

Markscheme

May 2024

Chemistry

Higher level

Paper 3

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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**].

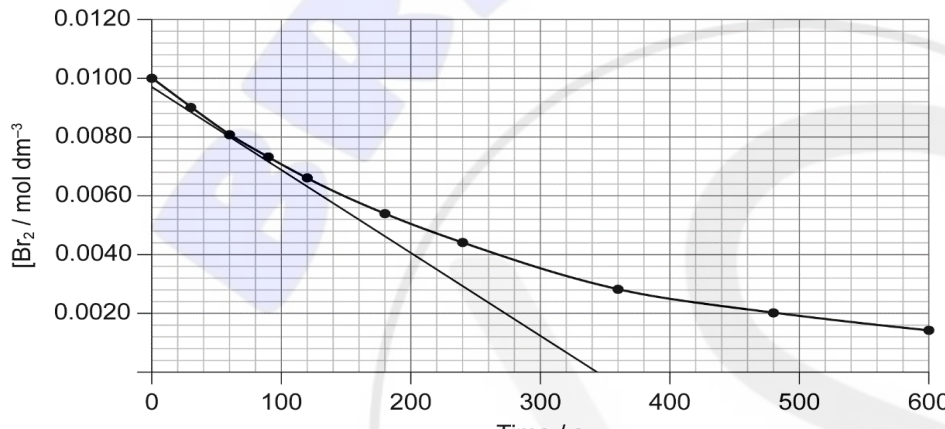
1. Each row in the “Question” column relates to the smallest subpart of the question.
2. The maximum mark for each question subpart is indicated in the “Total” column.
3. Each marking point in the “Answers” column is shown by means of a tick (✓) at the end of the marking point.
4. A question subpart 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	<p>ALTERNATIVE 1: «monitor/measure» with colorimetry/spectrophotometry/colour change related to $[\text{Br}_2]$ ✓ $[\text{Br}_2]$ is proportional to absorbance/transmittance/colour «intensity» ✓</p> <p>ALTERNATIVE 2: «monitor/measure» mass loss/pressure change/volume of gas/CO_2 ✓ moles of CO_2 proportional to mass loss/pressure change/volume ✓</p> <p>ALTERNATIVE 3: «monitor/measure» conductivity/pH ✓ conductivity/pH proportional to ion concentration ✓</p> <p>M3 for all ALTERNATIVES: with respect to time ✓</p>	<p>Accept other alternatives (e.g., monitor IR absorption of $\text{C}=\text{O}$ or ^1H NMR of the $\text{H}-\text{C}$ proton) with suitable descriptions.</p> <p>Award [up to 2] for any two correct methods (M1 in each alternative).</p> <p>Accept “weight” for “mass” for Alternative 2.</p> <p>M3 must involve some reference to measurement of M1 over time.</p>	3

(continued...)

(Question 1 continued)

Question			Answers	Notes	Total
1.	b	i	 <p>[Source: With permission from Alex Sullivan (www.scienceskool.co.uk).]</p> <p>tangent drawn on curve at 0.0080 mol dm⁻³ ✓</p> <p>«Rate = $\frac{\Delta[\text{Br}_2]}{\Delta t}$ = » 2.8 × 10⁻⁵ «mol dm⁻³ s⁻¹» ✓</p> <p>two significant figures in final answer ✓</p>	<p>Accept range of 2.6 × 10⁻⁵ to 3.1 × 10⁻⁵ «mol dm⁻³ s⁻¹».</p> <p>Award [2 max] for 3.3 × 10⁻⁵ «mol dm⁻³ s⁻¹».</p> <p>Award [1 max] for 3.33 × 10⁻⁵ «mol dm⁻³ s⁻¹».</p> <p>Ignore negative sign for M2.</p> <p>Award M3 for any numerical result with 2 significant figures.</p>	3

(continued...)

