

Markscheme

May 2023

Chemistry

Higher level

Paper 3

29 pages

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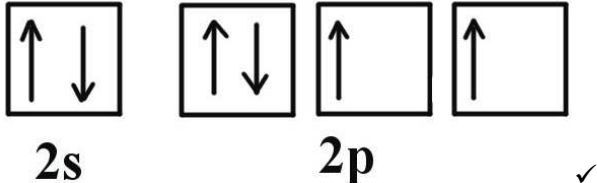
Subject details: Chemistry higher level Paper 3 Markscheme

Candidates are required to answer ALL questions in Section A [15 marks] and all questions from ONE option in Section B [30 marks].

Maximum total = [45 marks].

1. Each row in the “Question” column relates to the smallest subpart of the question.
2. The maximum mark for each question subpart is indicated in the “Total” column.
3. Each marking point in the “Answers” column is shown by means of a tick (✓) at the end of the marking point.
4. A question subpart may have more marking points than the total allows. This will be indicated by “max” written after the mark in the “Total” column. The related rubric, if necessary, will be outlined in the “Notes” column.
5. An alternative word is indicated in the “Answers” column by a slash (/). Either word can be accepted.
6. An alternative answer is indicated in the “Answers” column by “OR”. Either answer can be accepted.
7. An alternative markscheme is indicated in the “Answers” column under heading ALTERNATIVE 1 *etc.* Either alternative can be accepted.
8. Words inside chevrons « » in the “Answers” column are not necessary to gain the mark.
9. Words that are underlined are essential for the mark.
10. The order of marking points does not have to be as in the “Answers” column, unless stated otherwise in the “Notes” column.
11. If the candidate’s answer has the same “meaning” or can be clearly interpreted as being of equivalent significance, detail and validity as that in the “Answers” column then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by *OWTTE* (or words to that effect) in the “Notes” column.
12. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.
13. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then follow through marks should be awarded. When marking, indicate this by adding ECF (error carried forward) on the script.
14. Do not penalize candidates for errors in units or significant figures, unless it is specifically referred to in the “Notes” column.
15. If a question specifically asks for the name of a substance, do not award a mark for a correct formula unless directed otherwise in the “Notes” column. Similarly, if the formula is specifically asked for, do not award a mark for a correct name unless directed otherwise in the “Notes” column.
16. If a question asks for an equation for a reaction, a balanced symbol equation is usually expected, do not award a mark for a word equation or an unbalanced equation unless directed otherwise in the “Notes” column.
17. Ignore missing or incorrect state symbols in an equation unless directed otherwise in the “Notes” column.

Section A

| Question | | Answers | Notes | Total |
|----------|-----|---|---|-------|
| 1. | (a) | ionization energy breaks bond/attractive force between nucleus and electron AND electron affinity forms bond/attractive force between nucleus and electron ✓ | <i>Accept for ionization energy “energy needed/endergonic to remove an electron”. AND for electron affinity “energy released/exothermic adding an electron”.</i> | 1 |
| 1. | (b) | electron «removed» from 2p in B AND 2s in Be ✓ shielding effect of 2s «reduces energy needed to remove 2p» OR 2p at higher energy level/further from nucleus OR full 2s more stable «than single electron in p» ✓ | <i>Accept electron configurations of both B and Be for M1.</i> | 2 |
| 1. | (c) |  <p style="text-align: center;">2s 2p ✓</p> | <i>Accept second arrow, representing opposite spin, in any 2p box. Accept half-arrows.</i> | 1 |

| Question | | Answers | Notes | Total |
|----------|-----|--|--|-------|
| 1. | (d) | greater repulsion when electrons occupy same orbital ✓ | Accept electron added to stable half-filled p sublevel. | 1 |
| 1. | (e) | <p><i>Largest first ionization energy:</i> highest nuclear charge «for a similar radius/same energy level» OR smallest radius OR stable octet ✓</p> <p><i>Largest positive first electron affinity:</i> adding to new principal energy level OR «much» further from nucleus OR shielded by completed inner shell ✓</p> | Do not accept “complete octet” without reference to stability for M1. | 2 |

