

Markscheme

November 2018

Chemistry

Higher level

Paper 3

This markscheme is the property of the International Baccalaureate and must **not** be reproduced or distributed to any other person without the authorization of the IB Global Centre, Cardiff.

Section A

Question		Answers	Notes	Total
1.	a	NO ₂ /NO/NO _x /HNO ₃ /gas is poisonous/toxic/irritant ✓	Accept formula or name. Accept "HNO ₃ is corrosive" OR "poisonous/toxic gases produced". Accept "reaction is harmful/hazardous".	1
1.	b	Slope (gradient): 40 ✓ Equation: absorbance = 40 × concentration OR y = 40x ✓	Accept any correct relationship for slope such as $\frac{1.00}{0.025}$. Award [2] if equation in M2 is correct.	2
1.	c	orange is opposite blue «in the colour wheel» OR the complementary colour «blue» is seen/transmitted ✓ 585–647 «nm would be absorbed» ✓	Accept any value or range within 550–680 «nm» for M2.	2

Question			Answers	Notes	Total
1.	d		dilute 1.00 cm ³ «of the standard solution with water» to 100 cm ³ OR dilute sample of standard solution «with water» 100 times ✓ «graduated/volumetric» pipette/pipet ✓ volumetric flask ✓	Accept any 1:100 ratio for M1. Accept “mix 1 cm ³ of the standard solution with 99 cm ³ of water” for M1. Do not accept “add 100 cm ³ of water to 1.00 cm ³ of standard solution” for M1. Accept “burette/buret” for M2. Accept “graduated/measuring flask” for M3 but not “graduated/measuring cylinder”, “conical/Erlenmeyer flask”.	3
1.	e	i	concentration of copper = 0.0080 «mol dm ⁻³ » ✓ mass of copper in 250.0 cm ³ = «0.0080 mol dm ⁻³ × 0.2500 dm ³ × 63.55 g mol ⁻¹ ⇒» 0.127 «g» OR mass of brass in 1 dm ³ = «4 × 0.200 g ⇒» 0.800 g AND [Cu ²⁺] = «0.0080 mol dm ⁻³ × 63.55 g mol ⁻¹ ⇒» 0.5084 g dm ⁻³ ✓ «% copper in this sample of brass = $\frac{0.127}{0.200} \times 100 \Rightarrow 64$ «%» OR «% copper in this sample of brass = $\frac{0.5084}{0.800} \times 100 \Rightarrow 64$ «%» ✓	Accept any value in range 0.0075–0.0085 «mol dm ⁻³ » for M1. Accept annotation on graph for M1. Award [3] for correct final answer. Accept “65 «%»”.	3
1.	e	ii	two ✓	Do not apply ECF from 1(e)(i).	1

Question			Answers	Notes	Total
1.	f	i	«since it is greater than 60 %» it will reduce the presence of bacteria «on door handles» ✓		1
1.	f	ii	resistant to corrosion/oxidation/rusting OR low friction surface «so ideal for connected moving components» ✓	Accept “hard/durable”, “«high tensile» strength”, “unreactive”, “malleable” or any reference to the appearance/ colour of brass (eg “gold-like”, “looks nice” etc.). Do not accept irrelevant properties, such as “high melting/boiling point”, “non-magnetic”, “good heat/electrical conductor”, “low volatility”, etc. Do not accept “ductile”.	1
1.	g		precipitate/copper(I) iodide/CuI makes colour change difficult to see OR release of I ₂ /iodine from starch-I ₂ complex is slow so titration must be done slowly ✓		1

Section B

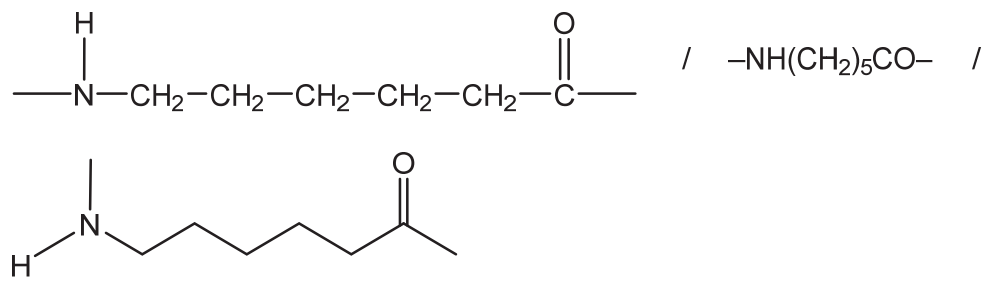
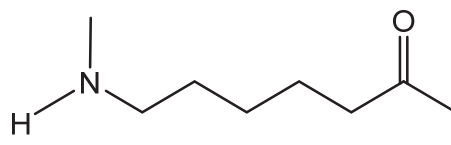
Option A — Materials

