p. 436)

"It has been estimated that sea levels around the world would rise by more than 60 m if the ice caps completely melted. This would permanently flood most coastal cities like Singapore since 60 m is about 20 storeys high (Figure 22.26)!"

Ch 22 Maintaining Air Quality › 22.5 What Are Global Warming and Climate Change? (Table 22.4 Effects of climate change phenomena, last row) › p. 424 (PDF p. 436)

"glacial retreat and melting of polar ice caps • Glacier-fed river levels would change. • Sea levels would rise and permanently flood coastal areas. • Climate-stabilising ocean currents would be disrupted."

Ch 22 Maintaining Air Quality (Answer Key) › Let's Review (chapter review questions), Section B, answer 3(c) › p. 437 (PDF p. 449)

"(c) An increase in atmospheric greenhouse gases leads to an enhanced greenhouse effect, which causes global warming. This leads to extreme weather conditions and melting of polar ice caps. (Accept other possible answers.)"

In the textbook

LO: 12(h)

Question 2 — Enzyme-catalysed synthesis of vanillin [7]

2(a) **[2]**

Describe the role of the enzyme in the reaction that makes vanillin from aqueous glucose at 20 °C.

- biological catalysts are known as enzymes: the enzyme is a catalyst, it increases the rate of the chemical reaction without being chemically changed at the end of the reaction [1]
- it provides an alternative pathway of lower activation energy for the reaction to occur; this speeds up the rate of reaction [1]

The second mark may also be given for 'is not used up / is chemically unchanged at the end of the reaction' or for 'lets the reaction go quickly at the mild temperature of 20 °C'. Reject 'provides energy', 'increases the yield' (the book: 'They increase reaction rates but not the yield'), 'is a reactant' and 'speeds up the reaction by raising the temperature'.

Ch 17 Rate of Reactions › 17.3 What Are Catalysts and How Do They Affect the Rate of Reactions? › p. 311 (PDF p. 323)

"Yeast is added to dough during the bread-making process to help the bread rise. Yeast contains enzymes that break down the glucose in the dough into carbon dioxide gas and alcohol."

Ch 17 Rate of Reactions › 17.3 What Are Catalysts and How Do They Affect the Rate of Reactions? › p. 311 (PDF p. 323)

"Enzymes are part of a special group of substances called catalysts. A catalyst increases the rate of chemical reactions without being chemically changed at the end of the reaction."

Ch 17 Rate of Reactions › 17.3 What Are Catalysts and How Do They Affect the Rate of Reactions? (Effect of Catalyst on Reaction Rates) › p. 312 (PDF p. 324)

"Catalysts provide an alternative pathway of lower activation energy for the reaction to occur. This speeds up the rate of reaction."

Ch 17 Rate of Reactions › 17.3 What Are Catalysts and How Do They Affect the Rate of Reactions? (Effect of Catalyst on Reaction Rates) › p. 312 (PDF p. 324)

"Due to the alternative pathway with lower activation energy, more reactant particles will have energy greater than or equal to activation energy. This increases the frequency of effective collisions. Hence, the rate of reaction increases."

Ch 17 Rate of Reactions › 17.3 What Are Catalysts and How Do They Affect the Rate of Reactions? (Catalysts have the following characteristics) › p. 312 (PDF p. 324)

"Catalysts have the following characteristics: • They increase reaction rates but not the yield. • They are not used up in the reaction. • They are selective (i.e. they only catalyse certain reactions). • Impurities can poison them. • Their physical appearance may change but they remain chemically the same. • They provide an alternative pathway with a lower activation energy for the reaction."

Ch 17 Rate of Reactions › 17.3 What Are Catalysts and How Do They Affect the Rate of Reactions? (Biological Catalysts) › p. 314 (PDF p. 326)

"Biological catalysts are known as enzymes."

In the textbook

LO: 10(b), 10(d), 10(c)

2(b) **[2]**

A student says vanillin will be made more quickly at a higher temperature. Explain why the student is only partly correct.

- higher temperatures result in faster reaction rates: reactant particles have more kinetic energy, so they move and vibrate faster, and more reactant particles possess energy greater than or equal to the activation energy, increasing the frequency of effective collisions [1]
- but enzymes are temperature-sensitive: at high temperatures (above about 35–40 °C, where most enzymes operate best) the enzyme is denatured and is unable to catalyse the reaction, so the rate falls [1]

Both halves are needed: the 'true' half and the 'but' half. Accept 'enzyme is destroyed / stops working at high temperature' for the second mark; 'denatured' is the book's word and the expected one. Examiners usually reject 'enzyme is killed' (an enzyme is not alive) and 'enzyme melts'. Note 20 °C is below the optimum, so a modest rise would help; it is the high temperature that is the problem.

Ch 17 Rate of Reactions › 17.3 What Are Catalysts and How Do They Affect the Rate of Reactions? (Biological Catalysts, characteristic 2) › p. 314 (PDF p. 326)

"They are temperature-sensitive. A lot of enzymes operate best at body temperature (i.e. between 35 °C and 40 °C). Below these temperatures, the enzymes are dormant or can also be denatured. This reduces the catalytic activity. At high temperatures, enzymes are denatured and are unable to catalyse reactions."

Ch 17 Rate of Reactions › 17.2 What Determines the Rate of Reactions? (Effect of Temperature) › p. 308 (PDF p. 320)

"At higher temperatures, the rate of reaction is affected in two ways: 1. At higher temperatures, reactant particles have more kinetic energy. This means that they move and vibrate faster, increasing the frequency of effective collisions. 2. At higher temperatures, more reactant particles possess energy that is greater than or equal to activation energy. This increases the frequency of effective collisions."

Ch 17 Rate of Reactions › 17.2 What Determines the Rate of Reactions? (Effect of Temperature) › p. 308 (PDF p. 320)

"Hence, higher temperatures result in faster reaction rates (Figure 17.18). An increase in the temperature of reactants results in an increase in the rate of reaction."

Ch 20 Alcohols, Carboxylic Acids and Esters › Fermentation of Glucose (Link note beside Let's Investigate 20A) › p. 368 (PDF p. 380)

"We have learnt in Chapter 17 that high temperatures would denature the enzymes in yeast."

Ch 20 Alcohols, Carboxylic Acids and Esters › Fermentation of Glucose (Let's Investigate 20A, Procedure step 2) › p. 368 (PDF p. 380)

"Ensure that the temperature of the solution does not exceed 37 °C."

In the textbook

LO: 10(a), 10(b)

2(c) **[3]**

Explain, using ideas about particles, how decreasing the concentration of glucose affects the rate of the reaction.

- the rate of reaction decreases with decreasing reactant concentration [1]
- the concentration of a solution shows the number of particles in a given volume: at a lower concentration the number of reacting (glucose) particles per unit volume is smaller [1]
- so they collide less frequently (with the enzyme's active site) and hence the frequency of effective collisions is lower [1]

The book states the effect of an INCREASE in concentration; the answer is its converse (decrease). The third mark needs a time idea ('frequency', 'per unit time', 'less often'); 'fewer collisions' on its own is often not credited. 'Use ideas about particles' means an answer that only says 'less concentrated' scores at most the first mark. Reject any idea that the particles have less energy (temperature is unchanged).

Ch 17 Rate of Reactions › 17.2 What Determines the Rate of Reactions? (Effect of Concentration) › p. 303 (PDF p. 315)

"The concentration of a solution shows the number of particles in a given volume. As the concentration of reactants increases, the number of reacting particles per unit volume increases. They collide more frequently and hence, the frequency of effective collisions also increases (Figure 17.10)."

Ch 17 Rate of Reactions › 17.2 What Determines the Rate of Reactions? › p. 303 (PDF p. 315)

"When more effective collisions occur between reactant particles, the rate of reaction increases."

Ch 17 Rate of Reactions › 17.2 What Determines the Rate of Reactions? (Effect of Concentration) › p. 303 (PDF p. 315)

"An increase in concentration of reactants increases the rate of reaction."

Ch 17 Rate of Reactions › 17.2 What Determines the Rate of Reactions? (Let's Investigate 17C, Figure 17.11) › p. 304 (PDF p. 316)

"Flask A has the steepest initial gradient followed by flask B, then flask C. This shows that the rate of reaction decreases with decreasing reactant concentration."

Ch 17 Rate of Reactions › 17.3 What Are Catalysts and How Do They Affect the Rate of Reactions? (Biological Catalysts, characteristic 4) › p. 314 (PDF p. 326)

"They have a specific catalytic action. Enzymes are specific in their catalytic activity. Living cells contain many different types of enzymes, and each catalyses a specific reaction. As seen in Figure 17.26, the active site of each enzyme is specific. The active site can only fit certain reactant molecule(s) in a specific orientation."

In the textbook

LO: 10(a)

Question 3 — Bromine isotopes and nuclide notation [6]

3(a) **[2]**

State how the structure of an atom of ^{79}Br differs from an atom of ^{81}Br.

- isotopes are atoms of the same element that have the same proton (atomic) number but different nucleon (mass) numbers: ^{79}Br has fewer neutrons than ^{81}Br (they have different numbers of neutrons) [1]
- ^{79}Br has 44 neutrons and ^{81}Br has 46 neutrons (two fewer in ^{79}Br); both have 35 protons and 35 electrons [1]

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number of neutrons = nucleon number (A) – proton number (Z); proton number of Br = 35 (Periodic Table)
⁷⁹Br: 79 – 35 = 44 neutrons
⁸¹Br: 81 – 35 = 46 neutrons
(the book's own answer key, p. 427, lists bromine-79 as 35 protons, 44 neutrons, 35 electrons and bromine-81 as 35, 46, 35)
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If the scheme splits the marks as 'different number of neutrons' + 'same number of protons and electrons (35)', this answer still covers it. Reject 'different number of protons' and 'different number of electrons'; 'different mass / nucleon number' alone names the label, not the structural difference.

Ch 3 Atomic Structure › 3.2 How Many Sub-atomic Particles Does An Atom Have? (Isotopes) › p. 50 (PDF p. 62)

"Protons and neutrons are found clustered together in the nucleus of an atom. The number of protons is fixed for all atoms of a given element. However, the number of neutrons in the nucleus can vary. Neutrons do not affect the electrical charge of the atom, although they affect the total mass."

Ch 3 Atomic Structure › 3.2 How Many Sub-atomic Particles Does An Atom Have? (Isotopes) › p. 50 (PDF p. 62)

"Isotopes are atoms of the same element that have the same proton (atomic) number but different nucleon (mass) numbers. This means that they have different numbers of neutrons."

Ch 3 Atomic Structure › 3.2 How Many Sub-atomic Particles Does An Atom Have? (Proton (Atomic) Number and Nucleon (Mass) Number) › p. 48 (PDF p. 60)

"The relationship between the proton and nucleon numbers can be used to determine the number of neutrons in an atom: Number of neutrons = Nucleon number (A) – Proton number (Z)"

Ch 3 Atomic Structure › Let's Review, Section B, question 4(a) (Table 3.4 lists sulfur-32, bromine-79, bromine-81 and lead-204) › p. 58 (PDF p. 70)

"Complete the following table of isotopes."

Ch 3 Atomic Structure (Answer Key) › Let's Review, Section B, answer 4(a) (Table columns: Isotope Name, Protons, Neutrons, Electrons, Nuclide Notation) › p. 427 (PDF p. 439)

"bromine-79 • 35 • 44 • 35 • $^{79}_{35}$Br bromine-81 • 35 • 46 • 35 • $^{81}_{35}$Br"

Ch 3 Atomic Structure › Let's Map It (chapter summary map) › p. 56 (PDF p. 68)

"Isotopes • Atoms of the same element with different numbers of neutrons • Same proton (atomic) number (Z) • Different nucleon (mass) numbers (A)"

In the textbook

LO: 2.2(e), 2.2(f)

3(b) **[1]**

Explain why atoms of ^{79}Br have identical chemical properties to atoms of ^{81}Br.

- isotopes of the same element have the same number of protons, so they also have the same number of electrons (the same electronic configuration, so the same number of valence electrons); the chemical properties of an element are largely dependent on the number of valence electrons, so they undergo the same kind of chemical reactions [1]

Accept 'same number of valence / outer-shell electrons' or 'same electronic configuration'. 'Same number of protons and electrons' is likely to be credited if electrons are mentioned; 'same number of protons' alone is risky, and 'same number of neutrons' is wrong. Do not push students to write bromine's full configuration (2, 8, 18, 7): the book only teaches the 2, 8, 8 rule (p. 54) and the question does not need it. The book's own review question 4(b) on p. 58 ('Will bromine-79 and bromine-81 atoms undergo different types of chemical reactions? Explain your answer.') is this question's twin.

Ch 3 Atomic Structure › 3.2 How Many Sub-atomic Particles Does An Atom Have? (Isotopes, after Table 3.2) › p. 51 (PDF p. 63)

"Because isotopes of the same element have the same number of protons, they also have the same number of electrons. This means that they undergo the same kind of chemical reactions but may have different physical properties. Such physical properties may include density, melting point, and boiling point."

Ch 3 Atomic Structure › 3.3 How Are Sub-atomic Particles Distributed in An Atom? (How Are Electrons Arranged in the Atom?, after Table 3.2) › p. 54 (PDF p. 66)

"Elements in the same group have the same number of valence electrons. The chemical properties of an element is largely dependent on the number of valence electrons it has. Hence, elements in the same group tend to exhibit similar chemical properties."

Ch 3 Atomic Structure › 3.3 How Are Sub-atomic Particles Distributed in An Atom? (after Table 3.2) › p. 54 (PDF p. 66)

"Since isotopes of the same element have the same proton number, they also have the same number of electrons, and the same electronic configuration."

Ch 3 Atomic Structure › 3.3 How Are Sub-atomic Particles Distributed in An Atom? (Electron Shells and Electrons) › p. 52 (PDF p. 64)

"The outermost shell is also called the valence shell, and electrons in that shell are called valence electrons."

Ch 3 Atomic Structure › Let's Review, Section B, question 4(b) › p. 58 (PDF p. 70)

"Will bromine-79 and bromine-81 atoms undergo different types of chemical reactions? Explain your answer."

In the textbook

LO: 2.2(e), 2.2(b)

3(c) **[1]**

State the charge on the nucleus of an atom of ^{79}Br.

- +35 [1]
- (the nucleus holds the protons, relative charge +1 each, and the neutrons, relative charge 0; bromine has 35 protons)

```
nucleus = 35 protons (charge +1 each) + 44 neutrons (charge 0) → total charge +35
```

Accept 35+ and +35. Reject '35' with no sign, '−35', '0', and '+79' or '+44' (nucleon number or neutron number confused with the proton number).

Ch 3 Atomic Structure › 3.1 What Is An Atom Made Up Of? (Relative Sizes and Charges of Sub-atomic Particles) › p. 47 (PDF p. 59)
"Table 3.1 provides a summary of the mass, charge and location of these three particles, relative to each other."