| Question | | | Answers | Notes | Total |
|----------|-----|------|--|---|-------|
| 1. | (f) | | <p>ALTERNATIVE 1: «Xe» lower/smaller/less positive AND larger radius OR «Xe» lower/smaller/less positive AND smaller energy gap to next «principal» energy level ✓</p> <p>ALTERNATIVE 2: «Xe» greater AND very high nuclear charge OR «Xe » greater AND poor shielding by inner «d» orbitals ✓</p> | <p><i>Accept converse arguments for either alternative only if it is clear that Ne being referred to.</i></p> | 1 |
| 2 | (a) | (i) | +2/II ✓ | <p><i>Do not accept A^{2+}, A^{+2}, 2 OR 2+.</i></p> | 1 |
| 2. | (a) | (ii) | C A B D E ✓ | <p><i>Do not accept reverse order unless the answer makes it clear which is the most reactive.</i></p> | 1 |

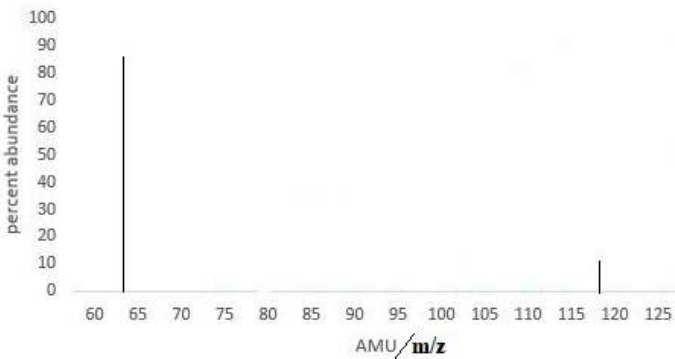
Section B

Option A — Materials

| Question | | | Answers | Notes | Total |
|----------|-----|-------|---|--|-------|
| 3. | (a) | (i) | $2\text{CO(g)} \rightarrow \text{C(s)} + \text{CO}_2\text{(g)}$ ✓ | <i>Accept reversible arrows.</i> | 1 |
| 3. | (a) | (ii) | $\llcorner 100 \times 12.01 / 2 \times (12.01 + 16.00) = \gg 21.44\%$ ✓ | | 1 |
| 3. | (a) | (iii) | «gaseous» reactants adsorb onto «metal» surface OR catalyst provides surface for reaction to occur ✓ weakens «reactant» bonds OR products desorb ✓ | <i>Accept lowers activation energy for M2.</i> | 2 |
| 3. | (a) | (iv) | bottom up AND molecular assembly «rather than decomposition» ✓ | | 1 |

| Question | | | Answers | Notes | Total |
|----------|-----|-----|---|--|-------|
| 3. | (a) | (v) | <p>Any one of: more easily airborne/inhaled ✓ have similar dimensions as biological molecules/interfere with biochemical reactions ✓ easily absorbed into body ✓ may cross cell membranes ✓ large surface area could increase toxicity ✓ human defence system not effective with small size ✓</p> | <p>Do not accept just large surface area OR toxic/increased toxicity.</p> | 1 max |
| 3. | (b) | (i) | <p>fluids with «some» properties that are anisotropic/depend on molecular orientation «relative to a fixed axis» ✓</p> | <p>Do not accept general references to a mesophase.</p> | 1 |