Question		Answers	Notes	Total
2.	a	$\Delta\chi = 0.7$ AND average $\chi = 1.7$ ✓ bonding between metallic and ionic OR more than one type of bonding present OR bond type difficult to determine as close to several regions/several types/named bonding types «eg ionic and covalent etc.» OR bond is mostly covalent «based on % covalent scale on diagram» OR bond has « $\frac{0.7}{3.2} \times 100 \Rightarrow$ 22% ionic character ✓	Accept “EN” for “ χ ”. Accept “bond is ionic but close to several regions/several types/other named bonding type(s) (eg covalent, metallic and covalent etc.)”. Do not accept just “bond is ionic”. Accept any value for % ionic character in range 15–24% or % covalent character in range 76–85%.	2

Question			Answers	Notes	Total
2.	b		<p><i>Thermoplastic polymer:</i> PMA AND «weak» intermolecular forces/IMFs/London/dispersion/van der Waals/vdW/dipole-dipole forces «between layers/chains» OR PMA AND no/few cross-links «between layers/chains» ✓</p> <p><i>Thermosetting polymer:</i> Bakelite® AND «strong» covalent bonds «between layers/chains» OR Bakelite® AND extensive cross-links «between layers/chains» ✓</p>	<p><i>Do not accept “hydrogen bonding” for M1.</i></p> <p><i>Award [1 max] for correct reasons for both polymer classes even if named polymers are incorrectly classified.</i></p>	2
2.	c		<p>pores/cavities/channels/holes/cage-like structures «in zeolites» have specific shape/size ✓ only reactants «with appropriate size/geometry» fit inside/go through/are activated/can react ✓</p>		2
2.	d	i	<p>amino AND carboxyl ✓</p>	<p><i>Do not accept “carbonyl”, “hydroxyl”.</i></p>	1

(continued...)

(Question 2d continued)

Question			Answers	Notes	Total
2.	d	ii	 $\text{---N---CH}_2\text{---CH}_2\text{---CH}_2\text{---CH}_2\text{---CH}_2\text{---C(=O)---}$ $\text{---NH(CH}_2\text{)}_5\text{CO---}$  ✓	Continuation bonds at NH and CO are required for mark. Ignore any brackets and n.	1
2.	d	iii	Name and reason: PET/PETE AND peak for C=O «at 1700–1750 cm ⁻¹ » ✓ RIC: 1 ✓	Accept “PET/PETE AND peak for C–O «at 1050–1410 cm ⁻¹ »” for M1. Accept “PET/PETE AND peak(s) for COO” for M1. Accept name or abbreviation for polymer. No ECF for M2.	2
3.	a		positive ions/cations/Pb ²⁺ OR free electrons ✓	Accept “ions” OR “charged species/particle”.	1

Question			Answers	Notes	Total
3.	b	i	$[\text{Pb}^{2+}] = 0.50 \times 10^{-6} / 5.0 \times 10^{-7} \text{ «g dm}^{-3}\text{» } \checkmark$ $[\text{Pb}^{2+}] \llcorner = \frac{0.50 \times 10^{-6} \text{ g dm}^{-3}}{207.20 \text{ g mol}^{-1}} \llcorner = 2.4 \times 10^{-9} \text{ «mol dm}^{-3}\text{» } \checkmark$	Award [2] for correct final answer.	2
3.	b	ii	$\llcorner K_{\text{sp}} = 1.43 \times 10^{-20}\llcorner$ <p>ALTERNATIVE 1:</p> $\llcorner Q = [\text{Pb}^{2+}] [\text{OH}^{-}]^2 = 2.4 \times 10^{-9} \times (1.0 \times 10^{-2})^2 \llcorner = 2.4 \times 10^{-13} \checkmark$ <p>$Q > K_{\text{sp}}$ AND precipitate will form OR $2.4 \times 10^{-13} > 1.43 \times 10^{-20}$ AND precipitate will form \checkmark</p> <p>ALTERNATIVE 2:</p> <p>critical $[\text{Pb}^{2+}]$ for hydroxide solution $\llcorner = \frac{K_{\text{sp}}}{[\text{OH}^{-}]^2} = \frac{1.43 \times 10^{-20}}{(1.0 \times 10^{-2})^2} \llcorner = 1.4 \times 10^{-16} \checkmark$</p> <p>initial concentration > critical concentration AND precipitate will form OR $2.4 \times 10^{-9} > 1.4 \times 10^{-16}$ AND precipitate will form \checkmark</p> <p><i>If value given is used:</i></p> <p>ALTERNATIVE 3:</p> $\llcorner Q = [\text{Pb}^{2+}] [\text{OH}^{-}]^2 = 2.4 \times 10^{-4} \times (1.0 \times 10^{-2})^2 \llcorner = 2.4 \times 10^{-8} \checkmark$ <p>$Q > K_{\text{sp}}$ AND precipitate will form OR $2.4 \times 10^{-8} > 1.43 \times 10^{-20}$ AND precipitate will form \checkmark</p>		2

