

# 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» <b>OR</b> solution becoming saturated <b>OR</b> concentration of lead ions/[Pb <sup>2+</sup> ] in the solution has increased «over time» <b>OR</b> acid concentration has decreased «as reacted with lead» <b>OR</b> surface lead has decreased/formed a compound/forms insoluble layer on surface <b>OR</b> acid reacts with other metals «because it is an alloy» ✓	Do <b>not</b> accept "concentration of cola, orange juice, etc... has decreased"  Do <b>not</b> accept a response that only discusses mathematical or proportional relationships.	1
1.	b	ii	no <b>AND</b> experiment 7/beer has lowest rate and intermediate acidity/pH <b>OR</b> no <b>AND</b> experiment 6/orange juice has fastest rate but lower acidity/higher pH than lemonade <b>OR</b> no <b>AND</b> experiment 6/orange juice has highest rate and intermediate acidity/pH ✓	Accept no <b>AND</b> any comparison, <b>with experimental support</b> , 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 <b>OR</b> concentration of lead «ions»/[Pb <sup>2+</sup> ] decreases ✓	Award [2] for “equilibrium shifts to the left/towards reactants due to common ion effect”.  Accept “lead ions/[Pb <sup>2+</sup> ] removed from solution” for M2.	2
1.	c	ii	«daily limit = $5.0 \times 10^{-6} \text{ g kg}^{-1} \times 80.0 \text{ kg} \Rightarrow 4.0 \times 10^{-4} \text{ «g of lead»}$ ✓  «volume = $\frac{4.0 \times 10^{-4} \text{ g}}{1.5 \times 10^{-2} \text{ g dm}^{-3}} \Rightarrow 2.7 \times 10^{-2} / 0.027 \text{ «dm}^3\text{»}$ ✓	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><b>ALTERNATIVE 1</b>                      colour ✓  <math>\text{Br}_2</math> /reactant is coloured «<math>\text{Br}^-</math> (aq) is not» ✓</p> <p><b>ALTERNATIVE 2</b>                      conductivity ✓                      greater/increased concentration of ions in products ✓</p> <p><b>ALTERNATIVE 3</b>                      mass/pressure ✓                      gas is evolved/produced ✓</p> <p><b>ALTERNATIVE 4</b>                      pH ✓                      methanoic acid is weak <b>AND</b> HBr is strong  <b>OR</b>                      increase in <math>[\text{H}^+]</math> ✓</p>	<p>Do <b>not</b> accept “changes in temperature” or “number of bubbles”.</p> <p>Do <b>not</b> accept “mass of products is less than mass of reactants”.</p>	2

Question			Answers	Notes	Total
2.	c	i	<p><b>ALTERNATIVE 1</b></p> <p>gas may leak/be lost/escape</p> <p><b>OR</b></p> <p>plunger may stick/friction «so pressure is greater than atmospheric pressure»</p> <p><b>OR</b></p> <p>syringe may be tilted «up» so plunger moves less «with gravity acting on plunger»</p> <p><b>OR</b></p> <p>CO<sub>2</sub> dissolved in water ✓</p> <p>calculated rate lower ✓</p> <p><b>ALTERNATIVE 2</b></p> <p>syringe may be tilted «down» so plunger moves more «with gravity acting on plunger»</p> <p><b>OR</b></p> <p>syringe is held in hand so gets warmer and gas expands ✓</p> <p>calculated rate higher ✓</p>	<p><i>Calculated rate is lower or higher must be stated for M2.</i></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

