

Markscheme

May 2024

Chemistry

Higher level

Paper 3

35 pages

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Subject details: Chemistry higher level paper 3 Markscheme

Candidates are required to answer **ALL** questions in Section A [**15 marks**] and all questions from **ONE** option in Section B [**30 marks**].
Maximum total = [**45 marks**].

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

Section A

Question			Answers	Notes	Total
1.	a		a leak «of gas from the system» ✓	Accept amount/volume/concentration H_2O_2 much lower. Do not accept answers that refer to MnO_2 .	1
1.	b	i	scientific claims must be falsifiable OR it should be possible to test a scientific prediction by an experiment ✓	Accept answers that imply this principle such as if hypothesis not supported underlying theory needs to be examined.	1
1.	b	ii	doubling mass will double surface area ✓ «doubling surface area will» double collision rate / frequency of collisions ✓	Accept increasing instead of doubling for both M1 and M2. Do not accept more/greater probability/chance of collisions.	2
1.	b	iii	temperature OR concentration «of hydrogen peroxide»/[H_2O_2] ✓	Accept different specific surface area / particle size. Do not accept simply surface area.	1

(continued...)

(Question 1 continued)

Question			Answers	Notes	Total
1.	c	i	tangent drawn to curve at $t = 0$ s ✓ slope/gradient calculation ✓	Accept start of reaction for $t=0$ s for M1. Do not accept line instead of tangent for M1. Do not accept simply taking a derivative for M2.	2
1.	c	ii	yes AND rate is negligible when no catalyst is present OR no AND reaction still occurs even when no catalyst is present ✓	Accept yes AND rate is zero when no catalyst is present. Do not accept yes AND the line gives a better fit with the data.	1

Question	Answers	Notes	Total
2. a	<p>ALTERNATIVE 1</p> $n(\text{CuSO}_4) \llcorner = \frac{6.4 \text{ g}}{(63.55 + 32.07 + (4 \times 16.00)) \text{ g mol}^{-1}} = \frac{6.4 \text{ g}}{159.62 \text{ g mol}^{-1}} \llcorner$ $= 0.040 \llcorner \text{ mol} \llcorner$ <p>AND</p> $n(\text{H}_2\text{O}) \llcorner = \frac{(10.0 - 6.4) \text{ g}}{(2 \times 1.01) + 16.00 \text{ g mol}^{-1}} = \frac{3.6 \text{ g}}{18.02 \text{ g mol}^{-1}} \llcorner = 0.20 \llcorner \text{ mol} \llcorner \checkmark$ $n(\text{CuSO}_4) : n(\text{H}_2\text{O}) \llcorner = \frac{0.040 \text{ mol}}{0.20 \text{ mol}} \llcorner = 5.0 \llcorner \checkmark$ <p>ALTERNATIVE 2</p> <p>% CuSO₄ in CuSO₄•5H₂O</p> $\llcorner = 100 \times \frac{63.55 + 32.07 + (4 \times 16.00) \text{ g mol}^{-1}}{63.55 + 32.07 + (9 \times 16.00) + (10 \times 1.01) \text{ g mol}^{-1}} = \frac{159.62 \text{ g mol}^{-1}}{249.72 \text{ g mol}^{-1}} \llcorner$ $= 63.92 \llcorner \checkmark$ $\text{mass of CuSO}_4 \llcorner = 10.0 \text{ g} \times \frac{63.92}{100} \llcorner = 6.392 \text{ g} \llcorner \checkmark$ <p>ALTERNATIVE 3</p> <p>mass of H₂O in CuSO₄•5H₂O</p> $\llcorner = 10 \text{ g} \times \frac{(5 \times 16.00) + (10 \times 1.01) \text{ g mol}^{-1}}{(63.55 + 32.07 + (9 \times 16.00) + (10 \times 1.01)) \text{ g mol}^{-1}} = \frac{90.1 \text{ g}}{249.72} \llcorner$ $= 3.6 \text{ g} \llcorner \checkmark$ <p>mass of CuSO₄ in CuSO₄•5H₂O $\llcorner = 10.0 \text{ g} - 3.6 \text{ g} \llcorner = 6.4 \text{ g}$</p> <p>OR</p> <p>comparison with graph shows mass lost is 3.6 g $\llcorner \checkmark$</p>	Accept other valid methods.	2

(continued...)

