

Markscheme

May 2019

Chemistry

Higher level

Paper 3

37 pages

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Section A

| Question | | | Answers | Notes | Total |
|----------|---|----|--|---|-------|
| 1. | a | | 6 ✓ | Accept "orange juice". | 1 |
| 1. | b | i | equilibrium is being established «between lead in solution and in mug» OR solution becoming saturated OR concentration of lead ions/[Pb ²⁺] in the solution has increased «over time» OR acid concentration has decreased «as reacted with lead» OR surface lead has decreased/formed a compound/forms insoluble layer on surface OR acid reacts with other metals «because it is an alloy» ✓ | Do not accept "concentration of cola, orange juice, etc... has decreased" Do not accept a response that only discusses mathematical or proportional relationships. | 1 |
| 1. | b | ii | no AND experiment 7/beer has lowest rate and intermediate acidity/pH OR no AND experiment 6/orange juice has fastest rate but lower acidity/higher pH than lemonade OR no AND experiment 6/orange juice has highest rate and intermediate acidity/pH ✓ | Accept no AND any comparison, with experimental support , that concludes no pattern/increase with acidity eg: "rate of Pb/lead dissolving generally decreases with acidity as tap water has highest rate (after orange juice) while lemonade (lower pH) has lower rate". | 1 |

| Question | | | Answers | Notes | Total |
|----------|---|----|---|--|-------|
| 1. | c | i | equilibrium shifts to the left/towards reactants ✓ lead «compounds/ions» precipitate OR concentration of lead «ions»/[Pb ²⁺] decreases ✓ | Award [2] for “equilibrium shifts to the left/towards reactants due to common ion effect”. Accept “lead ions/[Pb ²⁺] removed from solution” for M2. | 2 |
| 1. | c | ii | «daily limit = $5.0 \times 10^{-6} \text{ g kg}^{-1} \times 80.0 \text{ kg} \Rightarrow 4.0 \times 10^{-4} \text{ «g of lead»} \checkmark$ «volume = $\frac{4.0 \times 10^{-4} \text{ g}}{1.5 \times 10^{-2} \text{ g dm}^{-3}} \Rightarrow 2.7 \times 10^{-2} / 0.027 \text{ «dm}^3\text{»} \checkmark$ | Award [2] for correct final answer | 2 |

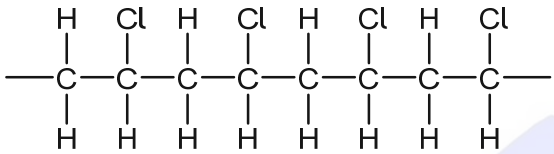
| Question | | Answers | Notes | Total |
|----------|---|--|---|-------|
| 2. | a | tangent drawn to curve at $t = 20 \text{ s}$ ✓ slope/gradient calculation ✓ $0.35 \text{ cm}^3 \text{ s}^{-1}$ ✓ | Accept values in the range $0.32\text{--}0.42 \text{ cm}^3 \text{ s}^{-1}$. | 3 |
| 2. | b | <p>ALTERNATIVE 1 colour ✓ Br_2 /reactant is coloured «Br^- (aq) is not» ✓</p> <p>ALTERNATIVE 2 conductivity ✓ greater/increased concentration of ions in products ✓</p> <p>ALTERNATIVE 3 mass/pressure ✓ gas is evolved/produced ✓</p> <p>ALTERNATIVE 4 pH ✓ methanoic acid is weak AND HBr is strong OR increase in $[\text{H}^+]$ ✓</p> | <p>Do not accept “changes in temperature” or “number of bubbles”.</p> <p>Do not accept “mass of products is less than mass of reactants”.</p> | 2 |

| Question | | | Answers | Notes | Total |
|----------|---|----|---|--|-------|
| 2. | c | i | <p>ALTERNATIVE 1</p> <p>gas may leak/be lost/escape</p> <p>OR</p> <p>plunger may stick/friction «so pressure is greater than atmospheric pressure»</p> <p>OR</p> <p>syringe may be tilted «up» so plunger moves less «with gravity acting on plunger»</p> <p>OR</p> <p>CO₂ dissolved in water ✓</p> <p>calculated rate lower ✓</p> <p>ALTERNATIVE 2</p> <p>syringe may be tilted «down» so plunger moves more «with gravity acting on plunger»</p> <p>OR</p> <p>syringe is held in hand so gets warmer and gas expands ✓</p> <p>calculated rate higher ✓</p> | <p>Calculated rate is lower or higher must be stated for M2.</p> <p><i>Do not accept "scale on syringe is inaccurate", "errors in reading syringe", or "bubbles in syringe".</i></p> | 2 |
| 2. | c | ii | <p>human reaction time/delay «starting/stopping the stopwatch» ✓</p> | <p><i>Do not accept "inaccurate stopwatch".</i></p> | 1 |

