

Markscheme

November 2017

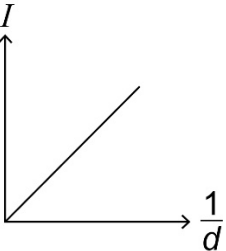
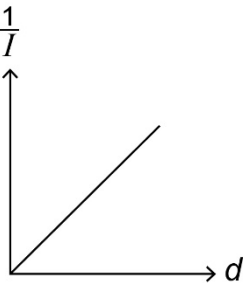
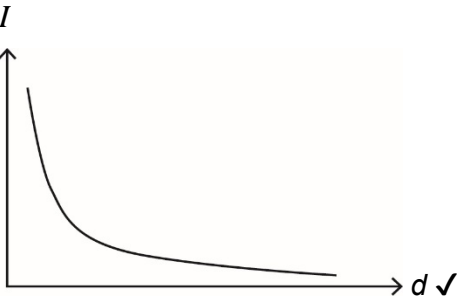
Chemistry

Higher level

Paper 3

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Section A

| Question | | Answers | Notes | Total |
|----------|---|--|--|-------|
| 1. | a | <p>I</p>  <p>OR</p>  <p>OR</p>  | <p>Correct labels of axes required for mark.</p> <p>Accept d^{-1} instead of $\frac{1}{d}$.</p> <p>Accept I^{-1} instead of $\frac{1}{I}$.</p> <p>Plot of I vs d should not be linear.</p> | 1 |

| Question | | | Answers | Notes | Total |
|----------|---|-----|---|---|-------|
| 1. | b | i | negative correlation OR model/prediction matches results OR 99% of variance accounted for ✓ | | 1 |
| 1. | b | ii | $I = -0.001631 d + 0.09939$ OR $y = -0.001631 x + 0.09939$ ✓ | Accept correctly rounded values for m and b in equation. Do not accept “ $y = mx + b$ ”. | 1 |
| 1. | b | iii | ions move «across electrolyte» ✓ | | 1 |

| Question | | Answers | Notes | Total |
|----------|---|---|---|-------|
| 2. | a | $\text{Mg(OH)}_2(\text{s}) + 2\text{HCl}(\text{aq}) \rightarrow \text{MgCl}_2(\text{aq}) + 2\text{H}_2\text{O}(\text{l}) \checkmark$ | Accept full or net ionic equation. | 1 |
| 2. | b | <p>Any two from:</p> <p>volume «of HCl» \checkmark</p> <p>concentration «of HCl»/[HCl] \checkmark</p> <p>temperature «of HCl» \checkmark</p> <p>mass of antacid/tablets \checkmark</p> <p>size of antacid particles/tablets</p> <p>OR</p> <p>surface area of antacid «particles»/tablets \checkmark</p> | <p>Accept “number of tablets/different doses”.</p> <p>Do not accept “same pH meter” OR “initial pH” OR “concentration of antacid/[antacid]”.</p> <p>A variable must be given so do not accept answers such as “stirring”, “whether tablets are whole or crushed” etc.</p> | 2 max |
| 2. | c | <p>(\pm) 0.04</p> <p>OR</p> <p>(\pm) 0.03 \checkmark</p> | | 1 |

| Question | | Answers | Notes | Total |
|----------|---|--|---|-------|
| 2. | d | <p>Any two of:</p> <p>uncertainty «$(\pm)0.04/(\pm)0.03$» means A and C cannot be distinguished ✓</p> <p>each measurement was conducted once ✓</p> <p>stomach pH should not be raised a lot «so antacid B is not necessarily effective» ✓</p> <p>mass/number of tablets/dose «of antacid» used was not controlled ✓</p> <p>actual environment in stomach is different ✓</p> | <p>Accept “amount of tablets” for “dose”.</p> <p>Do not accept “nature/composition of tablets differs”.</p> <p>Accept an answer such as “time frame is too short since some antacids could be long-acting drugs if they contain a gelatinisation/delaying agent” but not just “time frame is too short since some antacids could be long-acting drugs”.</p> | 2 max |

| Question | | Answers | Notes | Total |
|----------|---|-----------------|---|-------|
| 3. | a | -21 «°C» ✓ | | 1 |
| 3. | b | <p>28 «%» ✓</p> | Accept any specific answer in the range 27 to 29 «%». | 1 |

| Question | | Answers | Notes | Total |
|----------|---|---|--|-------|
| 3. | c | $M_r = 94.48 \checkmark$ $\llcorner 2 \frac{(1.01 \times 2 + 16.00)}{94.48} \times 100 \Rightarrow 38.15 \llcorner \% \llcorner \checkmark$ | <p>Award M2 only if answer is to 2 decimal places.</p> <p>Award [2] for correct final answer.</p> <p>Award [1 max] for 38.10 %.</p> | 2 |
| 3. | d | rust/corrosion «of cars and bridges» OR waste of important raw material OR soil/water salination/pollution «from run off» OR erosion of/damage to the road surface OR specific example of damage to the ecosystem OR «outdoor» temperatures may go below effective levels for NaCl «to lower freezing point» so NaCl could be wasted OR roads can refreeze causing hazards \checkmark | <p>Do not accept “tyre damage”.</p> <p>Do not accept “economic issues” OR “environmental issues” unless specified (eg accept “increase in costs for local councils road budgets” but not “cost” alone).</p> <p>Do not accept “makes roads more slippery”.</p> | 1 |