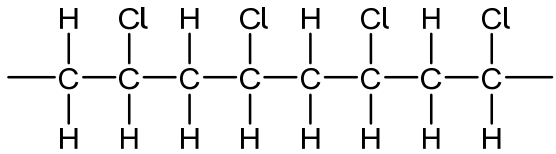
## Section B

## Option A — Materials

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

Question		Answers	Notes	Total
4.	a	moles of electrons $\llcorner = \frac{48\,250\text{ C}}{96\,500\text{ C mol}^{-1}} \llcorner = 0.5000 \llcorner \text{mol} \llcorner \checkmark$ moles of aluminium $\llcorner = \frac{0.5000\text{ mol}}{3} \llcorner = 0.1667 \llcorner \text{mol} \llcorner \checkmark$ mass of aluminium $\llcorner = 26.98\text{ g mol}^{-1} \times 0.1667\text{ mol} \llcorner = 4.50 \llcorner \text{g} \llcorner \checkmark$	<i>Award [3] for correct final answer.</i>	3
4.	b	<i>Any two of:</i> larger linear calibration $\checkmark$ «accurate» detection of multiple elements/metals $\checkmark$ «accurate» detection of elements in low concentration $\checkmark$ temperature around 10 000 K atomises/ionises every material $\checkmark$		2 max
4.	c	<i>Any two of:</i> reactant(s) adsorb onto active sites/surface $\checkmark$  bonds weakened/broken/stretched «in adsorbed reactants» <b>OR</b> activation energy lowered $\checkmark$  products desorbed $\checkmark$	<i>Accept "products released" for M3.</i>	2 max
4.	d	<i>Conduct electricity:</i> «delocalized/valence» electrons free to move «under potential difference» $\checkmark$  <i>Harder than pure metals:</i> atoms/ions of different sizes prevent layers «of atoms/ions» from sliding over one another $\checkmark$		2
4.	e	$2\text{CO (g)} \rightarrow \text{C (s)} + \text{CO}_2\text{ (g)} \checkmark$		1



Question		Answers	Notes	Total
5.	a	 <p>correct bonding ✓ Cl atoms all on same side and alternate ✓</p>	<p><i>Continuation bonds must be shown.</i></p> <p><i>Award [1 max] if less than or more than four units shown.</i></p> <p><i>Accept a stereo formula with all atoms and bonds shown.</i></p>	2
5.	b	«strong additional» absorption at 600–800 «cm <sup>-1</sup> » ✓		1
5.	c	<p><i>Any two of:</i></p> <p>embedded/fit between chains of polymers ✓</p> <p>prevent chains from forming crystalline regions ✓</p> <p>keep polymer strands/chains/molecules separated/apart ✓</p> <p>increase space/volume between chains ✓</p> <p>weaken intermolecular/dipole-dipole/London/dispersion/instantaneous dipole-induced dipole/van der Waals/vdW forces «between chains» ✓</p> <p>increase flexibility/durability/softness ✓</p> <p>make polymers less brittle ✓</p>	Accept “lowers density/melting point”.	2 max
5.	d	<p>leach into foodstuffs/environment</p> <p><b>OR</b></p> <p>«unknown» health/environmental consequences ✓</p>	Accept “plasticizers cannot be recycled”.	1

Question		Answers	Notes	Total
5.	e	<p>addition produces only the polymer «<b>AND</b> more green»</p> <p><b>OR</b></p> <p>addition has no by/side-product/condensation produces by-product/small molecules/HCl/NH<sub>3</sub> «<b>AND</b> less green»</p> <p><b>OR</b></p> <p>addition has high atom economy/condensation has lower atom economy «<b>AND</b> less green»</p> <p><b>OR</b></p> <p>condensation polymers «often» more biodegradable than addition polymers «<b>AND</b> more green» ✓</p>	<p>Accept "if water produced by condensation «<b>AND</b> 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 <b>not</b> 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><b>OR</b></p> <p>volume of unit cell = <math>\llcorner (5.572 \times 10^{-10} \text{ m})^3 \times 10^6 = \llcorner 1.73 \times 10^{-22} \llcorner \text{cm}^3 \llcorner \checkmark</math></p> <p>mass of unit cell = <math>\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</math></p> <p>density = <math>\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</math></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  <b>OR</b>                      compete for active sites of enzymes/cellular receptors  <b>OR</b>                      form complexes with/inhibit enzymes  <b>OR</b>                      denature proteins  <b>OR</b>                      change shape of active site ✓</p> <p>participate in redox reactions  <b>OR</b>                      disturb normal redox balance «in cells» ✓</p> <p>initiate «free» radical reactions «in electron transfer» ✓</p>		1 max
8.	b	<p>«<math>K_{sp} = 7.40 \times 10^{-14}</math>»  <math>K_{sp} = [Pb^{2+}][CO_3^{2-}]</math> ✓  <math>[Pb^{2+}] \ll \frac{7.40 \times 10^{-14}}{1.10 \times 10^{-4}} \gg = 6.73 \times 10^{-10}</math> «mol dm<sup>-3</sup>» ✓</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	$\beta$ /beta pleated/sheet ✓		1
9.	a	ii	<p><i>One similarity:</i> hydrogen bonding <b>OR</b> attractions between C=O and N–H «on main chain» ✓</p> <p><i>One difference:</i> <math>\alpha</math>-helix has hydrogen bonds between amino acid residues that are closer than <math>\beta</math>-pleated sheet <b>OR</b> H-bonds in <math>\alpha</math>-helix parallel to helix axis <b>AND</b> perpendicular to sheet in <math>\beta</math>-pleated sheet <b>OR</b> <math>\alpha</math>-helix has one strand <b>AND</b> <math>\beta</math>-pleated sheet has two «or more» strands <b>OR</b> <math>\alpha</math>-helix is more elastic «since H-bonds can be broken easily» <b>AND</b> <math>\beta</math>-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 <b>OR</b> «interactions responsible for» for tertiary/quaternary structures altered ✓</p> <p>shape of active site changes <b>OR</b> fewer substrate molecules fit into active sites ✓</p>		2