Section B

Option A — Materials

| Question | | | Answers | Notes | Total |
|----------|--|--|--|--------------------------|-------|
| 3. | | | Shape of molecules: linear OR rod «shaped» ✓ Distribution: no positional order AND «some» directional order ✓ | Accept “partly ordered”. | 2 |

| Question | | Answers | Notes | Total |
|----------|---|---|---|-------|
| 5. | a |  <p>correct bonding ✓ Cl atoms all on same side and alternate ✓</p> | <p>Continuation bonds must be shown. Award [1 max] if less than or more than four units shown. Accept a stereo formula with all atoms and bonds shown.</p> | 2 |
| 5. | b | «strong additional» absorption at 600–800 «cm ⁻¹ » ✓ | | 1 |
| 5. | c | <p>Any two of:</p> <ul style="list-style-type: none"> embedded/fit between chains of polymers ✓ prevent chains from forming crystalline regions ✓ keep polymer strands/chains/molecules separated/apart ✓ increase space/volume between chains ✓ weaken intermolecular/dipole-dipole/London/dispersion/instantaneous dipole-induced dipole/van der Waals/vdW forces «between chains» ✓ increase flexibility/durability/softness ✓ make polymers less brittle ✓ | Accept “lowers density/melting point”. | 2 max |
| 5. | d | <p>leach into foodstuffs/environment OR «unknown» health/environmental consequences ✓</p> | Accept “plasticizers cannot be recycled”. | 1 |

| Question | | Answers | Notes | Total |
|----------|---|--|---|-------|
| 5. | e | <p>addition produces only the polymer «AND more green»</p> <p>OR</p> <p>addition has no by/side-product/condensation produces by-product/small molecules/HCl/NH₃ «AND less green»</p> <p>OR</p> <p>addition has high atom economy/condensation has lower atom economy «AND less green»</p> <p>OR</p> <p>condensation polymers «often» more biodegradable than addition polymers «AND more green» ✓</p> | <p>Accept "if water produced by condensation «AND condensation and addition equally green»".</p> <p>Accept for addition "all of reactants change into products".</p> | 1 |
| 5. | f | $\begin{array}{c} \text{H} \quad \text{O} \\ \quad \\ \text{---N---C---} \end{array} \checkmark$ | <p>Continuation bonds must be shown.</p> <p>Do not accept condensed formula.</p> | 1 |

| Question | | Answers | Notes | Total |
|----------|---|--|--|-------|
| 6. | a | $\llcorner 8 \times \frac{1}{8} + 6 \times \frac{1}{2} = \llcorner 4 \checkmark$ | | 1 |
| 6. | b | $a = \llcorner \frac{4r}{\sqrt{2}} = \frac{4 \times 1.97 \times 10^{-10} \text{ m}}{\sqrt{2}} = \llcorner 5.572 \times 10^{-10} \llcorner \text{m} \llcorner$ <p>OR</p> <p>volume of unit cell = $\llcorner (5.572 \times 10^{-10} \text{ m})^3 \times 10^6 = \llcorner 1.73 \times 10^{-22} \llcorner \text{cm}^3 \llcorner \checkmark$</p> <p>mass of unit cell = $\llcorner \frac{40.08 \text{ g mol}^{-1} \times 4}{6.02 \times 10^{23} \text{ mol}^{-1}} = \llcorner 2.66 \times 10^{-22} \llcorner \text{g} \llcorner \checkmark$</p> <p>density = $\llcorner \frac{2.66 \times 10^{-22} \text{ g}}{(5.572 \times 10^{-10})^3 \times 10^6} = \llcorner 1.54 \llcorner \text{g cm}^{-3} \llcorner \checkmark$</p> | <i>Award [3] for correct final answer.</i> | 3 |
| 7. | a | $\llcorner \text{material with} \llcorner$ no electrical resistance \checkmark | | 1 |
| 7. | b | Type 1 has sharper transition to superconductivity \checkmark | <i>Accept annotated plot of electrical resistance against temperature.</i> | 1 |

| Question | | Answers | Notes | Total |
|----------|---|---|-------------------------------------|-------|
| 8. | a | <p>Any one of: disrupt endocrine system OR compete for active sites of enzymes/cellular receptors OR form complexes with/inhibit enzymes OR denature proteins OR change shape of active site ✓</p> <p>participate in redox reactions OR disturb normal redox balance «in cells» ✓</p> <p>initiate «free» radical reactions «in electron transfer» ✓</p> | | 1 max |
| 8. | b | <p>«$K_{sp} = 7.40 \times 10^{-14}$» $K_{sp} = [Pb^{2+}][CO_3^{2-}]$ ✓ $[Pb^{2+}] \ll \frac{7.40 \times 10^{-14}}{1.10 \times 10^{-4}} = 6.73 \times 10^{-10}$ «mol dm⁻³» ✓</p> | Award [2] for correct final answer. | 2 |
| 8. | c | <p>Any one of: chelation «by EDTA/polydentate ligand anchored» ✓ ion exchange systems ✓ adsorption by «water» plants ✓</p> | Accept “use of zeolites”. | 1 max |