Section B

Option A — Materials

| Question | | Answers | Notes | Total |
|----------|---|---|---|-------|
| 4. | a | <p><i>Alloy:</i> mixture of <u>metal</u> with other metals/non-metals OR mixture of elements that retains the properties of a <u>metal</u> ✓</p> <p><i>Composite:</i> reinforcing phase embedded in matrix phase ✓</p> | <p><i>Award [1 max] for implying “composites only have heterogeneous/non-homogeneous compositions”.</i></p> | 2 |
| 4. | b | <p>difference in ionic/atomic radius prevents layers sliding over each other ✓</p> | <p><i>Accept “difference in diameter/packing of cations prevents layers sliding over each other”.</i></p> | 1 |
| 4. | c | <p><i>Any three of:</i> sample injected into argon «plasma» ✓ atoms «of sample» are excited/ionised OR electrons are promoted ✓ electrons drop back/recombine with ions AND emit photons of characteristic energies/wavelengths/frequencies ✓ total number of photons is proportional to concentration of element ✓ actual concentration found from <u>calibration/standard</u> curve ✓</p> | <p><i>Accept “graph/plot” for “curve”.</i></p> | 3 max |

| Question | Answers | Notes | Total |
|----------|--|-------|--------------|
| 5. | <p><i>Any two of:</i></p> <ul style="list-style-type: none"> greater selectivity ✓ higher efficiency ✓ longer life expectancy <p>OR</p> <ul style="list-style-type: none"> not easily poisoned ✓ easier to recover ✓ low«er» environmental impact ✓ large range of conditions/temperatures/pressures supported ✓ lower energy costs ✓ increase in yield «per unit time» offsets cost of catalyst ✓ | | 2 max |

| Question | | | Answers | Notes | Total |
|----------|---|----|---|---|-------|
| 6. | a | | <p>Any two of:</p> <p>ability to form a LC phase ✓</p> <p>chemically stable ✓</p> <p>«LC phase that is» stable over suitable temperature range ✓</p> <p>polar</p> <p>OR</p> <p>being able to change orientation with applied electric field ✓</p> <p>rapid switching speed «responds to changes of voltage quickly» ✓</p> | <p>Accept “ability of molecules to transmit light under certain conditions” OR “rod-shaped molecules” OR “stable to light/not light sensitive”.</p> | 2 max |
| 6. | b | | <p>Any two of:</p> <p>have higher critical temperatures/T_c «than Type 1»</p> <p>OR</p> <p>can act at higher temperatures ✓</p> <p>have higher critical magnetic fields/B_c «than Type 1» ✓</p> <p>less time needed to cool to operating temperature ✓</p> <p>less energy required to cool down/maintain low temperature ✓</p> | <p>Do not accept “Type 2 has a gradual transition to a superconducting state but in Type 1 it is a sharp transition”.</p> | 2 max |
| 6. | c | i | <p>$\text{Fe}(\text{CO})_5(\text{g}) \rightarrow \text{Fe}(\text{s}) + 5\text{CO}(\text{g})$ ✓</p> <p>$2\text{CO}(\text{g}) \rightarrow \text{C}(\text{s}) + \text{CO}_2(\text{g})$ ✓</p> | | 2 |
| 6. | c | ii | <p>large surface area «on which carbon nanotubes form» ✓</p> | | 1 |

| Question | | Answers | Notes | Total |
|----------|---|--|--|-------|
| 7. | a | branching in LDPE prevents close packing «of chains» ✓ LDPE is more flexible/less rigid OR LDPE has lower «tensile» strength ✓ | Do not accept “difference in density”. Award [1 max] for stating “branching in LDPE AND little/no branching in HDPE”. | 2 |
| 7. | b | addition: C=C AND condensation: two functional groups needed on each monomer ✓ | Accept “alkene/alkenyl” OR “double bond” OR “multiple bond”. | 1 |
| 7. | c | hydrogen bonds ✓ | Accept “ π - π stacking/interactions”. | 1 |
| 7. | d | B AND absence of «absorption of» C–H at 2850–3090 «cm ⁻¹ » OR B AND presence of «absorption of» C–F at 1000–1400 «cm ⁻¹ » ✓ | | 1 |
| 7. | e | $(-C_2H_3Cl-)_2(s) + 5O_2(g) \rightarrow 4CO_2(g) + 2H_2O(l) + 2HCl(g)$ correct species in reactants and products ✓ balanced ✓ | Accept “ $(-C_2H_3Cl-)_2(s) + 5.5O_2(g) \rightarrow 4CO_2(g) + 3H_2O(l) + Cl_2(g)$ ”. Award M2 only if M1 correct. | 2 |