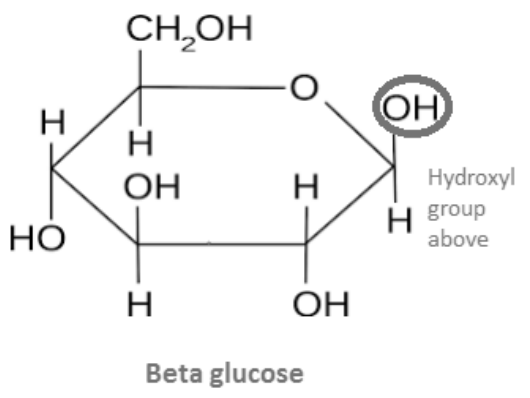
| Question | | | Answers | Notes | Total |
|----------|-----|-------|---|--|-------|
| 3. | (b) | (ii) | polar «molecules» ✓ change orientation upon application of electric field OR «in some orientations» molecules rotate plane of polarization «of polarized light» ✓ | | 2 |
| 3. | (b) | (iii) | 7 ✓ | | 1 |
| 3. | (b) | (iv) | 3300 to 3500 ✓ | <i>Accept amine/amide/N-H bond.</i> | 1 |
| 3. | (b) | (v) | <i>Monomers:</i> addition: unsaturated/containing C=C/C≡C ✓ condensation: monomers have two reactive sites/functional groups ✓ <i>Products:</i> addition: one product/no by-products AND condensation: small molecule/HCl eliminated/two products ✓ | <i>Double/triple bond must be stated as between carbon atoms.</i> <i>Accept H₂O eliminated in condensation reaction.</i> | 3 |

| Question | | | Answers | Notes | Total |
|----------|-----|------|--|---|-------|
| 4. | (a) | | metal ions/atoms have different sizes ✓ cations/atoms/layers do not slide over each other as easily ✓ «irregularities» obstruct free movement of electrons ✓ | <i>Accept electrons move less easily/less delocalized for M3.</i> | 3 |
| 4. | (b) | | straight line increasing and going through origin/(0,0) ✓ | | 1 |
| 4. | (c) | (i) | <p>Mass spectrum for elements in shield EHR</p>  <p>89% at 63.5 AND 10% at 118 ✓</p> | <i>Accept range 62.5-64.5 for Cu and 117-119 for Sn. Accept 85-95 % for Cu and 5-15 % for Sn.</i> | 1 |
| 4. | (c) | (ii) | vapourize «the sample» ✓ ionize «the sample» ✓ | <i>Accept relevant equations.</i> | 2 |

| Question | | | Answers | Notes | Total |
|----------|-----|------|--|--|-------|
| 5. | (a) | (i) | Coordination number: 12 ✓ Number of atoms per unit cell: 4 ✓ | | 2 |
| 5. | (a) | (ii) | $V = \ll (3.61 \times 10^{-8} \text{ cm})^3 = \gg 4.70 \times 10^{-23} \text{ cm}^3 \gg \checkmark$ Mass of unit cell = $\ll 63.55 \text{ g mol}^{-1} \times 4 \div 6.02 \times 10^{23} \gg 4.22 \times 10^{-22} \text{ g} \gg \checkmark$ $4.22 \times 10^{-22} \text{ g} \div 4.70 \times 10^{-23} \text{ cm}^3 \gg 8.98 \text{ g cm}^{-3} \gg \checkmark$ | <i>Award [3] for correct final answer.</i> | 3 |
| 5. | (b) | | $K_{sp} = [\text{Cu}^{2+}][\text{OH}^-]^2$ OR $2.2 \times 10^{-20} = [\text{Cu}^{2+}] \times (10^{-5})^2 \checkmark$ $[\text{Cu}^{2+}] \ll = K_{sp}/[\text{OH}^-]^2 = 2.2 \times 10^{-20}/(10^{-5})^2 \gg$ $= 2.2 \times 10^{-10} \text{ mol dm}^{-3} \gg \checkmark$ | <i>Award [2] for correct final answer.</i> | 2 |
| 5. | (c) | | $\text{Cu}^{2+} + \bullet\text{O}_2^- \rightarrow \text{Cu}^+ + \text{O}_2 \checkmark$ $\text{Cu}^+ + \text{H}_2\text{O}_2 \rightarrow \text{Cu}^{2+} + \text{OH}^- + \bullet\text{OH} \checkmark$ | | 2 |