(Question 1 continued)

Question			Answers	Notes	Total
1.	b	ii	<p><i>Reason for negative slope:</i> reactants consumed/used up/fewer reactant molecules «as reaction progresses» OR [Br₂] decreasing ✓</p> <p><i>Reason for non-linear slope:</i> reaction is first order with respect to bromine/Br₂ OR lower frequency of collisions «between molecules» OR fewer «successful» collisions per unit time «so rate of reaction decreases»</p>	<p>Accept “reaction is not zero order wrt Br₂” for M2.</p> <p>Do not accept order of reaction without relation to Br₂ stated.</p> <p>Do not accept “reaction is second order wrt Br₂” for M2.</p> <p>Do not accept just “rate of reaction decreases” without reference to collisions</p>	2

Question			Answers	Notes	Total										
2.	a	i	<table border="1"> <thead> <tr> <th>Measure</th> <th>Result that yields maximum effective green chemistry</th> </tr> </thead> <tbody> <tr> <td>Process mass intensity (PMI)</td> <td>1</td> </tr> <tr> <td>E-factor</td> <td>0</td> </tr> <tr> <td>Atom economy</td> <td>1</td> </tr> <tr> <td>Eco-Scale</td> <td>100</td> </tr> </tbody> </table>	Measure	Result that yields maximum effective green chemistry	Process mass intensity (PMI)	1	E-factor	0	Atom economy	1	Eco-Scale	100	<p>Award [2] for three correct answers, [1] for two correct.</p> <p>Accept "100 %" for "1" and "100". Accept "0 %" for "0".</p>	2
			Measure	Result that yields maximum effective green chemistry											
			Process mass intensity (PMI)	1											
			E-factor	0											
			Atom economy	1											
Eco-Scale	100														
2.	a	ii	atom economy ✓	Accept "E-factor".	1										
2.	a	iii	products need to be purified/many side products/many isomers OR small mass of active substance per pill/package OR more solvent used OR produces more waste OR «use of» batch chemistry methods/more steps/process aids/raw materials OR «pharmaceutical industry» much lower yield ✓		1										

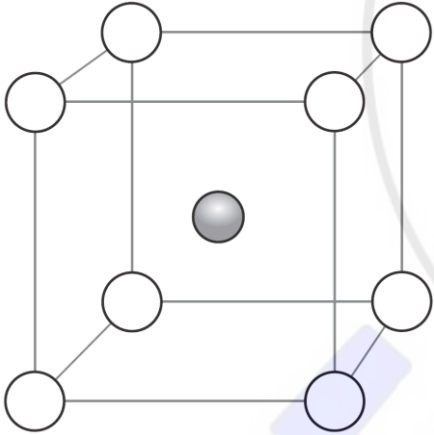
(continued...)

(Question 2 continued)

Question			Answers	Notes	Total
2.	b	i	$\llcorner 100 - [5 \text{ (bromobenzene)} + 5 \text{ (formamide)} + 5 \text{ (KOBU-}t\text{)} + 5 \text{ (dppf)} + \frac{100 - 82}{2} + 2 \text{ (microwave)} + 1 \text{ (N}_2\text{ atmosphere)} + 2 \text{ (heating < 1 hr)}] \Rightarrow 66 \checkmark\checkmark$	<p>Award [2] for correct final answer.</p> <p>Award [1 max] for answers in range of 62 to 65 OR 67 to 71.</p>	2
2.	b	ii	<p>sum of «MSDS-related» penalty points greater/uses more reagents that are penalized</p> <p>OR</p> <p>lower «%» yield</p> <p>OR</p> <p>uses CO/F+ atmosphere «which is toxic/extremely flammable»</p> <p>OR</p> <p>more flammable reagents used</p> <p>OR</p> <p>has a longer heating time ✓</p>	<p>Apply List Principle.</p> <p>Accept “uses $P(C_6H_5)_3$ «which is dangerous for the environment»”.</p>	1

Section B

Option A — Materials

Question			Answers	Notes	Total
3.	a		<p>at least one metal in an alloy AND composites may or may not contain metals ✓</p> <p>alloys are homogenous «or heterogeneous mixtures » AND composites are heterogenous/composed of two phases ✓</p>	<p><i>Apply List Principle.</i></p> <p><i>Accept “composites do not contain metals” for M1.</i></p>	2
3.	b	i	 <p>Coordination number: 8 ✓</p>	<p><i>Accept sketch with corner atoms contained within cell.</i></p> <p><i>Size of atoms do not have to be the same.</i></p>	2

(continued...)