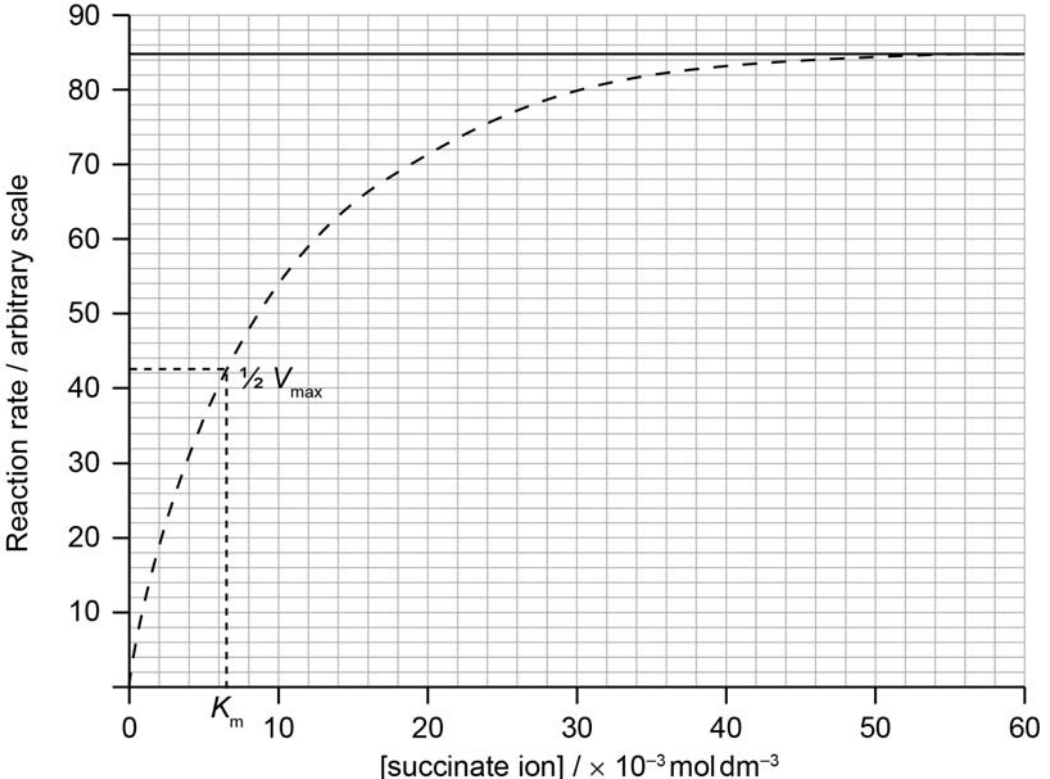
| Question | | | Answers | Notes | Total |
|----------|---|----|---|--|-------|
| 8. | a | | $\llcorner 8 \times \frac{1}{8} + 6 \times \frac{1}{2} \Rightarrow 4 \checkmark$ | | 1 |
| 8. | b | i | <p>face diagonal = $\sqrt{2}a = 4r$</p> $\llcorner a = \frac{(4 \times 1.18 \times 10^{-8} \text{ cm})}{\sqrt{2}} \Rightarrow 3.34 \times 10^{-8} \llcorner \text{cm} \checkmark$ | | 1 |
| 8. | b | ii | <p>mass of 4 atoms = $\frac{4 \times 58.93 \text{ gmol}^{-1}}{6.02 \times 10^{23} \text{ mol}^{-1}} = 3.916 \times 10^{-22} \llcorner \text{g} \checkmark$</p> $\llcorner \text{density} = \frac{3.916 \times 10^{-22} \text{ g}}{(3.34 \times 10^{-8} \text{ cm})^3} \Rightarrow 10.5 \llcorner \text{g cm}^{-3} \checkmark$ <p><i>Answer using $3.00 \times 10^{-8} \text{ cm}$:</i></p> <p>mass of 4 atoms = $\frac{4 \times 58.93 \text{ gmol}^{-1}}{6.02 \times 10^{23} \text{ mol}^{-1}} = 3.916 \times 10^{-22} \llcorner \text{g} \checkmark$</p> $\llcorner \text{density} = \frac{3.916 \times 10^{-22} \text{ g}}{(3.00 \times 10^{-8} \text{ cm})^3} \Rightarrow 14.5 \llcorner \text{g cm}^{-3} \checkmark$ | <i>Award [2] for correct final answer.</i> | 2 |

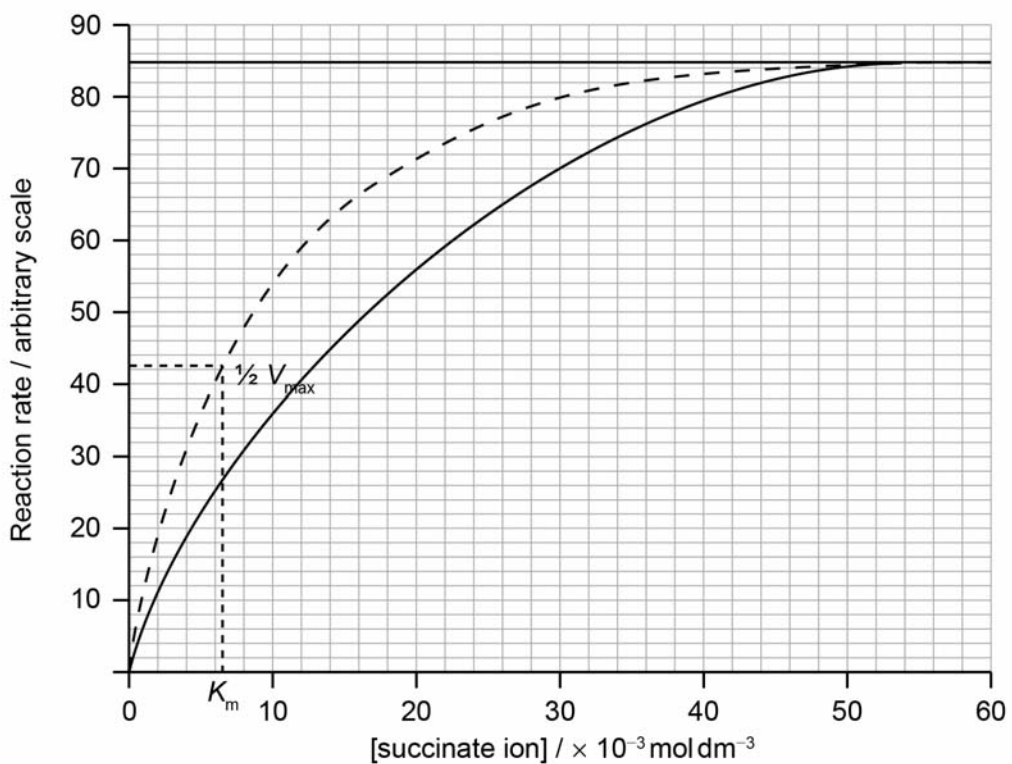
| Question | | Answers | Notes | Total |
|----------|---|--|---|-------|
| 9. | a | adsorption OR chelation OR ion exchange ✓ | Accept other valid methods such as “phytoremediation” OR “Fenton reaction” OR “electrolysis”. | 1 |
| 9. | b | Calculation: $K_{sp} = [Cd^{2+}] \times [S^{2-}]$ ✓ $[Cd^{2+}] = 8.0 \times 10^{-26}$ «mol dm ⁻³ » ✓ Assumption: volume of solution remains 1.0 dm ³ OR concentration of sulfide ions in original solution is negligible OR hydrolysis of sulfide ions is negligible ✓ | Award [2] for correct numerical answer of $[Cd^{2+}]$ for M1 and M2. Accept “0.10 + x ~ 0.10 «mol dm ⁻³ »”. | 3 |