Question			Answers	Notes	Total
3.	c		<p>«Faraday's constant, $F = 9.65 \times 10^4 \text{ C mol}^{-1}$ and $1 \text{ A} = 1 \text{ C s}^{-1}$»</p> <p>$Q \llcorner = 0.0500 \text{ mol} \times 2 \times 96500 \text{ C mol}^{-1} \llcorner = 9650 \llcorner \text{C} \llcorner \checkmark$</p> <p>$t \llcorner = \frac{Q}{I} = \frac{9650 \text{ C}}{1.34 \text{ C s}^{-1}} \approx 7200 \text{ s}$ so $\frac{7200 \text{ s}}{60 \times 60 \text{ s h}^{-1}} \llcorner = 2.00 \llcorner \text{hours} \llcorner \checkmark$</p>	<i>Award [2] for correct final answer.</i>	2
3.	d	i	<p>Any one of:</p> <p>two «or more» lone/non-bonding pairs on different atoms</p> <p>OR</p> <p>two «or more» atoms/centres that act as Lewis bases \checkmark</p> <p>form «at least» two coordination/coordinate bonds</p> <p>OR</p> <p>«at least» two atoms can form coordination/coordinate bonds \checkmark</p>	<p><i>Reference to "on DIFFERENT atoms" required.</i></p> <p><i>Accept "dative «covalent» bond" for "coordination/coordinate bond".</i></p>	1 max
3.	d	ii	<p>increase in entropy</p> <p>OR</p> <p>$\Delta S > 0 / \Delta S$ positive \checkmark</p>	<i>Accept "$\Delta G < 0$" but not "$\Delta H < 0$".</i>	1

Question		Answers	Notes	Total
4.	a	<p>Any two of:</p> <p>cloudy/foggy/hazy phase «at first melting point» ✓</p> <p>clear liquid phase «at second melting point/higher temperature» ✓</p> <p>two «different» melting points</p> <p>OR</p> <p>new phase observed over a wide temperature range ✓</p>	<p>Accept “exhibit both liquid and solid properties at the same time” for M3.</p>	2 max
4.	b	<p>ALTERNATIVE 1:</p> <p>«bulky/long» C₅H₁₁/R/alkyl «group/chain» AND prevents molecules from packing closer together «to form solid state» ✓</p> <p>ALTERNATIVE 2:</p> <p>biphenyl «fragment»/two benzene rings/two aromatic rings AND «makes molecule» rigid/rod-shaped ✓</p>	<p>Accept “rigid/rod-shaped molecule, so aligns with other molecules” for ALTERNATIVE 2.</p>	1
4.	c	<p>«average» oxidation state of C in C₆H₁₂/cyclohexane = -2 AND in CNTs = 0</p> <p>OR</p> <p>oxidation state of C in CNTs is higher than in C₆H₁₂/cyclohexane</p> <p>OR</p> <p>loss of H's/hydrogens ✓</p> <p>«oxidation at» positive/+ «electrode»/anode ✓</p>	<p>Accept “oxidation number” for “oxidation state”.</p>	2

Question			Answers	Notes	Total
5.	a	i	face-centred cube/fcc OR cubic close packed/ccp ✓		1
5.	a	ii	$\frac{1}{2}$ «atom per face» × 6 «faces per cube» = 3 «atoms» AND $\frac{1}{8}$ «atom per corner» × 8 «corners per cube» = 1 «atom» ✓ «atoms per unit cell = 3 + 1 ⇒ 4 ✓	<i>Award [1 max] for "4" without working shown.</i>	2
5.	b		«4 atoms per unit cell» mass of 4 atoms «= 4 × $\frac{196.97 \text{ g mol}^{-1}}{6.02 \times 10^{23} \text{ mol}^{-1}}$ ⇒ 1.31 × 10 ⁻²¹ «g» ✓ volume of unit cell «= (4.08 × 10 ⁻⁸) ³ cm ³ » = 6.79 × 10 ⁻²³ «cm ³ » ✓ density = « $\frac{1.31 \times 10^{-21} \text{ g}}{6.79 \times 10^{-23} \text{ cm}^3}$ » = 1.93 × 10 ¹ /19.3 «g cm ⁻³ » ✓	<i>Award [3] for correct final answer.</i>	3

Option B — Biochemistry

Question		Answers	Notes	Total
6.	a	catabolism «of food/nutrients» OR «cellular» respiration ✓	<i>Accept "ATP" but not "burning of food/nutrients".</i>	1
6.	b	not enough sunlight/UV light «for synthesis of vitamin D in the skin» ✓		1
6.	c	cannot be metabolized/broken down OR not biodegradable OR accumulates in lipid/fat tissues ✓ increased concentration as one species feeds on another «in the food chain» ✓		2