Option B — Biochemistry

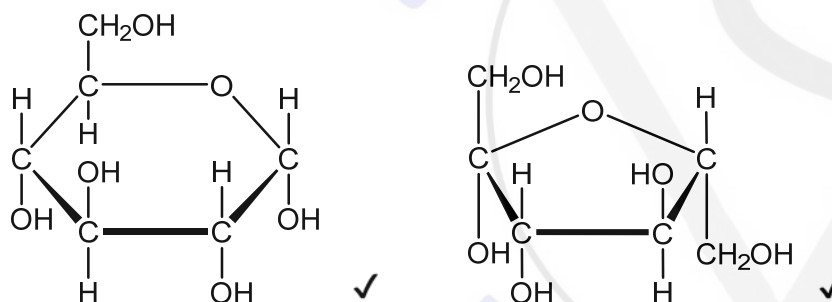
| Question | | | Answers | Notes | Total |
|----------|---|----|--|---|-------|
| 9. | a | i | β /beta pleated/sheet ✓ | | 1 |
| 9. | a | ii | <p><i>One similarity:</i> hydrogen bonding OR attractions between C=O and N–H «on main chain» ✓</p> <p><i>One difference:</i> α-helix has hydrogen bonds between amino acid residues that are closer than β-pleated sheet OR H-bonds in α-helix parallel to helix axis AND perpendicular to sheet in β-pleated sheet OR α-helix has one strand AND β-pleated sheet has two «or more» strands OR α-helix is more elastic «since H-bonds can be broken easily» AND β-pleated sheet is less elastic «since H-bonds are difficult to break» ✓</p> | <p>Accept a diagram which shows hydrogen bonding between O of C=O and H of NH groups for M1.</p> <p>Accept “between carbonyl/amido/amide/carboxamide” but not “between amino/amine” for M1.</p> | 2 |
| 9. | b | | <p>enzyme denatured/ loss of 3-D structure/conformational change OR «interactions responsible for» for tertiary/quaternary structures altered ✓</p> <p>shape of active site changes OR fewer substrate molecules fit into active sites ✓</p> | | 2 |

| Question | | | Answers | Notes | Total |
|----------|---|----|--|--|-------|
| 9. | c | | V_{\max} unchanged ✓ at high substrate concentration substrate outcompetes inhibitor/need a higher substrate concentration to reach V_{\max} ✓ | Accept suitable labelled diagram. | 2 |
| 9. | d | i | Any two of: surface water is warmer «so faster reaction rate»/more light/energy from the sun ✓ more oxygen «for aerobic bacteria/oxidation of oil» ✓ greater surface area ✓ | | 2 max |
| 9. | d | ii | Any one of: non-hazardous/toxic to the environment/living organisms ✓ energy requirements «during production» ✓ quantity/type of waste produced «during production» OR atom economy ✓ safety of process ✓ | Accept “use of solvents/toxic materials «during production»”. Do not accept “more steps involved”. | 1 max |

| Question | | | Answers | Notes | Total |
|----------|---|----|---|-------|-------|
| 10. | a | i | <p>pK_{a2} AND pH of solution > pH of isoelectric point «as anion present» OR pK_{a2} AND zwitterion has lost H^+ to become anion «so in basic solution» OR pK_{a2} AND «only» anion «and zwitterion» present ✓</p> | | 1 |
| 10. | a | ii | <p>«$pH = 9.1 + \log \left[\frac{0.30}{0.60} \right]$» «= $9.1 + (-0.3)$» = 8.8 ✓</p> | | 1 |
| 10. | b | | <p>sequence of bases in DNA ✓ codon/triplet code/each set of three bases codes for an amino acid ✓</p> | | 2 |

| Question | | | Answers | Notes | Total |
|----------|---|----|---|---|-------|
| 11. | a | i | $ \begin{array}{c} \text{O} \\ \parallel \\ \text{H}_2\text{C}-\text{O}-\text{P}-\text{O}-\text{CH}_2-\text{CH}_2-\text{N}^+(\text{CH}_3)_3 \\ \\ \text{O}^- \\ \text{HC}-\text{O}-\text{C}-\text{(CH}_2\text{)}_{10}\text{CH}_3 \\ \parallel \\ \text{O} \\ \text{H}_2\text{C}-\text{O}-\text{C}-\text{(CH}_2\text{)}_{10}\text{CH}_3 \\ \parallel \\ \text{O} \end{array} $ <p>phosphodiester correctly drawn ✓ both ester groups correctly drawn ✓</p> | <p>Accept protonated phosphate. Accept phosphodiester in centre position.</p> | 2 |
| 11. | a | ii | condensation ✓ | <p>Accept "esterification". Accept "nucleophilic substitution/S_N".</p> | 1 |
| 11. | b | | <p>phospholipid bilayer/double layer OR two layers of phospholipids ✓</p> <p>polar/hydrophilic heads facing aqueous environment AND non-polar/hydrophobic tails facing away from aqueous environment ✓</p> | <p>Award [2] for a suitably labelled diagram. Award [1] for a correct but unlabelled diagram.</p> <p>Accept "polar/hydrophilic heads on outside AND non-polar/hydrophobic tails on inside" for M2.</p> | 2 |