Option B — Biochemistry

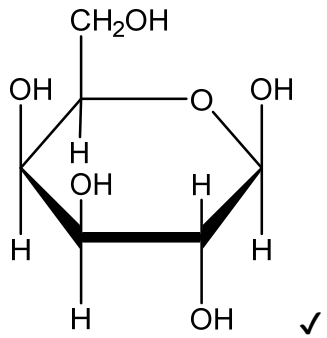
| Question | | | Answers | Notes | Total |
|----------|---|----|---|--|-------|
| 10. | a | i | $C_9H_{16}O$ ✓ | | 1 |
| 10. | a | ii | ratio of oxygen to carbon in linoleic acid lower OR linoleic acid less oxidized OR linoleic acid more reduced ✓ | Accept «average» oxidation state of carbon in linoleic acid is lower”. | 1 |
| 10. | b | | $\llcorner \frac{1.24 \text{ g}}{280.50 \text{ g mol}^{-1}} \Rightarrow 0.00442 \text{ «mol»} \checkmark$ 0.00884 mol of C=C OR ratio of linoleic acid : iodine = 1:2 ✓ $\llcorner \text{volume of } I_2 \text{ solution} = \frac{0.00884 \text{ mol}}{0.300 \text{ mol dm}^{-3}} \Rightarrow 0.0295 \text{ «dm}^3\text{»} / 29.5 \text{ «cm}^3\text{»} \checkmark$ | Award [3] for correct final answer. | 3 |

| Question | | Answers | Notes | Total |
|----------|---|--|--|-------|
| 10. | c | <p><i>Any two of:</i></p> <p>increases «ratio of» HDL «to LDL» cholesterol OR decreases LDL cholesterol «level» ✓</p> <p>removes plaque from/unblocks arteries OR decreases risk of heart disease ✓</p> <p>decreases risk of stroke «in the brain» ✓</p> | <p><i>Accept "essential fatty acid".</i> Do not accept "bad cholesterol" for "LDL cholesterol" OR "good cholesterol" for "HDL cholesterol".</p> <p><i>Do not accept general answers such as "source of energy" OR "forms triglycerides" OR "regulates permeability of cell membranes" etc.</i></p> | 2 max |

| Question | Answers | Notes | Total |
|--------------|--|---|----------|
| <p>11. a</p> |  <p>K_m labelled on x-axis as the [succinate ion] at $\frac{1}{2} V_{\max}$</p> <p>OR</p> <p>horizontal line at $\frac{1}{2} V_{\max}$ AND vertical line down to x-axis ✓</p> <p>«$K_m =$» 6.5×10^{-3} «mol dm³» ✓</p> | <p>Annotation of graph required for M1.</p> <p>Accept any specific value in the range 6.0×10^{-3} to 7.5×10^{-3} «mol dm⁻³».</p> | <p>2</p> |

| Question | | | Answers | Notes | Total |
|----------|---|----|--|---|-------|
| 11. | b | i | similar shape/size/structure «as succinate ion/substrate» ✓ competes for the active site «with the succinate ion/substrate» ✓ | Accept "competitive inhibitor" for M2. Award [1 max] if non-competitive inhibition is correctly described. | 2 |
| 11. | b | ii |  <p>same V_{max} reached at higher [substrate] ✓</p> | | 1 |

| Question | | Answers | Notes | Total |
|----------|---|---|--|-------|
| 11. | c | conformation/shape altered OR active site altered OR tertiary structure altered ✓ acidic/basic/ionizable/COOH/carboxyl/NH ₂ /amino groups in the R groups/side chains «react» ✓ exchange/lose/gain protons/H ⁺ ✓ ionic/H-bonds altered ✓ | Accept “substrate doesn't fit/fits poorly into active site” OR “enzyme denatures” for M1 but not “affects potential of enzyme to form complex with substrate”. | 4 |