Ch 3 Atomic Structure › 3.1 What Is An Atom Made Up Of? (Table 3.1 rows; columns: Sub-atomic Particle, Relative Mass, Relative Charge, Location in the Atom) › p. 47 (PDF p. 59)
"proton • 1 • +1 • nucleus neutron • 1 • 0 • nucleus electron • 1/1840 • –1 • electron shell"

Ch 3 Atomic Structure › 3.1 What Is An Atom Made Up Of? (The Three Main Sub-atomic Particles) › p. 46 (PDF p. 58)
"Protons and neutrons are heavier particles grouped together in the centre of the atom, which is called the nucleus."

Ch 3 Atomic Structure › 3.1 What Is An Atom Made Up Of? (Figure 3.2 labels) › p. 46 (PDF p. 58)
"Protons • Carry a positive electrical charge. Neutrons • Neutral particles with no net electrical charge • Found in the nucleus between protons"

Ch 3 Atomic Structure › 3.2 How Many Sub-atomic Particles Does An Atom Have? (Proton (Atomic) Number and Nucleon (Mass) Number) › p. 48 (PDF p. 60)
"The proton number (Z) of an atom is the number of protons in its nucleus."

Ch 3 Atomic Structure › Let's Map It (chapter summary map) › p. 56 (PDF p. 68)
"Protons • Number identifies the element • Relative charge: +1 • Relative mass: 1 • Shown by the proton (atomic) number. Neutrons • Keep the nucleus together • Relative charge: 0 • Relative mass: 1"

Partly in the textbook

Gap: The book gives the charge of a proton (+1) and a neutron (0), puts both in the nucleus, and defines the proton number as the number of protons in the nucleus (pp. 46–48, 56), but it never states that the charge on the nucleus equals +(proton number), and no exercise asks for it. The student must combine 'Br has 35 protons' (Periodic Table or the book's table on p. 427) with 'proton = +1, neutron = 0'. The sign must be written.
LO: 2.2(a), 2.2(b), 2.2(c)

3(d) **[2]**

Write the nuclide symbol for the isotope of selenium (Group 16) that has 41 neutrons, given $^{80}_{36}Kr$ as the krypton symbol.

- the proton (atomic) number of selenium is 34 (Group 16, between arsenic 33 and bromine 35 in the Periodic Table) [1]
- the nucleon number (A) = proton number (Z) + number of neutrons = 34 + 41 = 75, so the nuclide symbol is $^{75}_{34}Se$ (nucleon number top left, proton number bottom left) [1]

```
Se is in Period 4, Group 16: proton number 34 (Br = 35 and Kr = 36 in the same row, as the
stem's krypton symbol hints)
nucleon number A = Z + number of neutrons = 34 + 41 = 75
symbol: nucleon number 75 as superscript, proton number 34 as subscript, then Se
```

Both numbers must be in the correct positions beside the symbol Se. Error carried forward: if the proton number is read wrongly from the table, nucleon number = (that number) + 41 earns the second mark. Reject $^{80}_{34}Se$ (copying the krypton nucleon number; 41 neutrons fixes A = 75).

Ch 3 Atomic Structure › 3.2 How Many Sub-atomic Particles Does An Atom Have? (Nuclide Notation) › p. 49 (PDF p. 61)
"We can represent the proton and nucleon numbers of an atom using nuclide notation (Figure 3.7)."

Ch 3 Atomic Structure › 3.2 How Many Sub-atomic Particles Does An Atom Have? (Nuclide Notation) › p. 49 (PDF p. 61)
"For example, $^{12}_{6}C$ represents a specific type of carbon atom, with 12 nucleons and 6 protons. Other types of carbon atoms with different numbers of nucleons can be represented as $^{13}_{6}C$ and $^{14}_{6}C$ using nuclide notation."

Ch 3 Atomic Structure › 3.2 How Many Sub-atomic Particles Does An Atom Have? (Nuclide Notation) › p. 49 (PDF p. 61)
"The atomic symbol and the proton number both tell us the type of atom we are referring to. Atoms of different elements have different numbers of protons."

Ch 3 Atomic Structure › 3.2 How Many Sub-atomic Particles Does An Atom Have? (Proton (Atomic) Number and Nucleon (Mass) Number) › p. 48 (PDF p. 60)
"The proton number (Z) of an atom is the number of protons in its nucleus. The nucleon number (A) is the total number of protons and neutrons in the nucleus. Nucleon number (A) = proton number (Z) + number of neutrons"

Ch 3 Atomic Structure › 3.2 How Many Sub-atomic Particles Does An Atom Have? (Worked Example 3A) › p. 49 (PDF p. 61)
"Since its nucleon number is 184, an atom of tungsten has 184 nucleons, or the total number of protons and neutrons. The proton number of 74 tells us that it has 74 protons. We can subtract the proton number from the nucleon number to find the number of neutrons."

Ch 3 Atomic Structure › Let's Map It (chapter summary map, Nuclide notation box) › p. 56 (PDF p. 68)
"X: atomic symbol of element • A: nucleon (mass) number • Z: proton (atomic) number"

In the textbook
LO: 2.2(d), 2.2(c), 2.2(f)

Question 4 — Precipitation of lead(II) chromate [5]

4(a) **[2]**
Complete the equation for the precipitation of $PbCrO_4$ from aqueous lead(II) nitrate and aqueous K_2CrO_4, with state symbols.

- $Pb(NO_3)_2(aq) + K_2CrO_4(aq) \rightarrow PbCrO_4(s) + 2KNO_3(aq)$
- correct formulae $Pb(NO_3)_2$ and KNO_3 [1]
- correct state symbols (aq), (s), (aq) [1]

```
Pb²⁺ + 2 NO₃⁻ → Pb(NO₃)₂ (Roman numeral II = Pb²⁺; the nitrate ion is a polyatomic ion with a valency of 1); K⁺ + NO₃⁻ → KNO₃
atom check (python-verified): left Pb 1, N 2, O 6 + 4 = 10, K 2, Cr 1; right Pb 1, Cr 1, O 4 + 6 = 10, K 2, N 2 → balanced with the printed coefficient 2
the book's own lead(II) precipitation (Worked Example 9A, p. 175): 2KCl(aq) + Pb(NO₃)₂(aq) → PbCl₂(s) + 2KNO₃(aq)
```

All three state symbols are needed for the second mark: lead(II) nitrate is (aq) because the stem says 'aqueous' (and all nitrates are soluble), $PbCrO_4$ is (s) because it is the precipitate, and KNO_3 is (aq) because all nitrates and all potassium salts are soluble. Reject $PbNO_3$ (wrong charge balance) and KNO_3(s). The mark split between formulae and state symbols may differ in the official scheme; the content needed is the same.

Ch 9 Salts › 9.2 How Are Salts Prepared? (Worked Example 9A, Thought Process) › p. 175 (PDF p. 187)
"Lead(II) chloride is insoluble in water, so it must be prepared by the precipitation method."

Ch 9 Salts › 9.2 How Are Salts Prepared? (Worked Example 9A, Answer, steps 2 and 3) › p. 175 (PDF p. 187)
"Step 2 Filter to remove unreacted lead(II) carbonate. The filtrate is lead(II) nitrate solution. Step 3 Add excess aqueous potassium chloride to the filtrate to precipitate lead(II) chloride. $2KCl(aq) + Pb(NO_3)_2(aq) \rightarrow PbCl_2(s) + 2KNO_3(aq)$"

Ch 9 Salts › 9.2 How Are Salts Prepared? (Method 3: Precipitation) › p. 174 (PDF p. 186)
"Precipitation involves mixing two solutions to form an insoluble solid that separates out from the reaction mixture. The general equation for the preparation of salts by precipitation is: aqueous solution AB + aqueous solution XY → insoluble salt AY + aqueous solution XB"

Ch 9 Salts › 9.2 (Preparing Barium Sulfate, Table 9.4 Step 3) › p. 174 (PDF p. 186)

"barium nitrate + sodium sulfate → barium sulfate + sodium nitrate $Ba(NO_3)_2(aq) + Na_2SO_4(aq) \rightarrow BaSO_4(s) + 2NaNO_3(aq)$"

Ch 9 Salts › 9.1 What Are Salts? (Solubility of Salts in Water, Table 9.1) › p. 166 (PDF p. 178)

"Although salts are ionic compounds, not all salts are soluble in water. The solubility of a salt must be determined before we can choose a suitable method to prepare the salt."

Ch 9 Salts › 9.1 What Are Salts? (Table 9.1 Solubility rules for common salts in water, Soluble Salts column) › p. 166 (PDF p. 178)

"all sodium salts • all potassium salts • all ammonium salts • all nitrates"

Ch 6 Chemical Formulae and Equations › 6.3 What Are Chemical Equations and How Do We Balance Them? (Chemical Equations) › p. 115 (PDF p. 127)

"The state symbol shows the physical state of the substance during the reaction. Common states are: • solid (s) • liquid (l) • gas (g) • aqueous (aq)"

Ch 6 Chemical Formulae and Equations › 6.2 How Are Chemical Formulae Constructed? (Valences of Polyatomic Ions; Table 6.7 lists nitrate, NO_3^-, valency 1) › p. 112 (PDF p. 124)

"Polyatomic ions are ions which are made up of more than one atom covalently bonded together. They carry overall charges, and their overall valences is the charge on the ions (Table 6.7)."

Ch 6 Chemical Formulae and Equations › 6.2 (Worked Example 6B) › p. 113 (PDF p. 125)

"Write the chemical formula of magnesium nitrate. Thought Process: Magnesium is in Group 2 and has a valency of 2. The nitrate ion is a polyatomic ion with a valency of 1. Overall, two NO_3^- ions are needed to exactly cancel out the +2 charge on the Mg^{2+} ion. Answer: Hence, the chemical formula of magnesium nitrate is $Mg(NO_3)_2$."

Ch 6 Chemical Formulae and Equations › 6.2 (Valences from Roman Numerals) › p. 111 (PDF p. 123)

"Transition metals can form more than one stable ion and so they have variable valences. Their valences are indicated using Roman numerals in brackets (Table 6.5)."

In the textbook

LO: 4.1(e), 4.1(c), 5.2(b)

4(b) **[3]**

Calculate the total percentage by mass of the metallic elements in lead(II) chromate, $PbCrO_4$.

- relative formula mass (Mr) of $PbCrO_4$ = 207 + 52 + (4 × 16) = 323 [1]
- number of atoms of the element in the formula × Ar of the element: the metals are lead (1 × 207) and chromium (1 × 52), a total of 259 [1]
- percentage mass = 259 ÷ 323 × 100 % = 80.2 % [1]

```
Ar from the paper's Periodic Table: Pb 207, Cr 52, O 16
Mr(PbCrO4) = 207 + 52 + 4(16) = 323
metals = Pb + Cr = 207 + 52 = 259
% metals = 259 / 323 × 100 = 80.19... = 80.2 %
check: % Pb = 207/323 × 100 = 64.1 ; % Cr = 52/323 × 100 = 16.1 ; 64.1 + 16.1 = 80.2
```

Accept 80, 80.19 or 80.2 (3 s.f.). Error carried forward from a wrong Mr. A candidate who counts only lead (64.1 %) has missed that chromium (a transition metal) is a metal and loses the last two marks. Reject answers above 100 %.

Ch 7 Mole Concept and Stoichiometry › 7.2 What Is Percentage Mass? (Calculating Percentage Mass) › p. 124 (PDF p. 136)

"The percentage mass of an element in a compound can be calculated using this formula: Percentage mass = (number of atoms of the element in the formula × Ar of the element) / Mr of compound × 100 %"

Ch 7 Mole Concept and Stoichiometry › 7.2 (Worked Example 7A) › p. 124 (PDF p. 136)

"Find the percentage mass of nitrogen in ammonium sulfate, $(NH_4)_2SO_4$. Answer: Relative formula mass of $(NH_4)_2SO_4$ = 2[14 + 4(1)] + 32 + 4(16) = 132. Percentage mass of nitrogen in $(NH_4)_2SO_4$ = (14 × 2) / 132 × 100 % = 21.2 %"

Ch 7 Mole Concept and Stoichiometry › 7.1 What Are Relative Atomic Mass and Relative Molecular Mass? (Relative Formula Mass) › p. 123 (PDF p. 135)

"Ionic compounds do not exist as molecules. We use the term relative formula mass to refer to the relative mass of an ionic compound. The relative formula mass (Mr) of an ionic compound is the average mass of one unit of that compound relative to 1/12 the mass of an atom of carbon-12. Relative formula mass is calculated the same way as relative molecular mass and also has the symbol Mr (Table 7.2)."

Ch 7 Mole Concept and Stoichiometry › 7.1 (Relative Molecular Mass) › p. 123 (PDF p. 135)

"To find the relative molecular mass (Mr) of a substance, we add together the relative atomic masses (Ar) of all the atoms in its chemical formula (Table 7.1)."

Ch 14 The Periodic Table › 14.3 What Are Transition Elements? › p. 253 (PDF p. 265)

"Transition elements are the block of metals found in Groups 3 to 12 of the periodic table (Figure 14.17). They are also called the transition metals. Examples of some common transition metals include chromium (Cr), manganese (Mn), iron (Fe) and copper (Cu)."

In the textbook

LO: 4.2(d), 4.2(b)

Question 5 — Hydrocarbons, empirical formula and the bromine test [6]

5(a) **[1]**

Explain what is meant by the term hydrocarbon.

- a compound that is made up of only (covalently-bonded) carbon and hydrogen atoms [1]

Accept 'contains carbon and hydrogen only'. Reject 'contains carbon and hydrogen' without 'only', 'an element', and 'a mixture'.

Ch 19 Hydrocarbons › Chapter opener › p. 337 (PDF p. 349)

"When a compound is made up of only covalently-bonded carbon and hydrogen atoms, we call it a hydrocarbon."

Ch 7 Mole Concept and Stoichiometry › Let's Review, Section B, question 3 › p. 143 (PDF p. 155)

"Hydrocarbons are compounds that only contain hydrogen and carbon atoms."

Ch 19 Hydrocarbons › 19.2 What Are Alkanes? (Formulae and Names of Alkanes) › p. 341 (PDF p. 353)

"Alkanes are hydrocarbons that contain only carbon–carbon single bonds and carbon–hydrogen bonds."

In the textbook

LO: 11.2(b), 11.1(b)

5(b) **[3]**

A hydrocarbon contains 81.8 % carbon by mass. Determine its empirical formula, showing working.

- assume 100 g of the substance is present, so the masses are equal to the percentage masses: C = 81.8 g and H = 100 − 81.8 = 18.2 g (a hydrocarbon has only C and H); number of moles: C 81.8 ÷ 12 = 6.82, H 18.2 ÷ 1 = 18.2 [1]
- divide each mole value by the smallest of the mole values to give the mole ratio: C 1, H 2.67, i.e. C : H = 1 : 2.67, which as whole numbers is 3 : 8 (multiply by 3) [1]
- write out the empirical formula using the simplest mole ratio: C_3H_8 [1]

```
take 100 g: C = 81.8 g, H = 100 − 81.8 = 18.2 g
n(C) = 81.8 / 12 = 6.817 mol ; n(H) = 18.2 / 1 = 18.2 mol
ratio = 6.817 : 18.2 = 1 : 2.67 (18.2 / 6.817 = 2.670)
× 3 → 3 : 8 → C₃H₈
check: C₃H₈, Mr 44, % C = 36/44 × 100 = 81.8 %
```

Error carried forward for the later marks. The common error is rounding 2.67 to 3 and writing CH_3; a ratio must be turned into whole numbers by multiplying (× 3), not by rounding. Because the question says 'show your working', a correct

formula with no working may not earn all three marks. The book's own review question 3 (p. 143, 80.0 % carbon, same style) is this question's twin.