(Question 3 continued)

Question			Answers	Notes	Total
3.	b	ii	$d = \frac{\lambda}{2 \sin \theta} = \frac{0.1789 \text{ nm}}{2 \times \sin 17.25^\circ} \Rightarrow 0.3016 \text{ «nm»} \checkmark$		1
3.	b	iii	<p>Volume = $\text{«}(0.3016 \times 10^{-7} \text{ cm})^3 \Rightarrow 2.743 \times 10^{-23} \text{ «cm}^3\text{»} \checkmark$</p> <p>$\text{«}M_r = \frac{2.743 \times 10^{-23} \text{ cm}^3 \times 6.45 \text{ g cm}^{-3} \times 6.02 \times 10^{23}}{2} = \text{» } 53.25 \text{ «g mol}^{-1}\text{»} \checkmark$</p>	<p>Accept $\text{«} \frac{M_r(\text{Ti}) + M_r(\text{Ni})}{2},$ $\frac{47.87 + 58.69}{2} \Rightarrow 53.28 \text{ «g mol}^{-1}\text{»}.$</p> <p>Award [2] for correct final answer.</p> <p>Accept range 52.4 to 53.5 «g mol⁻¹».</p>	2
3.	b	iv	<p>creation of mirror image/opposing magnetic field of external field «below critical temperature/T of superconductor» \checkmark</p> <p>expulsion of magnetic field from superconductor «below critical temperature/T» \checkmark</p>		2
3.	c	i	<p>electrons AND positive ions «in gaseous state» \checkmark</p>	<p>Accept “gaseous atoms, «many of» which have lost their electrons”.</p> <p>Do not accept “gaseous ions” alone.</p>	1

(continued...)

(Question 3 continued)

Question			Answers	Notes	Total
3.	c	ii	helium/He OR neon/Ne OR argon/Ar ✓	Accept "nitrogen/N ₂ ".	1
3.	c	iii	Any two of: inert/non-reactive gas ✓ «highly reactive» titanium will not oxidize/react ✓ produces high temperature to melt titanium/nickel ✓ «more» corrosion resistant/less pitting/contamination ✓		2 max
3.	d		Source of carbon: hydrocarbon/carbon-containing gas/compound ✓ Conditions: Any two of: mixed with inert gas ✓ heat/high temperature/vaporize compound ✓ «transition metal» catalyst ✓ hydrocarbon/carbon compound decomposes to form carbon «nanotubes» ✓ nanotubes form on catalyst surface ✓	Accept "ethanol" or specific hydrocarbons for M1. Accept "N ₂ ", "H ₂ ", "NH ₃ " or specific inert gases for M2. Accept temperature OR range within 600–800 °C for M3. Accept specific metals such as Ni, Co or Fe for M5.	3 max

(continued...)

(Question 3 continued)

Question		Answers	Notes	Total
3.	e	<p><i>Advantage:</i> Any one of: highly selective/specific ✓ «requires» milder conditions /lower concentration ✓ not surface area dependent/no need to be finely divided ✓ offer a broader range of reactions ✓</p> <p><i>Disadvantage:</i> Any one of: difficult to be separated/distil/recover OR contributes to more environmental waste ✓</p> <p>poor thermal stability ✓</p> <p>«often» limited to liquid/aqueous conditions only OR not as effective with gases ✓</p>	<p><i>Apply List Principle</i></p> <p><i>Do not accept converse of advantage as disadvantage.</i></p>	2 max

Question		Answers	Notes	Total
4.	a	$\left\langle \frac{12.01 \times 8 + 1.01 \times 8}{12.01 \times 8 + 1.01 \times 10 + 16} \times 100 \Rightarrow 85.25 \text{ «\%»} \right\rangle \checkmark$		1

(continued...)