| Question | Answers | Notes | Total |
|--------------|--|--|----------|
| <p>12. a</p> | <p>«reaction in which» two reactants/molecules/functional groups bond/react «to form a larger molecule/single main product» ✓ small/tiny molecule OR H₂O formed ✓</p> | <p>Accept formula or name of a specified small molecule other than water such as ammonia, ethanoic/acetic acid, ethanol, hydrogen sulfide etc. for M2.</p> <p>Do not accept just “molecule formed”.</p> <p>Award [1 max] for an example giving an equation of a condensation reaction such as the formation of a disaccharide.</p> | <p>2</p> |
| <p>12. b</p> |  | <p>Accept “alpha” or “beta” form of galactose.</p> | <p>1</p> |

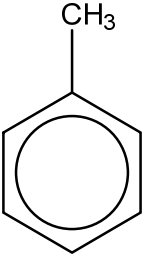
| Question | | Answers | Notes | Total |
|----------|---|---|---|-------|
| 12. | c | <p><i>Any two of:</i></p> <p>makes the plastic more hydrophilic/water soluble ✓</p> <p>carbohydrates are broken down/hydrolysed by bacteria/microorganisms ✓</p> <p>makes plastic more accessible to bacteria as holes/channels are created</p> <p>OR</p> <p>plastic of lower density is more permeable/susceptible to water/oxygen/heat/pressure ✓</p> <p>weakens intermolecular/London/dispersion/instantaneous induced dipole-induced dipole forces «between polymer chains in the plastic» ✓</p> | <p><i>Accept “van der Waals/vdW” for “London” forces.</i></p> | 2 max |
| 13. | | <p><i>Water:</i></p> <p>hydrogen/H-bonds</p> <p>OR</p> <p>ion-dipole interactions ✓</p> <p><i>Proteins:</i></p> <p>ionic bonds/interactions</p> <p>OR</p> <p>hydrogen/H-bonds</p> <p>OR</p> <p>ion-dipole interactions ✓</p> | <p><i>Ignore “London/dispersion/vdW/dipole-dipole interactions” stated for water and/or proteins.</i></p> | 2 |

| Question | | Answers | Notes | Total |
|----------|---|--|--|-------|
| 14. | a | $\text{O}_2 + 4\text{H}^+(\text{aq}) + 4\text{e}^- \rightarrow 2\text{H}_2\text{O}(\text{l}) \checkmark$ | <i>Accept any balanced equation with any integer or fractional coefficients.</i> | 1 |
| 14. | b | +2 to +3 OR +1 OR increases «by 1» \checkmark | | 1 |

| Question | | Answers | Notes | Total |
|----------|---|--|--|-------|
| 15. | a | <p>«mainly» hydrocarbon/non-polar «structure» ✓</p> <p>forms London/dispersion/instantaneous induced dipole-induced dipole forces</p> <p>«with fats» ✓</p> | <p>Accept “forms van der Waals’/vdW forces”.</p> <p>Award [1 max] for “contains only one OH/hydroxyl AND cannot form «enough» H-bonds”.</p> | 2 |
| 15. | b | <p>Any three of:</p> <p><i>cis</i>-retinal binds to «the protein» opsin</p> <p>OR</p> <p><i>cis</i>-retinal «binds to opsin and» forms rhodopsin ✓</p> <p>rhodopsin extends conjugation in retinal</p> <p>OR</p> <p>rhodopsin allows absorption of visible/blue/green light ✓</p> <p>when visible light is absorbed <i>cis</i>-retinal changes to <i>trans</i>-retinal ✓</p> <p>change «to <i>trans</i>-retinal» triggers an electrical/nerve signal ✓</p> <p><i>trans</i>-retinal detaches from opsin AND is converted back to <i>cis</i>-retinal</p> <p>OR</p> <p><i>trans</i>-retinal is converted back to <i>cis</i>-retinal through enzyme activity ✓</p> | <p>Do not accept “<i>cis</i>-retinal to <i>trans</i>-retinal” alone without reference to absorption of visible light.</p> | 3 max |

Option C — Energy

| Question | | Answers | Notes | Total |
|----------|---|--|---|-------|
| 16. | a | $M_r(\text{C}_8\text{H}_{18}) = 114.26$ AND $\Delta H_c^\ominus = -5470 \text{ «kJ mol}^{-1}\text{»} \checkmark$ «specific energy = $\frac{5470 \text{ kJ}}{0.11426 \text{ kg}} \Rightarrow 4.79 \times 10^4/47873/47900 \text{ «kJ kg}^{-1}\text{»} \checkmark$ | Award [2] for correct final answer. Accept “ $48 \times 10^3 \text{ «kJ kg}^{-1}\text{»}$ ” OR “ $47.9 \times 10^3 \text{ «kJ kg}^{-1}\text{»}$ ”. | 2 |
| 16. | b | wood is less useful because it requires «about three times» more mass for same energy \checkmark | Accept “octane is more useful because it has higher specific energy”. | 1 |
| 16. | c | Any one of: wind \checkmark tidal/wave \checkmark hydro-electric \checkmark solar \checkmark thermal/geothermal \checkmark plant oil \checkmark | Accept “biofuel/biodiesel/«bio»ethanol”, but not just “water” or “fuel cells”. | 1 max |