> **Ch 7 Mole Concept and Stoichiometry › 7.4 What Are Empirical and Molecular Formulae? (Table 7.6 Deriving the empirical formula of a compound) › p. 131 (PDF p. 143)**
> *"Step 1 Assuming that 100 g of the substance is present, the masses of each element would then be equal to their percentage mass. Step 2 Fill in the relative atomic mass values from the periodic table. Calculate the number of moles of each element present. Step 3 Divide each mole value by the smallest of the mole values. This gives the mole ratio of the elements. Step 4 Write out the empirical formula using the simplest mole ratio derived in step 3."*

> **Ch 7 Mole Concept and Stoichiometry › 7.4 What Are Empirical and Molecular Formulae? › p. 130 (PDF p. 142)**
> *"The simplest ratio of elements in a compound is called its empirical formula."*

> **Ch 7 Mole Concept and Stoichiometry › Let's Review, Section B, question 3 › p. 143 (PDF p. 155)**
> *"Hydrocarbons are compounds that only contain hydrogen and carbon atoms. A certain hydrocarbon contains 80.0 % carbon by mass. What is its empirical formula?"*

> **Ch 7 Mole Concept and Stoichiometry › 7.4 (Let's Practise 7.4, question 1) › p. 132 (PDF p. 144)**
> *"Plexiglass is a plastic that is commonly used for making spectacle lenses and optical panels. Plexiglass has the following composition by mass: 59.9 % carbon, 8.1 % hydrogen and 32.0 % oxygen. Find its empirical formula."*

In the textbook

LO: 4.2(e)

5(c) **[2]**

A hydrocarbon has empirical formula C_3H_7. Predict what is observed when aqueous bromine is added to it and explain the reasoning.

- observation: aqueous bromine remains brown (it is not decolourised) [1]
- explanation: aqueous bromine is a reagent used to test for unsaturation; the hydrocarbon is an alkane, C_6H_{14} (a saturated hydrocarbon: it only contains single covalent bonds between the carbon atoms), so no atoms can be added across a carbon–carbon double bond and it does not decolourise aqueous bromine [1]

C_3H_7 has an odd number of hydrogen atoms, which cannot be a real hydrocarbon molecule, so the molecular formula is a multiple of C_3H_7 (the molecular formula is a multiple of the empirical formula)
n = 1: C_3H_7 (impossible) ; n = 2: C_6H_{14} = C_nH_{2n+2} with n = 6, an alkane ; n = 3: C_9H_{21} (impossible, the most H that 9 carbons can hold is 2(9) + 2 = 20)
so it is C_6H_{14} (hexane or an isomer): saturated, no C=C, aqueous bromine stays brown

Accept orange, brown, yellow-brown, orange-brown or 'no (visible) change / no reaction' for the observation. Reject 'colourless', 'decolourised' and 'turns clear'. For the explanation mark, 'saturated', 'alkane', 'no C=C double bond' or 'only single bonds' will probably each be credited without the C_6H_{14} deduction; the deduction is shown because it is what makes the question work (a C_3H_7 molecule does not exist).

> **Ch 19 Hydrocarbons › 19.5 How Do Saturated and Unsaturated Compounds Differ? (Saturated and Unsaturated Hydrocarbons) › p. 357 (PDF p. 369)**
> *"Hexane is an alkane whereas hexene is an alkene (Figure 19.23). Although both alkanes and alkenes are hydrocarbons, their chemical properties are very different. Alkanes are saturated hydrocarbons as they only contain single covalent bonds between the carbon atoms. In saturated hydrocarbons, all carbon atoms are bonded to four other atoms."*

> **Ch 19 Hydrocarbons › 19.5 (Test for Unsaturation) › p. 357 (PDF p. 369)**
> *"Aqueous bromine is a reagent commonly used in laboratories to test for unsaturation. Aqueous bromine is a brown solution which consists of bromine dissolved in water. Figure 19.24 shows how aqueous bromine can be used to distinguish alkenes from alkanes."*

Ch 19 Hydrocarbons › 19.5 (Figure 19.24 labels) › p. 357 (PDF p. 369)

"aqueous bromine remains brown when shaken with alkanes • aqueous bromine decolourises when shaken with alkenes"

Ch 19 Hydrocarbons › 19.5 (Saturated and Unsaturated Hydrocarbons) › p. 357 (PDF p. 369)

"On the other hand, alkenes are unsaturated hydrocarbons as they contain double covalent bonds between the carbon atoms. In unsaturated hydrocarbons, more atoms can be added across the carbon–carbon double bond."

Ch 19 Hydrocarbons › 19.2 What Are Alkanes? (General Formula of Alkanes) › p. 341 (PDF p. 353)

"The general molecular formula of alkanes is C_nH_{2n+2}, where n is the number of carbon atoms in each molecule (n = 1, 2, 3, 4 and so on)."

Ch 7 Mole Concept and Stoichiometry › 7.4 What Are Empirical and Molecular Formulae? › p. 130 (PDF p. 142)

"The molecular formula is a multiple of the empirical formula. The molecular formula of a compound reflects the exact number of atoms of each element found in one molecule of the compound."

Ch 7 Mole Concept and Stoichiometry › 7.4 (Finding the Molecular Formula of a Compound from Its Empirical Formula and Molecular Mass) › p. 132 (PDF p. 144)

"We know that the molecular formula is a multiple of the empirical formula. We can find the multiple, n, using the formula below: n = relative molecular mass (Mr) of compound / Mr from empirical formula. By multiplying the numbers of elements in the empirical formula by n, we can then work out the molecular formula."

Partly in the textbook

Gap: The book teaches that alkanes are saturated and leave aqueous bromine brown (p. 357), the alkane formula C_nH_{2n+2} (p. 341) and how to turn an empirical formula into a molecular formula when the Mr is GIVEN (p. 132), but it never asks the student to deduce a molecular formula by testing multiples of an empirical formula against a general formula (no Mr is given here). The step 'C_3H_7 cannot exist, so it is C_6H_{14}, an alkane' is a synthesis the student must make unaided.
LO: 11.2(i), 11.2(b), 4.2(e)

Question 6 — Ethene and steam: addition reaction, bonds and energy profile [8]

6(a) **[1]**

Explain what is meant by an addition reaction (ethene + steam gives ethanol).

- In an addition reaction, two reactants combine to form one product (only): the carbon-carbon double bond breaks to form new single bonds, so the added atoms/groups (here H and OH from steam) attach across the C=C bond [1]

Accept: two (or more) reactants/molecules join (combine) to form a single product; atoms are added across the C=C double bond of an unsaturated molecule and nothing else is formed. Reject: 'two things react' with no mention of ONE product or of the double bond; 'two products'; a statement that only describes this equation without the general idea.

Ch 19 Hydrocarbons › 19.3 What Are Alkenes? (Chemical Properties of Alkenes - Addition Reactions, Helpful Note) › p. 348 (PDF p. 360)

"In an addition reaction, two reactants combine to form one product."

Ch 19 Hydrocarbons › 19.3 What Are Alkenes? (Chemical Properties of Alkenes - Addition Reactions) › p. 348 (PDF p. 360)

"The carbon–carbon double bonds in alkenes are reactive. Hence, alkenes will readily undergo addition reactions."

Ch 19 Hydrocarbons › 19.3 What Are Alkenes? (Chemical Properties of Alkenes - Addition Reactions) › p. 348 (PDF p. 360)

"The carbon-carbon double bond breaks to form new single bonds. As a result, each carbon atom which was originally part of the C=C bond forms four single covalent bonds instead."

Ch 19 Hydrocarbons › 19.3 What Are Alkenes? (Addition of Steam (Hydration)) › p. 349 (PDF p. 361)

"Alkenes can react with steam to produce alcohols. The conditions required are a temperature of 300 °C and a pressure of 60 atm. The reaction also requires a catalyst (phosphoric(V) acid, H_3PO_4)."

In the textbook

LO: 11.2(j)

6(b) **[3]**

Complete the tables showing the type and number of each bond in the reactants (C=C = 1 is given) and in the product, ethanol.

- Reactants table: C–H = 4 and O–H = 2 (C=C = 1 given) [1]
- Product table: C–C = 1 and C–H = 5 [1]
- Product table: C–O = 1 and O–H = 1 (no C=C left: it has become a C–C single bond) [1]

Ethene $H_2C=CH_2$ has 1 C=C and 4 C–H. Steam H–O–H has 2 O–H. So reactants: C=C 1, C–H 4, O–H 2.
Ethanol $H_3C–CH_2–O–H$ (C_2H_5OH, displayed formula H–C(H)(H)–C(H)(H)–O–H) has C–C 1, C–H 3 + 2 = 5, C–O 1, O–H 1.
Check: the C=C opens to C–C; one O–H of water breaks (O–H 2 → 1) and its H joins carbon (C–H 4 → 5); the OH joins the other carbon (new C–O). Check on shared pairs: reactants C=C 2 + C–H 4 + O–H 2 = 8; product C–C 1 + C–H 5 + C–O 1 + O–H 1 = 8 (the C=C counts as one table entry but two shared pairs).

The four product rows may be in any order. The reactants table has C–H and O–H only to fill (the C=C row is given). Reject C=C anywhere in the product table; 4 or 6 for C–H in the product; 2 for O–H in the product. Marks are independent: count each table separately (ecf is not needed).

Ch 19 Hydrocarbons › 19.3 What Are Alkenes? (Addition of Steam (Hydration)) › p. 349 (PDF p. 361)

"ethene + steam → ethanol • $C_2H_4(g) + H_2O(g) \rightarrow C_2H_5OH(aq)$"

Ch 19 Hydrocarbons › 19.3 What Are Alkenes? (Addition Reactions) › p. 348 (PDF p. 360)

"The carbon-carbon double bond breaks to form new single bonds. As a result, each carbon atom which was originally part of the C=C bond forms four single covalent bonds instead."

Ch 20 Alcohols, Carboxylic Acids and Esters › 20.1 What Are Alcohols? (General Formula of Alcohols) › p. 364 (PDF p. 376)

"When there are two carbon atoms in each molecule, n = 2. So, the number of hydrogen atoms will be 2(2) + 1 = 5. Hence, when n = 2, the formula of the alcohol is C_2H_5OH (Figure 20.4)."

Ch 19 Hydrocarbons › 19.3 What Are Alkenes? (Formulae and Names of Alkenes) › p. 346 (PDF p. 358)

"A carbon-carbon double bond is a double covalent bond between two carbon atoms (Figure 19.14)."

Partly in the textbook

Gap: The book prints the displayed formulae of ethene, steam and ethanol (p. 349, with the added H and OH coloured; Table 20.1, p. 365) but never asks students to count bonds by type or to complete a bond table; Chapter 16 handles bond breaking and bond making only qualitatively (p. 286). The candidate must draw ethanol's full structure and count: 5 C–H, 1 C–C, 1 C–O, 1 O–H.

LO: 3.2(a); 3.2(c); 11.3(d); 9(c)

6(c)(i) **[3]**

Complete the energy profile diagram for the exothermic reaction (reactants level given), labelling the activation energy Ea and the reaction enthalpy change ΔH.

- A smooth curve starts at the end of the reactants line, rises to a maximum (peak) above the reactants level and then falls to a 'products' level drawn BELOW the reactants line (exothermic: the products have less energy than the reactants) [1]
- Ea shown: a vertical arrow from the reactants level up to the top of the peak, labelled Ea (activation energy) [1]
- ΔH shown: a vertical arrow between the reactants level and the products level with the arrowhead pointing DOWN at the products, labelled ΔH (negative, ΔH < 0) [1]

```
Sketch (energy up the y-axis, progress of reaction along the x-axis): reactants line at the
given height, a hump above it, the curve ends on a lower products line; Ea = peak minus
reactants; ΔH = products minus reactants = negative.
```

Ea arrow must start on the reactants line (reject an arrow from the x-axis or from the products level) and end at the maximum of the curve. ΔH arrow must join the two horizontal levels and point downwards (accept a labelled double-headed arrow if 'ΔH negative' or a minus sign is shown). Reject a products level above the reactants (endothermic), a curve with no peak, or a curve that goes straight down. The products level need not be labelled if it is clearly the end of the curve.

Ch 16 Chemical Energetics › 16.1 What Is Enthalpy Change? (Exothermic Changes) › p. 290 (PDF p. 302)

"Like endothermic reactions, we can represent an exothermic reaction using an energy level diagram (Figure 16.15) and an energy profile diagram (Figure 16.16)."

Ch 16 Chemical Energetics › 16.1 What Is Enthalpy Change? (Exothermic Changes; Figure 16.16 labels) › p. 290 (PDF p. 302)

"reactants • activation energy (Ea) • enthalpy change (ΔH = negative) • products • Progress of reaction"

Ch 16 Chemical Energetics › 16.1 What Is Enthalpy Change? (Exothermic Changes) › p. 290 (PDF p. 302)

"Since exothermic changes involve a net release of energy to the surroundings, the products have less energy than the reactants. Hence, exothermic changes are indicated by a negative enthalpy change."

Ch 16 Chemical Energetics › 16.1 What Is Enthalpy Change? (Exothermic Changes) › p. 290 (PDF p. 302)

"Exothermic changes have a negative enthalpy change (ΔH < 0)."

Ch 16 Chemical Energetics › 16.1 What Is Enthalpy Change? (Endothermic Changes) › p. 288 (PDF p. 300)

"Energy level diagrams show the overall enthalpy change of a reaction. Energy profile diagrams show the enthalpy change and the activation energy of a reaction."

Ch 16 Chemical Energetics › 16.1 What Is Enthalpy Change? (Enthalpy Change) › p. 288 (PDF p. 300)

"Enthalpy change, ΔH, measures the difference in energy content of the reactants and products. • ΔH = total energy of products – total energy of reactants"

Ch 16 Chemical Energetics › 16.1 What Is Enthalpy Change? (Activation Energy) › p. 287 (PDF p. 299)

"The activation energy, Ea, is the minimum amount of energy that colliding reactant particles must possess to react with each other."

In the textbook

LO: 9(a); 9(b)

6(c)(ii) **[1]**

Explain why the reaction does not take place at room temperature (the conditions include 300 °C).

- At room temperature the reactant particles do not have enough energy: their collisions have energy less than the activation energy, so they are unable to break their bonds and no reaction occurs (no effective collisions) [1]

Accept: not enough (few) particles/molecules have energy greater than or equal to the activation energy; the collisions are not effective; the activation energy is not reached. Reject: 'the rate is slow' with no reference to energy or activation energy; 'it is exothermic'. An answer that only says water is a liquid at room temperature is true but is not what the question (conditions 300 °C) is testing; do not expect credit.

Ch 16 Chemical Energetics › 16.1 What Is Enthalpy Change? (Activation Energy) › p. 287 (PDF p. 299)

"When reactant particles with insufficient energy (i.e. energy less than the activation energy) collide, they are unable to break their bonds. Hence, no chemical reaction occurs (Figure 16.7)."