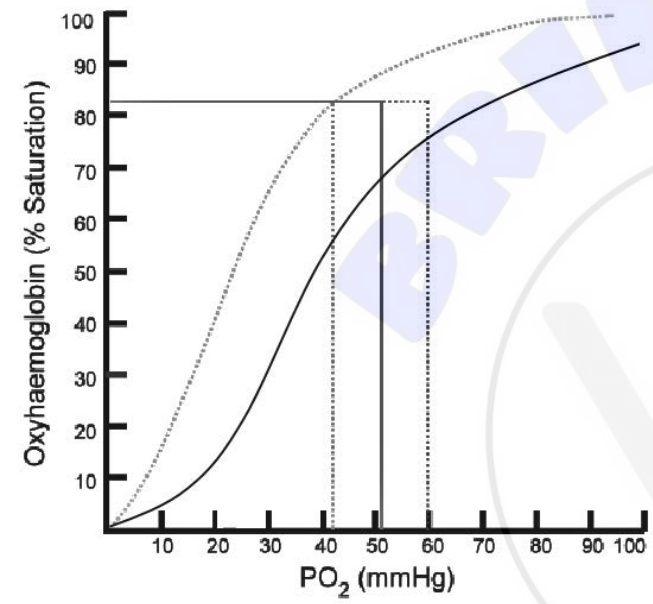
| Question | | Answers | Notes | Total |
|----------|---|---|---|-------|
| 11. | c | <p>long non-polar/hydrocarbon chain «and only one hydroxyl group» OR forms London/dispersion/van der Waals/vdW interactions with fat ✓</p> | <p>Accept "alcohol/hydroxy/OH" for "hydroxyl" but not "hydroxide".</p> | 1 |
| 11. | d | <p><i>Any one of:</i> atherosclerosis/cholesterol deposition «in artery walls» ✓ increases risk of heart attack/stroke/cardiovascular/heart disease/CHD ✓</p> | <p>Accept "arteries become blocked/walls become thicker", "increases blood pressure", or "blood clots". Do not accept "high cholesterol".</p> | 1 max |

| Question | | Answers | Notes | Total |
|----------|---|--|---|-------|
| 12. | a | acetal OR ether ✓ | Accept "glycosidic bond/linkage" but not "glucosidic". Do not accept "hemiacetal". | 1 |
| 12. | b | α -isomer AND hydroxyl group on carbon 1 and $-\text{CH}_2\text{OH}$ are trans OR α -isomer AND hydroxyl group on carbon 1 is below plane of ring OR α -isomer AND glycosidic linkage between rings is below plane of ring ✓ | Accept "ether linkage" for M3. | 1 |
| 12. | c |  | | 2 |

| Question | | | Answers | Notes | Total |
|----------|---|---|--|--|-------|
| 13. | a | | extensive conjugated system OR extensive delocalized bonding system OR extended system of alternating double and single bonds ✓ absorbs green OR complementary to red light ✓ | | 2 |
| 13. | b | i | sigmoid/S-shaped OR as oxygen binds to one active site, shape of other active sites change ✓ affinity of other sites for oxygen increases/ability to bind oxygen is increased by initial binding of oxygen OR cooperative binding ✓ | Accept description of sigmoid/S-shaped curve if not stated for M1. | 2 |

(continued...)

(Question 13b continued)

| Question | | | Answers | Notes | Total |
|----------|---|----|---|-------|-------|
| 13. | b | ii |  <p>The graph plots Oxyhaemoglobin (% Saturation) on the y-axis (0 to 100) against PO₂ (mmHg) on the x-axis (0 to 100). Two sigmoidal curves are shown. The solid curve represents the original dissociation curve, and the dotted curve represents a rightward shift. Key points are marked: on the original curve, PO₂ = 50 mmHg corresponds to 80% saturation; on the shifted curve, PO₂ = 40 mmHg corresponds to 80% saturation. A vertical line is drawn at PO₂ = 50 mmHg, showing that at this partial pressure, the saturation is lower on the shifted curve (approximately 70%).</p> <p>curve to right of original ✓</p> <p>[Source: Ratznium, https://commons.wikimedia.org/wiki/File:Oxyhaemoglobin_dissociation_curve.png]</p> | | 1 |

Option C — Energy

| Question | Answers | Notes | Total |
|----------|--|---|-------|
| 14. | <p>Advantage Any one of: renewable ✓ predictable supply ✓ tidal barrage may prevent flooding ✓ effective at low speeds ✓ long life-span ✓ low cost to run ✓</p> <p>Disadvantage Any one of: cost of construction ✓ changes/unknown effects on marine life ✓ changes circulation of tides in the area ✓ power output is variable ✓ limited locations where feasible ✓ equipment maintenance can be challenging ✓ difficult to store energy ✓</p> | <p>Do not accept vague generalisations. Do not accept economic issues for both advantage and disadvantage. Do not accept sustainable. Accept “energy” or “electricity” for “power”.</p> | 2 max |