Question		Answers	Notes	Total
7.	a	<p>«triplet» sequence/«specific» order of «nitrogenous» bases</p> <p>OR</p> <p>codon ✓</p>		1
7.	b	<p><i>Any one of:</i></p> <p>long-term «health» effects unknown ✓</p> <p>can cause allergic reactions ✓</p> <p>possible transfer of genetic material to other/wild species ✓</p> <p>concern that power over farming is concentrated in hands of multinationals</p> <p>OR</p> <p>dependent on multinationals ✓</p> <p>labelling differences between countries «means informed choice not possible» ✓</p>	<p><i>Accept “outcrossing”.</i></p>	1 max

Question		Answers	Notes	Total
8.	a	hydrogen bonding ✓ between C=O and H-N «groups» ✓	Accept a diagram which shows hydrogen bonding for M1 and shows the interaction between O of C=O and H of NH for M2. Accept “between amido/amide/carboxamide” but not “between amino/amine” for M2.	2
8.	b	Enzyme action: Any two of: substrate binds to active site ✓ weakens bonds in substrate ✓ lowers activation energy OR provides alternate pathway ✓ increases rate of reaction OR acts as catalyst ✓ substrate specific ✓ Limitation: Any one of: temperature dependent ✓ pH dependent ✓ can be sensitive to heavy metal ions ✓ sensitive to denaturation ✓ can be inhibited ✓ substrate specific ✓	Accept “favourable orientation/conformation of the substrate «enforced by enzyme»” for M1. Do not accept “substrate specific” as both an enzyme action and a limitation.	3 max

Question		Answers			Notes	Total	
8.	c		Action of inhibitor	Effect on V_{max}	Effect on K_m	Award [1] for each action. Award [1] for any two effects stated correctly. Award [2 max] if both actions and effects are switched to incorrect inhibitor types.	4
		Non-competitive	allosteric site occupied OR active site shape changed ✓	lower	AND no effect ✓		
		Competitive	active site occupied ✓	no effect	AND greater ✓		

9.	a	<p>ALTERNATIVE 1:</p> <p>4 C=C bonds/4 carbon to carbon double bonds ✓</p> <p>mass of iodine per mole of acid = «$4 \times 253.80 \text{ g mol}^{-1} \Rightarrow 1015.2 \text{ «g mol}^{-1}\text{»}$» ✓</p> <p>iodine number «$= \frac{1015.2 \text{ g mol}^{-1}}{276.46 \text{ g mol}^{-1}} \times 100$» = 367 ✓</p> <p>ALTERNATIVE 2:</p> <p>4 C=C bonds/4 carbon to carbon double bonds ✓</p> <p>«$\frac{100 \text{ g}}{276.46 \text{ g mol}^{-1}} \times 4 \Rightarrow 1.447 \text{ mol of I}_2$ «reacts with 100 g» ✓</p> <p>iodine number «$= 1.447 \text{ mol} \times 253.80 \text{ g mol}^{-1}$» = 367 ✓</p>	<p>Award [3] for correct final answer.</p>	3
----	---	--	--	---

Question		Answers	Notes	Total
9.	b	<p><i>Any two of:</i></p> <p>«structural» components of cell membranes ✓</p> <p>energy storage/utilization ✓</p> <p>«thermal/electrical» insulation ✓</p> <p>transport «of lipid-soluble molecules» ✓</p> <p>hormones/chemical messengers ✓</p>	<p><i>Accept other specific functions, such as “prostaglandin/cytokine/bile acid synthesis”, “cell differentiation/growth”, “myelination”, “storage of vitamins/biomolecules”, “signal transmission”, “protection/padding of organs”, “precursors/starting materials for the biosynthesis of other lipid”.</i></p>	2 max
9.	c	<p><i>Any one of:</i></p> <p>atherosclerosis/cholesterol deposition «in artery walls» ✓</p> <p>heart/cardiovascular disease ✓</p> <p>stroke ✓</p>	<p><i>Accept “arteries become blocked/walls become thicker”.</i></p>	1 max

Question			Answers	Notes	Total
10.	a		«1,4-»glycosidic ✓	<i>Do not accept "glucosidic".</i>	1
10.	b		H and OH are reversed/in different positions on C-4 ✓	<i>C-4 must be specified. Do not penalize if reference is made to H and OH above and below ring/in alpha and beta positions on C-4 incorrectly.</i>	1
10.	c	i	<i>Starch: α«-glucose/links» AND Cellulose: β«-glucose/links» ✓</i>	<i>Accept "Starch: coiled/spiral structure OR cross-links AND Cellulose: uncoiled OR straight chains/linear polymer OR no/few cross-links".</i>	1
10.	c	ii	<i>Any two of: helps food pass through intestine OR adds bulk/dietary fibre ✓ reduces appetite OR helps prevent obesity ✓ prevents constipation OR reduces risk of hemorrhoids/diverticulosis/Crohn's disease/irritable bowel syndrome/bowel cancer ✓</i>		2 max