| Question | Answers | Notes | Total |
|----------|--|---|-------|
| 17. a | <p> $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3 \rightarrow \text{CH}_3\text{CH}(\text{CH}_3)\text{CH}_2\text{CH}(\text{CH}_3)_2$ OR $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3 \rightarrow$  $+ 4\text{H}_2 \checkmark$ </p> <p>isomerisation/reforming/platforming/cracking ✓</p> <p>Pt/Re/Rh/Pd/Ir OR catalyst ✓</p> | <p><i>A structural formula is only required for the organic product, not heptane.</i></p> <p><i>Accept any correctly balanced equation showing increased branching OR cyclization OR aromatization OR cracking.</i></p> <p><i>Suitable supports for catalysts may be included for M3 (eg silica, alumina, zeolite) but the symbol or name of an appropriate metal must be given (typically a noble metal). Ignore temperature and other conditions.</i></p> <p><i>Award M2 AND M3 for “catalytic isomerisation” OR “catalytic reforming” OR “catalytic cracking”.</i></p> | 3 |

| Question | | Answers | Notes | Total |
|----------|---|---|--|-------|
| 17. | b | <p>which specific carbon-based greenhouse gases are included OR whether non-carbon based greenhouse gases should be included OR whether CO/incomplete combustion should be included «as can be oxidized to CO₂» OR how to “sum” all steps in a process creating CO₂ OR difficult to determine both direct and indirect production of GHG/greenhouse gas emissions ✓</p> | <p><i>Ignore reference to geopolitical issues (eg false recording of data by governments etc.).</i></p> <p><i>Accept “difficult to measure all sources of CO₂” but not “difficult to measure CO₂ released in atmosphere”.</i></p> | 1 |
| 17. | c | <p><i>Any three of:</i> incoming solar radiation is short wavelength/high frequency/high energy/UV ✓ radiated/emitted as long wavelength/low frequency/low energy/IR «radiation» ✓ energy/IR «radiation» absorbed by «bonds in» greenhouse gases ✓ energy radiated/emitted as IR «radiation» some of which returns back to Earth ✓</p> | <p><i>Do not accept “reflected” OR “bounced” OR “trapped”.</i></p> | 3 max |

| Question | | | Answers | Notes | Total |
|----------|---|----|--|--|-------|
| 18. | a | i | <p><i>Fission: heavy nuclei AND Fusion: light nuclei ✓</i></p> <p>both increase in binding energy/energy yield «per nucleon» ✓</p> | <p><i>Accept “large nuclei” OR “greater atomic masses of nuclei” for fission AND “small nuclei” OR “smaller atomic masses of nuclei” for fusion.</i></p> <p><i>Award [1 max] for “Fission: heavy nuclei AND increase in binding energy «per nucleon»” OR “Fusion: light nuclei AND increase in binding energy” «per nucleon»”.</i></p> | 2 |
| 18. | a | ii | <p><i>Any two of:</i></p> <p>no/less radioactive waste produced ✓</p> <p>abundance/low cost of fuel ✓</p> <p>larger amounts of energy released per unit mass ✓</p> <p>does not require a critical mass ✓</p> <p>can be used continuously ✓</p> <p>fusion reactor less likely to cause large-scale technological disaster ✓</p> | <p><i>Do not accept “no/less waste produced”.</i></p> <p><i>Accept “higher specific energy”.</i></p> | 2 max |
| 18. | b | | 6 «hours» ✓ | | 1 |

| Question | | | Answers | Notes | Total |
|----------|---|----|---|---|-------|
| 18. | c | i | <p><i>Loss in mass:</i></p> $\llcorner (3.78532 \times 10^{-25} \text{ kg} - 9.109383 \times 10^{-31} \text{ kg} - 3.78528 \times 10^{-25} \text{ kg}) \times 0.00100 \times 6.02 \times 10^{23} \Rightarrow 1.86 \times 10^{-9} \text{ «kg» } \checkmark$ <p><i>Energy released:</i></p> $\llcorner E = mc^2 = 1.86 \times 10^{-9} \text{ kg} \times (3.00 \times 10^8 \text{ m s}^{-1})^2 \Rightarrow 1.67 \times 10^8 \text{ «J» } \checkmark$ | | 2 |
| 18. | c | ii | $\llcorner 1.67 \times 10^8 \text{ J} \times \frac{7}{8} \Rightarrow 1.46 \times 10^8 \text{ «J» } \checkmark$ | | 1 |
| 18. | d | | <p>production of radicals/$\bullet\text{O}_2^-/\bullet\text{OH}$</p> <p>OR</p> <p>direct effect such as breaking bonds/atom migration \checkmark</p> | <p><i>Ignore missing dots on radical species.</i></p> <p><i>Accept named radical eg “superoxide radical” OR “hydroxyl radical”.</i></p> <p><i>An example must be given for second alternative.</i></p> | 1 |