(Question 2 continued)

Question			Answers	Notes	Total
2.	b	i	uncertainty in mass loss $\llcorner = 0.05 + 0.05 \llcorner = \llcorner \pm \llcorner 0.1 \text{ g } \checkmark$ percentage uncertainty in mass loss $\llcorner = \frac{0.1 \text{ g}}{(10.0 - 6.4)} \times 100 \llcorner = \llcorner \pm \llcorner 2.78 / 3 \% \checkmark$	Award [2] for correct final answer. Accept 2.77.	2
2.	b	ii	absolute uncertainty in water of crystallization $\llcorner = 5 \times \frac{2.78}{100} \llcorner = \llcorner \pm \llcorner 0.14 \checkmark$	Accept $\llcorner \pm \llcorner 0.15$ if percentage uncertainty taken as 3%. Do not award marks for answers with more or less significant figures.	1
2.	c		water molecules in different «chemical» environments OR water molecules have different type of bonding \checkmark present in a 4:1 / 1:4 ratio \checkmark	Do not accept different kinds of water molecules. Accept answers that clearly communicate the ratio.	2

Section B

Option A — Materials

Question			Answers	Notes	Total
3.	a	i	electronegativity difference $\Delta X \llcorner = 3.2 - 0.8 \llcorner = 2.4$ AND average electronegativity $\Sigma X \llcorner = \frac{1}{2} (3.2 + 0.8) \llcorner = 2.0 \checkmark$ falls in "ionic" region of bonding diagram \checkmark	Accept 75% ionic and 25% covalent for M2. Do not accept ionic without reference to diagram.	2
3.	a	ii	electrostatic attraction OR attraction between oppositely charged ions \checkmark	Do not accept ionic.	1
3.	a	iii	«small» displacement brings ions of same charge close together OR «small» displacement results in repulsion «between same charged ions» \checkmark	Do not accept bonds are weak.	1
3.	b		all electrons are paired/have paired spins \checkmark		1
3.	c	i	«caesium» very reactive / very high in reactivity series OR cannot be reduced by chemical methods \checkmark	Do not accept simply caesium is reactive. Accept difficult to reduce «caesium ions». Accept Cs is higher on activity series than C.	1
3.	c	ii	$\text{Cs}^+(\text{l}) + \text{e}^- \rightarrow \text{Cs}(\text{l}) \checkmark$		1

(continued...)

(Question 3 continued)

Question			Answers	Notes	Total
3.	c	iii	amount of Cs « $= \frac{1.00 \text{ g}}{132.91 \text{ g mol}^{-1}}$ » = 0.00752 «mol» ✓ charge « $= 0.00752 \text{ mol} \times 9.65 \times 10^4 \text{ C mol}^{-1}$ » = 726 «C» ✓	Accept 0.007 for M1. Award [2] for correct final answer.	2
3.	d	i	<p>Similarity: Any one of: increase rate of reaction ✓ provide an alternative mechanism ✓ reduce activation energy/E_a «for the reaction» ✓ not consumed «in overall reaction» ✓</p> <p>Difference: Any one of: heterogeneous are in different phase to reactants AND homogeneous in same phase ✓ heterogeneous are solids AND homogeneous are fluids/liquids/gases/ in solution ✓ heterogeneous act on surface AND homogeneous act in fluid/medium ✓ heterogeneous remain unchanged AND homogeneous consumed at one stage and regenerated at another ✓ heterogeneous more easily removed «from product than homogenous» ✓</p>	Accept state for phase.	2
3.	d	ii	«very» large surface area «to mass ratio» ✓		1
3.	d	iii	prevents oxidation ✓	Accept prevents reaction with air.	1

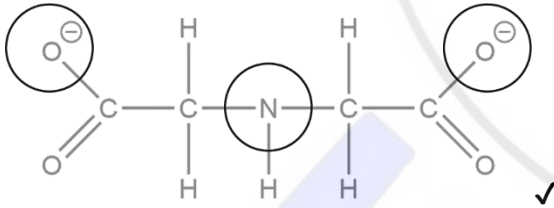
(continued...)

(Question 3 continued)

Question			Answers	Notes	Total
3.	d	iv	negative effect on/harmful to environment/human health ✓	Accept uncertain effect on human health. Do not award mark for poisonous/toxic.	1
3.	e	i	2 ✓		1
3.	e	ii	volume «= (614 pm) ³ » = 2.31 × 10 ⁸ «pm ³ » ✓	Accept 2.31 × 10 ⁻²² «cm ³ » OR 2.31 × 10 ⁻²⁸ «m ³ ». Whilst units are not required, if given, they must correspond to the numerical value. Do not , for example, award the mark for 2.31 × 10 ⁻²² pm ³ .	1

(continued...)



(Question 3 continued)

Question			Answers	Notes	Total
3.	e	iii	<p>ALTERNATIVE 1: volume of one mol « = $\frac{1}{2}(2.31 \times 10^{-22} \text{ cm}^3 \times 6.02 \times 10^{23})$ » = 69.5 «cm³» ✓ «density = $\frac{132.91 \text{ g mol}^{-1}}{69.5 \text{ cm}^3 \text{ mol}^{-1}}$ » ⇒ 1.91 «g cm⁻³» ✓</p> <p>ALTERNATIVE 2: volume of one mol of unit cells « = $2.31 \times 10^{-22} \text{ cm}^3 \times 6.02 \times 10^{23}$ » = 139.1 «cm³» ✓ «density = $\frac{2 \times 132.91 \text{ g mol}^{-1}}{139.1 \text{ cm}^3 \text{ mol}^{-1}}$ » ⇒ 1.91 «g cm⁻³» ✓</p>	Award [2] for correct final answer.	2
3.	f		entropy change with a polydentate ligand more favourable/less negative «than change with many monodentate ligands» ✓	Accept chelate effect. Accept positive entropy change.	1
3.	g			Accept answers that include the C=O oxygens in the circle.	1