Ch 16 Chemical Energetics › 16.1 What Is Enthalpy Change? (Activation Energy) › p. 287 (PDF p. 299)

"The activation energy, Ea, is the minimum amount of energy that colliding reactant particles must possess to react with each other."

Ch 17 Rate of Reactions › 17.2 What Determines the Rate of Reactions? (Effective Collisions) › p. 303 (PDF p. 315)

"For an effective collision to occur, the reactant particles must collide with energy that is greater than or equal to the activation energy (Figure 17.9)."

Ch 17 Rate of Reactions › 17.2 What Determines the Rate of Reactions? (Effect of Temperature) › p. 308 (PDF p. 320)

"At higher temperatures, more reactant particles possess energy that is greater than or equal to activation energy. This increases the frequency of effective collisions."

In the textbook

LO: 9(b); 10(a); 10(c)

Question 7 — Electrolysis of dilute copper(II) sulfate [10]

7(a) **[4]**

Dilute $CuSO_4(aq)$ is electrolysed with inert electrodes. Describe the appearance of the solution after 6 minutes and predict its pH; explain.

- appearance: colourless (no longer blue) [1]
- pH: below 7 (acidic), e.g. pH 1 [1]
- explanation: after 6 minutes the graph has levelled off at 0.32 g, so all the Cu^{2+} ions have been discharged at the cathode, $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$; the colour intensity of the electrolyte fades from blue to colourless once the reservoir of Cu^{2+} ions is exhausted [1]
- OH^- ions are discharged at the anode, $4OH^-(aq) \rightarrow O_2(g) + 2H_2O(l) + 4e^-$; after Cu^{2+} and OH^- ions are discharged, H^+ and SO_4^{2-} ions remain in the solution (dilute sulfuric acid), so the solution becomes acidic [1]

Overall: $2Cu^{2+}(aq) + 4OH^-(aq) \rightarrow 2Cu(s) + O_2(g) + 2H_2O(l)$, i.e. $2CuSO_4 + 2H_2O \rightarrow 2Cu + O_2 + 2H_2SO_4$.
The plateau (0.32 g) equals all the copper in the original solution (part (b) gives 0.32 g of Cu^{2+}): $0.32 \div 64 = 0.0050$ mol Cu^{2+}.
0.0050 mol Cu^{2+} leaves 0.0050 mol H_2SO_4 in 0.0500 dm^3 = 0.10 mol/dm^3 H_2SO_4 ($[H^+]$ = 0.20 mol/dm^3, pH about 0.7). Calculating pH is not required by the syllabus (5.1(b)); only 'acidic, pH below 7' is expected.

appearance: colourless (accept clear, 'no longer blue'; reject 'paler blue' or 'light blue'). pH: any value below 7 (0 to 6); a strong-acid value of 1 or 2 is chemically sensible; reject 7 or above. Explanation: M3 needs Cu^{2+} ions used up/removed/discharged (accept 'all the copper has been deposited' read from the flat part of the graph); M4 needs H^+ ions left in solution (accept 'sulfuric acid formed' or 'OH^- ions are removed so H^+ ions are in excess'). Reject 'the copper sulfate has all gone' unless the Cu^{2+} ions are mentioned.

Ch 13 Electrochemistry › 13.3 How Is Electrolysis Used in Industries? (Metal Purification) › p. 231 (PDF p. 243)

"If the anode is replaced with an inert electrode, some pure copper can still be deposited at the cathode. This copper is produced from the Cu^{2+} ions in the electrolyte. The colour intensity of the electrolyte gradually fades from blue to colourless. The deposition of copper at the cathode ceases once the reservoir of Cu^{2+} ions is exhausted."

Ch 13 Electrochemistry › 13.2 How Do We Predict the Products of Electrolysis? (Table 13.5, Step 5) › p. 227 (PDF p. 239)

"After Cu^{2+} and OH^- ions are discharged, H^+ and SO_4^{2-} ions remain in the solution. • Hence, the resulting solution becomes increasingly acidic as electrolysis progresses."

Ch 13 Electrochemistry › 13.2 How Do We Predict the Products of Electrolysis? (Table 13.5, Steps 2 and 3) › p. 227 (PDF p. 239)

"Since OH^- ions are lower than SO_4^{2-} ions in the electrochemical series, OH^- ions are selectively discharged. • Since copper is below hydrogen in the reactivity series, Cu^{2+} ions are selectively discharged over the H^+ ions."

Ch 13 Electrochemistry › 13.2 How Do We Predict the Products of Electrolysis? (Table 13.5, Step 4) › p. 227 (PDF p. 239)

"$2Cu^{2+}(aq) + 4OH^-(aq) \rightarrow 2Cu(s) + O_2(g) + 2H_2O(l)$"

Ch 8 Acids and Bases › 8.4 How Do We Compare Relative Acidity and Alkalinity? › p. 155 (PDF p. 167)

"pH <7: The concentration of H^+ ions is higher than that of OH^- ions, so the solution is acidic."

Ch 8 Acids and Bases › 8.4 How Do We Compare Relative Acidity and Alkalinity? (Helpful Note) › p. 155 (PDF p. 167)

"Strong acids such as hydrochloric acid, nitric acid and sulfuric acid exist around pH 1 to 3."

In the textbook

LO: 7.2(e); 7.2(g); 5.1(b)

7(b) **[3]**

The 50.0 cm^3 of solution contains 0.32 g of Cu^{2+} ions at the start. Calculate the concentration of Cu^{2+} ions at 2.5 minutes (use Figure 7.2).

- Read from the line of best fit at 2.5 minutes: mass of copper deposited = 0.13 g (accept 0.12–0.14 g) [1]
- Mass of Cu^{2+} left = 0.32 − 0.13 = 0.19 g; amount = 0.19 ÷ 64 = 0.0030 mol (0.00297 mol) [1]
- Concentration = 0.00297 ÷ 0.0500 dm^3 = 0.059 mol/dm^3 [1]

```
Ar(Cu) = 64 (Periodic Table, p. 24). Volume = 50.0 cm³ ÷ 1000 = 0.0500 dm³.
Graph: the best-fit line is 0.32 g at 6 min, so 0.32 × 2.5/6 = 0.133 g at 2.5 min (reading 0.13
g; the crosses at 2 and 3 min are 0.11 g and 0.16 g).
Cu²⁺ remaining = 0.32 − 0.13 = 0.19 g → n = 0.19 ÷ 64 = 0.002969 mol.
c = n ÷ V = 0.002969 ÷ 0.0500 = 0.0594 → 0.059 mol/dm³ (2 s.f.; 0.058 if 0.133 g is used).
Check: the starting concentration was 0.32 ÷ 64 ÷ 0.0500 = 0.100 mol/dm³ and 0.19/0.32 of it is
left = 0.059 mol/dm³.
```

Accept readings of 0.12–0.14 g for M1; M2 and M3 then follow by error carried forward (final answers 0.056–0.063 mol/dm^3 are within range). Accept 0.058–0.059 or 0.06 (2 s.f.). Common errors to reject: using 0.13 g as the Cu^{2+} remaining (it is the copper deposited); dividing by 50.0 instead of 0.0500 dm^3; giving 0.19 ÷ 0.05 = 3.8 (a g/dm^3 value without dividing by 64). The volume is taken as 50.0 cm^3 throughout (as the question implies).

Ch 7 Mole Concept and Stoichiometry › 7.3 What Is the Mole? (Moles and Molar Mass) › p. 126 (PDF p. 138)

"Number of moles of a substance = (mass of substance in g) / (molar mass of the substance in g/mol)"

Ch 7 Mole Concept and Stoichiometry › 7.3 What Is the Mole? (Concentration in mol/dm^3) › p. 128 (PDF p. 140)

"Concentration in mol/dm^3 = (number of moles of solute) / (volume of solvent in dm^3)"

Ch 7 Mole Concept and Stoichiometry › 7.3 What Is the Mole? (Concentration of a Solution) › p. 127 (PDF p. 139)

"The concentration of a solution is the amount of a solute dissolved in a unit volume of the solvent."

Ch 7 Mole Concept and Stoichiometry › 7.3 What Is the Mole? (Moles and Gaseous Volumes, Link note) › p. 127 (PDF p. 139)

"In Chapter 1, we learnt that 1 dm^3 is equivalent to 1 litre. There are 1000 cm^3 in 1 dm^3."

Ch 7 Mole Concept and Stoichiometry › 7.3 What Is the Mole? (Worked Example 7E) › p. 128 (PDF p. 140)

"A 200 cm^3 solution was made by dissolving 1.74 g of potassium sulfate (K_2SO_4) in water. Find the concentration of the potassium sulfate solution in mol/dm^3."

Ch 7 Mole Concept and Stoichiometry › 7.1 What Are Relative Atomic Mass and Relative Molecular Mass? › p. 122 (PDF p. 134)

"The relative atomic masses of elements are given in the periodic table."

In the textbook

LO: 4.2(c); 4.2(g)

7(c)(i) **[1]**

The positive electrode is replaced by a 5.0 g piece of copper (same apparatus, volume and concentration). Predict its mass after 6 minutes.

- 4.68 g (accept 4.7 g): the copper anode dissolves and loses the same mass as the copper gained at the negative electrode in 6 minutes (0.32 g), so 5.0 − 0.32 = 4.68 g [1]

```
Same apparatus, so the same current: the cathode gains 0.32 g of copper in 6 minutes (Figure 7.2). Cu(s) → Cu²⁺(aq) + 2e⁻ at the anode and Cu²⁺(aq) + 2e⁻ → Cu(s) at the cathode involve the same number of electrons, so the anode loses 0.32 g: 5.0 − 0.32 = 4.68 g.
```

Accept 4.68, 4.7 (2 s.f.); reject 5.0 (no change), 5.32 (gain instead of loss) and 0 or 'dissolves completely'. The prediction assumes the same current and time as in the first experiment (Figure 7.2 gives 0.32 g in 6 minutes).

> **Ch 13 Electrochemistry › 13.3 How Is Electrolysis Used in Industries? (Electrolysis Using Reactive Electrodes, Figure 13.13) › p. 230 (PDF p. 242)**
>
> *"The copper anode dissolves to form Cu^{2+} ions and decreases in mass. • Red-brown copper is deposited onto the copper cathode which increases in mass."*

> **Ch 13 Electrochemistry › 13.3 How Is Electrolysis Used in Industries? (Electrolysis Using Reactive Electrodes) › p. 231 (PDF p. 243)**
>
> *"These processes do not have a net reaction as the metal that is being oxidised at the anode is simultaneously being reduced at the cathode."*

Partly in the textbook

Gap: The book says the copper anode dissolves and decreases in mass while the cathode gains copper (p. 230) and that there is 'no net reaction' (p. 231), but it never states that the mass lost by the anode equals the mass gained by the cathode (same number of electrons), nor asks for a numerical prediction. The candidate must take 0.32 g from Figure 7.2 and subtract it from 5.0 g.

LO: 7.2(h); 7.2(g)

7(c)(ii) **[2]**

Explain the answer to (c)(i), including ionic equations.

- At the positive electrode (anode) the copper is oxidised and dissolves, so the electrode loses mass: $Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$ [1]
- At the negative electrode copper is deposited: $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$; the copper lost from the anode replaces the Cu^{2+} ions reduced at the cathode, so the mass lost at the anode (0.32 g) equals the mass gained at the cathode and the concentration of Cu^{2+} ions stays the same [1]

```
Net: no overall reaction in the solution, because Cu(s) at the anode → Cu²⁺(aq) → Cu(s) at the cathode; copper is transferred from the anode to the cathode. Equations checked: charge balances on both sides of both half-equations (0 = 2+ + 2−).
```

Both ionic equations must balance for charge (accept $Cu - 2e^- \rightarrow Cu^{2+}$; state symbols not required). M2 needs the cathode equation and the link 'mass lost at the anode = mass gained at the cathode' (accept 'Cu^{2+} ions are replaced', 'concentration of Cu^{2+} ions stays constant'). Reject the $OH^- \rightarrow O_2$ equation at the anode: with a copper anode the OH^- ions are not discharged.

> **Ch 13 Electrochemistry › 13.3 How Is Electrolysis Used in Industries? (Electrolysis Using Reactive Electrodes) › p. 230 (PDF p. 242)**
>
> *"Reactive electrodes, unlike inert electrodes, can take part in the electrolysis process. In industries, reactive electrodes are often used to introduce a metal cation into the electrolyte. When a reactive metal is used as the anode, it is oxidised to form its cation. This cation may then be reduced back to the original metal on the cathode."*

> **Ch 13 Electrochemistry › 13.3 How Is Electrolysis Used in Industries? (Figure 13.13, anode and cathode half-equations) › p. 230 (PDF p. 242)**
>
> *"$Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$ • $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$"*

Ch 13 Electrochemistry › 13.3 How Is Electrolysis Used in Industries? (Figure 13.13, Summary) › p. 230 (PDF p. 242)

"The copper deposited onto the cathode comes mainly from the electrolyte. • The copper anode is constantly oxidising and dissolving into the electrolyte, replenishing the Cu^{2+} ions which are reduced at the cathode. • Since the concentration of Cu^{2+} ions remains unchanged, the colour intensity of the blue electrolyte also remains constant."

Ch 13 Electrochemistry › 13.3 How Is Electrolysis Used in Industries? (Helpful Note) › p. 231 (PDF p. 243)

"None of the components in the electrolyte are oxidised if the anode is reactive."

In the textbook

LO: 7.2(g); 7.2(h)

Question 8 — Lithium-ion batteries (data-based question) [12]

8(a)(i) **[3]**

A new battery has a mass of 30.0 g and is 15.0 % cobalt by mass, present as CoO_2. Calculate the mass of CoO_2 in the battery.

- Mass of cobalt = 15.0 % × 30.0 g = 4.50 g [1]
- Amount of Co = 4.50 ÷ 59 = 0.0763 mol, which is also the amount of CoO_2 (1 Co per CoO_2) [1]
- Mass of CoO_2 = 0.0763 × (59 + 2 × 16 = 91) = 6.94 g [1]

```
Ar: Co 59, O 16 (Periodic Table); Mr(CoO₂) = 59 + 2(16) = 91.
m(Co) = 0.150 × 30.0 = 4.50 g; n(Co) = 4.50 ÷ 59 = 0.07627 mol = n(CoO₂); m(CoO₂) = 0.07627 × 91 = 6.94 g.
Alternative: percentage mass of Co in CoO₂ = 59/91 × 100 = 64.8 %; m(CoO₂) = 4.50 ÷ 0.648 = 6.94 g (python-checked: 4.50 × 91/59 = 6.9407).
```

Accept 6.9 or 6.94 (6.95 from rounding in the middle). Either method earns full marks. Reject an unrounded 7 without working; reject 4.50 g (mass of Co only), 30.0 × 0.15 × 2 or any use of Mr = 59 + 16 = 75. ecf from a wrong mass of Co if the method is right.