| Question | | Answers | Notes | Total |
|----------|---|--|--|-------|
| 19. | a | $ \begin{array}{c} \text{H}_2\text{C}-\text{O}-\overset{\text{O}}{\parallel}{\text{C}}-(\text{CH}_2)_6\text{CH}_3 \\ \\ \text{HC}-\text{O}-\overset{\text{O}}{\parallel}{\text{C}}-(\text{CH}_2)_6\text{CH}_3 \\ \\ \text{H}_2\text{C}-\text{O}-\overset{\text{O}}{\parallel}{\text{C}}-(\text{CH}_2)_6\text{CH}_3 \end{array} + 3\text{CH}_3\text{OH} \longrightarrow \begin{array}{c} \text{H}_2\text{C}-\text{OH} \\ \\ \text{HC}-\text{OH} \\ \\ \text{H}_2\text{C}-\text{OH} \end{array} + 3\text{CH}_3-\text{O}-\overset{\text{O}}{\parallel}{\text{C}}-(\text{CH}_2)_6\text{CH}_3 $ <p>ester product ✓ glycerol AND correct balancing ✓</p> | <p><i>Catalyst not required for equation.</i></p> <p><i>Award M2 only if M1 is correct.</i></p> | 2 |
| 19. | b | <p><i>Any three of:</i></p> <p>dye has conjugated system ✓</p> <p>dye absorbs a photon «and injects an electron into TiO₂» ✓</p> <p>electrons transferred to semiconductor «and dye ionized» ✓</p> <p>dye oxidizes/takes electron from electrolyte ✓</p> <p>electron flows through external circuit «to reduce electrolyte» ✓</p> | <p><i>M4 may also be scored from more detailed answers involving iodide species (eg "iodide/I⁻ oxidized to I₃⁻/triiodide" OR "I⁻/iodide reduces dye" OR "I⁻/iodide releases electron to dye" OR "I₃⁻/triiodide reduced to I⁻/iodide").</i></p> | 3 max |

| Question | | Answers | Notes | Total |
|----------|---|---|---|-------|
| 20. | a | <p><i>Negative electrode (anode):</i> $\text{CH}_3\text{OH}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{CO}_2(\text{g}) + 6\text{H}^+(\text{aq}) + 6\text{e}^- \checkmark$</p> <p><i>Positive electrode (cathode):</i> $\text{O}_2(\text{g}) + 4\text{H}^+(\text{aq}) + 4\text{e}^- \rightarrow 2\text{H}_2\text{O}(\text{l}) \checkmark$</p> <p><i>Overall equation:</i> $2\text{CH}_3\text{OH}(\text{aq}) + 3\text{O}_2(\text{g}) \rightarrow 2\text{CO}_2(\text{g}) + 4\text{H}_2\text{O}(\text{l}) \checkmark$</p> | <p><i>Accept any whole or fractional coefficients in balanced equations.</i></p> <p><i>Award [1 max] for correct half-equations at wrong electrodes for M1 and M2.</i></p> | 3 |
| 20. | b | <p><i>Advantage:</i> Any one of: liquid methanol is easier to transport/store than gaseous hydrogen OR hydrogen is explosive \checkmark longer membrane life «as it operates in aqueous environment» \checkmark methanol has greater energy density than hydrogen \checkmark</p> <p><i>Disadvantage:</i> Any one of: lower voltage \checkmark lower power per unit mass «of the cell» \checkmark lower efficiency \checkmark toxic/can be mistaken for ethanol \checkmark lower specific energy \checkmark</p> | <p><i>Ignore any cost references throughout.</i></p> <p><i>Accept "CO₂/greenhouse gas produced" OR "requires a more highly efficient catalyst".</i></p> <p><i>Do not award marks for converse statements for the advantage and disadvantage.</i></p> | 2 |

Option D — Medicinal chemistry

| Question | | Answers | Notes | Total |
|----------|---|--|---|-------|
| 21. | a | ${}_{71}^{177}\text{Lu} \rightarrow {}_{72}^{177}\text{Hf} + {}_{-1}^0\text{e} \llcorner + \nu \llcorner$ Hf ✓ correct A and Z AND beta product ✓ | Accept " $\beta/ \beta^-/e/e^-$ " for " ${}_{-1}^0\text{e}$ ". Accept " ${}^{177}\text{Lu} \rightarrow {}^{177}\text{Hf} + e^- \llcorner + \nu \llcorner$ ". | 2 |
| 21. | b | number of half-lives = $\frac{t}{\frac{t_1}{2}} = 2.08$ OR $\frac{N(t)}{N_0} = 0.5^{\frac{14.0}{6.73}}$ OR $\lambda = \llcorner \frac{\ln 2}{\frac{t_1}{2}} = \frac{\ln 2}{6.73} \llcorner \Rightarrow 0.103 \llcorner \text{day}^{-1} \llcorner$ OR $\frac{N(t)}{N_0} = e^{-0.103 \times 14.0} \checkmark$ 23.6 «%» ✓ | Award [2] for correct final answer. | 2 |

| Question | | Answers | Notes | Total |
|----------|---|--|--|---------------------|
| 21. | c | <p>Any two of:</p> <p>emits weak ionising radiation</p> <p>OR</p> <p>low activity/radioactivity ✓</p> <p>can be stored until material becomes inactive AND then disposed with normal waste ✓</p> <p>«isotopes» have short lives</p> <p>OR</p> <p>exist for a short period of time ✓</p> | <p>Award [1 max] for “low-level waste/LLW”.</p> | <p>2 max</p> |