Question			Answers	Notes	Total
4.	a		increase flexibility ✓ reduce intermolecular forces between «polymer» chains ✓	Accept increase softness / reduce density / make less brittle for M1. Accept increase distance between chains for M2. Accept allow chains to slide past each other more easily for M2.	2
4.	b		Class: «polychlorinated dibenzo» dioxin «s» ✓ Effect: hormone disrupting/disrupts metabolic processes OR cellular damage OR genetic damage OR carcinogenic ✓	Do not accept toxic (given in question stem) for M2.	2
4.	c	i	«facilitates sorting for» recycling ✓		1
4.	c	ii	A AND it has C=O/~1700 «cm ⁻¹ » absorption ✓	Accept A AND B has C-Cl/~700 «cm ⁻¹ » absorption.	1

(continued...)

(Question 4 continued)

Question			Answers	Notes	Total
4.	d		<p>Monomer A</p>  <p>✓</p> <p>Monomer B</p>  <p>✓</p>	<p>Accept any structures that have one -OH and one -COOH on each.</p> <p>Award [1 max] if one has two -OH and the other has two -COOH.</p> <p>Accept -COCl or -COOR instead of -COOH.</p>	2
4.	e	i	physical properties depend on molecular orientation «to a fixed axis in the material» ✓		1
4.	e	ii	dissolved AND phase transitions occur over range of concentrations OR only possible to vary concentration when dissolved OR pure liquids have «almost» fixed concentration ✓	Accept at any concentration for range of concentrations.	1

Option B — Biochemistry

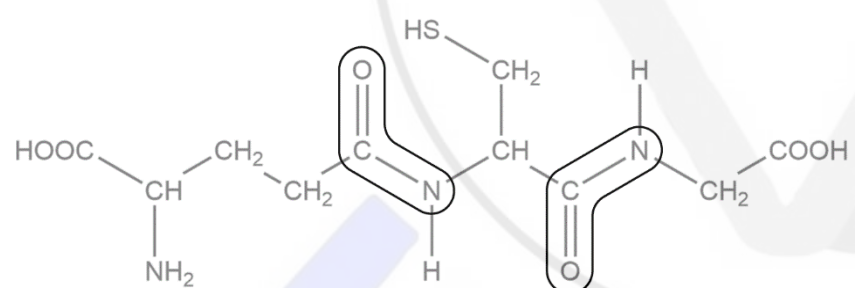
Question			Answers	Notes	Total
5.	a		$6\text{CO}_2(\text{g}) + 6\text{H}_2\text{O}(\text{l}) \rightarrow \text{C}_6\text{H}_{12}\text{O}_6(\text{aq}) + 6\text{O}_2(\text{g}) \checkmark$	<i>Ignore light in the equation.</i>	1
5.	b	i	Type of reaction: condensation AND By-product: water \checkmark	<i>Accept addition–elimination for Type of reaction.</i>	1
5.	b	ii	insoluble «in water»/cytoplasm \checkmark	<i>Accept stored as solid grains.</i>	1
5.	b	iii	hydrolyze \checkmark	<i>Accept convert back to glucose. Accept break down starch «into smaller units/components/monomers».</i>	1

Question			Answers	Notes	Total
6.	a		corn oil AND highest content of polyunsaturated fatty acids OR corn oil AND highest number of C=C/double bonds «per molecule/triglyceride» \checkmark	<i>Do not accept least saturated/most unsaturated.</i>	1
6.	b		« $n(\text{I}_2) = 0.0330 \text{ dm}^3 \times 0.500 \text{ mol dm}^{-3} \Rightarrow 0.0165 \text{ «mol»} \checkmark$ « $m(\text{I}_2) = 0.0165 \text{ mol} \times 253.8 \text{ g mol}^{-1} \Rightarrow 4.19 \text{ «g»} \checkmark$ «iodine number = $\frac{4.19 \text{ g} \times 100}{5.00 \text{ g}}$ » = 83.8 \checkmark	<i>Award [3] for correct final answer. Award [2 max] for 41.9.</i>	3

(continued...)