(Question 4 continued)

Question		Answers	Notes	Total
4.	b	<p><i>Liquid crystal:</i> fluids with properties that depend on molecular orientation relative to fixed axis ✓</p> <p><i>Lyotropic:</i> solutions that show liquid-crystal state at certain concentrations/concentration range «s» ✓</p>		2
4.	c	<p>strength due to «strong» intermolecular forces/hydrogen bonds «between chains» ✓</p> <p>Intermolecular forces/hydrogen bonds can be broken «as O atoms are protonated»</p> <p>OR</p> <p>hydrolysis/breaking of amide linkage ✓</p>		2
4.	d	<p><i>Bond causing peak A: C–H AND Bond causing peak B: C–Cl</i> ✓</p> <p><i>RIC:</i> 3 ✓</p>		2

Question		Answers	Notes	Total
5.	a	<p><i>Any three of:</i></p> <ul style="list-style-type: none"> form coordination bond/complexes/bonds with ligands ✓ variable oxidation states/redox reactions ✓ catalysts/initiators «of radical reactions» ✓ bind with/inhibit/compete with active site enzymes ✓ change shape of active site ✓ replace ions «(Ca²⁺) etc» ✓ bioaccumulation/xenobiotics /interfere with cellular activity ✓ disrupt endocrine system ✓ denature proteins ✓ 		3 max

(continued...)

(Question 5 continued)

Question		Answers	Notes	Total
5.	b	<p>ALTERNATIVE 1: chelation ✓ binding with polydentate ligand «which is then excreted» ✓</p> <p>ALTERNATIVE 2: adsorption ✓ use of solid surface «such as charcoal» ✓</p> <p>ALTERNATIVE 3: precipitation ✓ reacting with anion which creates low solubility salt «so solid precipitates out» ✓</p> <p>ALTERNATIVE 4: ion exchange system ✓ replacing toxic ions with less toxic/harmful ions «with same charge» ✓</p>	<p><i>Apply List Principle</i></p> <p><i>Accept an appropriate example for M2 for all Alternatives.</i></p>	2

Option B — Biochemistry

Question			Answers	Notes	Total
6.	a	i	amide OR peptide bond ✓	Accept "C(O)-NH". Do not accept "covalent". Do not accept "C-N".	1
6.	a	ii	anabolism/anabolic «condensation» ✓		1
6.	a	iii	triplet code/codon/sequence of three bases ✓ instruction/code for an amino acid OR 64 different combinations for 20 amino acids ✓		2

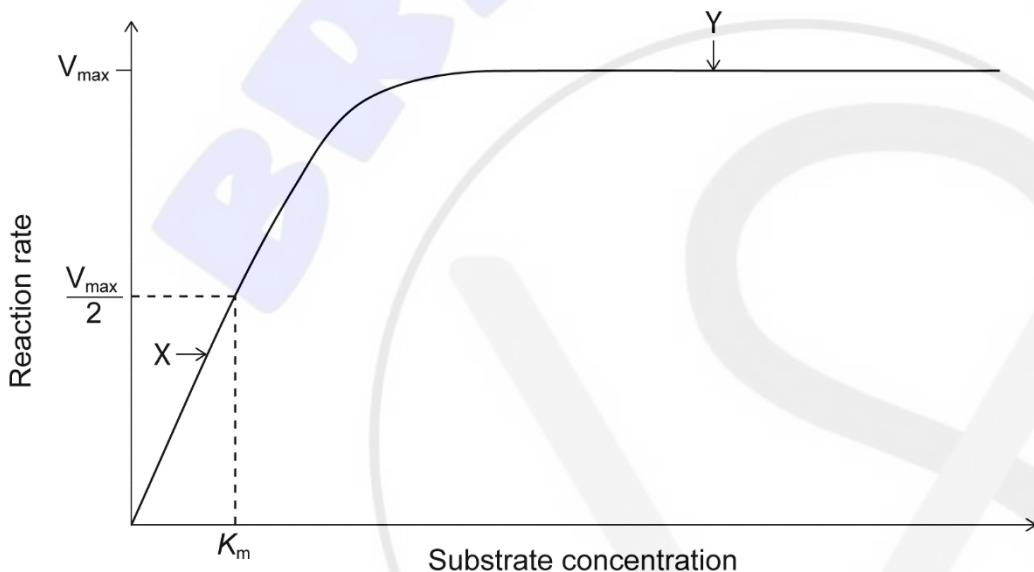
(continued...)