Ch 7 Mole Concept and Stoichiometry › 7.2 What Is Percentage Mass? (Calculating Percentage Mass) › p. 124 (PDF p. 136)

"The percentage mass of an element in a compound can be calculated using this formula: • Percentage mass = (number of atoms of the element in the formula × Ar of the element) / (Mr of compound) × 100 %"

Ch 7 Mole Concept and Stoichiometry › 7.2 What Is Percentage Mass? (Helpful Note) › p. 124 (PDF p. 136)

"The percentage mass of an element in a compound allows us to quickly calculate how much of that element is present in a given sample. For example, if a compound is 62.5% carbon by mass, then 1000 kg of that compound should contain 625 kg of carbon."

Ch 7 Mole Concept and Stoichiometry › 7.3 What Is the Mole? (Moles and Molar Mass) › p. 126 (PDF p. 138)

"One mole of any substance has a mass equal to its relative atomic mass (Ar), relative molecular mass or relative formula mass (Mr) in grams. This mass is the molar mass of the substance."

Ch 7 Mole Concept and Stoichiometry › 7.3 What Is the Mole? (Moles and Molar Mass) › p. 126 (PDF p. 138)

"Number of moles of a substance = (mass of substance in g) / (molar mass of the substance in g/mol)"

Ch 7 Mole Concept and Stoichiometry › 7.1 What Are Relative Atomic Mass and Relative Molecular Mass? › p. 122 (PDF p. 134)

"The relative atomic masses of elements are given in the periodic table."

In the textbook

LO: 4.2(b); 4.2(c); 4.2(d)

8(a)(ii) **[1]**

Explain why the mass ratio of cobalt to lithium in a battery is a much higher value than the mole ratio of cobalt to lithium.

- A cobalt atom is much heavier than a lithium atom (Ar of Co = 59, Ar of Li = 7), so one mole of cobalt has a much larger mass than one mole of lithium: the same mass of cobalt contains far fewer moles (atoms) than the same mass of lithium [1]

```
Mass ratio Co : Li = 15.0 : 9.0 = 1.67 (about 5 : 3). Mole ratio Co : Li = (15.0 ÷ 59) : (9.0 ÷ 7) = 0.254 : 1.29 = 0.20 (about 1 : 5). The mass ratio is the mole ratio multiplied by Ar(Co) ÷ Ar(Li) = 59 ÷ 7 = 8.4: 0.20 × 8.4 = 1.67.
```

Accept: Co has a much larger Ar / molar mass than Li; Co atoms are heavier; there are fewer moles of Co because each mole is heavier. Reject: 'there is more cobalt than lithium' (that restates the mass ratio, it does not explain it); 'cobalt is denser'; 'cobalt is less reactive'.

> **Ch 7 Mole Concept and Stoichiometry › 7.3 What Is the Mole? (Moles and Molar Mass) › p. 126 (PDF p. 138)**
> *"One mole of any substance has a mass equal to its relative atomic mass (Ar), relative molecular mass or relative formula mass (Mr) in grams. This mass is the molar mass of the substance."*

> **Ch 7 Mole Concept and Stoichiometry › 7.3 What Is the Mole? (Moles and Molar Mass) › p. 126 (PDF p. 138)**
> *"Number of moles of a substance = (mass of substance in g) / (molar mass of the substance in g/mol)"*

> **Ch 7 Mole Concept and Stoichiometry › 7.1 What Are Relative Atomic Mass and Relative Molecular Mass? › p. 122 (PDF p. 134)**
> *"The relative atomic masses of elements are given in the periodic table."*

In the textbook

LO: 4.2(a); 4.2(c)

8(b) **[3]**

For each electrode reaction on discharging ($Li \rightarrow Li^+ + e^-$ and $CoO_2 + Li^+ + e^- \rightarrow LiCoO_2$), identify the element oxidised/reduced and state the change in oxidation state.

- element oxidised: lithium (Li), oxidation state changes from 0 to +1 [1]
- element reduced: cobalt (Co) [1]
- oxidation state of cobalt changes from +4 (in CoO_2) to +3 (in $LiCoO_2$) [1]

```
Li is an element: oxidation state 0 (Rule 0); in Li⁺ it is +1 (Group 1, Rule 1(a)) → increase = oxidation (loss of e⁻).
CoO₂: oxygen is −2 (Rule 2(c)); compound adds to zero: Co + 2(−2) = 0 → Co = +4.
LiCoO₂: Li +1, O 2 × (−2) = −4: (+1) + Co + (−4) = 0 → Co = +3. Decrease +4 → +3 = reduction (gain of e⁻).
Oxygen stays at −2 in both (not oxidised or reduced). Python-checked sums: 0 = 4 − 4; 0 = 1 + 3 − 4.
```

Signs must be shown (+1, +4, +3). Accept 'Li' / 'lithium' and 'Co' / 'cobalt' / 'cobalt in CoO_2'. Mark the three points independently, but 'oxidised' and 'reduced' must not be swapped (if swapped, no marks for the identities). Reject 'electrode 1/2', '$LiCoO_2$' or 'Li^+' as the element, and oxygen.

> **Ch 12 Oxidation and Reduction › 12.1 What Are Oxidation and Reduction? (Increase or Decrease in Oxidation State) › p. 205 (PDF p. 217)**
> *"An increase in oxidation state (more positive, less negative) refers to the loss of electrons, and hence oxidation. A decrease in oxidation state (more negative, less positive) refers to a gain of electrons, and hence reduction."*

> **Ch 12 Oxidation and Reduction › 12.1 What Are Oxidation and Reduction? (Calculating Oxidation States) › p. 206 (PDF p. 218)**
> *"For a compound with no net charge, all the oxidation states must add up to zero. For an ion with a net charge, the oxidation states will add up to that net charge."*

Ch 12 Oxidation and Reduction › 12.1 What Are Oxidation and Reduction? (Table 12.1, Rule 0) › p. 206 (PDF p. 218)

"Rule 0 (all elements) • Atoms of the same element, such as: single atoms; molecules of an element; and metallic elements. • 0 • Atoms of the same element have no net charge."

Ch 12 Oxidation and Reduction › 12.1 What Are Oxidation and Reduction? (Table 12.1, Rule 1(a)) › p. 206 (PDF p. 218)

"(a) Group 1 elements in their compounds • +1 • Atoms from Group 1 will lose an electron (e.g. Na^+, K^+)."

Ch 12 Oxidation and Reduction › 12.1 What Are Oxidation and Reduction? (Table 12.1, Rule 2(c)) › p. 206 (PDF p. 218)

"(c) oxygen in its compounds (usually) • –2 • Oxygen, after fluorine, is next most likely to gain electrons. It usually has an oxidation state of –2."

Ch 12 Oxidation and Reduction › 12.1 What Are Oxidation and Reduction? (Table 12.1, Rule 4) › p. 206 (PDF p. 218)

"elements from Groups 3 to 12 in their compounds, and elements with proton numbers 57 to 71 or 89 to 103 • always positive • Elements in Groups 3 to 12 can have different oxidation states in their compounds. Roman numerals indicate the oxidation state present in the named species (e.g. chromium(III) indicates that chromium has an oxidation state of +3)."

Ch 12 Oxidation and Reduction › 12.1 What Are Oxidation and Reduction? (Worked Example 12B, Thought Process) › p. 207 (PDF p. 219)

"Oxygen's oxidation state is –2, based on rule 2(c). • Since this is a compound, the overall charge must be 0."

Ch 12 Oxidation and Reduction › 12.1 What Are Oxidation and Reduction? (Worked Example 12D, Thought Process) › p. 208 (PDF p. 220)

"The oxidation state of iodine increased from –1 in potassium iodide to 0 in aqueous iodine. • The oxidation state of chlorine decreased from 0 in chlorine gas to –1 in potassium chloride."

In the textbook

LO: 7.1(b); 7.1(c)

8(c) **[2]**

Write an overall equation for the reaction in the battery while it is charging.

- Correct species: $LiCoO_2$ on the left; Li and CoO_2 on the right [1]
- Balanced and the exact reverse of the overall discharge reaction, with Li^+ and e^- cancelled: $LiCoO_2 \rightarrow Li + CoO_2$ [1]

```
Discharging: electrode 1 Li → Li⁺ + e⁻; electrode 2 CoO₂ + Li⁺ + e⁻ → LiCoO₂. Adding and
cancelling Li⁺ and e⁻: Li + CoO₂ → LiCoO₂.
Charging reverses both reactions (stated on p. 13 of the paper): Li⁺ + e⁻ → Li and LiCoO₂ →
CoO₂ + Li⁺ + e⁻; adding and cancelling: LiCoO₂ → Li + CoO₂.
Python-checked: Li 1 = 1, Co 1 = 1, O 2 = 2, charge 0 = 0.
```

State symbols not required. Accept the arrow ⇌ only if it is clear that charging is $LiCoO_2 \rightarrow Li + CoO_2$. Accept the two reversed half-equations written out and then combined. If Li^+ and e^- are left in the 'overall' equation (e.g. $LiCoO_2 \rightarrow CoO_2 + Li^+ + e^-$) give 1 mark at most. Reject $Li + CoO_2 \rightarrow LiCoO_2$ (that is discharging).

Ch 13 Electrochemistry › 13.2 How Do We Predict the Products of Electrolysis? (Electrolysis of Dilute Sodium Chloride Solution, Summary) › p. 228 (PDF p. 240)

"From the reactions that occur at the anode and cathode, the overall equation for this electrolysis is: • $4H^+(aq) + 4OH^-(aq) \rightarrow 2H_2(g) + O_2(g) + 2H_2O(l)$"

Ch 13 Electrochemistry › 13.2 How Do We Predict the Products of Electrolysis? (Table 13.5, Step 4) › p. 227 (PDF p. 239)

"Write the overall equation for the reaction. • $2Cu^{2+}(aq) + 4OH^-(aq) \rightarrow 2Cu(s) + O_2(g) + 2H_2O(l)$"

Ch 13 Electrochemistry › Let's Map It (Electrochemistry summary map) › p. 240 (PDF p. 252)

"Electrolytic Cell • Converts electrical energy to chemical energy • Simple Cell • Converts chemical energy to electrical energy"

Ch 13 Electrochemistry › 13.4 What Are Simple Cells and Hydrogen Fuel Cells? (Past to Present) › p. 237 (PDF p. 249)

"Today, the battery has evolved into a variety of more portable forms. Disposable alkaline batteries and rechargeable nickel metal-hydride cells (NiMH) are widely used to power low-voltage electronics like remote controls. Our laptops and mobile phones are powered by lithium ion (Li-ion) batteries."

Partly in the textbook

Gap: The book shows how to combine electrode half-equations into an overall equation (Table 13.5 and p. 228) but never combines the two electrode reactions of a simple cell, and it does not teach that charging a rechargeable battery reverses the discharge reactions (rechargeable cells and Li-ion batteries appear only in a 'Past to Present' box, p. 237). The paper's information page supplies the reversal; the candidate must add the half-equations and cancel Li^+ and e^-.
LO: 7.2(j); 4.1(e)

8(d) **[1]**

Explain why the structure of graphite makes it suitable for use as an electrode.

- Either of these two points earns the mark [1]: (i) each carbon atom in graphite is bonded to only three others, leaving one unbonded (delocalised) electron per carbon atom that is free and mobile to conduct electricity (along the layers); OR (ii) graphite has layers with only weak intermolecular forces of attraction between them, so the layers can be separated easily and lithium ions fit in the spaces between the layers

```
One mark only: either point (i) or point (ii) earns it (see accept).
```

Either idea earns the mark: (conduction) delocalised/mobile electrons, so it is a conductor of electricity; or (layers) weak forces between layers, spaces for Li^+ ions to fit/move in and out. The stem has already told candidates that 'lithium ions fit inside spaces between the layers', so the examiners most likely want the conduction point (an electrode must conduct) but should accept the layers point because the question says 'the structure'. Reject: 'graphite is soft/slippery' alone; 'it is a metal'; 'giant covalent so very strong'; 'graphite is inert' alone.

Ch 5 Structure and Properties of Materials › 5.3 What Are the Properties of Covalent Substances? (Giant Covalent Structures, Electrical Conductivity) › p. 92 (PDF p. 104)

"However, in graphite, each carbon atom is bonded to three other carbon atoms. This leaves 1 unbonded electron per carbon atom, which is free and mobile to conduct electricity."

Ch 5 Structure and Properties of Materials › 5.3 What Are the Properties of Covalent Substances? (Giant Covalent Structures, Structural Properties) › p. 91 (PDF p. 103)

"Graphite is slightly different from other giant covalent molecules because of its layered structure. Strong covalent bonds are found within each layer, but weak intermolecular forces of attraction exist between the layers."

Ch 5 Structure and Properties of Materials › 5.3 What Are the Properties of Covalent Substances? (Giant Covalent Structures, Structural Properties) › p. 91 (PDF p. 103)

"This means that graphite layers can be easily separated from each other, but each layer is hard to break apart."

Ch 5 Structure and Properties of Materials › 5.3 What Are the Properties of Covalent Substances? (Hardness) › p. 92 (PDF p. 104)

"Only a small amount of energy is needed to overcome the weak intermolecular forces of attraction between the layers of carbon atoms. Hence, these layers of carbon atoms can slide over each other easily."

Ch 5 Structure and Properties of Materials › 5.3 What Are the Properties of Covalent Substances? (Table 5.4, Graphite column: Molecular Structure and Electrical Conductivity rows) › p. 92 (PDF p. 104)

"two-dimensional layers (strong covalent bonds between carbon atoms, but weak intermolecular forces of attraction between the layers of carbon atoms) • conducts electricity along layers"

In the textbook

LO: 3.4(f)

8(e) **[1]**

Explain why lithium ions are smaller than most other metal ions.

- A lithium ion has only one occupied electron shell (electronic configuration 2, like helium) because the lithium atom (2, 1) loses its outer electron and so its whole second shell; most other metal ions have two or more occupied electron shells (e.g. Na^+ 2, 8; K^+ 2, 8, 8), so Li^+ has fewer electron shells and is smaller [1]

```
Li atom: 2, 1 (two shells). Li → Li⁺ + e⁻ removes the outermost (second) shell: Li⁺ is 2 (one shell). Na atom 2, 8, 1 → Na⁺ 2, 8 (two shells); K atom 2, 8, 8, 1 → K⁺ 2, 8, 8 (three shells). Size follows the number of occupied shells.
```

Accept: Li^+ has fewer (electron) shells than other metal ions; Li^+ has only one shell; lithium is at the top of Group 1 so its atom has the fewest shells and its ion has lost the outer shell. Reject: 'it loses an electron' alone (all metal ions do); 'it has fewer protons' (not the reason); 'it is lighter'. Mention of the stronger pull of 3 protons on 2 electrons is a valid extra but is not needed.

Ch 3 Atomic Structure › 3.3 How Are Sub-atomic Particles Distributed in an Atom? (Electronic Configuration) › p. 53 (PDF p. 65)

"The first shell can hold a maximum of 2 electrons and cannot accommodate any more. • The third electron must occupy a new, higher energy electron shell. • This arrangement is called the electronic configuration or electronic structure of lithium. We can write it as 2, 1."