(Question 6 continued)

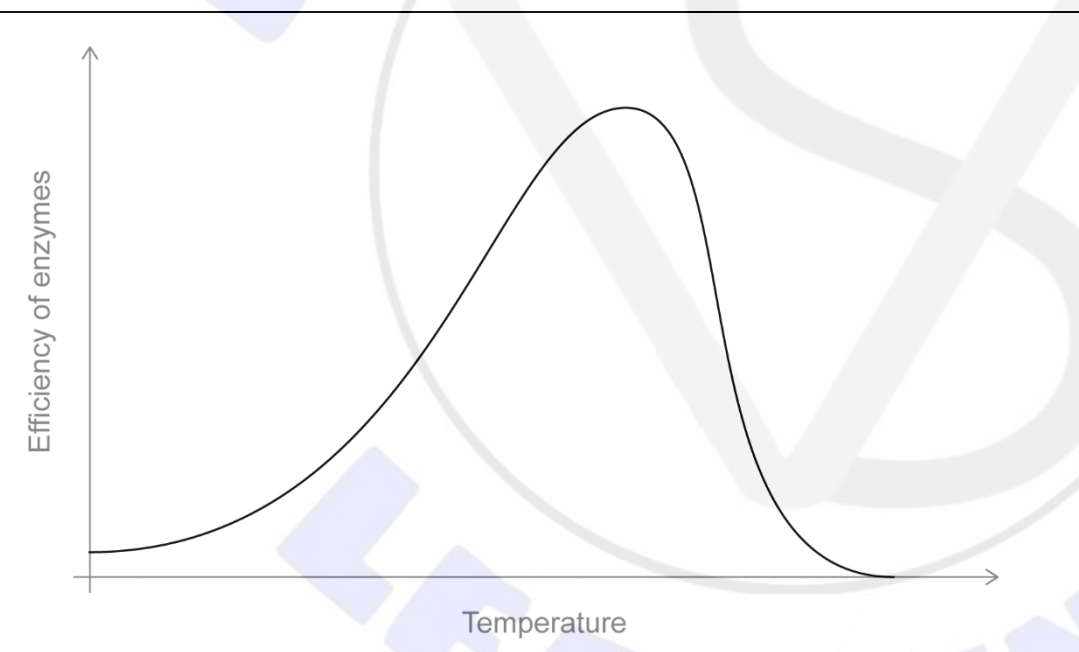
Question		Answers	Notes	Total
6.	c	<p>higher proportion of «triglycerides of» saturated fatty acids OR saturated fatty acids have greater surface area/higher electron density OR molecules of «triglycerides of» saturated fatty acids are packed more closely/have a linear structure ✓</p> <p>stronger London/dispersion/instantaneous induced dipole-induced dipole forces «between linear chains» ✓</p>	<p>For M1 do not accept butter is saturated without reference to proportions.</p> <p>For M2 accept stronger intermolecular forces.</p> <p>Accept LDF for London dispersion forces</p>	2

Question		Answers	Notes	Total
7.	a	 <p>correct identification of both bonds ✓</p>	Accept circle including H.	1
7.	b	glycine/gly AND glutamic acid/glu AND cysteine/cys ✓	Accept structures. Accept in any order.	1

(continued...)

(Question 7 continued)

Question			Answers	Notes	Total
7.	c		glycine/gly ✓	Accept structure.	1
7.	d		glutamic acid/glu ✓	Accept structure. Apply ECF from 7(b).	1

Question			Answers	Notes	Total
8.	a		 <p>typical curve as shown ✓</p>	<p>Accept any curve with a single maximum.</p> <p>Ignore other annotations, such as temperature values on the x-axis.</p> <p>Do not penalize if curve does not touch the x-axis at high temperature.</p>	1

(continued...)

(Question 8 continued)

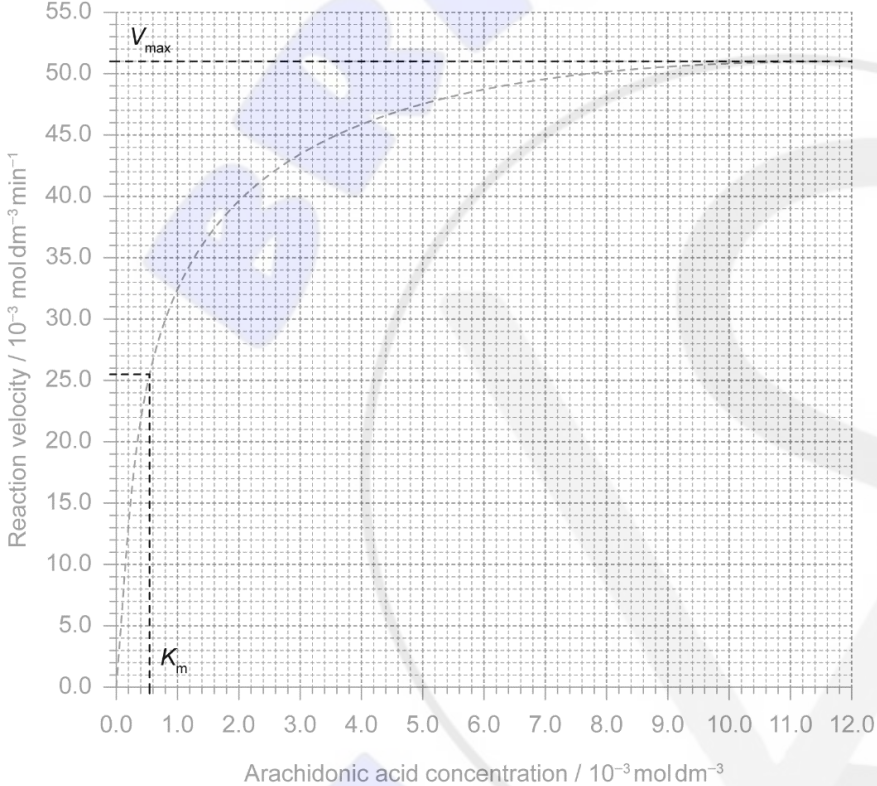
Question		Answers	Notes	Total
8.	b	partial replacement of «non-/scarcely biodegradable» detergent by biodegradable enzymes OR save energy as require lower temperature OR biodegradable ✓	<i>Do not accept references to eutrophication, phosphates, nitrates, etc.</i> <i>Accept break down naturally.</i>	1
8.	c	<i>Award [1] for any of:</i> «treatment of» oil spills ✓ «treatment of harmful» effluents from sewage/paper mills/leather processing/textile industry/food industry ✓	<i>Accept other reasonable examples.</i> <i>Do not accept plastics.</i>	1