Question		Answers	Notes	Total
11.	a	binding of oxygen/O ₂ «to one active site» affects shape of Hb/other active sites OR binding of one oxygen/O ₂ «molecule» affects binding of other oxygen/O ₂ «molecules» ✓ increasing affinity of Hb to oxygen/O ₂ OR enhanced binding of «further» oxygen/O ₂ «molecules» OR cooperative binding ✓		2
11.	b	<i>Toxicity:</i> carboxyhemoglobin/Hb-CO does not readily dissociate OR $\text{CO} + \text{Hb} \rightleftharpoons \text{Hb-CO}$ AND forward reaction favoured OR affinity of carbon monoxide/CO for hemoglobin is «200 times/much» higher than that of oxygen/O ₂ OR competitive inhibitor of oxygen/O ₂ binding ✓ <i>Treatment:</i> moving patient to fresh air OR «in severe cases» inhaling pure oxygen/O ₂ OR high pressure oxygen/O ₂ chamber ✓	Accept “move away from carbon monoxide/CO source” OR “remove carbon monoxide/CO source”.	2

Option C — Energy

Question			Answers	Notes	Total
12.	a		small/lighter <u>nuclei</u> combine to form larger/heavier <u>nuclei</u> ✓ product has higher binding energy «per nucleon» ✓	Accept binding energy curve with explanation.	2
12.	b	i	converts non-fissile « ²³⁸ U» material into fissile « ²³⁹ Pu» material OR produces more fissile material than it consumes ✓		1
12.	b	ii	$^{239}\text{Pu} + {}^1_0\text{n} \rightarrow {}^{133}\text{Xe} + {}^{103}\text{Zr} + 4{}^1_0\text{n}$ ✓	Accept equation with correct atomic numbers included. Accept notation for neutrons of “n”. Accept a correctly described equation in words.	1
12.	c		ALTERNATIVE 1: $\left\langle \frac{240}{30} \Rightarrow 8 \frac{t_1}{2} \right\rangle$ 8 half-lives «required» ✓ % remaining = $\langle 0.50^8 \times 100 \Rightarrow 0.39 \text{ \%} \rangle$ ✓ ALTERNATIVE 2: $\lambda = \left\langle \frac{0.693}{30} \Rightarrow 0.023 \right\rangle$ ✓ % remaining = $\langle 100 \times e^{-0.023 \times 240} \Rightarrow 0.39 \text{ \%} \rangle$ ✓	Award [2] for correct final answer.	2

Question			Answers	Notes	Total
12.	d	i	$\left[\begin{array}{c} \cdot\ddot{\text{O}}:\ddot{\text{O}}:\ddot{\text{O}} \\ \cdot\ddot{\text{O}}:\ddot{\text{O}}:\ddot{\text{O}} \end{array} \right]^{-}$ <p>OR</p> $\left[\begin{array}{c} \cdot\ddot{\text{O}}-\ddot{\text{O}}-\ddot{\text{O}} \\ \cdot\ddot{\text{O}}-\ddot{\text{O}}-\ddot{\text{O}} \end{array} \right]^{-} \checkmark$	<p>Accept any combination of dots, crosses and lines to represent electrons.</p> <p>Do not penalize missing brackets.</p> <p>Penalize missing negative charge.</p>	1
12.	d	ii	<p>highly reactive</p> <p>OR</p> <p>start redox reactions ✓</p> <p>damage/mutate DNA</p> <p>OR</p> <p>cause cancer</p> <p>OR</p> <p>damage enzymes ✓</p>		2

Question		Answers	Notes	Total
13.	a	<p>ALTERNATIVE 1: $2\text{C (s)} + 2\text{H}_2\text{O (g)} \rightarrow \text{CH}_4\text{(g)} + \text{CO}_2\text{(g)} \checkmark$</p> <p>ALTERNATIVE 2: $\text{C (s)} + \text{H}_2\text{O (g)} \rightarrow \text{CO (g)} + \text{H}_2\text{(g)}$ AND $3\text{H}_2\text{(g)} + \text{CO (g)} \rightarrow \text{CH}_4\text{(g)} + \text{H}_2\text{O (g)} \checkmark$</p>	Accept " $3\text{C (s)} + 2\text{H}_2\text{O (g)} \rightarrow \text{CH}_4\text{(g)} + 2\text{CO (g)}$ ".	1
13.	b	<p>$\ll \frac{141.6}{55.5} \gg$ hydrogen/H_2 produces 2.6 times/more than twice the energy of methane/CH_4 «per mass/g»</p> <p>OR</p> <p>less mass of hydrogen/H_2 required «to produce same amount of energy»</p> <p>OR</p> <p>hydrogen/H_2 more energy efficient \checkmark</p>	Accept "hydrogen/ H_2 produces «nearly» three times more energy than methane/ CH_4 «per mass/g»".	1
13.	c	<p>$m_{\text{octane}} \ll = 72.0 \text{ dm}^3 \times 703 \text{ g dm}^{-3} \gg = 5.06 \times 10^4 \text{ «g»/50.6 «kg}} \checkmark$</p> <p>$m_{\text{carbon dioxide}} \ll = \frac{8 \times 44.01}{114.26} \times 50.6 \gg = 156 \text{ «kg}} \checkmark$</p>	Award [2] for correct final answer.	2