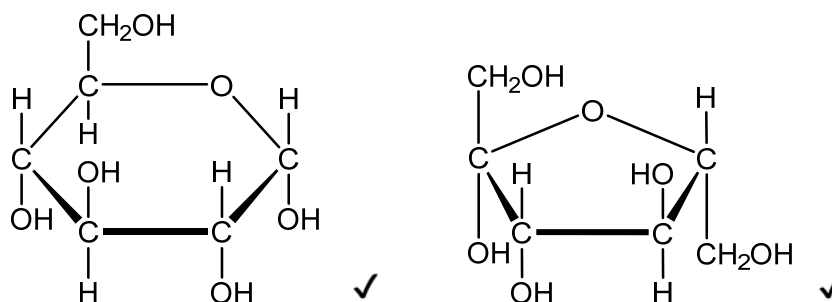
Question			Answers	Notes	Total
9.	c		$V_{\max}$ unchanged ✓ at high substrate concentration substrate outcompetes inhibitor/need a higher substrate concentration to reach $V_{\max}$ ✓	Accept suitable labelled diagram.	2
9.	d	i	Any two of: surface water is warmer «so faster reaction rate»/more light/energy 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» <b>OR</b> atom economy ✓  safety of process ✓	Accept “use of solvents/toxic materials «during production»”.  Do <b>not</b> accept “more steps involved”.	1 max

Question			Answers	Notes	Total
10.	a	i	<p><math>pK_{a2}</math> <b>AND</b> pH of solution &gt; pH of isoelectric point «as anion present»  <b>OR</b>  <math>pK_{a2}</math> <b>AND</b> zwitterion has lost <math>H^+</math> to become anion «so in basic solution»  <b>OR</b>  <math>pK_{a2}</math> <b>AND</b> «only» anion «and zwitterion» present ✓</p>		1
10.	a	ii	<p>«<math>pH = 9.1 + \log \left[ \frac{0.30}{0.60} \right]</math>»                      «= <math>9.1 + (-0.3)</math>» = 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)_{10}\text{CH}_3 \\  \parallel \\  \text{O} \\  \text{H}_2\text{C}-\text{O}-\text{C}-(\text{CH}_2)_{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<sub>N</sub>".</p>	1
11.	b		<p>phospholipid bilayer/double layer <b>OR</b> two layers of phospholipids ✓</p> <p>polar/hydrophilic heads facing aqueous environment <b>AND</b> 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 <b>AND</b> non-polar/hydrophobic tails on inside" for M2.</p>	2



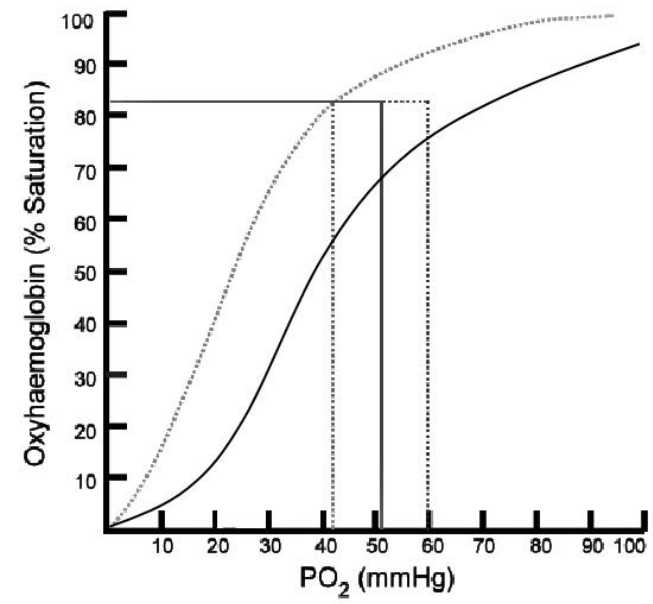
Question			Answers	Notes	Total
11.	c		long non-polar/hydrocarbon chain «and only one hydroxyl group» <b>OR</b> forms London/dispersion/van der Waals/vdW interactions with fat ✓	Accept "alcohol/hydroxy/OH" for "hydroxyl" but <b>not</b> "hydroxide".	1
11.	d		Any one of: atherosclerosis/cholesterol deposition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