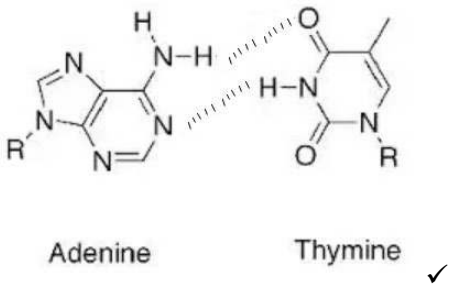
Option B — Biochemistry

| Question | | | Answers | Notes | Total |
|----------|-----|------|---|---|-------|
| 6. | (a) | | cannot be synthesized «by the human body» ✓ | | 1 |
| 6. | (b) | | temperature AND pH ✓ | | 1 |
| 7. | (a) | (i) | $C_x(H_2O)_y$ ✓ | | 1 |
| 7. | (a) | (ii) | « $n=10.5g/180.18g\ mol^{-1}=\Rightarrow 0.0583\ \text{«mol»}$ ✓ « $0.0583\ mol \times 2810\ kJ\ mol^{-1} =\Rightarrow 164\ \text{«kJ»}$ ✓ | <i>Award [2] for correct final answer.</i> <i>Award [1 max] for –164 «kJ».</i> | 2 |

| Question | | | Answers | Notes | Total |
|----------|-----|------|--|--|-------|
| 7. | (b) | |  <p style="text-align: center;">Beta glucose ✓</p> | <p><i>Entire structure must be correct to score the mark.</i></p> <p><i>Ignore incorrect connectivity.</i></p> | 1 |
| 7. | (c) | | «provides dietary» fibre/roughage ✓ | <i>Accept prevents constipation, etc.</i> | 1 |
| 7. | (d) | (i) | $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ ✓ $C_{57}H_{110}O_6 + 81.5O_2 \rightarrow 57CO_2 + 55H_2O$ OR $2C_{57}H_{110}O_6 + 163O_2 \rightarrow 114CO_2 + 110H_2O$ ✓ | | 2 |
| 7. | (d) | (ii) | more AND contains less oxygen/contains more carbon/more reduced ✓ | | 1 |

| Question | | | Answers | Notes | Total |
|----------|-----|------|---|--|-------|
| 7. | (e) | | <p><i>Chemical composition:</i> glycerol AND «two» fatty acids AND «one» phosphate ✓</p> <p><i>Function:</i> cell/plasma membrane ✓</p> | <p>Accept suitable diagram for M1. Do not accept "hydrophilic head and hydrophobic tail" for M1.</p> <p>Accept insulation or lipid transport for M2.</p> <p>Do not accept cell wall for cell membrane.</p> | 2 |
| 8. | (a) | (i) | <p><i>Identity of spot C:</i> leucine ✓</p> | | 1 |
| 8. | (a) | (ii) | <p>serine AND more polar «than phenylalanine» OR serine AND OH group «on side chain» ✓</p> <p>hydrogen bonding/greater affinity with stationary phase OR less soluble/poor affinity in solvent/mobile phase ✓</p> | <p>M2 may be scored without M1.</p> | 2 |
| 8. | (b) | | <p>bind to substrate at active site ✓ «provide» alternative pathway with lower «activation» energy ✓</p> | <p>Must have idea of binding to substrate AND a specific active site for M1.</p> | 2 |

| Question | | Answers | Notes | Total |
|----------|-----|--|--|-------|
| 8. | (c) | additives to detergents/washing powders/liquids OR breakdown oil spills/industrial waste ✓ | <i>Accept other industrial use.</i> <i>Do not accept non-industrial uses, such as pregnancy testing.</i> | 1 |
| 8. | (d) | <i>Effect on K_m:</i> remains the same/no change AND <i>Effect on V_{max}:</i> decreases/reduced ✓ <i>Explanation for K_m:</i> no decrease in affinity of enzyme for substrate ✓ <i>Explanation for V_{max}:</i> binds at allosteric site OR binds away from active site OR changes shape of active site OR renders active site ineffective ✓ | | 3 |