Question		Answers	Notes	Total
9.	a	yes AND third spot «from bottom» $R_f = 0.36$ ✓	<i>Accept values in the range of 0.35–0.37 for R_f of third spot.</i> <i>Accept answers with YES implied, as in the third spot from the bottom has an R_f of 0.36.</i> <i>Accept alternative working such as determination of d using R_f and D, where $D = 64$ mm, to identify the third spot as lutein.</i>	1

(continued...)

(Question 9 continued)

Question			Answers	Notes	Total
9.	b		«highly» conjugated bonds/ delocalized bonds OR «many» alternating single AND double/multiple bonds ✓ «intense» absorption «bands» in visible region ✓		2

Question	Answers	Notes	Total
<p>10 a</p>	 <p>K_m: $0.55 \llcorner \times 10^{-3} \text{ mol dm}^{-3} \llcorner \checkmark$</p> <p>$V_{\text{max}}$: $51 \llcorner \times 10^{-3} \text{ mol dm}^{-3} \text{ min}^{-1} \llcorner \checkmark$</p>	<p>For M1, accept values in the range of $0.45\text{--}0.60 \llcorner \times 10^{-3} \text{ mol dm}^{-3} \llcorner$.</p> <p>Award [1 max] if both are correctly labelled on the graph without giving the values.</p>	<p>2</p>

(continued...)

(Question 10 continued)

Question		Answers	Notes	Total
10.	b	<p>lower initial gradient AND tending towards same V_{max} at higher [substrate] ✓</p>	<p>Accept graph finishing at V_{max}.</p>	1

(continued...)

(Question 10 continued)

Question			Answers	Notes	Total
10.	c		Any two of: K_m higher OR compete for the active site ✓ higher concentration of substrate/arachidonic acid to reach same V_{max} ✓ slower production of prostaglandin «precursor» ✓		2 max

Question			Answers	Notes	Total
11.			«many» OH/hydroxyl «groups» ✓ can H-bond to water ✓	Accept alcohol/hydroxy, but not hydroxide for hydroxyl.	2

Question			Answers	Notes	Total
12.	a		H-bonds ✓ between «complementary» nitrogenous/purine/pyrimidine bases OR between amino and carbonyl groups ✓	Accept AT and CG for M2.	2
12.	b		TACCGTTCG ✓		1

Option C — Energy

Question		Answers	Notes	Total
13.	a	$\text{CH}_4(\text{g}) + 2\text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) \checkmark$		1
13.	b	amount of CH_4 in 1.00 g clathrate «= $4 \times \frac{1 \text{ g}}{478.7 \text{ g mol}^{-1}}$ » = 0.008356 «mol» \checkmark specific energy «= $0.008356 \text{ mol g}^{-1} \times 891 \text{ kJ mol}^{-1}$ » = 7.45 «kJ g ⁻¹ » \checkmark	Award [2] for correct final answer.	2
13.	c	<i>Lower specific energy:</i> not all methane clathrate is methane OR part of methane clathrate does not burn \checkmark <i>Higher energy density:</i> methane is gas AND methane clathrate is solid OR methane has much lower density «than methane clathrate» OR methane clathrate occupies a much smaller volume than «same mass of» methane \checkmark	For M1 accept reference to water molecules in methane clathrate as indicating it is not all methane.	2
13.	d	asymmetric «stretch» AND produces/changes dipole moment \checkmark		1

(continued...)