Ch 4 Chemical Bonding › 4.2 What Is Ionic Bonding? (Ion Formation: Loss or Gain of Electrons, Positive Ions) › p. 62 (PDF p. 74)

"A positive ion or cation is formed when an atom loses one or more electrons. It is no longer an atom, since atoms are overall electrically neutral. The ion formed is positively charged, because it has more protons than electrons. Metal atoms tend to lose electrons and form positive ions."

Ch 4 Chemical Bonding › 4.2 What Is Ionic Bonding? (Positive Ions) › p. 62 (PDF p. 74)

"Positive ions (cations) have a net positive charge and usually have a noble gas electronic configuration."

Ch 14 The Periodic Table › 14.1 How Are Elements Arranged in the Periodic Table? (Metallic Properties of Elements Down a Group) › p. 247 (PDF p. 259)

"This is because the size of the atom increases going down a group. Hence, the outermost electrons of the element will be further away from the attractive force of the nucleus."

Ch 14 The Periodic Table › 14.2 What Group Trends Are There? (Chemical Properties of Alkali Metals) › p. 249 (PDF p. 261)

"As we go down Group 1, the size of the atom increases, as seen in Figure 14.9. It is easier to lose the valence electron from bigger atoms."

Partly in the textbook

Gap: The book never states that an ion is smaller than its atom because the outer shell has been lost, nor that ion size follows the number of occupied shells. It gives the ingredients: electron shells and lithium's configuration 2, 1 (p. 53), cations form by losing electrons (p. 62), and atom size grows down a group (pp. 247, 249). The candidate must assemble 'Li^+ has only one shell, most other metal ions have two or more'. Ion size is not an explicit syllabus learning outcome.

LO: 2.2(b); 3.1(a); 8.1(d)

8(f) **[1]**

Explain why water is not used as the solvent in the electrolyte (the lithium metal in electrode 1 touches the electrolyte).

- Lithium (an alkali metal) reacts with water (quickly), forming lithium hydroxide and hydrogen gas, $2Li(s) + 2H_2O(l) \rightarrow 2LiOH(aq) + H_2(g)$, so the lithium would be used up / the hydrogen is flammable [1]

```
2Li(s) + 2H₂O(l) → 2LiOH(aq) + H₂(g): Li 2 = 2; H 4 = 2 + 2; O 2 = 2 (python-checked).
```

Accept: lithium reacts with water; water would react with the lithium (electrode); hydrogen gas is made (dangerous/explosive/flammable); lithium is reactive with water. Reject: 'water conducts electricity' (an aqueous electrolyte would conduct too), 'lithium dissolves in water' (it reacts, it does not just dissolve), and 'water would be electrolysed' (not the point of the question).

> **Ch 14 The Periodic Table › 14.2 What Group Trends Are There? (Chemical Properties of Alkali Metals, Table 14.5) › p. 249 (PDF p. 261)**
> *"lithium • Reacts quickly. Lithium floats on the water. • lithium + water → lithium hydroxide + hydrogen • $2Li(s) + 2H_2O(l) \rightarrow 2LiOH(aq) + H_2(g)$"*

> **Ch 14 The Periodic Table › 14.2 What Group Trends Are There? (Chemical Properties of Alkali Metals) › p. 249 (PDF p. 261)**
> *"Alkali metals are highly reactive. They are stored in oil to prevent them from reacting with air and water."*

> **Ch 14 The Periodic Table › 14.2 What Group Trends Are There? (Worked Example 14B, Thought Process) › p. 249 (PDF p. 261)**
> *"All Group 1 elements, or the alkali metals, react with cold water to form hydrogen and an alkali."*

In the textbook

LO: 8.2(a)

Question 9 — PAA, an addition polymer (disposal, structure and weak acid) [8]

9(a)(i) **[1]**

Name two products of the complete combustion of PAA (a polymer of C, H and O).

- carbon dioxide and water [1] (both needed)

PAA contains only carbon, hydrogen and oxygen; complete combustion (excess oxygen) gives CO_2 and H_2O.

Accept CO_2 and H_2O, 'water vapour' or 'steam'. Reject carbon monoxide and carbon/soot (products of incomplete combustion), 'oxygen', 'hydrogen', and 'poisonous gases' (the question asks for named products of complete combustion).

> **Ch 19 Hydrocarbons › 19.3 What Are Alkenes? (Chemical Properties of Alkenes - Combustion) › p. 348 (PDF p. 360)**
> *"Like alkanes, alkenes burn in excess oxygen to produce carbon dioxide and water."*

> **Ch 20 Alcohols, Carboxylic Acids and Esters › 20.1 What Are Alcohols? (Chemical Properties of Alcohols - Combustion) › p. 366 (PDF p. 378)**
> *"Complete combustion of alcohol produces carbon dioxide and water."*

> **Ch 21 Polymers › 21.4 How Does the Disposal of Plastics Affect Our Environment? (Figure 21.28, Air pollution) › p. 396 (PDF p. 408)**
> *"Plastics are mostly flammable. When plastics are incinerated, they produce poisonous gases. For example, PVC produces corrosive hydrogen chloride gas on combustion."*

Partly in the textbook

Gap: The book states the products of complete combustion for alkanes, alkenes and alcohols (all C, H and O compounds) but never for a polymer; its only polymer statement is that incinerated plastics 'produce poisonous gases' (PVC gives hydrogen chloride). Applying 'complete combustion of a compound of C, H and O gives CO_2 and H_2O' to PAA is a one-step extension.

LO: 11.2(j); 11.3(c)

9(a)(ii) **[2]**

Describe the pollution problems caused by other methods of disposal (not incineration) of non-biodegradable plastics.

- Land pollution: plastics do not decompose (they are non-biodegradable), so burying plastic waste in landfills leads to an increasing amount of built-up waste [1]
- Water pollution: plastics thrown into the sea endanger marine animals (e.g. turtles mistake plastic bags for food and choke on them) / plastics clog up rivers and drains, which might become breeding grounds for mosquitoes [1]

Any two distinct pollution problems from different disposal routes: landfill fills up / takes up land / plastic stays for many years; litter in the sea or rivers harming or killing marine animals; blocked drains and rivers (flooding, mosquito breeding). Reject air pollution from burning (incineration is the method already given); 'plastics are harmful' with no problem described; 'the plastic rots/decays'.

> **Ch 21 Polymers › 21.4 How Does the Disposal of Plastics Affect Our Environment? (Figure 21.28, Land pollution) › p. 396 (PDF p. 408)**
> *"Plastics do not decompose. Thus, burying plastic waste in landfills leads to an increasing amount of built-up waste."*

> **Ch 21 Polymers › 21.4 How Does the Disposal of Plastics Affect Our Environment? (Figure 21.28, Water pollution) › p. 396 (PDF p. 408)**
> *"Plastics thrown into the sea endanger marine animals. For example, turtles often mistake plastic bags for food and choke on them. Plastics may also clog up rivers and drains, which might become breeding grounds for mosquitoes."*

> **Ch 21 Polymers › 21.4 How Does the Disposal of Plastics Affect Our Environment? › p. 396 (PDF p. 408)**
> *"However, most plastics are non-biodegradable. This means that they cannot be broken down by bacteria and other living organisms in the soil. Hence, the biggest problem with the use of plastics is how to dispose of them after they are used or no longer required."*

In the textbook

LO: 11.4(g)

9(b) **[3]**

Complete the dot-and-cross diagram of the monomer C_2H_3COOH (CH_2=CH–COOH): add the hydrogen atoms and show the arrangement of outer electrons.

- Four hydrogen atoms added in the right places: two H on the left-hand carbon, one H on the middle carbon, one H on the lower oxygen (the –OH oxygen); each H shares one pair of electrons with its atom [1]
- Correct shared pairs between the heavy atoms: C=C (two shared pairs, 4 electrons in the overlap), C–C (one pair), C=O (two pairs, 4 electrons in the overlap), C–O (one pair) [1]
- Non-bonding electrons: two lone pairs (4 electrons) on each oxygen atom, so every C and O has 8 outer electrons and every H has 2; electrons from different atoms shown with different symbols (dots/crosses) [1]

Structure: H_2C=CH–C(=O)–O–H. In the printed frame (three C circles in a row, the third C overlapping the upper O and the lower O): upper O = carbonyl oxygen (double bond to C3); lower O = hydroxyl oxygen (single bond to C3 and a shared pair with the added H).
Overlap electron counts: C1/C2 4; C2/C3 2; C3/upper O 4; C3/lower O 2; lower O/H 2; each C–H overlap 2. Lone pairs: upper O 4 electrons, lower O 4 electrons.
Python-checked: formula $C_3H_4O_2$ = C_2H_3COOH; each C has 4 bonds (C1: 2 H + C=C; C2: C=C, H, C–C; C3: C–C, C=O, C–O); O(upper) 2 bonds + 2 lone pairs = 8 electrons; O(lower) 2 bonds + 2 lone pairs = 8 electrons; each H 1 bond.

The two oxygen positions are interchangeable: one oxygen must be double-bonded to C3 and the other single-bonded to C3 and carry the H. Accept the lone pairs drawn as pairs of dots or crosses and any consistent choice of symbols; accept the hydrogens placed above or below the carbons. Reject: an O–O bond or overlap; a single C=C shown as one shared pair; H on the carbonyl oxygen; missing lone pairs on oxygen; more than 2 electrons around H.

> **Ch 4 Chemical Bonding › 4.3 What Is Covalent Bonding? (The Covalent Bond) › p. 70 (PDF p. 82)**
> *"The overlap shows that this pair of electrons is shared between the two atoms. These electrons are called a bonding pair. A single covalent bond has been formed."*

Ch 4 Chemical Bonding › 4.3 What Is Covalent Bonding? (The Covalent Bond, Figure 4.16) › p. 71 (PDF p. 83)

"The overlap shows two bonding pairs of electrons. A double covalent bond has been formed."

Ch 4 Chemical Bonding › 4.3 What Is Covalent Bonding? (Worked Example 4C: carbon dioxide) › p. 75 (PDF p. 87)

"A carbon atom has 4 electrons in its outermost or valence shell. It has a valency of 4. • An oxygen atom has 6 electrons in its outermost or valence shell. It has a valency of 2. • Thus, a carbon atom will form four covalent bonds and each oxygen atom will form two covalent bonds."

Ch 4 Chemical Bonding › 4.3 What Is Covalent Bonding? (Worked Example 4C: carbon dioxide) › p. 75 (PDF p. 87)

"The dot-and-cross diagram should show the following: • a carbon atom with 4 electrons spaced around its outermost shell • two oxygen atoms, each sharing 2 electrons with the carbon atom • the carbon atom sharing 2 electrons with each oxygen atom"

Ch 19 Hydrocarbons › 19.3 What Are Alkenes? (Formulae and Names of Alkenes, Figure 19.15) › p. 346 (PDF p. 358)

"A carbon-carbon double bond is a double covalent bond between two carbon atoms (Figure 19.14). Figure 19.15 shows how two pairs of electrons are shared between the carbon atoms to form the double bond."

Ch 20 Alcohols, Carboxylic Acids and Esters › 20.2 What Are Carboxylic Acids? (Formulae and Names of Carboxylic Acids) › p. 369 (PDF p. 381)

"Carboxylic acids are organic compounds with the carboxyl (–COOH) functional group."

Partly in the textbook

Gap: The book teaches dot-and-cross diagrams for H_2O, CH_4, CO_2 (Worked Examples 4B and 4C, p. 75), ethene (Figure 19.15) and ethanol (Figure 20.4), and shows the displayed formula of the –COOH group (Figure 20.11, p. 369), but it never draws a dot-and-cross diagram for a carboxylic acid or for a molecule that combines C=C, C=O and O–H. The candidate must combine the valency rules (C 4, O 2, H 1). Syllabus 3.2(c), 'deduce the arrangement of electrons in other covalent molecules', covers this.

LO: 3.2(b); 3.2(c)

9(c)(i) **[1]**

Explain what is meant by weak acid.

- A weak acid is an acid that is only partially ionised in an aqueous solution (in water) [1]

Accept: only partially dissociates / ionises in water; only some of the acid molecules ionise (produce H^+ ions). Reject: 'low pH', 'dilute' or 'low concentration' (strength is not concentration), 'does not ionise at all', 'completely ionises' (strong acid).

Ch 8 Acids and Bases › 8.2 What Are Strong and Weak Acids? (Weak Acids) › p. 150 (PDF p. 162)

"A weak acid is an acid that is only partially ionised in an aqueous solution."

Ch 8 Acids and Bases › 8.2 What Are Strong and Weak Acids? (Weak Acids) › p. 150 (PDF p. 162)

"Only some CH_3COOH molecules will ionise in an aqueous solution (Figure 8.12)."

Ch 8 Acids and Bases › 8.2 What Are Strong and Weak Acids? (Strength of Acids and Concentration of Acids) › p. 150 (PDF p. 162)

"The strength of an acid is its degree of ionisation whereas concentration is related to the number of acid molecules present in a given volume of water."

In the textbook

LO: 5.1(c)

9(c)(ii) **[1]**

Deduce the formula of the anion formed when the PAA monomer, C_2H_3COOH, acts as an acid.

- $C_2H_3COO^-$ (CH_2=$CHCOO^-$), formed with H^+ by $C_2H_3COOH \rightleftharpoons C_2H_3COO^- + H^+$ [1]

Acids ionise by losing H^+ from the –COOH group: $C_2H_3COOH(aq) \rightleftharpoons C_2H_3COO^-(aq) + H^+(aq)$; atoms 3 C, 4 H, 2 O both sides; charge 0 = −1 + 1 (python-checked).

Accept CH_2CHCOO^-, $CH_2{=}CHCOO^-$ or $C_3H_3O_2^-$ (the charge must be shown). Reject C_2H_3COO (no charge), $C_2H_3COO^{2-}$, $C_2H_3COOH^-$, $C_2H_2COO^-$, and the name 'carboxylate' without a formula.

Ch 20 Alcohols, Carboxylic Acids and Esters › 20.2 What Are Carboxylic Acids? (Chemical Properties of Carboxylic Acids) › p. 371 (PDF p. 383)

"Carboxylic acids are weak acids because they partially ionise in water to form a carboxylate ion and hydrogen ion. The partial ionisation of carboxylic acids could be represented by the following equation: • carboxylic acid ⇌ carboxylate ion + hydrogen ion • $RCOOH(aq) \rightleftharpoons RCOO^-(aq) + H^+(aq)$"

Ch 8 Acids and Bases › 8.2 What Are Strong and Weak Acids? (Weak Acids) › p. 150 (PDF p. 162)

"$CH_3COOH(aq) \rightleftharpoons CH_3COO^-(aq) + H^+(aq)$"

In the textbook

LO: 11.3(g); 5.1(c)

Question 10 — Section B option 1: element X, silicon dioxide and sodium chloride (structure and properties) [10]

10(a) **[3]**

Complete Table 10.1 (element X: X_2, mp −218 °C, bp −183 °C, covalent; SiO_2 giant, does not conduct; NaCl ionic, does not conduct): the four blank cells.