Question		Answers	Notes	Total
12.	a	acetal <b>OR</b> ether ✓	Accept "glycosidic bond/linkage" but <b>not</b> "glucosidic". Do <b>not</b> accept "hemiacetal".	1
12.	b	$\alpha$ -isomer <b>AND</b> hydroxyl group on carbon 1 and $-\text{CH}_2\text{OH}$ are trans <b>OR</b> $\alpha$ -isomer <b>AND</b> hydroxyl group on carbon 1 is below plane of ring <b>OR</b> $\alpha$ -isomer <b>AND</b> 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 <b>OR</b> extensive delocalized bonding system <b>OR</b> extended system of alternating double and single bonds ✓  absorbs green <b>OR</b> complementary to red light ✓		2
13.	b	i	sigmoid/S-shaped <b>OR</b> 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 <b>OR</b> 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 PO<sub>2</sub> (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 shifted curve. A horizontal line at 80% saturation intersects the solid curve at approximately 40 mmHg and the dotted curve at approximately 60 mmHg. Vertical dashed lines connect these intersection points to the x-axis. The dotted curve is shifted to the right of the solid curve, indicating a rightward shift of the dissociation curve.</p> <p>curve to right of original ✓</p> <p>[Source: Ratznum, <a href="https://commons.wikimedia.org/wiki/File:Oxyhaemoglobin_dissociation_curve.png">https://commons.wikimedia.org/wiki/File:Oxyhaemoglobin_dissociation_curve.png</a>]</p>		1

Option C — Energy

Question	Answers	Notes	Total
14.	<p><b>Advantage</b>  <i>Any one of:</i>                      renewable ✓                      predictable supply ✓                      tidal barrage may prevent flooding ✓                      effective at low speeds ✓                      long life-span ✓                      low cost to run ✓</p> <p><b>Disadvantage</b>  <i>Any one of:</i>                      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><i>Do not accept vague generalisations.</i>  <i>Do not accept economic issues for both advantage and disadvantage.</i>  <i>Do not accept sustainable.</i>                      Accept “energy” or “electricity” for “power”.</p>	2 max

Question		Answers		Notes	Total
15.	a	<p><b>Fractional distillation:</b> Any two of: <b>1 max</b></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><b>Cracking:</b> Any two of: <b>1 max</b></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 <b>[1]</b> for any two correct answers from one column <b>OR</b> one from each column.</p> <p>Award <b>[2]</b> for any two correct from each column; eg: fractional distillation – any two correct award <b>[1 max]</b> <b>AND</b> cracking – any two correct, award <b>[1 max]</b>.</p>	2 max
		<p>specific energy = «<math>\frac{4163 \text{ kJ mol}^{-1}}{86.2 \text{ g mol}^{-1}}</math>» ⇒ 48.3 «kJ g<sup>-1</sup>» ✓</p> <p>energy density = «48.3 kJ g<sup>-1</sup> × 0.660 g cm<sup>-3</sup>» ⇒ 31.9 «kJ cm<sup>-3</sup>» ✓</p>	<p>Award <b>[1 max]</b> 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</p> <p><b>OR</b></p> <p>branching/aromatisation occurs</p> <p><b>OR</b></p> <p>isomerisation/reforming/platforming/cracking ✓</p> <p>zeolite separates branched from non-branched</p> <p><b>OR</b></p> <p>products are distilled</p> <p><b>OR</b></p> <p>«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 <b>OR</b> if mass of fissile material is too small, too many neutrons produced pass out of the nuclear fuel <b>OR</b> 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 <sub>2</sub> ) but <b>not</b> 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 <b>not</b> accept “no/less waste produced for fusion”.  Accept specific example for a disaster.	1 max
16.	c		mass difference between reactants and products <b>AND</b> $E = mc^2$ ✓		1