Question		Answers	Notes	Total
14.	a	<p><i>Advantage:</i> renewable «energy source» OR does not produce greenhouse gases OR can be installed «almost» anywhere OR low maintenance costs ✓</p> <p><i>Disadvantage:</i> widely dispersed/not concentrated «form of energy» OR geography/weather/seasonal dependent OR not available at night OR energy storage is difficult/expensive OR toxic/hazardous materials used in production OR concerns about space/aesthetics/environment where installed OR need to be «constantly» cleaned ✓</p>	<p><i>Accept “can be used for passive/active heating”, “can be converted to electric energy”.</i></p> <p><i>Accept any specific greenhouse gas name or formula for “greenhouse gases”.</i></p> <p><i>Accept “solar cells require large areas”, “solar cell manufacture produces pollution/greenhouse gases”, “higher cost of solar cells «compared with traditional sources such as fossil fuels or hydroelectric»”.</i></p>	2

Question			Answers	Notes	Total
14.	b	i	high viscosity ✓	Accept "low volatility", just "viscous/viscosity" OR "does not flow easily".	1
14.	b	ii	convert to esters of monoatomic alcohols OR react with short-chain alcohols «in the presence of acid or base» ✓	Accept "convert to shorter «carbon chain» esters" OR "transesterification". Accept specific alcohols, such as methanol or ethanol.	1
14.	c		carbon dioxide/CO ₂ more/most abundant «GHG than methane/CH ₄ » OR carbon dioxide/CO ₂ has «much» longer atmospheric life «than methane/CH ₄ » ✓ methane/CH ₄ «much» better/more effective at absorbing IR radiation «than carbon dioxide/CO ₂ » OR methane/CH ₄ has a greater greenhouse factor «than carbon dioxide/CO ₂ » OR methane/CH ₄ has a greater global warming potential/GWP «than carbon dioxide/CO ₂ » ✓	Accept "carbon dioxide/CO ₂ contributes more to global warming «than methane/CH ₄ »".	2
14.	d		CO ₂ (g) + H ₂ O (l) ⇌ H ⁺ (aq) + HCO ₃ ⁻ (aq) OR CO ₂ (g) ⇌ CO ₂ (aq) AND CO ₂ (aq) + H ₂ O (l) ⇌ H ⁺ (aq) + HCO ₃ ⁻ (aq) ✓ «increasing [CO ₂ (g)]» shifts equilibrium/reaction to right AND pH decreases ✓	Accept "H ₂ CO ₃ (aq)" for "CO ₂ (aq) + H ₂ O (l)". Equilibrium arrows required for M1. State symbols required for CO ₂ (g) ⇌ CO ₂ (aq) equation only for M1. Accept "concentration of H ⁺ /[H ⁺] increases AND pH decreases" for M2.	2

Question		Answers	Notes	Total
15.	a	<p>«redox» reaction in rechargeable battery is reversible «but not in a primary cell»</p> <p>OR</p> <p>secondary cells need to be charged before use</p> <p>OR</p> <p>secondary cells have greater rate of self-discharge ✓</p>	<p>Accept “primary cells cannot be recharged/reused”, “primary cells can be used only once” OR “lithium batteries may explode”.</p>	1
15.	b	<p><i>Anode (negative electrode):</i></p> <p>$\text{Li (graphite)} \rightarrow \text{Li}^+ \text{ (electrolyte)} + \text{e}^-$</p> <p>OR</p> <p>$\text{LiC}_6 \text{ (s)} \rightarrow 6\text{C (s)} + \text{Li}^+ \text{ (electrolyte)} + \text{e}^-$ ✓</p> <p><i>Cathode (positive electrode):</i></p> <p>$\text{Li}^+ \text{ (electrolyte)} + \text{e}^- + \text{MnO}_2 \text{ (s)} \rightarrow \text{LiMnO}_2 \text{ (s)}$</p> <p>OR</p> <p>$\text{Li}^+ \text{ (electrolyte)} + \text{e}^- + \text{NiO}_2 \text{ (s)} \rightarrow \text{LiNiO}_2 \text{ (s)}$</p> <p>OR</p> <p>$\text{Li}^+ \text{ (electrolyte)} + \text{e}^- + \text{CoO}_2 \text{ (s)} \rightarrow \text{LiCoO}_2 \text{ (s)}$</p> <p>OR</p> <p>$2\text{Li}^+ \text{ (electrolyte)} + 2\text{e}^- + 2\text{CoO}_2 \text{ (s)} \rightarrow \text{Co}_2\text{O}_3 \text{ (s)} + \text{Li}_2\text{O (s)}$ ✓</p>	<p>Accept “polymer” for “electrolyte”.</p> <p>Award [1 max] if electrodes are reversed.</p> <p>Do not accept “CO” for “Co”.</p>	2