(Question 13 continued)

Question		Answers	Notes	Total
13.	e	methane more potent greenhouse gas/higher GWP than carbon dioxide «produced by burning it» ✓	<i>Accept answers that imply we could be harnessing the energy released by the combustion.</i>	1
13.	f	<p><i>Support:</i> overall increase in both the carbon dioxide concentration and the temperature «anomaly» ✓</p> <p><i>Refute:</i> CO₂ increases between ~1940 and ~1970 without corresponding increase in temperature OR global temperatures rose between ~1935 and ~1945 despite [CO₂] remaining relatively constant OR increases in global temperature between ~1900 and ~1940 and between ~1970 and ~2010 are similar, but increase in CO₂ levels much higher in latter period ✓</p>	<p><i>For M1, accept there is a good/close correlation «in their shapes».</i></p> <p><i>For M2, accept the connection may just be coincidental «not causative».</i></p> <p><i>Do not accept comments about fluctuations.</i></p> <p><i>Accept years that are approximately the same as these listed.</i></p>	2

Question			Answers	Notes	Total
14.	a	i	methane produces less CO ₂ per kJ of energy ✓ methane produces fewer pollutants/particulates/CO/VOCs ✓	<i>For M1 do not accept simply methane produces less CO₂. For M2 accept gasoline undergoes incomplete combustion.</i>	2
14.	a	ii	greater energy density OR longer range «for same volume of fuel»/requires smaller fuel tank ✓	<i>Accept more concentrated source of energy. Accept greater distance between refuelling. Accept gasoline more readily available. Accept gasoline fuelled cars safer / have lower explosion/auto-ignition risk. Accept gasoline easier to handle / store / transport.</i>	1
14.	b	i	A: CH ₃ OH AND B: CH ₃ -O-CO-R OR A: C ₂ H ₅ OH AND B: C ₂ H ₅ -O-CO-R ✓	<i>Accept R-OH/R'-OH AND R-O-CO-R/R'-O-CO-R. Do not accept names.</i>	1
14.	b	ii	low«er» viscosity ✓ «simple esters have» weaker London/dispersion forces «than vegetable oils» ✓	<i>Do not accept intermolecular forces or van der Waals' forces instead of London/dispersion forces.</i>	2

Question		Answers	Notes	Total
15.	a	<p><i>Similarity:</i> both convert mass into energy OR both increase the binding energy «per nucleon» ✓</p> <p><i>Difference:</i> fusion «two smaller/lighter» nuclei combine «to produce a larger/heavier one» AND fission «heavy» nucleus splits «into fragments/smaller/lighter nuclei» ✓</p>	<p><i>For similarity accept that mass is lost/mass of products is less than that of reactants.</i> <i>For similarity accept change of atomic number / new elements produced.</i></p> <p><i>Do not accept atoms/s instead of nucleus/i.</i></p>	2
15.	b	«dark» lines in spectrum of sunlight ✓	<p><i>Do not accept simply spectrometry/spectroscopy.</i> <i>Do not accept references to emission spectra.</i></p>	1
15.	c	«oxygen» free radical «species»/O ₂ ⁻ /O ₂ ²⁻ /HO ₂ /HO ✓	<i>Do not penalize incorrect dots on radicals.</i>	1
15.	d	«nuclear reactor technology can be adapted for» nuclear weapons «production» ✓	<i>Do not accept geopolitical reasons.</i>	1

(continued...)

(Question 15 continued)

Question			Answers	Notes	Total
15.	e	i	low proportion/percentage/abundance of fissile/ ²³⁵ U isotope ✓	<i>Accept only one isotope/²³⁵U will undergo fission.</i>	1
15.	e	ii	diffusion/centrifuging requires a gas OR «only common» gaseous compound of uranium ✓		1
15.	e	iii	lighter molecules/ ²³⁵ UF ₆ /containing ²³⁵ U diffuse more rapidly OR rate of diffusion inversely proportional to «square root of» molar mass ✓	<i>Accept U-238/heavier particles move to the outside wall of the centrifuge OR U-235/lighter particles stay in the middle.</i> <i>Accept rate of diffusion decreases with increasing molar mass.</i>	1