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



Question	Answers	Notes	Total
17.	<p><b>Strength</b>  <i>Any one of:</i>                      less flammable «than diesel» ✓                      recycles carbon «lower carbon footprint»  <b>OR</b>                      lower greenhouse gas emissions ✓                      easily biodegradable «in case of spill» ✓                      renewable  <b>OR</b>                      does not deplete fossil fuel reserves ✓                      economic security/availability in countries without crude oil ✓</p> <p><b>Limitation</b>  <i>Any one of:</i>                      more difficult to ignite inside the engine «than diesel» ✓                      more viscous «than diesel» ✓                      lower energy content/specific energy/energy density ✓                      uses food sources  <b>OR</b>                      uses land that could be used for food ✓                      «production is» more expensive ✓                      less suitable in low temperatures ✓                      increased NO<sub>x</sub> emissions for biodiesel ✓                      greenhouse gases still produced ✓</p>	<p><i>Accept “«close to» carbon neutral”, “produce less greenhouse gases/CO<sub>2</sub>”.</i></p> <p><i>Accept “engines have to be modified if biodiesel used” as limitation.</i></p> <p><i>Do <b>not</b> award marks for strength and limitation that are the same topic/concept.</i></p>	2 max

Question		Answers	Notes	Total
18.	a	bond length/C=O distance changes <b>OR</b> «asymmetric» stretching «of bonds» <b>OR</b> bond angle/OCO changes ✓  polarity/dipole «moment» changes <b>OR</b> 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 <b>OR</b> 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> $\text{C}_6\text{H}_{12}\text{O}_6 (\text{aq}) + 6\text{H}_2\text{O} (\text{l}) \rightarrow 6\text{CO}_2 (\text{g}) + 24\text{H}^+ (\text{aq}) + 24\text{e}^-$ <p><b>OR</b></p> <p>electrons released by oxidation of glucose ✓</p> <p>enzymes «in bacteria» oxidize glucose</p> <p><b>OR</b></p> <p>«bacteria» transfer «released» electrons directly to anode ✓</p> $24\text{H}^+ (\text{aq}) + 6\text{O}_2 (\text{g}) + 24\text{e}^- \rightarrow 12\text{H}_2\text{O} (\text{l})$ <p><b>OR</b></p> <p>electrons consumed by reduction of oxygen ✓</p> <p>PEM/membrane separates two half reactions</p> <p><b>OR</b></p> <p>PEM/membrane allows proton/<math>\text{H}^+</math> transfer from anode to cathode ✓</p> <p>electrons flow through external circuit ✓</p>	<p>Accept <math>4\text{H}^+ (\text{aq}) + \text{O}_2 (\text{g}) + 4\text{e}^- \rightarrow 2\text{H}_2\text{O} (\text{l})</math>.</p>	<p><b>3 max</b></p>

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%;"></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;"><b>AND</b></td> <td>«electrode» materials can be regenerated/reused ✓</td> </tr> <tr> <td>non-reversible reaction(s)</td> <td style="text-align: center;"><b>AND</b></td> <td>reversible reaction(s) ✓</td> </tr> <tr> <td>lower rate of self-discharge</td> <td style="text-align: center;"><b>OR</b></td> <td>higher rate of self-discharge ✓</td> </tr> <tr> <td>only lower current demands</td> <td style="text-align: center;"><b>OR</b></td> <td>can deliver stronger current demands ✓</td> </tr> </tbody> </table>		Primary		Secondary	«electrode» materials cannot be reused/regenerated	<b>AND</b>	«electrode» materials can be regenerated/reused ✓	non-reversible reaction(s)	<b>AND</b>	reversible reaction(s) ✓	lower rate of self-discharge	<b>OR</b>	higher rate of self-discharge ✓	only lower current demands	<b>OR</b>	can deliver stronger current demands ✓	Accept “primary cannot be recharged <b>AND</b> “secondary can be recharged”.
Primary		Secondary																	
«electrode» materials cannot be reused/regenerated	<b>AND</b>	«electrode» materials can be regenerated/reused ✓																	
non-reversible reaction(s)	<b>AND</b>	reversible reaction(s) ✓																	
lower rate of self-discharge	<b>OR</b>	higher rate of self-discharge ✓																	
only lower current demands	<b>OR</b>	can deliver stronger current demands ✓																	