(Question 6 continued)

Question			Answers	Notes	Total
6.	b	i	<p><i>Point X:</i> rate increases as substrate concentration increases OR rate proportional to [S] ✓</p> <p>frequency of successful collisions between enzyme and substrate increases OR [E]>[S] OR many active sites available/free OR free active sites in excess ✓</p> <p><i>Point Y:</i> all active sites are occupied «by substrate» ✓</p> <p>rate of substrate entering equals rate of product leaving «active site» OR rate depends only on how long substrate remains attached to active site ✓</p>	<p>Accept “maximum rate not yet reached” for M1.</p> <p>Do not accept just “enzymes are available” OR “enzymes are in excess” OR “enzymes are occupied” without some reference to active sites for M2 OR M3.</p> <p>Accept “reaction has reached maximum rate” for M4</p>	4

(continued...)

(Question 6 continued)

Question			Answers	Notes	Total
6.	b	ii	 <p>two lines indicating $\frac{1}{2} V_{max}$ AND K_m ✓</p>	<p>Students are permitted to have rulers during the exam so $V_{max}/2$ must be close to the half-way point, over X.</p> <p>Both $V_{max}/2$ AND K_m must be correctly labeled.</p>	1

(continued...)

(Question 6 continued)

Question			Answers	Notes	Total
6.	b	iii	<p>«K_m is» inverse measure of affinity of enzyme for substrate</p> <p>OR</p> <p>«K_m» is inversely proportional to enzyme activity</p> <p>OR</p> <p>high value «of K_m» indicates higher substrate concentration needed for enzyme saturation</p> <p>OR</p> <p>low value «of K_m» means reaction is fast at low substrate concentration ✓</p>	<p><i>Idea of inverse relationship must be conveyed.</i></p> <p><i>Accept “high value «of K_m» indicates low affinity of enzyme for substrate/less stable ES complex/lower enzyme activity”.</i></p> <p><i>Accept “low value «of K_m» indicates high affinity of enzyme for substrate/stable ES complex/greater enzyme activity”.</i></p> <p><i>Do not accept “at ½ V_{max} substrate concentration equal to V_{max}” OR “«K_m» can be used to determine V_{max}”.</i></p>	1
6.	b	iv	<p>V_{max} unchanged ✓</p> <p>at high substrate concentration substrate outcompetes inhibitor/need a higher substrate concentration to reach V_{max} ✓</p>	<p><i>Accept suitable labelled diagram.</i></p>	2

Question			Answers	Notes	Total
7.	a	i	<p>Alternative 1:</p> $n(\text{acid}) \llcorner = \frac{100}{308.56} \Rightarrow 0.324 \llcorner \text{mol} \llcorner \text{ AND}$ $n(\text{I}_2) \llcorner = \frac{164.5}{2 \times 126.90} \Rightarrow 0.648 \llcorner \text{mol} \llcorner \checkmark$ <p>« <u>0.648 mol</u> \Rightarrow 2 «C=C bonds» \checkmark 0.324 mol</p> <p>Alternative 2:</p> $\llcorner \frac{164.5 \text{ g} \times 308.56 \text{ g mol}^{-1}}{100 \text{ g}} = \llcorner 507.7 \checkmark$ $\llcorner \frac{507.7}{253.8} = \llcorner 2 \llcorner \text{ «C=C bonds» } \checkmark$	<p>Do not award M1 or M2 without correct work.</p>	2

(continued...)