| Question | | Answers | Notes | Total | |
|----------|---|---|--|---|-------|
| 15. | a | <p>Fractional distillation: Any two of: 1 max</p> <p>physical process</p> <p>separation of compounds by boiling point/vapour pressure</p> <p>breaking intermolecular forces</p> <p>different molar masses</p> <p>does not use catalyst</p> | <p>Cracking: Any two of: 1 max</p> <p>chemical process</p> <p>new compounds formed</p> <p>increasing branching/ring formation</p> <p>short hydrocarbon chains formed</p> <p>breaking «and remaking»/changing covalent bonds</p> <p>uses catalyst</p> | <p>Award [1] for any two correct answers from one column OR one from each column.</p> <p>Award [2] for any two correct from each column; eg: fractional distillation – any two correct award [1 max] AND cracking – any two correct, award [1 max].</p> | 2 max |
| | | <p>specific energy = «$\frac{4163 \text{ kJ mol}^{-1}}{86.2 \text{ g mol}^{-1}}$» ⇒ 48.3 «kJ g⁻¹» ✓</p> <p>energy density = «48.3 kJ g⁻¹ × 0.660 g cm⁻³» ⇒ 31.9 «kJ cm⁻³» ✓</p> | <p>Award [1 max] if either or both answers not expressed to three significant figures.</p> | 2 | |
| 15. | c | <p>Any two of:</p> <p>«hydrocarbons are heated with» catalyst ✓</p> <p>long chains break and reform OR branching/aromatisation occurs OR isomerisation/reforming/platforming/cracking ✓</p> <p>zeolite separates branched from non-branched OR products are distilled OR «distillation» separates reformed and cracked products ✓</p> | <p>Accept a specific catalyst name or formula for M1 such as Pt/Re/Rh/Pd/Ir.</p> | 2 max | |

| Question | | | Answers | Notes | Total |
|----------|---|-----|---|---|-------|
| 16. | a | i | $^{103}_{40}\text{Zr}$ ✓ | | 1 |
| 16. | a | ii | minimum mass to «self-»sustain chain reaction OR if mass of fissile material is too small, too many neutrons produced pass out of the nuclear fuel OR at least one neutron produced causes further reaction ✓ | | 1 |
| 16. | a | iii | <i>Any one of:</i> reduction in emission of greenhouse gases «from burning fossil fuels» ✓ economic independence/self-sufficiency «from crude oil/producing states» ✓ uranium is more abundant on Earth «in terms of total energy that can be produced from this fuel» than fossil fuels ✓ | Accept specific greenhouse gases (such as carbon dioxide/CO ₂) but not pollutants or other general statements. | 1 max |
| 16. | b | | <i>Any one of:</i> fuel is inexpensive/readily available ✓ no/less radioactive waste is formed ✓ lower risk of accidents/large-scale disasters ✓ impossible/harder to use for making materials for nuclear weapons ✓ larger amounts of energy released per unit mass ✓ does not require a critical mass ✓ can be used continuously ✓ | Accept “higher specific energy for fusion”. Do not accept “no/less waste produced for fusion”. Accept specific example for a disaster. | 1 max |
| 16. | c | | mass difference between reactants and products AND $E = mc^2$ ✓ | | 1 |

| Question | | Answers | Notes | Total |
|----------|---|--|-------------------------------------|-------|
| 16. | d | $\ll N = N_0 e^{-\lambda t} \gg$ $\lambda \ll \frac{-\ln\left(\frac{N}{N_0}\right)}{t} = \frac{-\ln\left(\frac{4.0 \times 10^{-5}}{5.0 \times 10^{-5}}\right)}{31.4 \text{ s}} \gg$ $= 7.106 \times 10^{-3} \text{ s}^{-1} \checkmark$ $\ll t_{\frac{1}{2}} = \frac{\ln 2}{\lambda} = \gg 98/97.5 \text{ «s» } \checkmark$ | Award [2] for correct final answer. | 2 |

| Question | Answers | Notes | Total |
|----------|---|---|-------|
| 17. | <p>Strength Any one of: less flammable «than diesel» ✓ recycles carbon «lower carbon footprint» OR lower greenhouse gas emissions ✓ easily biodegradable «in case of spill» ✓ renewable OR does not deplete fossil fuel reserves ✓ economic security/availability in countries without crude oil ✓</p> <p>Limitation Any one of: more difficult to ignite inside the engine «than diesel» ✓ more viscous «than diesel» ✓ lower energy content/specific energy/energy density ✓ uses food sources OR uses land that could be used for food ✓ «production is» more expensive ✓ less suitable in low temperatures ✓ increased NO_x emissions for biodiesel ✓ greenhouse gases still produced ✓</p> | <p>Accept “«close to» carbon neutral”, “produce less greenhouse gases/CO₂”.</p> <p>Accept “engines have to be modified if biodiesel used” as limitation.</p> <p>Do not award marks for strength and limitation that are the same topic/concept.</p> | 2 max |