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 TiO<sub>2</sub>/semiconductor/electrolyte/cell</p> <p><b>OR</b></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><b>OR</b></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 <b>AND</b> diamorphine has «two» ester/ethanoate/acetate groups</p> <p><b>OR</b></p> <p>molecule of diamorphine is less polar than morphine</p> <p><b>OR</b></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><b>OR</b></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<sup>-1</sup> due to C–O» ✓</p> <p>1700–1750 «cm<sup>-1</sup> due to C=O in acids and esters» ✓</p> <p>2500–3000 «cm<sup>-1</sup> due to O–H in acids» ✓</p> <p>2850–3090 «cm<sup>-1</sup> due to C–H in alkanes and arenes» ✓</p>		1 max
22.	b	i	<p><math>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</math></p> <p><math>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</math></p>	Award [2] for correct final answer.	2
22.	b	ii	<p><math>\llcorner \frac{0.293 \text{ g}}{0.300 \text{ g}} \times 100 \% \llcorner = 97.7 \llcorner \% \llcorner \checkmark</math></p>		1
22.	c		<p>convert to a salt</p> <p><b>OR</b></p> <p>react with sodium hydroxide ✓</p>	<p>Accept other reactions forming soluble salts.</p> <p>Accept “to ionize” but <b>not</b> “more polar”.</p>	1
22.	d		<p>synergistic effect/increased toxicity</p> <p><b>OR</b></p> <p>increased risk of stomach/intestines bleeding/ulcers/heartburn</p> <p><b>OR</b></p> <p>increased risk of liver toxicity/damage</p> <p><b>OR</b></p> <p>increased risk of nausea/vomiting ✓</p>		1

Question			Answers	Notes	Total
23.	a	i	blocks/binds H2/histamine receptors «in cells of stomach lining» <b>OR</b> prevents histamine molecules binding to H2/histamine receptors «and triggering acid secretion» ✓		1
23.	a	ii	<i>Any two of:</i> 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 ✓	<i>Accept “ranitidine stops the over production of acid in the stomach while antacids neutralise the excess acid giving temporary relief” for M2.</i>	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><b>OR</b></p> <p>inhibit the synthesis of viral components by blocking enzymes inside the cell ✓</p> <p>prevent viruses from entering «host» cell</p> <p><b>OR</b></p> <p>bind to cellular receptors targeted by viruses</p> <p><b>OR</b></p> <p>bind to virus-associated proteins/VAPs which target cellular receptors</p> <p><b>OR</b></p> <p>prevents removal of protein coat/capsid</p> <p><b>OR</b></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><b>Do not accept just "mimics nucleotides".</b></p>	<p><b>1 max</b></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><b>OR</b></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><b>OR</b></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>  <b>OR</b>                      sustainable because synthesized and not obtained from yew trees ✓                        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  <b>OR</b>                      light passes through polarizer/polarizing filter ✓                        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><b>ALTERNATIVE 1</b></p> $\frac{N(t)}{N_0} = \left(\frac{1}{2}\right)^{\frac{t}{t_{1/2}}} \quad \checkmark$ <p>31 «% remaining» ✓</p> <p><b>ALTERNATIVE 2</b></p> $\lambda \text{ «} = \frac{\ln 2}{t_{1/2}} \text{»} = 0.1155 \text{ hours}^{-1} \quad \checkmark$ $\text{«} \frac{N}{N_0} \times 100 = e^{-\lambda t} \times 100 = 0.31498 \times 100 \text{»}$ <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><i>Any three of:</i></p> <p>ethanol «in breath» is oxidized «to ethanoic acid» ✓</p> <p>electrons pass through external circuit/meter ✓</p> <p>«to cathode where» O<sub>2</sub> is reduced ✓</p> <p>current is proportional to alcohol concentration ✓</p>	<p><i>Accept equations for oxidation of ethanol or reduction of oxygen.</i></p>	<p><b>3 max</b></p>
27.	b	<p><i>Bond:</i></p> <p>C–O</p> <p><b>OR</b></p> <p>C–H ✓</p> <p><i>Reason:</i></p> <p>cannot use O–H bonds as in water «found in breath» ✓</p>	<p><i>Accept “C–O/C–H «bonds in molecules in breath» most likely to be in ethanol”.</i></p> <p><i>Do not apply ECF here.</i></p>	<p><b>2</b></p>