Question			Answers	Notes	Total
15.	c		$\llcorner E = E^\ominus - \left(\frac{RT}{nF} \right) \ln Q \llcorner$ $0.19 = 0.14 - \left(\frac{8.31 \times 298}{2 \times 96500} \right) \ln \left(\frac{[\text{Cd}^{2+}]}{[1]} \right)$ <p>OR</p> $0.05 = -0.01283 \ln [\text{Cd}^{2+}]$ <p>OR</p> $\ln [\text{Cd}^{2+}] = -3.897 \checkmark$ $[\text{Cd}^{2+}] = 0.020 \llcorner \text{mol dm}^{-3} \llcorner \checkmark$	<p><i>Award [2] for correct final answer.</i></p>	2
15.	d	i	<p>«extensive» conjugation</p> <p>OR</p> <p>«extensive» alternate single and double bonds ✓</p>	<p><i>Accept “delocalization”.</i></p>	1
15.	d	ii	<p>electrons excited/released «from dye» ✓</p>	<p><i>Accept “photooxidation/oxidizes dye”.</i></p>	1
15.	d	iii	<p>transfers e⁻ to external circuit ✓</p>	<p><i>Accept “provides large surface area”.</i></p>	1
15.	d	iv	<p>$\text{I}_3^- (\text{aq}) + 2\text{e}^- \rightarrow 3\text{I}^- (\text{aq}) \checkmark$</p>	<p><i>Accept “$3\text{I}_2 (\text{aq}) + 2\text{e}^- \rightarrow 2\text{I}_3^- (\text{aq})$”.</i></p>	1

Option D — Medicinal chemistry

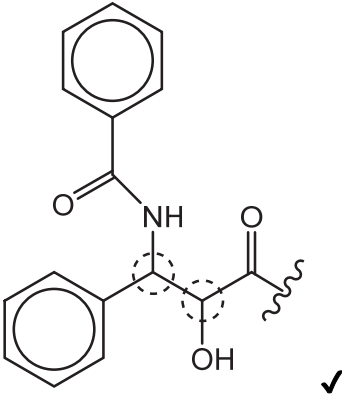
Question		Answers	Notes	Total										
16.	a	<table border="1"> <tr> <td></td> <td>Bond angle</td> </tr> <tr> <td>β-lactam ring</td> <td>90° ✓</td> </tr> <tr> <td>sp²</td> <td>120°</td> </tr> <tr> <td></td> <td>AND</td> </tr> <tr> <td>sp³</td> <td>109.5° ✓</td> </tr> </table>		Bond angle	β-lactam ring	90° ✓	sp ²	120°		AND	sp ³	109.5° ✓	Accept "109°".	2
	Bond angle													
β-lactam ring	90° ✓													
sp ²	120°													
	AND													
sp ³	109.5° ✓													
16.	b	<p>«irreversibly» binds/bonds to enzyme/transpeptidase OR inhibits enzyme/transpeptidase «in bacteria» that produces cell walls OR prevents cross-linking of bacterial cell walls ✓</p> <p>cells absorb water AND burst OR cells cannot reproduce ✓</p>	<p>Accept "reacts with" for "bonds to" for M1. Do not accept "cell membrane" for "cell wall" for M1.</p> <p>Accept "cells burst due to osmotic pressure" for M2. Accept "bacteria" for "cells" for M2.</p>	2										
16.	c	«modify» side-chain ✓	Accept "«modify» R".	1										
16.	d	no cell walls OR humans do not have transpeptidase ✓		1										

Question		Answers	Notes	Total
17.	a	blood-brain barrier is hydrophobic/non-polar/made of lipids ✓ morphine has hydroxyl/OH «groups»/is more polar AND diamorphine has ester/ethanoate/OCOCH ₃ /acetate «groups»/is less polar/is lipid soluble ✓	Accept "fats" for "lipid(s)". Accept "alcohol/hydroxy" for "hydroxyl" but not "hydroxide". Accept "non-polar" for "less polar" in M2.	2
17.	b	fraction/proportion/percentage of «administered dosage» that enters blood/plasma/circulation ✓	Accept "fraction/proportion/percentage of «administered dosage» that reaches target «part of human body»".	1

18.	a	<p>ALTERNATIVE 1:</p> <p>Using: $pH = pK_a + \log \left(\frac{[A^-]}{[HA]} \right)$</p> <p>$pK_a = 10.32$ ✓</p> <p>$pH = \llcorner 10.32 + \log \left(\frac{0.0200}{0.0100} \right) = \gg 10.62$ ✓</p> <p>ALTERNATIVE 2:</p> <p>$[H^+] \llcorner K_a \times \left(\frac{0.0100}{0.0200} \right) = 2.4 \times 10^{-11}$ ✓</p> <p>$pH = 10.62$ ✓</p>	<p>Award [2] for correct final answer.</p> <p>Accept answers for M2 between 10.6 and 10.7.</p> <p>Award [1 max] for $pH = 10.02$.</p>	2
-----	---	--	--	---