| Question | | Answers | Notes | Total |
|----------|-----|--|---|-------|
| 8. | (e) | $\log_{10} \frac{I_0}{I} = \epsilon lc$ « and $\log_{10} I_0/I = A$ » $\epsilon lc = 0.50$ ✓ « $c = 0.50 / (0.75 \text{ dm}^3 \text{ cm}^{-1} \text{ mol}^{-1} \times 1 \text{ cm})$ » 0.67 mol dm^{-3} » ✓ | Award [2] for correct final answer. | 2 |
| 9. | (a) | phosphate AND deoxyribose AND nitrogenous base ✓ | Accept named base. Do not accept 'sugar' or 'pentose sugar' in place of deoxyribose. | 1 |
| 9. | (b) |  <p style="text-align: center;">Adenine Thymine ✓</p> | Only 2 H bonds must be shown. Accept H bond from either H in NH ₂ of Adenine, but not from both. Accept solid lines instead of dashes. | 1 |

| Question | | Answers | Notes | Total |
|----------|-----|--|---|-------|
| 10. | (a) | X AND «high pH moves» equilibrium left OR X AND loss of proton/H ⁺ «at high pH/due to excess OH ⁻ (aq)» OR X AND positive ion unlikely «at high pH» ✓ | | 1 |
| 10. | (b) | temperature OR light ✓ | <i>Accept other reasonable answer, eg. metal ions, enzymes, oxidising agent, etc.</i> | 1 |
| 10. | (c) | <i>Similarity:</i> heme group OR Fe cation/Fe ²⁺ ✓ <i>Difference:</i> myoglobin has one polypeptide chain AND hemoglobin has four polypeptide chains OR myoglobin has one heme «group» AND hemoglobin has four heme «groups» OR myoglobin has no quaternary structure AND hemoglobin has quaternary structure ✓ | <i>Accept both are globular proteins or both are metalloproteins.</i> <i>Do not accept both are polymers of amino acids.</i> | 2 |
| 11. | | chemicals found in an organism that are not normally present ✓ | | 1 |

Option C — Energy

| Question | | | Answers | Notes | Total |
|----------|-----|-------|--|--|-------|
| 12. | (a) | (i) | 33% of energy input/released «in fission» is converted to electricity ✓ | <i>Do not accept generalizations, such as “Only produces 33% useful energy.”</i> | 1 |
| 12. | (a) | (ii) | X ${}^3_2\text{He}$ AND Y ${}^3_1\text{H}$ ✓ | | 1 |
| 12. | (a) | (iii) | 2 nd /Y/ ${}^3_1\text{H}$ AND formation ${}^3_1\text{H}$ has greater increase in binding energy «per nucleon than formation ${}^3_2\text{He}$ ✓ | <i>Accept 2nd/Y/${}^3_1\text{H}$ AND “It is higher on the binding energy curve”.</i> | 1 |

| Question | | | Answers | Notes | Total |
|----------|-----|------|--|--|-------|
| 12. | (a) | (iv) | <p>$m(\text{deuteron}) = 2.013553 \text{ «amu»} \times 1.660540 \times 10^{-27} \text{ «kg amu}^{-1}\text{=»}$ OR $3.343585 \times 10^{-27} \text{ «kg»} \checkmark$</p> <p>«$\Delta m = (\text{mass of reactants} - \text{mass of products})$» $\Delta m = \text{«}(1.672622 \times 10^{-27} \text{ kg} + 1.674927 \times 10^{-27} \text{ kg}) - 3.343585 \times 10^{-27} \text{ kg} =\text{»}$ $3.964 \times 10^{-30} \text{ «kg»} \checkmark$</p> <p>$E = \text{«}mc^2 = 3.964 \times 10^{-30} \text{ kg} \times (3.00 \times 10^8 \text{ m s}^{-1})^2 =\text{»} 3.568 \times 10^{-13} \text{ «J»} \checkmark$</p> | <i>Award [3] for correct final answer.</i> | 3 |
| 12. | (a) | (v) | <p>deuterium contains more atoms per unit mass «than uranium as it has a lower molar mass» \checkmark</p> <p>fusion releases more energy per atom than fission \checkmark</p> <p>«solid» uranium «much» more dense «than deuterium» OR uranium contains more atoms per unit volume «than deuterium, as it is a solid» \checkmark</p> <p>increase in density has a greater effect than fusion releasing more energy than fission \checkmark</p> | | 4 |