- element X, electrical conductivity at room temperature: does not conduct (X_2 is a gas made of neutral molecules, with no mobile charge carriers) [1]
- element X, type of structure: simple molecular (simple covalent) [1]
- silicon dioxide, type of bonding: covalent; sodium chloride, type of structure: giant (a giant ionic lattice) [1] (both cells needed for this mark)

Completed row by row: X: conductivity 'does not conduct', structure 'simple molecular'. SiO_2: bonding 'covalent'. NaCl: structure 'giant' (ionic lattice).
Reasoning for X: its melting point (−218 °C) and boiling point (−183 °C) are both far below room temperature, so X_2 is a gas of small covalent molecules with weak intermolecular forces (the book's Table 5.3 lists oxygen, O_2, with exactly these values).

Mark scheme banding is an assumption: four cells for 3 marks (likely: 4 correct = 3 marks, 2 or 3 correct = 2 marks, 1 correct = 1 mark). X structure: accept simple molecular, simple covalent, simple molecule(s), molecular; reject 'covalent' alone and 'giant'. X conductivity: accept does not conduct, insulator, non-conductor, poor conductor. SiO_2 bonding: accept covalent, giant covalent. NaCl structure: accept giant, giant ionic, giant ionic lattice, lattice; reject 'ionic' alone (that is the bonding column) and 'simple'.

Ch 5 Structure and Properties of Materials › 5.3 What Are the Properties of Covalent Substances? (Table 5.3 Some simple covalent substances, Elements) › p. 89 (PDF p. 101)

"oxygen (O_2) • –218 • –183 • gas"

Ch 5 Structure and Properties of Materials › 5.3 What Are the Properties of Covalent Substances? (Electrical Conductivity) › p. 90 (PDF p. 102)

"Since simple covalent substances typically exist as neutral molecules, they do not have any mobile charge carriers to conduct electricity."

Ch 5 Structure and Properties of Materials › 5.3 What Are the Properties of Covalent Substances? (Giant Covalent Structures) › p. 91 (PDF p. 103)

"Silicon dioxide consists of many silicon and oxygen atoms linked to each other by strong covalent bonds. The atoms are joined to each other in a regular arrangement, forming a giant covalent structure."

Ch 5 Structure and Properties of Materials › 5.2 What Are the Properties of Ionic Substances? (Structural Properties) › p. 86 (PDF p. 98)

"Ionic compounds have giant ionic crystal lattice structures (Figure 5.6). The lattice consists of large numbers of alternating positive and negative ions held together by electrostatic forces of attraction."

Ch 5 Structure and Properties of Materials › 5.3 What Are the Properties of Covalent Substances? (Melting Point and Boiling Point) › p. 89 (PDF p. 101)

"The weak intermolecular forces of attraction between molecules are easily overcome with a small amount of energy. Thus, simple covalent molecules have low melting and boiling points."

In the textbook

LO: 3.4(e); 3.1(c); 3.2(d)

10(b) **[4]**

SiO_2 and NaCl are each heated to 1000 °C. Predict the state and electrical conductivity of each at 1000 °C and explain.

- Silicon dioxide is a solid at 1000 °C because 1000 °C is below its melting point (1713 °C) [1]
- Silicon dioxide does not conduct electricity: it is a giant covalent structure with no mobile electrons or ions [1]
- Sodium chloride is a liquid (molten) at 1000 °C because 1000 °C is above its melting point (801 °C) and below its boiling point (1465 °C) [1]
- Molten sodium chloride conducts electricity because its ions are mobile (free to move) [1]

```
Compare 1000 °C with each substance's melting and boiling points: SiO₂ 1713 / 2950 °C → 1000 < 1713 → solid. NaCl 801 / 1465 °C → 801 < 1000 < 1465 → liquid.
```

Accept 'molten' for liquid. M2 needs the reason (no mobile ions or electrons / electrons are in covalent bonds); M4 needs mobile/free ions (reject 'free electrons' or 'ions vibrate'). Reject 'solid' or 'gas' for NaCl and 'melts' or 'liquid' for SiO_2. A common error is to say NaCl is still a solid (its melting point is 801 °C, well below 1000 °C).

Ch 2 Kinetic Particle Theory › 2.1 How Are Solids, Liquids and Gases Different? (Changes of State) › p. 28 (PDF p. 40)

"At certain temperatures, heating or cooling a substance results in changes of state instead of changes in temperature. These temperatures are the freezing, melting and boiling points of the substance, also known as transition temperatures."

Ch 5 Structure and Properties of Materials › 5.2 What Are the Properties of Ionic Substances? (Electrical Conductivity) › p. 87 (PDF p. 99)

"When an ionic compound is in the solid state, the ions in the lattice are only able to vibrate about their fixed positions. Hence, the ions are not mobile. However, when the compound is molten (in the liquid state) or in the aqueous state, the ions are mobile and can conduct electricity. Therefore, ionic compounds can conduct electricity in the liquid and aqueous states but not in the solid state (Figure 5.9)."

Ch 5 Structure and Properties of Materials › 5.3 What Are the Properties of Covalent Substances? (Electrical Conductivity) › p. 92 (PDF p. 104)

"Giant covalent structures with no mobile electrons, like diamond and silicon dioxide, do not conduct electricity."

Ch 5 Structure and Properties of Materials › 5.3 What Are the Properties of Covalent Substances? (Melting Point and Boiling Point) › p. 92 (PDF p. 104)

"To melt these giant covalent substances, a large amount of energy is required to break the strong covalent bonds. Hence, they are solids at room temperature, with very high melting and boiling points."

Ch 5 Structure and Properties of Materials › 5.2 What Are the Properties of Ionic Substances? (Melting Point and Boiling Point) › p. 86 (PDF p. 98)

"Because the mutual electrostatic attraction between oppositely charged ions are strong, a large amount of energy is needed to overcome these forces. Hence, ionic compounds tend to have very high melting and boiling points. They are solids at room temperature."

Partly in the textbook

Gap: The book teaches the conductivity of molten ionic compounds and of giant covalent substances, and the meaning of melting and boiling points (p. 28), but never works the data skill 'compare a given temperature with the melting and boiling points to decide solid, liquid or gas' (Table 5.3 only lists the state at r.t.p.). That step is a data skill (syllabus 1.2(e), 2.1(a)).
LO: 2.1(a); 1.2(e); 3.1(d); 3.4(e)

10(c) **[3]**

Explain why element X and sodium chloride have different melting points, using ideas about energy, bonds and forces between particles.

- Sodium chloride has a giant ionic lattice in which oppositely charged ions are held together by strong electrostatic forces of attraction (ionic bonds) [1]
- Element X (X_2) is a simple molecular substance with only weak intermolecular forces of attraction between its molecules; these weak forces are overcome on melting and the strong covalent bonds within the molecules are not broken [1]
- A large amount of energy is needed to overcome the strong forces in sodium chloride but only a small amount of energy to overcome the weak forces in X, so sodium chloride has the much higher melting point (801 °C compared with −218 °C) [1]

M1: 'strong electrostatic attraction between (oppositely charged) ions' or 'strong ionic bonds in a giant lattice'. M2: 'weak intermolecular forces (forces between molecules)'. M3: a comparison of the energy needed (large vs small). Reject: 'the covalent bonds in X break on melting' (the common error; M2 and M3 then not awarded); 'ionic bonds are stronger than covalent bonds' as the explanation; 'NaCl has stronger bonds so it melts at a higher temperature' with no mention of forces between particles; 'intermolecular bonds' is tolerated but 'intermolecular forces' is preferred.

Ch 5 Structure and Properties of Materials › 5.2 What Are the Properties of Ionic Substances? (Melting Point and Boiling Point) › p. 86 (PDF p. 98)

"Because the mutual electrostatic attraction between oppositely charged ions are strong, a large amount of energy is needed to overcome these forces. Hence, ionic compounds tend to have very high melting and boiling points. They are solids at room temperature."

Ch 5 Structure and Properties of Materials › 5.2 What Are the Properties of Ionic Substances? (Structural Properties) › p. 86 (PDF p. 98)

"Ionic compounds have giant ionic crystal lattice structures (Figure 5.6). The lattice consists of large numbers of alternating positive and negative ions held together by electrostatic forces of attraction."

Ch 5 Structure and Properties of Materials › 5.3 What Are the Properties of Covalent Substances? (Melting Point and Boiling Point) › p. 89 (PDF p. 101)

"The weak intermolecular forces of attraction between molecules are easily overcome with a small amount of energy. Thus, simple covalent molecules have low melting and boiling points."

Ch 5 Structure and Properties of Materials › 5.3 What Are the Properties of Covalent Substances? (Giant Covalent Structures) › p. 90 (PDF p. 102)

"This is very different from simple covalent molecules that have weak intermolecular forces of attraction."

Ch 2 Kinetic Particle Theory › 2.1 How Are Solids, Liquids and Gases Different? (Changes of State, Figure 2.7, B–C) › p. 28 (PDF p. 40)

"The particles with increased energy can overcome the forces of attraction in the solid state."

In the textbook

LO: 3.1(d); 3.2(d); 3.4(g)

Question 11 — Section B option 2: element Y, lead(II) bromide and element Z (metallic and ionic structure) [10]

11(a)(i) **[3]**

Explain the properties of element Y in Table 11.1 (metallic, solid at room temperature, mp 420 °C, conducts, malleable) in terms of the particles in Figure 11.1.

- Solid with a high melting point: strong electrostatic attraction (metallic bonds) between the positive ions and the delocalised electrons holds the giant lattice together, so a large amount of energy is needed to overcome it [1]
- Conducts electricity: the delocalised (mobile) electrons are free to move through the lattice and carry charge [1]
- Malleable: the layers of positive ions can slide over one another, and the 'sea' of delocalised electrons continues to hold the metal ions together [1]

Each mark must refer to the particles in the figure (positive ions, delocalised electrons). Accept 'mobile electrons', 'sea of electrons', 'layers of ions/atoms slide'. Reject: 'metal atoms/ions conduct'; 'electrons are shared between atoms' (covalent); 'the bonds break when hammered'; 'free electrons' is tolerated. State 'solid at room temperature' and 'melting point 420 °C' as one property (M1).

Ch 5 Structure and Properties of Materials › 5.4 What Are the Properties of Metals and Alloys? (Structure of Metals and Alloys) › p. 96 (PDF p. 108)

"The metallic bond is the mutual electrostatic attraction between positively charged metal ions and the "sea of delocalised electrons". In a giant metallic lattice, the atoms occupy fixed positions that are evenly distributed throughout the solid."

Ch 5 Structure and Properties of Materials › 5.4 What Are the Properties of Metals and Alloys? (Melting Point and Boiling Point) › p. 98 (PDF p. 110)

"Metals usually have high melting and boiling points because the atoms are held together in a lattice by strong metallic bonds."

Ch 5 Structure and Properties of Materials › 5.4 What Are the Properties of Metals and Alloys? (Electrical Conductivity) › p. 98 (PDF p. 110)

"The "sea of delocalised electrons" found in both metals and alloys make them good electrical conductors."

Ch 5 Structure and Properties of Materials › 5.4 What Are the Properties of Metals and Alloys? (Properties of Metals and Alloys, Structural Properties) › p. 97 (PDF p. 109)

"Pure metals have a regular structure, as shown in Figure 5.27. If enough force is applied, the layers of atoms can slide over one another easily. Thus, when hammered, pure metals can be bent or flattened into a thin sheet (malleable). They can also be pulled into a wire without breaking (ductile). The "sea of delocalised electrons" will continue to hold the metal ions together unless a much greater force is applied."

Ch 4 Chemical Bonding › 4.4 What Is Metallic Bonding? (The Metallic Bond) › p. 76 (PDF p. 88)

"The metallic bond is the mutual electrostatic attraction between positively charged ions in a metal and the "sea of mobile (or delocalised) electrons"."

In the textbook

LO: 3.3(a); 3.3(b)

11(a)(ii) **[2]**

An alloy of element Y is used in building materials. Describe how the structure of the alloy differs from the structure in Figure 11.1.

- The alloy contains atoms of another element/other elements, of a different size, mixed in with the atoms (ions) of Y [1]
- so the regular arrangement (layers) of the lattice is disrupted / irregular, and the layers cannot slide over each other as easily [1]

Accept 'atoms of different sizes', 'irregular lattice', 'regular lattice disrupted', 'a mixture of a metal with one or more other elements'. Reject: 'an alloy is a compound'; 'the atoms are all the same size'; 'the bonds are stronger' with no structural difference; 'more delocalised electrons' alone.

Ch 5 Structure and Properties of Materials › 5.4 What Are the Properties of Metals and Alloys? (Properties of Metals and Alloys, Structural Properties) › p. 97 (PDF p. 109)

"In an alloy, the atoms are of different sizes. The regular lattice arrangement in the pure metal is disrupted, so a larger force is needed to make the layers slide over each other (Figure 5.28)."

Ch 5 Structure and Properties of Materials › 5.4 What Are the Properties of Metals and Alloys? (Structure of Metals and Alloys) › p. 96 (PDF p. 108)

"An alloy is a mixture of a metal with one or more other elements."

Ch 5 Structure and Properties of Materials › 5.4 What Are the Properties of Metals and Alloys? (Structure of Metals and Alloys, bronze) › p. 97 (PDF p. 109)

"The regular arrangement of copper atoms is disrupted by the randomly distributed tin atoms, which are about 1.6 times the size of a copper atom."

In the textbook

LO: 3.4(b); 3.4(c); 3.4(d)

11(b) **[3]**

Describe how the structure of solid lead(II) bromide differs from the metallic lattice in Figure 11.1.

- Solid $PbBr_2$ is a giant ionic lattice containing two kinds of ions, positive Pb^{2+} ions and negative Br^- ions (in the ratio 1 : 2), whereas the metallic lattice contains only positive ions [1]
- The oppositely charged ions are held together by strong electrostatic forces of attraction (ionic bonds) in a regular alternating arrangement, not by attraction between positive ions and delocalised electrons [1]
- There are no delocalised (mobile) electrons in lead(II) bromide: its ions are fixed in position and can only vibrate, so it does not conduct as a solid [1]

Formula check: $Pb^{2+} + 2Br^- \rightarrow PbBr_2$ (charge 2+ and 2 × 1−; python-checked).

Charges must be shown or 'positive and negative ions' stated for M1. Accept 'alternating positive and negative ions', 'giant ionic lattice', 'ions cannot move in the solid'. Reject: '$PbBr_2$ is a molecule' or 'covalent'; 'electrons are shared'; 'the metallic lattice has no ions'. Any three of the points above earn 3 marks.

Ch 5 Structure and Properties of Materials › 5.2 What Are the Properties of Ionic Substances? (Structural Properties) › p. 86 (PDF p. 98)

"Ionic compounds have giant ionic crystal lattice structures (Figure 5.6). The lattice consists of large numbers of alternating positive and negative ions held together by electrostatic forces of attraction."

Ch 5 Structure and Properties of Materials › 5.2 What Are the Properties of Ionic Substances? (Electrical Conductivity) › p. 87 (PDF p. 99)

"When an ionic compound is in the solid state, the ions in the lattice are only able to vibrate about their fixed positions. Hence, the ions are not mobile."

Ch 4 Chemical Bonding › 4.4 What Is Metallic Bonding? (The Metallic Bond) › p. 76 (PDF p. 88)

"Hence, the metallic lattice structure is described as a lattice of positive ions surrounded by a "sea of mobile electrons"."