| Question | | | Answers | Notes | Total |
|----------|---|----|---|---|-------|
| 22. | a | i | C=O ✓ | Accept "carbonyl". | 1 |
| 22. | a | ii | <p>X (must be identified) AND</p> <p>Any two of:</p> <p>For X:</p> <p>N–H «absorption» AND at 3300 – 3500 «cm⁻¹» ✓</p> <p>O–H «absorption» in phenol AND at 3200 – 3600 «cm⁻¹» ✓</p> <p>absence of OH «absorption» in carboxylic acid AND 2500 – 3000 «cm⁻¹» ✓</p> | <p>Accept any specific wavenumber in the range 3300–3380 «cm⁻¹» for M1.</p> <p>Accept any specific wavenumber in the range 3100–3200 «cm⁻¹».</p> <p>Award [1 max] if Y is incorrectly identified for paracetamol but if a correct reason/reasons is/are given for the bond absorption(s).</p> | 2 max |
| 22. | b | | <p>prevents/interferes with the production of prostaglandins</p> <p>OR</p> <p>prevents/interferes with the production of substances responsible for inflammation/pain/fever ✓</p> <p>at the site of injury/source of pain ✓</p> | | 2 |

| Question | | | Answers | Notes | Total |
|----------|---|----|--|---|-------|
| 22. | c | i | react with CH ₃ I/methyl iodide «in alkaline solution» ✓ | <p>Accept “react with CH₃Cl/methyl chloride” OR “react with methyl halide”.</p> <p>Accept name or formula of a suitable specific methylating reagent (eg trimethylphenylammonium chloride etc.).</p> <p>Accept “hydroxy/alcohol” but not “hydroxide” for “hydroxyl”.</p> | 1 |
| 22. | c | ii | <p>Any two of:</p> <p>interact with opioid receptors in the brain ✓</p> <p>alter the structure of brain cells</p> <p>OR</p> <p>alter the way the brain works «so that it only works normally when the opiates are present»</p> <p>OR</p> <p>prevents transmission of pain impulses inside the brain ✓</p> <p>release dopamine «that the person craves»</p> <p>OR</p> <p>give a feeling of pleasure/euphoria «that the person craves» ✓</p> <p>withdrawal symptoms «prevent patient from terminating drug use» ✓</p> | <p>Accept specific withdrawal symptoms.</p> | 2 max |

| Question | | Answers | Notes | Total |
|----------|---|---|-------|-------|
| 23. | a | <p>in animal studies $\frac{LD50}{ED50}$ AND in humans $\frac{TD50}{ED50}$</p> <p>OR</p> <p>in animal studies lethal dose/LD50 AND in humans toxic dose/TD50 ✓</p> | | 1 |
| 23. | b | <p><i>Any three of:</i></p> <p>chiral auxiliary is optically active ✓</p> <p>is attached to non-optically active/non-chiral substrate ✓</p> <p>creates stereochemical condition necessary to follow a certain pathway ✓</p> <p>allows only the required enantiomer to form «so avoids need to separate a racemic mixture» ✓</p> | | 3 max |
| 23. | c | <p>intravenous/IV «injection»</p> <p>OR</p> <p>injection into the <u>bloodstream</u> ✓</p> | | 1 |

| Question | | Answers | Notes | Total |
|----------|---|---|--|-------|
| 24. | | <p>Any two of:</p> <p>amido ✓</p> <p>ether ✓</p> <p>carbonyl ✓</p> | <p>Accept "amide/carboxamide".</p> <p>Accept "alkenyl/alkene".</p> <p>Accept "amino/amine".</p> | 2 max |
| 25. | a | <p>blocks/binds to H2/histamine receptors «in cells of stomach lining»</p> <p>OR</p> <p>prevents histamine molecules binding to H2/histamine receptors «and triggering acid secretion» ✓</p> <p>prevents parietal cells from releasing/producing acid ✓</p> | <p>Accept "H2-receptor antagonist/H2RA"</p> <p>OR "blocks/inhibits action of histamine" for M1.</p> | 2 |
| 25. | b | <p>ALTERNATIVE 1</p> $\text{pH} = \text{p}K_a + \log \frac{[\text{A}^-]}{[\text{HA}]} \Rightarrow 6.35 + \log \left(\frac{0.400}{0.0200} \right) \checkmark$ <p>«pH ⇒ 7.65 ✓</p> <p>ALTERNATIVE 2</p> <p>$K_a = 4.5 \times 10^{-7} \checkmark$</p> $\text{«}K_a = 0.400 \times \frac{[\text{H}^+]}{0.0200}, [\text{H}^+] \Rightarrow 2.3 \times 10^{-8} \text{ «mol dm}^{-3}\text{»}$ <p>«pH ⇒ 7.64 ✓</p> | <p>Award [2] for correct final answer.</p> <p>Do not accept "pH = 8".</p> | 2 |

| Question | Answers | Notes | Total |
|----------|--|---|-------|
| 26. | <p>ring is «sterically» strained OR angles of 90° instead of 109.5/109/120° angles OR angles smaller than 109.5/109/120°/tetrahedral/trigonal planar/triangular planar angle ✓</p> <p>ring breaks up/opens/reacts «easily» OR amido/amide group «in ring» is «highly» reactive ✓</p> <p>binds to/reacts with/interferes with/inactivates <u>transpeptidase</u> OR binds to/reacts with/interferes with/inactivates <u>enzyme</u> responsible for bacterial cell wall formation/cross-linking ✓</p> | | 3 |
| 27. | <p>ethanol is oxidized «to ethanoic acid» OR electrons are released ✓</p> <p>current/potential proportional to concentration «of ethanol» OR current compared to a reference «to determine concentration» ✓</p> | <p><i>Accept "ethanol reacts with oxygen" for M1.</i></p> <p><i>Accept "voltage" for "potential".</i></p> | 2 |