| Question | | Answers | Notes | Total |
|----------|---|---|--|-------|
| 18. | a | bond length/C=O distance changes OR «asymmetric» stretching «of bonds» OR bond angle/OCO changes ✓ polarity/dipole «moment» changes OR dipole «moment» created «when molecule absorbs IR» ✓ | Accept appropriate diagrams. | 2 |
| 18. | b | Any one of: capture where produced «and store» ✓ use scrubbers to remove ✓ use as feedstock for synthesising other chemicals ✓ carbon credit/tax/economic incentive/fines/country specific action ✓ use alternative energy OR stop/reduce use of fossil fuels for producing energy ✓ use carbon reduced fuels «such as methane» ✓ increase efficiency and reduce energy use ✓ | Do not accept “planting more trees”. Accept specific correct examples. | 1 max |

| Question | | Answers | Notes | Total |
|----------|---|---|---|-------|
| 19. | a | <p>Any three of:</p> <p>$C_6H_{12}O_6(aq) + 6H_2O(l) \rightarrow 6CO_2(g) + 24H^+(aq) + 24e^-$</p> <p>OR</p> <p>electrons released by oxidation of glucose ✓</p> <p>enzymes «in bacteria» oxidize glucose</p> <p>OR</p> <p>«bacteria» transfer «released» electrons directly to anode ✓</p> <p>$24H^+(aq) + 6O_2(g) + 24e^- \rightarrow 12H_2O(l)$</p> <p>OR</p> <p>electrons consumed by reduction of oxygen ✓</p> <p>PEM/membrane separates two half reactions</p> <p>OR</p> <p>PEM/membrane allows proton/H^+ transfer from anode to cathode ✓</p> <p>electrons flow through external circuit ✓</p> | <p>Accept $4H^+(aq) + O_2(g) + 4e^- \rightarrow 2H_2O(l)$.</p> | 3 max |

| Question | | Answers | Notes | Total | | | | | | | | | | | | | | | |
|--|-----|--|-------------------------------------|-------|-----------|--|-----|--|----------------------------|-----|-------------------------------------|------------------------------|----|--|----------------------------|----|---|--|-------|
| 19. | b | $\llcorner E = E^\ominus - \frac{RT}{nF} \times \ln Q \llcorner$ $\ln Q = \llcorner \ln \frac{[\text{Mg}^{2+}]}{[\text{Ag}^+]^2} = \frac{0.0500}{0.100^2} = \ln 5.00 \Rightarrow 1.61 \checkmark$ $E = \llcorner 3.17 \text{ V} - \frac{8.31 \text{ J K}^{-1} \text{ mol}^{-1} \times 298 \text{ K}}{2 \times 96\,500 \text{ J V}^{-1} \text{ mol}^{-1}} \times \ln \frac{0.0500}{0.100^2} = 3.17 - 0.021 = + \llcorner 3.15 \text{ V} \llcorner \checkmark$ | Award [2] for correct final answer. | 2 | | | | | | | | | | | | | | | |
| 19. | c | <p>Any one of:</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 50%; text-align: center;">Primary</th> <th style="width: 10%; text-align: center;">AND</th> <th style="width: 40%; text-align: center;">Secondary</th> </tr> </thead> <tbody> <tr> <td>«electrode» materials cannot be reused/regenerated</td> <td style="text-align: center;">AND</td> <td>«electrode» materials can be regenerated/reused \checkmark</td> </tr> <tr> <td>non-reversible reaction(s)</td> <td style="text-align: center;">AND</td> <td>reversible reaction(s) \checkmark</td> </tr> <tr> <td>lower rate of self-discharge</td> <td style="text-align: center;">OR</td> <td>higher rate of self-discharge \checkmark</td> </tr> <tr> <td>only lower current demands</td> <td style="text-align: center;">OR</td> <td>can deliver stronger current demands \checkmark</td> </tr> </tbody> </table> | Primary | AND | Secondary | «electrode» materials cannot be reused/regenerated | AND | «electrode» materials can be regenerated/reused \checkmark | non-reversible reaction(s) | AND | reversible reaction(s) \checkmark | lower rate of self-discharge | OR | higher rate of self-discharge \checkmark | only lower current demands | OR | can deliver stronger current demands \checkmark | Accept "primary cannot be recharged" AND "secondary can be recharged". | 1 max |
| Primary | AND | Secondary | | | | | | | | | | | | | | | | | |
| «electrode» materials cannot be reused/regenerated | AND | «electrode» materials can be regenerated/reused \checkmark | | | | | | | | | | | | | | | | | |
| non-reversible reaction(s) | AND | reversible reaction(s) \checkmark | | | | | | | | | | | | | | | | | |
| lower rate of self-discharge | OR | higher rate of self-discharge \checkmark | | | | | | | | | | | | | | | | | |
| only lower current demands | OR | can deliver stronger current demands \checkmark | | | | | | | | | | | | | | | | | |

| Question | | Answers | Notes | Total |
|----------|---|---|---|-------|
| 20. | a | <p><i>Semiconductors:</i> increases ✓</p> <p><i>Metals:</i> decreases ✓</p> | <p><i>Accept any graph showing general increase for semiconductor.</i></p> <p><i>Accept any graph showing general decrease for metal.</i></p> <p><i>Accept a graph showing vertical section below transition temperature for a superconducting metal.</i></p> | 2 |
| 20. | b | <p>dye absorbs light ✓</p> <p>electrons from «excited» dye pass to TiO₂/semiconductor/electrolyte/cell</p> <p>OR</p> <p>dye undergoes photo-oxidation ✓</p> | | 2 |