(Question 7 continued)

Question			Answers	Notes	Total
7.	a	ii	<p>«eicosadienoic acid has» kinks in chain OR «eicosadienoic acid» chains pack less closely together ✓</p> <p>weaker London/dispersion/instantaneous dipole-induced dipole forces «between molecules» ✓</p>	<p>Accept “eicosadienoic acid has lower surface area/electron density” for M1.</p> <p>Do not accept “unsaturated” or “contains C=C bonds” for M1 as terms included in stem and previous question.</p> <p>Do not accept arguments based on size/molar mass/molecular mass of molecule alone.</p> <p>Accept “weaker intermolecular/van der Waals’/vdW forces” for M2.</p>	2

(continued...)

(Question 7 continued)

Question		Answers	Notes	Total
7.	b	<p>Any two of:</p> <ul style="list-style-type: none">« increased risk » of coronary heart disease/stroke/atherosclerosis ✓« increased risk of type 2» diabetes ✓« increased risk » obesity ✓ <p>difficult to metabolize/excrete</p> <p>OR</p> <ul style="list-style-type: none">accumulate in fatty tissue ✓increase levels of LDL cholesterol ✓decrease levels of HDL cholesterol ✓low-quality energy source ✓	<p>Apply List Principle</p>	<p>2 max</p>

(continued...)

(Question 7 continued)

Question			Answers	Notes	Total
7.	c	i	Any two of: «sun/UV»light ✓ heat/high temperature ✓ oxygen/O ₂ «from air» ✓ enzymes ✓ bacteria ✓ acid ✓ moisture ✓ metal ion catalysts ✓	Apply List Principle Accept answers related to oxidative and hydrolytic rancidity.	2 max
7.	c	ii	Any one of: aldehyde OR ketone OR alcohol ✓	Apply List Principle Accept “carbonyl”. Accept “hydroxyl” but not “hydroxide”.	1
7.	d		insoluble AND «many» hydroxyl/OH groups OR insoluble AND polar molecule/groups ✓	Apply List Principle Accept “no/not soluble” for insoluble. Accept “alcohol” for OH groups. Do not accept “hydroxide” OR “react(s) with water”	1

Question		Answers	Notes	Total
8.	a	highly conjugated system OR many alternating single and double bonds OR many delocalized electrons ✓ «strong» absorption of some/specific wavelengths/colours/visible light ✓		2
8.	b	absorbs «wavelengths of visible» light not absorbed by chlorophyll ✓	Accept “absorbs shorter wavelengths/higher energy light «than chlorophyll».	1

Question		Answers	Notes	Total
9.	a	beta/β-glucose ✓	Do not accept “glucose” or “α-glucose”.	1
9.	b	glucose is water soluble OR starch must be digested/hydrolyzed/is less water soluble ✓	Accept “broken/break down” instead of “digested/hydrolyzed” for starch.	1

Question		Answers	Notes	Total
10.	a	<p>Any one of:</p> <ul style="list-style-type: none"> mining/smelting ✓ «NiCd» batteries ✓ «stabilizers in» plastics ✓ metal plating ✓ pigments/paint ✓ sewage sludge ✓ electronic/e-waste ✓ 	<p>Apply List Principle</p>	<p>1 max</p>
10.	b	<p>«host selectively» bond/binds to cadmium/Cd/Cd²⁺/metal «ion»</p> <p>OR</p> <p>complementary chemical structure of host molecule and metal ✓</p> <p>«supramolecule/host and cadmium» anchored/filtered/precipitated ✓</p>	<p>Do not accept “specifically bind” for M1 as this is rare for synthetic host molecule.</p> <p>Do not accept “trap” for M1.</p> <p>Accept “supramolecule removed” for M2.</p> <p>Do not accept “removed” by itself for M2.</p>	<p>2</p>