| Question | | | Answers | Notes | Total |
|----------|-----|------|--|--|-------|
| 12. | (a) | (vi) | uranium converted to uranium hexafluoride/UF ₆ «gas» ✓ centrifuge OR lower mass isotope/ ²³⁵ U effuses/diffuses more rapidly OR higher mass isotope/ ²³⁸ U moves/closer to outside of centrifuge OR lower mass isotope/ ²³⁵ U stays in/removed from middle of centrifuge ✓ | | 2 |
| 12. | (b) | (i) | C ₇ H ₁₆ → C ₆ H ₅ CH ₃ + 4H ₂ ✓ | Accept C ₇ H ₈ for C ₆ H ₅ CH ₃ . | 1 |
| 12. | (b) | (ii) | any alkane AND alkene where total sum of C=7 and H=16; e.g. C ₅ H ₁₂ AND C ₂ H ₄ ✓ | | 1 |
| 13. | (a) | | C ₆ H ₁₂ O ₆ → 2C ₂ H ₅ OH + 2CO ₂ ✓ | | 1 |

| Question | | | Answers | Notes | Total |
|----------|-----|-------|---|--|-------|
| 13. | (b) | | <p>ester product ✓ glycerol AND correct balancing ✓</p> | | 2 |
| 13. | (c) | | conjugated bonds/alternating C=C bonds/delocalized electrons/bonding ✓ | Accept 'alternating single and double bonds'. Do not accept 'many double bonds'. | 1 |
| 13. | (d) | (i) | allow H ⁺ ions to pass through/diffuse/move «from anode to cathode» ✓ | Do not accept diffusion of electrons or small molecules. | 1 |
| 13. | (d) | (ii) | Anode: CH ₃ COO ⁻ (aq) + 2H ₂ O(l) → 2CO ₂ (g) + 7H ⁺ (aq) + 8e ⁻ ✓ Cathode: O ₂ (g) + 4H ⁺ (aq) + 4e ⁻ → 2H ₂ O(l) ✓ Overall Equation: CH ₃ COO ⁻ (aq) + H ⁺ (aq) + 2O ₂ (g) → 2CO ₂ (g) + 2H ₂ O(l) ✓ | | 3 |
| 13. | (d) | (iii) | fuel supply is wastewater/organic material ✓ | Accept bacterium reproduces. | 1 |

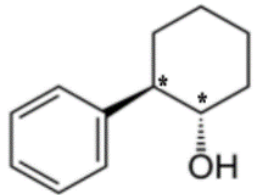
| Question | | Answers | Notes | Total |
|----------|-----|---|--|-------|
| 14. | (a) | glacier/ice sheets/ retreat/melting OR rising sea levels ✓ | Accept other reasonable answers, e.g. ocean acidification, severe weather patterns. Do not accept just 'climate change'. | 1 |
| 14. | (b) | «increase in bond» stretching/vibrating/bending OR bond angles/lengths change ✓ | Accept dipole moment changes. Accept light energy is converted into mechanical/potential/internal energy of the molecule. | 1 |
| 14. | (c) | « $M_r \text{ CH}_4: M_r \text{ CO}_2/ 16.05 \div 44.01 = \Rightarrow 0.365$ ✓ « $21 \times 0.365 = \Rightarrow 7.66$ «times» ✓ | Award [2] for correct final answer. Accept 7.64 «times» (integer M_r s). Award [1 max] for 57.6 «times» if inverted ratio is used. | 2 |
| 15. | (a) | negative above junction AND positive below junction ✓ e^- flow from n-type through wire to light globe OR from light globe to p-type through wire. ✓ | | 2 |
| 15. | (b) | silicon/Si OR germanium/Ge ✓ | | 1 |