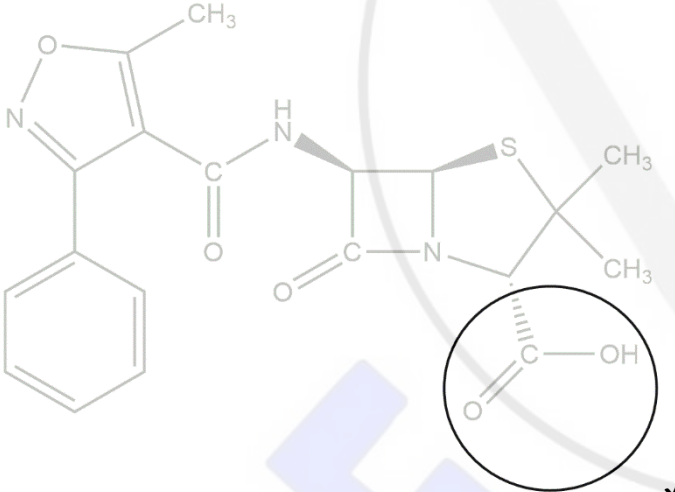
Question		Answers	Notes	Total
16.	a	<p>light «energy» excites dye molecules OR «excited» dye molecules oxidize/dye → dye⁺ + e⁻ OR electrons from dye pass into TiO₂ layer ✓</p> <p>oxidized dye molecules/dye⁺ oxidize iodide/I⁻ to tri-iodide/I₃⁻ OR 2 dye⁺ + 3I⁻ → 2 dye + I₃⁻ ✓</p> <p>electrons flow from TiO₂ layer «through external circuit back» to counter electrode OR tri-iodide/I₃⁻ flows «through electrolyte» to counter electrode ✓</p> <p>electrons reduce tri-iodide/I₃⁻ to iodide/I⁻ «at counter electrode» I₃⁻ + 2e⁻ → 3I⁻ ✓</p>	<p>Accept iodine/I₂ for tri-iodide/I₃⁻. Accept reversible arrows in equations.</p>	4

(continued...)

(Question 16 continued)

Question			Answers	Notes	Total
16.	b	i	<p><i>Positive electrode (cathode):</i> lead(IV) oxide/PbO₂ ✓</p> <p><i>Negative electrode (anode):</i> lead/Pb ✓</p>	<p>Do not accept lead(IV)/Pb⁴⁺.</p> <p>Accept correct reactants shown in half-equations.</p>	2
16.	b	ii	higher energy density/charge per unit mass ✓	<p>Do not accept lithium ion lighter/smaller without mentioning similar capacity.</p> <p>Do not accept references to toxicity.</p> <p>Accept does not involve a liquid/corrosive electrolyte.</p> <p>Accept lower internal resistance.</p>	1

Option D — Medicinal chemistry

Question			Answers	Notes	Total
17.	a		interfere with «bacteria» cell wall OR animal cells do not have a cell wall ✓	Do not accept transpeptidase without reference to cell wall.	1
17.	b	i	«bulky group/steric shield» prevents enzyme/penicillinase/beta-lactamase attacking β -lactam ring ✓	Accept harder for penicillinase to access/reach β -lactam ring. Accept shields/increases stability of β -lactam ring.	1
17.	b	ii		Circle must enclose the whole of the COOH group.	1

(continued...)

(Question 17 continued)

Question			Answers	Notes	Total
17.	c		«low doses of» antibiotics reach the water/soil/animal waste OR «low doses of» antibiotics are present in the animals / food produced from animals ✓ favours survival/spread of mutant/resistant bacteria ✓	Do not accept increased probability of mutation for M2.	2

Question			Answers	Notes	Total
18.	a		Any one of: addiction/dependency ✓ decreased breathing-rate ✓ decreased heart rates ✓ constipation ✓ reduced sex drive ✓ loss of appetite ✓ depression ✓	Do not accept vague responses such as suppression/decrease in brain activity.	1
18.	b	i	«phenolic» OH/hydroxyl replaced by OCH ₃ /ether/methoxy group ✓	Accept methylated. Accept alcohol/hydroxy, but not hydroxide for hydroxyl.	1

(continued...)

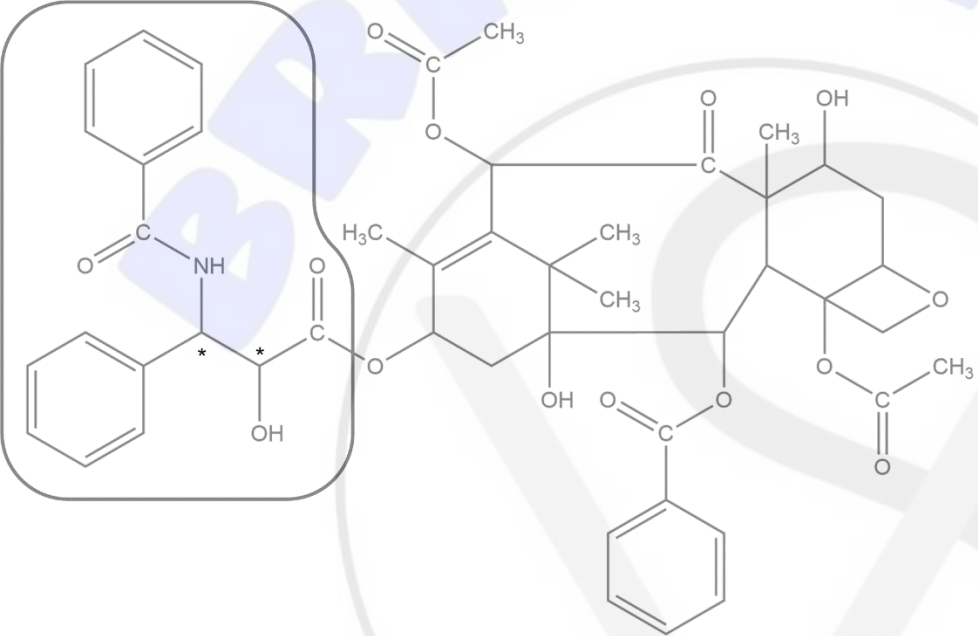
(Question 18 continued)