Option C — Energy

Question			Answers	Notes	Total
11.	a		smaller nuclei cannot increase binding energy «by splitting/fission» OR require less energy to overcome the nuclear forces of attraction ✓	<i>Do not accept answers only in terms of instability of heavy nuclei.</i>	1
11.	b	i	$^{254}\text{Cf} \rightarrow ^{118}\text{Pd} + ^{132}\text{Te} + 4\text{n}$ OR $^{254}_{98}\text{Cf} \rightarrow ^{118}_{46}\text{Pd} + ^{132}_{52}\text{Te} + 4^1_0\text{n}$ ✓	<i>Penalize incorrect atomic numbers. Do not accept equations induced by neutrons or other particles.</i>	1
11.	b	ii	mass of ^{254}Cf = « $254.087323 \times 1.660540 \times 10^{-27} \text{ kg} \Rightarrow 4.219222 \times 10^{-25}$ «kg»/4.22 $\times 10^{-25}$ «kg» ✓ mass of 98 protons = « $98 \times 1.672622 \times 10^{-27} \Rightarrow 1.639170 \times 10^{-25}$ «kg» AND mass of 156 neutrons = « $156 \times 1.674927 \times 10^{-27} = \Rightarrow 2.612886 \times 10^{-25}$ «kg» ✓ mass defect = « $1.639170 \times 10^{-25} + 2.612886 \times 10^{-25} - 4.219222 \times 10^{-25} \Rightarrow 3.2834$ $\times 10^{-27}$ «kg» ✓	<i>Award [3] for correct final answer. Accept answers in range 3.25×10^{-27} to 3.30×10^{-27} «kg».</i>	3

(continued...)

(Question 11 continued)

Question			Answers	Notes	Total
11.	b	iii	<p>«binding energy = $\frac{\Delta m \times c^2}{\text{nucleons} \times 1000}$</p> <p>$= \frac{3.2834 \times 10^{-27} \text{ kg} \times (3.00 \times 10^8 \text{ m s}^{-2})^2}{254 \times 1000} = \gg 1.16 \times 10^{-15} \text{ «kJ nucleon}^{-1}\text{»}.$ ✓</p>	<p>Accept range of 1.06×10^{-15} to 1.26×10^{-15} «kJ nucleon⁻¹».</p> <p>If 5.00×10^{-27} used then answer is 1.77×10^{-15} «kJ nucleon⁻¹».</p>	1
11.	c		<p>stored in cooling ponds/water OR allow for cooling time ✓</p> <p>encased in cement/glass/steel ✓</p> <p>buried/disposed «deep» underground/in stable geological locations ✓</p>	<p>Reference to store/time is needed for scoring M1.</p> <p>Do not accept “iron” for “steel” for M2.</p>	3
11.	d		<p>«very» high temperature needed «for fusion» OR lack of material capable of withstanding high heat «for fusion» OR high «electric» cost to heat chamber «for fusion» OR technology available for «controlling» fission «but not fusion» ✓</p>	<p>Do not accept generic answers about fusion reaction being dangerous or exploding.</p>	1

Question			Answers “	Notes	Total
12.	a		reduction in «sun’s» energy/light reaching Earth’s surface ✓ <i>Any two of:</i> pollutants/aerosols/particles create «nucleation sites for» cloud «formation» ✓ «some» pollutants/aerosols/particles absorb sunlight/light ✓ «some» clouds/pollutants/aerosols/particles reflect sunlight/light ✓		3 max
12.	b	i	highly conjugated systems OR many alternating single and double bonds OR many delocalized electrons ✓		1
12.	b	ii	$6\text{CO}_2 (\text{g}) + 6\text{H}_2\text{O} (\text{l}) \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 (\text{aq}) + 6\text{O}_2 (\text{g}) \checkmark$		1

(continued...)