Ch 4 Chemical Bonding › 4.4 What Is Metallic Bonding? (The Metallic Bond) › p. 76 (PDF p. 88)

"The metallic bond is the mutual electrostatic attraction between positively charged ions in a metal and the "sea of mobile (or delocalised) electrons"."

In the textbook

LO: 3.1(c); 3.1(d); 3.3(a)

11(c) **[2]**

State two ways in which the information in Table 11.1 shows that element Z is not a Group 1 element.

- 1 Z has a high melting point (1455 °C), but Group 1 metals have low melting points (e.g. lithium 180 °C; sodium 98 °C) [1]
- 2 Z forms coloured compounds, but Group 1 metals form white/colourless compounds; forming coloured compounds is a property of transition elements [1]

Table 11.1 data for Z: metallic; solid; mp 1455 °C; conducts; 'forms coloured compounds'. Properties shared with Group 1 (metallic, solid, conducts) cannot be used. Z is a transition element (high melting point; coloured compounds).

Accept either order. 'Z is a transition metal because it has a high melting point / forms coloured compounds' earns the matching mark. Reject: 'Z conducts', 'Z is solid' or 'Z is metallic' (all true of Group 1 too); 'Z is malleable' (that is element Y); 'Z has a high density' (not in Table 11.1).

> **Ch 14 The Periodic Table › 14.2 What Group Trends Are There? (Physical Properties of Alkali Metals) › p. 248 (PDF p. 260)**
> *"Alkali metals: • are soft and can be cut easily (Figure 14.8); • have low melting and boiling points; and • have low densities."*

> **Ch 14 The Periodic Table › 14.2 What Group Trends Are There? (Table 14.4 Physical properties of some Group 1 elements) › p. 248 (PDF p. 260)**
> *"lithium • 180 • 0.53 • sodium • 98 • 0.97 • potassium • 63 • 0.86 • rubidium • 39 • 1.53"*

> **Ch 14 The Periodic Table › 14.3 What Are Transition Elements? (High Melting Points And High Densities) › p. 254 (PDF p. 266)**
> *"Notice that the melting points and densities of the transition metals are higher than those of the Group 1 and Group 2 metals."*

> **Ch 14 The Periodic Table › 14.3 What Are Transition Elements? (Coloured Compounds) › p. 255 (PDF p. 267)**
> *"One of the most significant features of transition metals is that they usually form coloured compounds."*

> **Ch 14 The Periodic Table › 14.3 What Are Transition Elements? (Learning Outcomes) › p. 253 (PDF p. 265)**
> *"Describe typical transition elements as metals having high melting points, high densities, variable oxidation states and forming coloured compounds."*

Partly in the textbook

Gap: The book gives both sides of the melting-point contrast (Group 1: low, Table 14.4; transition metals: higher, Table 14.8 and p. 254) and says transition metals usually form coloured compounds (p. 255), but it never states that Group 1 compounds are colourless/white, so the 'coloured compounds, so not Group 1' deduction rests on an unstated contrast.
LO: 8.2(a); 8.3(a)

Section B choice

Q10 (element X, SiO_2 and NaCl) is the kinder option. Every part maps onto one textbook passage: Table 5.3 (p. 89) even prints the X_2 row (oxygen, −218 °C and −183 °C), the four table cells are single-word recalls, (b) is a prediction with the data supplied (SiO_2 solid and non-conducting, molten NaCl conducting) and (c) is the book's own 'strong forces between ions against weak intermolecular forces' explanation. Its traps are saying NaCl is still solid at 1000 °C (its melting point is 801 °C) and saying X's covalent bonds break on melting. Q11 (element Y, $PbBr_2$, element Z) is also standard content (metallic bonding, alloys, ionic lattice) but it is more open-ended: (a)(i) needs three properties each explained from Figure 11.1, (b) is a three-mark 'describe how it differs' with no model to copy, and (c) asks for an inference whose second half (Group 1 compounds are not coloured) is not stated in the book. Both options carry 10 marks and both are within the K324 syllabus, so a candidate who knows ionic and covalent structure well should choose Q10; Q11 suits a candidate who is confident with metals, alloys and the Group 1 / transition element contrast.

Notes

- Marks verified against the scan: Q1 = 2 + 1 + 2 + 1 + 2 = 8; Q2 = 2 + 2 + 3 = 7; Q3 = 2 + 1 + 1 + 2 = 6; Q4 = 2 + 3 = 5; Q5 = 1 + 3 + 2 = 6. These match the transcription and the printed totals; Q1–5 add to 32 of the 70 Section A marks.
- Transcription vs scan (Q1–5): no disagreement in any mark, formula, number or answer frame. Wording differs only because the transcription paraphrases: the scan's Q1(b) stem reads 'The carbon cycle regulates the amount of carbon dioxide in the atmosphere' (the transcription says 'controls how much'; the scan matches syllabus 12(g)(ii) word for word); Q1(a)(i) reads 'pollutant gases that cause acid rain'; Q2(b) reads 'A student states that vanillin will be made more quickly if a higher temperature is used'; Q4 reads

'made by a precipitation reaction between aqueous lead(II) nitrate and aqueous potassium chromate'; Q5(c) reads 'Another hydrocarbon has an empirical formula of C_3H_7'.

- Relative atomic masses and proton numbers were read from the Periodic Table on p. 24 of the paper (printed upside down in the scan): Pb 207, Cr 52, O 16, Br 80 (proton number 35), Kr 84 (36), Se 79 (34). Only Pb, Cr and O are needed for the calculation (Q4(b)); the proton numbers 35 and 34 are needed for Q3.
- Syllabus check (K324): every part in Q1–5 sits inside the 2023 syllabus (Q1: 12(b), 12(e), 12(g), 12(h); Q2: 10(a)–(d); Q3: 2.2(a)–(f); Q4: 4.1(c)/(e), 4.2(b)/(d), 5.2(b); Q5: 11.2(b)/(i), 4.2(e)). Two parts reach slightly past the explicit wording: Q2(b) needs enzyme denaturation and an optimum temperature, which 10(b)/(d) do not name (the TLSG, p. 56, lists 'fastest rate of an enzyme at a particular temperature and pH' as a Biology linkage), although Chemistry Matters teaches it on p. 314 and again on p. 368; and Q5(c) needs the C_6H_{14} deduction described in the gap above.
- Q3(d): the stem's talk of breaking down to krypton or selenium is context only; no radioactivity knowledge is needed (A = Z + neutrons). The decaying bromine isotope is not ^{79}Br or ^{81}Br (those cannot give a selenium with 41 neutrons); a student who assumes the selenium isotope has nucleon number 79 or 80 will go wrong.
- The book contains close twins of several parts, useful for teaching: Ch 3 Let's Review B4(a)/(b) (p. 58, bromine-79 and bromine-81; key p. 427) for 3(a)–(c); Ch 7 Let's Review B3 (p. 143, a hydrocarbon with 80.0 % carbon) for 5(b); Ch 22 Let's Review B2, B3(c) and B4 (p. 426; key p. 437) for 1(a), 1(b), 1(c); Ch 9 Let's Practise 9.1 question 1(c) asks whether lead(II) nitrate is soluble (p. 166).
- Evidence base for the quotations: every quotation was read from the rendered page image and its wording checked against the page's text layer. Where the Markdown copy differs from the printed page the printed page was followed: p. 253 prints 'Groups 3 to 12' (the Markdown copy reads 'Groups 3 to 11'). Table rows, list items and figure labels are quoted cell by cell or item by item, separated by a bullet (•) that is not in the book; fractions printed stacked in the book (the Mr and percentage-mass formulae, 1/12) are written with a slash.
- Ambiguities and rulings: (1) 1(b)(i) and 1(c) are open 'any two' answers; the sheet lists the syllabus-named processes and effects first because they are the likeliest scheme points. (2) 3(a): the 2 marks could be 'different number of neutrons' + 'same protons and electrons', or the numbers 44 and 46; the sheet's wording covers both. (3) 4(a): the 2 marks could be split by formulae and state symbols, as here, or one mark per product; the content is identical. (4) 5(c): the second mark is likely awarded for 'saturated / alkane / no C=C' alone. (5) 3(c): the sign is essential.
- Marks verified against the scan: Q6 = 1 + 3 + 3 + 1 = 8; Q7 = 4 + 3 + 1 + 2 = 10; Q8 = 3 + 1 + 3 + 2 + 1 + 1 + 1 = 12; Q9 = 1 + 2 + 3 + 1 + 1 = 8; Q10 = 3 + 4 + 3 = 10; Q11 = 3 + 2 + 3 + 2 = 10. These match the transcription and the printed [Total] on each question. Q6–9 = 38, so with Q1–5 (32) Section A = 70, and either Section B option (10) gives the paper's 80 marks. The mark-point lines in every part sum to the part marks (python-checked).
- Transcription vs scan (Q6–11): no disagreement in any mark, number, formula, figure value, table entry or answer frame. Only prose differs because the transcription paraphrases: Q6(c)(ii) scan 'The conditions used for the reaction include using a temperature of 300 °C'; Q7(a) scan 'At the start of the electrolysis, the aqueous solution is blue'; Q7(b) scan 'At the start of the electrolysis, 50.0 cm³ of aqueous copper(II) sulfate is used. The solution contains 0.32 g of aqueous Cu^{2+} ions'; Q7(c) scan 'The experiment is repeated using the same apparatus. The volume and concentration of aqueous copper(II) sulfate also stay the same'; Q8 scan 'Many devices, such as mobile phones, use lithium-ion batteries' and (b) 'Redox reactions occur at the electrodes when a battery is discharging'; Q9 scan 'One method of disposal of PAA is incineration. The PAA completely combusts' and (b) 'Waste PAA can be depolymerised into its monomers ... Show outer electrons only'; Q10(c) and Q11(c) scan 'State two reasons how the information in Table 11.1 shows that element Z is not a Group 1 element' (the transcription says 'two ways').
- Figure checks: Figure 7.2 crosses read from the scan are (0, 0.00), (1, 0.05), (2, 0.11), (3, 0.16), (4, 0.21), (5, 0.27), (6, 0.32), (7, 0.32), (8, 0.32) with the ruled line from the origin to (6, 0.32) then flat, exactly as transcribed; the best-fit line gives 0.13 g at 2.5 minutes. In Figure 7.1 the cell symbol has its long thin plate on the left and short thick plate on the right, so the left electrode is the positive electrode and the right one is negative (the stem calls the copper-gaining electrode the negative electrode). Figure 9.1 and the 9(b)

frame match the transcription (the two O circles in the frame touch but do not overlap, so there is no O–O bond). Table 11.1 and Table 10.1 match.

- Relative atomic masses used (read from the Periodic Table on p. 24 of the paper): Li 7, Co 59, O 16, Cu 64 (Br 80 and Pb 207 are only needed for the formula $PbBr_2$, not for any calculation). The Periodic Table is printed rotated in the scan.
- Syllabus check (K324): every part sits inside the 2023 syllabus. Q6: 11.2(j), 3.2, 9(a)–(d), 10(a)–(c); Q7: 7.2(e),(g),(h), 5.1(b), 4.2(c),(g); Q8: 4.2(b)–(d), 7.1(b),(c), 7.2(j), 3.4(f), 8.2(a); Q9: 11.2(j), 11.4(g), 3.2(b), (c), 5.1(c), 11.3(g); Q10: 3.1, 3.2(d), 3.4(e),(g), 2.1(a), 1.2(e); Q11: 3.3, 3.4(b)–(d), 3.1(c),(d), 8.2(a), 8.3(a). Parts that reach to the edge of the explicit wording: Q8(c) (reversing the discharge reactions of a rechargeable cell is supplied by the stem, syllabus 7.2(j) covers only simple cells), Q8(e) (ion size is not an explicit learning outcome; it follows from electronic configuration, 2.2(b) and 3.1(a)), and Q7(a) (the syllabus says calculation of pH is not required, so only 'acidic, pH below 7' is expected, not a calculated value). Q8 is the paper's data-based question (syllabus: last two Section A questions carry 20 marks, one of them data-based, 8–12 marks).
- Rulings on the most ambiguous parts: (1) Q8(d) graphite: either 'delocalised electrons conduct' or 'weak forces between layers so Li^+ fits' earns the mark; examiners most likely prefer the conduction point because the stem already says Li^+ fits between the layers. (2) Q10(a): four cells for 3 marks, banding assumed (4 correct = 3, 2 or 3 = 2, 1 = 1); NaCl structure 'giant' or 'giant ionic lattice' both fine. (3) Q7(c)(i): 4.68 g (accept 4.7) assumes the same current and time as the first experiment, so the anode loses the 0.32 g gained by the cathode. (4) Q7(a) pH: any value below 7 is accepted; the chemically correct value is about 0.7 (0.10 mol/dm³ H_2SO_4), so 1 is the best model value; 'colourless' is expected because the graph's plateau at 6 minutes shows all Cu^{2+} is used up. (5) Q9(b): the two oxygen positions in the frame are interchangeable (one C=O, one C–O–H); the examiners award for correct bonding, hydrogens and lone pairs, not for which O is which. Also: Q7(b) accepts a graph reading of 0.12–0.14 g (final answers 0.056–0.063 mol/dm³ by error carried forward); Q11(c) accepts 'Z is a transition metal because high melting point / coloured compounds' for the matching mark.
- Close twins in the book (useful for teaching): Ch 16 Let's Practise 16.1 question 3(b) (p. 290: 'Sketch labelled energy profile and energy level diagrams') for Q6(c)(i); Ch 13 Let's Review Section B question 2 (p. 241: copper(II) sulfate electrolysed with copper electrodes, then with graphite electrodes) for Q7(a) and Q7(c); Ch 5 Let's Practise 5.2 and 5.4 (pp. 87, 99: ionic conduction; why alloys are harder; why pure metals have fixed melting points) for Q10 and Q11(a); Ch 8 Let's Practise 8.2 question 1 (p. 150: strong against weak acid) for Q9(c)(i); Ch 21 Let's Practise 21.4 (p. 396: advantage and disadvantage of incineration) for Q9(a).
- Evidence base for the quotations: every quotation was read from the rendered page image (the text layer of the full PDF is scrambled) and re-checked by OCR of a 2.6x render of the same page: 117 of 119 quotations match the OCR text at 90 % or better by a letter-by-letter comparison. The remaining 2 were compared with the page image by eye: the Q8(a)(i) percentage-mass formula on p. 124 (typeset as a fraction, which the OCR garbles; it matches the Markdown copy exactly) and the Q9(a)(i) 'Air pollution' caption on p. 396 (Figure 21.28 is printed in three columns that the OCR interleaves). Table rows, list items and figure labels are quoted item by item, separated by a bullet (•) that is not in the book; formulas printed as fractions are written with the fraction bar as '/' inside brackets. The Markdown copy of Chapter 14 prints 'Groups 3 to 11' where the page says 'Groups 3 to 12' (not quoted here).
- Cross-check on Questions 1–5 (answers_2026_pure_1.json): all 95 pdf_page values there equal printed page + 12, the same as here; no conflicts found with the page numbers or classifications used in this file.