Question			Answers	Notes	Total
18.	b	ii	m/z = 299 ✓	Accept molecular ion = 300. Do not accept simply RMM = 300 Accept absence of m/z = 285.	1
18.	b	iii	codeine has fewer OH/hydroxyl groups «than morphine» ✓ can cross the blood-brain barrier more easily ✓	Accept codeine is more lipid soluble / less polar «than morphine» for M1.	2

Question			Answers	Notes	Total
19.	a		anticoagulant/prevention of blood clots ✓	Accept blood thinner / reducing chance/incidence of strokes/heart attacks.	1
19.	b		synergistic effect OR increases anticoagulant effect ✓	Accept the effect of one reinforces the effect of the other. Accept increased «risk of» stomach/gastrointestinal bleeding.	1

Question		Answers	Notes	Total
20.	a	inhibits enzyme/H ⁺ K ⁺ -ATPase /gastric proton pump which secretes H ⁺ «ions into gastric juice» ✓	Accept proton pump inhibitor/PPI.	1
20.	b	$\text{pH} - \text{p}K_a = \log \frac{[\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]} = 1.12 \checkmark$ $[\text{HCO}_3^-] = \llbracket 13.18 \times 2.03 \times 10^{-3} \rrbracket \Rightarrow 2.68 \times 10^{-2} \llbracket \text{mol dm}^{-3} \rrbracket \checkmark$	Award [2] for correct final answer.	2

Question		Answers	Notes	Total
21.	a	«drug» blocks/inhibits «viral» enzyme/neuraminidase/NA «activity» ✓ prevents virus from leaving/escaping host cells «thus cannot infect other cells» ✓		2
21.	b	zanamivir AND many OH/hydroxyl/NH/NH ₂ groups «that can H-bond with water» ✓	Accept alcohol/hydroxy, but not hydroxide for hydroxyl.	1

Question		Answers	Notes	Total
22.	a	 <p style="text-align: right;">✓</p>	Both chiral centres must be identified for the mark.	1
22.	b	<p>chiral auxiliary binds to reactant blocking one reaction site «by steric hindrance» OR chiral auxiliary creates stereochemical condition «necessary to follow a certain pathway» OR stereochemical induction OR existing chiral centre affects the configuration of new chiral centres ✓</p>	Accept «chemical synthesis» yields a racemic mixture/mixture of enantiomers/diastereomers.	1

Question			Answers	Notes	Total
23.	a		alpha emitters/radionuclides delivered by a carrier/drug/protein «directly to the cancer cells» ✓ alpha particles have low penetration OR «completely» absorbed within a short range ✓ high energy particles/highly ionising/high destructive power ✓	Accept lead-212 in M1.	3
23.	b	i	${}_{81}^{208}\text{Tl}$ ✓	Accept ${}^{208}\text{Tl}$ / thallium-208 / Tl-208. Accept correct product shown in an equation.	1
23.	b	ii	ALTERNATIVE 1: $\lambda = \left\langle \frac{\ln 2}{61.0} \Rightarrow 1.136 \times 10^{-2} \text{ «min}^{-1}\text{»} \right\rangle$ ✓ $t = \left\langle \frac{\ln \frac{N_0}{N_t}}{\lambda} = \frac{2.303}{1.136 \times 10^{-2}} \Rightarrow 203 \text{ «min»} \right\rangle$ ✓ ALTERNATIVE 2: $t = \frac{\log \frac{N_t}{N_0}}{\log 0.5} \times t_{\frac{1}{2}}$ ✓ $t = \left\langle \frac{61}{0.301} \Rightarrow 203 \text{ «min»} \right\rangle$ ✓	Award [2] for the correct final answer.	2

Question		Answers				Notes	Total	
24.	a	Compound	Number of signals	AND	Relative areas	Award [1] for any two correct cells. Accept ratio of areas in any order. Do not apply ECF for ratios.	2	
		<i>Ibuprofen</i>	3		3:1:1			✓
		<i>Impurity X</i>	3		2:2:1			✓
24.	b	<p>B AND:</p> <p>absorbance at 3200–3600 «cm⁻¹» OR absorbance due to O–H/hydroxyl in alcohol ✓</p> <p>absence of absorbance at 1700–1750 «cm⁻¹» OR absence of «absorbance for» C=O/carbonyl «in carboxyl» ✓</p>				<p>“B” only necessary once.</p> <p>Award M2 for not A AND «absorbance for» C=O/carbonyl «in carboxyl group».</p> <p>Accept any absorbance value in the ranges given.</p>	2	