Option D — Medicinal chemistry

| Question | | Answers | Notes | Total |
|----------|-----|--|---|-------|
| 16. | (a) | <p>Any two of:</p> <ul style="list-style-type: none"> oral ✓ inhalation ✓ topical/applied to the skin ✓ parenteral/injection ✓ suppositories ✓ eye/ear drops ✓ | <p>One mark for any two correct methods.</p> <p>Count multiple methods of injection (intramuscular, subcutaneous, intravenous) as just one method.</p> | 1 |
| 16. | (b) | <ul style="list-style-type: none"> interferes with pain at source «of injury» ✓ prevents release of prostaglandins/substances causing swelling/pain ✓ | | 2 |
| 16. | (c) | <p>ALTERNATIVE 1:</p> <ul style="list-style-type: none"> A: $\text{CH}_3\text{COOCOCH}_3$ ✓ B: CH_3COOH ✓ <p>ALTERNATIVE 2:</p> <ul style="list-style-type: none"> A: CH_3COOH ✓ B: H_2O ✓ <p>ALTERNATIVE 3:</p> <ul style="list-style-type: none"> A: CH_3COCl ✓ B: HCl ✓ | <p>Accept expanded structural formulas.</p> | 2 |

| Question | | Answers | Notes | Total |
|----------|-----|---|--|-------|
| 16. | (d) | <p><i>Advantage:</i> strong/severe/surgical pain relief OR stops coughing reflex OR fast action ✓</p> <p><i>Disadvantage:</i> addiction OR constipation OR tolerance «leading to overdose» ✓</p> | <p><i>Accept strong painkillers/analgesics for M1.</i></p> <p><i>Accept constipation for M1 if not given as a disadvantage.</i></p> <p><i>Accept small therapeutic window for M2.</i> <i>Accept other named specific side effect for M2.</i></p> | 2 |
| 17. | (a) | <p>$\text{MgCO}_3(\text{s}) + 2\text{HCl}(\text{aq}) \rightarrow \text{MgCl}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$ AND $\text{Al}(\text{OH})_3(\text{s}) + 3\text{HCl}(\text{aq}) \rightarrow \text{AlCl}_3(\text{aq}) + 3\text{H}_2\text{O}(\text{l})$ ✓</p> | <p><i>Accept appropriate ionic equations.</i></p> <p><i>Do not accept H_2CO_3 as a product of first reaction.</i></p> <p><i>Ignore equilibrium arrows.</i></p> | 1 |

| Question | | Answers | Notes | Total |
|----------|-----|--|---|-------|
| 17. | (b) | <p>$n(\text{MgCO}_3) = 2.00\text{g}/84.32\text{g mol}^{-1} = 0.0237$ « mol » AND $n(\text{Al}(\text{OH})_3) = 2.00\text{g}/78.01\text{g mol}^{-1} = 0.0256$ « mol » ✓</p> <p>$0.0237n(\text{MgCO}_3) \times 2 = 0.0474$ «n(HCl) neutralised» AND $0.0256 n(\text{Al}(\text{OH})_3) \times 3 = 0.0768$ «n(HCl) neutralised» ✓</p> | <p>Award [1 max] for any two correct calculations.</p> | 2 |
| 18. | (a) | <p>Any two of:</p> <ul style="list-style-type: none"> «bind to receptors to» prevent virus entering cell ✓ alter genetic material of cell/cytoplasm «to prevent replication» ✓ block enzyme activity in cell «to prevent replication» ✓ prevent virus leaving cell «by inhibiting viral enzyme/neuraminidase» ✓ | | 2 max |
| 18. | (b) | <p>side chain modified ✓ overcome antibiotic resistance/ penicillinase ineffective ✓</p> | <p>Accept R group instead of side chain. Accept increase the stability of penicillin in GIT/gastrointestinal tract for M2.</p> | 2 |