Question		Answers	Notes	Total
18.	b	$\text{CaCO}_3(\text{s}) + 2\text{HCl}(\text{aq}) \rightarrow \text{CaCl}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$ OR $\text{CaCO}_3(\text{s}) + 2\text{H}^+(\text{aq}) \rightarrow \text{Ca}^{2+}(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g}) \checkmark$		1
18.	c	«back» titration OR thermal decomposition OR atomic absorption/AA \checkmark	Accept "gravimetric analysis". Do not accept description of a technique without proper term given for the technique.	1
19.		Any two of: prevents virus attaching to host cell \checkmark alters cell's genetic material/DNA «so that virus cannot use it to multiply» \checkmark blocks enzyme activity in the host cell «so that virus cannot use it to multiply» \checkmark prevents removal of protein coat/capsid \checkmark prevents injection of viral DNA/RNA into cell \checkmark prevents release of «replicated» viruses from host cell \checkmark	Accept "prevents synthesis of virus by host cell". Accept "alters RNA/DNA/genetic material of virus". Do not accept just "mimics nucleotides".	2 max

Question	Answers	Notes	Total
20.	<p>Any two of:</p> <ul style="list-style-type: none"> «weak» C-Cl bonds break/produce radicals ✓ contribute to ozone depletion ✓ contribute to «photochemical» smog ✓ cause cancers ✓ damage respiratory system ✓ cause organ failure ✓ produce toxic chemicals/phosgene/dioxins ✓ 	<p>Accept "chlorinated solvents are toxic".</p>	<p>2 max</p>

21. a		<p>Do not penalize any other notation (eg *) used for a circle.</p>	<p>1</p>
-------	--	--	----------

Question		Answers	Notes	Total
21.	b	<p>chiral auxiliary creates stereochemical condition necessary to follow a certain pathway</p> <p>OR</p> <p>stereochemical induction</p> <p>OR</p> <p>existing chiral centre affects configuration of new chiral centres ✓</p> <p>chiral molecule/auxiliary/optically active species is used/added/connected to the starting molecule «to force reaction to follow a certain path»</p> <p>OR</p> <p>«after new chiral centre created» chiral auxiliary removed «to obtain desired product» ✓</p>		2
21.	c	<p><i>Any two of:</i></p> <p>immiscible solvents ✓</p> <p>partitioning of Taxol between the two solvents ✓</p> <p>Taxol more soluble in one solvent ✓</p> <p>extraction carried out multiple times «to improve extraction» ✓</p> <p>shaking/stirring the mixture ✓</p> <p>separating the two layers ✓</p> <p>evaporation of the solvent from the final solution «to obtain pure Taxol» ✓</p>		2 max

Question			Answers	Notes	Total
22.	a		<p>«alpha emitter» carried to/selectively absorbed by cancer cells «by antibody, carrier drug, protein» ✓</p> <p>low penetrating power</p> <p>OR</p> <p>short range ✓</p>	<p><i>Do not accept just “targets cancer cells and does not affect healthy cells”.</i></p>	2
22.	b	i	<p>ALTERNATIVE 1:</p> <p>« $\frac{48}{6.0} \Rightarrow 8 t_{\frac{1}{2}}/8$ half-lives «required» ✓</p> <p>% remaining = «$(0.5)^8 \times 100 \Rightarrow 0.39$ «%» ✓</p> <p>ALTERNATIVE 2:</p> <p>$\lambda = \left\langle \frac{0.693}{6.0} \Rightarrow 0.1155 \right\rangle$ ✓</p> <p>% remaining = «$100 \times e^{-0.1155 \times 48} \Rightarrow 0.39$ «%» ✓</p>	<p><i>Award [2] for correct final answer.</i></p> <p><i>Accept “0.32 «%»” in ALTERNATIVE 2.</i></p>	2
22.	b	ii	<p>removed by excretion ✓</p>	<p><i>Accept any method of excretion.</i></p>	1

Question		Answers	Notes	Total
23.	a	gas chromatography/GC OR high performance liquid chromatography/HPLC ✓	Accept "chromatography", "TLC/thin-layer chromatography", "paper chromatography" OR "extraction". Do not accept just "mass spectrometry/MS" but do not penalize any reference to MS with HPLC or GC (eg GC-MS).	1
23.	b	ALTERNATIVE 1: Any two of: «blow through tube of» acidified «orange» potassium dichromate(VI)/K ₂ Cr ₂ O ₇ /dichromate/Cr ₂ O ₇ ²⁻ ✓ Cr(VI)/Cr ⁶⁺ /Cr ₂ O ₇ ²⁻ reduced to Cr(III)/Cr ³⁺ ✓ colour changes «from orange» to green OR colour change is monitored ✓ ALTERNATIVE 2: oxygen reduced to water OR ethanol oxidized to ethanoic/acetic acid ✓ current measured ✓	Accept "ethanol oxidized to ethanal/acetaldehyde".	2 max