Option D — Medicinal chemistry

| Question | | Answers | Notes | Total |
|----------|---|---|--|-------|
| 21. | a | <p><i>Therapeutic window:</i> range of dosage «over which a drug» provides the therapeutic/desired effect without causing adverse/toxic effects ✓</p> <p><i>Therapeutic index:</i> toxic dose of drug for 50 % of population divided by minimum effective dose for 50 % of population</p> <p>OR</p> $\frac{TD50}{ED50} \checkmark$ | <p><i>M1 may be scored from a correctly labelled diagram.</i></p> <p><i>Do not accept reference to lethal dose used in therapeutic index in animal studies.</i></p> | 2 |
| 21. | b | <p>morphine has «two» hydroxyl groups AND diamorphine has «two» ester/ethanoate/acetate groups</p> <p>OR</p> <p>molecule of diamorphine is less polar than morphine</p> <p>OR</p> <p>groups in morphine are replaced with less polar/non-polar groups in diamorphine ✓</p> <p>«less polar molecules» cross the blood–brain barrier faster/more easily</p> <p>OR</p> <p>diamorphine is more soluble in non-polar environment of CNS/central nervous system than morphine ✓</p> | <p><i>Accept “alcohol/hydroxy” for “hydroxyl” but not “hydroxide”.</i></p> <p><i>Accept “fats” for “lipid”.</i></p> <p><i>Accept “heroin” for “diamorphine”.</i></p> | 2 |

| Question | | | Answers | Notes | Total |
|----------|---|----|--|---|-------|
| 22. | a | | <p>Any one of:</p> <p>1050–1410 «cm⁻¹ due to C–O» ✓</p> <p>1700–1750 «cm⁻¹ due to C=O in acids and esters» ✓</p> <p>2500–3000 «cm⁻¹ due to O–H in acids» ✓</p> <p>2850–3090 «cm⁻¹ due to C–H in alkanes and arenes» ✓</p> | | 1 max |
| 22. | b | i | <p>$n(\text{aspirin}) \llcorner n(\text{NaOH}) = \frac{16.25 \text{ cm}^3}{1000} \times 0.100 \text{ mol dm}^{-3} \llcorner = 1.625 \times 10^{-3} \llcorner \text{mol} \llcorner \checkmark$</p> <p>$m(\text{aspirin}) \llcorner = 1.625 \times 10^{-3} \text{ mol} \times 180.17 \text{ g mol}^{-1} \llcorner = 0.293 \llcorner \text{g} \llcorner \checkmark$</p> | Award [2] for correct final answer. | 2 |
| 22. | b | ii | <p>$\llcorner \frac{0.293 \text{ g}}{0.300 \text{ g}} \times 100 \% \llcorner = 97.7 \llcorner \% \llcorner \checkmark$</p> | | 1 |
| 22. | c | | <p>convert to a salt</p> <p>OR</p> <p>react with sodium hydroxide ✓</p> | <p>Accept other reactions forming soluble salts.</p> <p>Accept “to ionize” but not “more polar”.</p> | 1 |
| 22. | d | | <p>synergistic effect/increased toxicity</p> <p>OR</p> <p>increased risk of stomach/intestines bleeding/ulcers/heartburn</p> <p>OR</p> <p>increased risk of liver toxicity/damage</p> <p>OR</p> <p>increased risk of nausea/vomiting ✓</p> | | 1 |

| Question | | | Answers | Notes | Total |
|----------|---|----|--|--|-------|
| 23. | a | i | blocks/binds H ₂ /histamine receptors «in cells of stomach lining» OR prevents histamine molecules binding to H ₂ /histamine receptors «and triggering acid secretion» ✓ | | 1 |
| 23. | a | ii | Any two of: ranitidine can be effective in treating ulcers «but antacid is not» ✓ ranitidine can prevent long-term damage «from overproduction of acid and antacid does not» ✓ ranitidine has a long-term effect «and antacid has short-term effect only» ✓ ranitidine does not affect ionic balance in body «and antacid does» ✓ ranitidine does not produce bloating/flatulence ✓ | Accept "ranitidine stops the over production of acid in the stomach while antacids neutralise the excess acid giving temporary relief" for M2. | 2 max |
| 23. | b | | « $\text{pH} = \text{pK}_a + \log \frac{[\text{A}^-]}{[\text{HA}]}$ = 10.32 + $\log \frac{0.160}{0.200}$ = 10.32 - 0.097» «pH =»10.22 ✓ | | 1 |