| Question | | Answers | Notes | Total |
|----------|-----|--|---|-------|
| 19. | (a) |  <p style="text-align: center;">✓✓ one for each carbon correctly identified</p> | Apply 'list principle' if any answer has more than two carbon atoms marked. | 2 |
| 19. | (b) | needles «of European» yew «tree» ✓ | | 1 |
| 19. | (c) | <p>Any two of:</p> <p>energy efficiency ✓</p> <p>prevention of waste/recycling ✓</p> <p>atom economy/more efficient processes ✓</p> <p>safer/reduced use of solvents ✓</p> <p>design for degradation ✓</p> <p>more sustainable sourcing of reactants/feedstock ✓</p> | Accept specific examples. | 2 max |

| Question | | Answers | Notes | Total |
|----------|-----|--|--|-------|
| 20. | (a) | <p>TAT: spread to multiple sites AND alpha particles OR «cancers of the» blood/leukaemia AND alpha particles ✓</p> <p>BNCT: head/neck/brain «cancers» AND neutrons ✓</p> | <i>Award [1] for 2 correct cancers or 2 correct particles.</i> | 2 |
| 20. | (b) | <p><i>Any two of:</i> gamma radiation AND easily traced ✓</p> <p>weak/low-energy/low-frequency «gamma» radiation «low risk to patient» ✓</p> <p>short half-life «low risk to patient» ✓</p> <p>binds to range of biologically-active substances ✓</p> <p>«gamma-radiation of approximately» same frequency as X-rays «so can be detected using existing X-ray equipment» ✓</p> <p>easily obtained ✓</p> | <i>Accept non-ionising radiation.</i> | 2 max |
| 20. | (c) | <p>«$N_t = N_0(0.5)^{t/t_{1/2}} \Rightarrow 1.0 \times 10^{-7} \text{ mol dm}^{-3} \times (0.5)^{22.00/6.01}$ ✓</p> <p>«$N_t \Rightarrow 7.9 \times 10^{-9} \text{ «mol dm}^{-3}\text{»}$ ✓</p> | <i>Award [2] for correct final answer.</i> | 2 |

| Question | | | Answers | Notes | Total |
|----------|-----|------|---|--|-------|
| 21. | (a) | (i) | chromatography ✓ | Accept any named form of chromatography. Accept extraction. | 1 |
| 21. | (a) | (ii) | <i>m/z</i> 288: molecular ion/M ⁺ /C ₁₉ H ₂₈ O ₂ ⁺ ✓ <i>m/z</i> 273: C ₁₈ H ₂₅ O ₂ ⁺ OR loss of methyl/CH ₃ group" or "(M – CH ₃) ⁺ ✓ | Charge needed, penalize missing charge once only. | 2 |
| 21. | (b) | | ALTERNATIVE 1: C ₂ H ₅ OH(g) → C ₂ H ₄ O(aq) + 2H ⁺ + 2e ⁻ ✓ 3C ₂ H ₅ OH(g) + Cr ₂ O ₇ ²⁻ (aq) + 8H ⁺ (aq) → 3C ₂ H ₄ O(aq) + 2Cr ³⁺ (aq) + 7H ₂ O(l) ✓ ALTERNATIVE 2: C ₂ H ₅ OH(g) + H ₂ O(l) → CH ₃ COOH(aq) + 4H ⁺ + 4e ⁻ ✓ 3C ₂ H ₅ OH(g) + 2Cr ₂ O ₇ ²⁻ (aq) + 16H ⁺ (aq) → 3CH ₃ COOH(aq) + 4Cr ³⁺ (aq) + 11H ₂ O(l) ✓ | Accept C ₂ H ₆ O for C ₂ H ₅ OH. | 2 |