| Question | | Answers | Notes | Total |
|----------|---|--|--|---------------------|
| 24. | a | <p>Any one of:</p> <p>alter cell's genetic material so that virus cannot use it to multiply ✓</p> <p>prevent viruses from multiplying by blocking enzyme activity within host cell</p> <p>OR</p> <p>inhibit the synthesis of viral components by blocking enzymes inside the cell ✓</p> <p>prevent viruses from entering «host» cell</p> <p>OR</p> <p>bind to cellular receptors targeted by viruses</p> <p>OR</p> <p>bind to virus-associated proteins/VAPs which target cellular receptors</p> <p>OR</p> <p>prevents removal of protein coat/capsid</p> <p>OR</p> <p>prevents injection of viral DNA/RNA into cell ✓</p> <p>prevent/hinder the release of viruses from the cell ✓</p> | <p>Accept "prevents synthesis of virus by host cell".</p> <p>Accept "alters RNA/DNA/genetic material of virus".</p> <p>Do not accept just "mimics nucleotides".</p> | <p>1 max</p> |

| Question | | Answers | Notes | Total |
|----------|---|--|-------|-------|
| 24. | b | <p><i>Any two of:</i></p> <p>viruses lack cell structure so difficult to target with drugs ✓</p> <p>HIV is a retrovirus</p> <p>OR</p> <p>HIV genetic material is in the form of RNA instead of DNA ✓</p> <p>HIV affects/destroys helper/T-cells which are necessary to fight infection ✓</p> <p>HIV has great genetic diversity so difficult to produce «a» vaccine ✓</p> <p>anti-retroviral agents are expensive so not everyone/country can afford them ✓</p> <p>socio-cultural issues deter people from seeking treatment/prevention/diagnosis</p> <p>OR</p> <p>lack of education/conversation/stigma associated with being HIV-positive ✓</p> <p>mutation of virus/HIV ✓</p> <p>virus/HIV metabolism linked to that of host cell ✓</p> <p>drugs harm host cell as well as virus/HIV ✓</p> <p>HIV difficult to detect/remains dormant ✓</p> | | 2 max |

| Question | | Answers | Notes | Total |
|----------|---|--|-------|-------|
| 25. | a | <p><i>Any two of:</i> produced by genetically engineered/modified bacteria/<i>E. coli</i> OR sustainable because synthesized and not obtained from yew trees ✓</p> <p>chiral auxiliaries «isolated and» reused ✓ one enantiomer produced ✓ toxicity/recycling of solvents/materials used ✓ overall yield/atom economy/waste generated ✓</p> | | 2 max |
| 25. | b | <p><i>Any two of:</i> «plane-» polarized light OR light passes through polarizer/polarizing filter ✓</p> <p>enantiomers rotate plane of «plane-» polarized light «by equal angles» in opposite directions ✓ measure angle/direction of rotation ✓</p> | | 2 max |

| Question | | Answers | Notes | Total |
|----------|---|---|---|-------|
| 26. | a | <p>Any two of:</p> <p>can be readily “tagged” to variety of biologically active carriers «which will deliver it to specific locations for imaging uses» ✓</p> <p>frequency of radiation is compatible with existing X-ray detection apparatus ✓</p> <p>product of decay has low radioactivity/relatively short half-life/low total exposure to patient ✓</p> <p>«but small» increased risk of cancer to patient ✓</p> <p>must be made on site ✓</p> | <p>Accept other valid answers outlining advantages or limitations of Tc-99m, such as “produces only LLW”, “Tc is a transition element forming compounds in a variety of oxidation states”, “gamma-radiation «can escape the body and» be detected by external sensors”, “activity decreases quickly, so dose must be calculated prior to each injection”.</p> | 2 max |
| 26. | b | <p>ALTERNATIVE 1</p> $\frac{N(t)}{N_0} = \left(\frac{1}{2}\right)^{\frac{t}{6.0}} \quad \checkmark$ <p>31 «% remaining» ✓</p> <p>ALTERNATIVE 2</p> $\lambda \text{ «} = \frac{\ln 2}{t_{\frac{1}{2}}} \text{»} = 0.1155 \text{ hours}^{-1} \quad \checkmark$ $\text{«} \frac{N}{N_0} \times 100 = e^{-\lambda t} \times 100 = 0.31498 \times 100 \text{»}$ <p>31 «% remaining» ✓</p> | <p>M1 is for correct substitution of values.</p> <p>Award [2] for correct final answer.</p> | 2 |

| Question | | Answers | Notes | Total |
|----------|---|--|---|-------|
| 27. | a | <p>Any three of:</p> <p>ethanol «in breath» is oxidized «to ethanoic acid» ✓</p> <p>electrons pass through external circuit/meter ✓</p> <p>«to cathode where» O₂ is reduced ✓</p> <p>current is proportional to alcohol concentration ✓</p> | <p>Accept equations for oxidation of ethanol or reduction of oxygen.</p> | 3 max |
| 27. | b | <p>Bond:</p> <p>C–O</p> <p>OR</p> <p>C–H ✓</p> <p>Reason:</p> <p>cannot use O–H bonds as in water «found in breath» ✓</p> | <p>Accept “C–O/C–H «bonds in molecules in breath» most likely to be in ethanol”.</p> <p>Do not apply ECF here.</p> | 2 |