(Question 12 continued)

Question			Answers	Notes	Total
12.	c	i	<p>Any two of: photon/«sun»light absorbed by the dye/«transition» metal complex OR dye/«transition» metal complex excited by photon/«sun»light ✓</p> <p>dye is oxidized by releasing electrons into TiO₂ «nanoparticle layer» OR electron«s» move«s» to conduction band OR electron«s» transferred to semiconductor/TiO₂ ✓</p> <p>dye is reduced by electrolyte/iodide ions/I⁻ ✓</p>	<p>Do not accept Ti₂/O₂.</p>	2 max
12.	c	ii	<p>$I_3^- + 2e^- \rightarrow 3I^-$ «at cathode» OR triiodide ions/I₃⁻/ reduced into/produce iodide ions/I⁻ «at cathode» ✓</p> <p>iodide ions/I⁻ reduce dye/act as reducing agent AND oxidized into/produce triiodide ions/I₃⁻ OR $dye^+ + e^- \rightarrow dye$ AND $3I^- \rightarrow I_3^- + 2e^-$ ✓</p>		2

Question			Answers	Notes	Total
13.	a		energy density AND requires less storage space OR gases need «extra weight for» compression equipment OR «small volume» easier to transport/carry OR high specific energy with low energy density technologies are cost prohibitive ✓		1
13.	b	i	M_r ethylbenzene = 106.18 g mol ⁻¹ ✓ $\Delta H_c = \frac{-4.135 \times 10^7 \text{ J kg}^{-1}}{1000 \text{ g kg}^{-1}} \times \frac{106.18 \text{ g mol}^{-1}}{1000 \text{ J kJ}^{-1}} \Rightarrow -4391 \text{ «kJ mol}^{-1}\text{»} \checkmark$	Award [2] for correct final answer. Award [1 max] for missing negative sign in answer. Award [2] for -4380 «kJ mol ⁻¹ » for M2 when 106 g mol ⁻¹ used for M1.	2
13.	b	ii	passed over/use «metal/platinum» catalyst «with aluminium oxide» ✓ dehydrogenates/loses hydrogen/is oxidized ✓ reforms/cyclizes ✓	Award M1 and M3 for “catalytic reforming”. Correct structures/equations can be accepted for any mark.	3

(continued...)

(Question 13 continued)

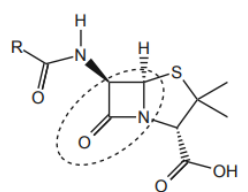
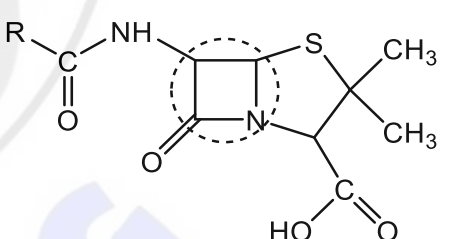
Question			Answers	Notes	Total
13.	c	i	<p>1 mol «of atoms only» 7 g for Li AND 207 g for Pb</p> <p>OR</p> <p>lower mass of Li for same number of atoms «oxidized»</p> <p>OR</p> <p>lower mass of Li per number of electrons «transferred» ✓</p> <p>«voltage per cell» oxidation potential of Li(s) is +3.04 V AND Pb(s) is +0.13 V</p> <p>OR</p> <p>higher voltage for Li ✓</p>	<p>Accept “higher charge density for Li” for M2.</p>	2
13.	c	ii	<p><i>Graphite:</i></p> <p>$\text{Li}^+ + \text{e}^- \rightarrow \text{Li(s)}$</p> <p>OR</p> <p>$6\text{C(s, graphite)} + \text{Li}^+ + \text{e}^- \rightarrow \text{LiC}_6\text{(s)}$ ✓</p> <p><i>Li CoO₂(s):</i></p> <p>$\text{LiCoO}_2\text{(s)} \rightarrow \text{Li}^+ + \text{CoO}_2\text{(s)} + \text{e}^-$ ✓</p>	<p>Award [1 max] for reversed half-equations given at the correct electrodes.</p>	2

(continued...)

(Question 13 continued)

Question			Answers	Notes	Total
13.	c	iii	sensitive to high temperature OR can overheat/explode/catch fire OR damaged if overcharged «so require circuit protection» OR ruined if completely discharged OR high cost OR ageing/loss of battery capacity/limited number of charge/discharge cycles ✓	<i>Apply List Principle</i>	1

Option D — Medicinal chemistry

Question			Answers	Notes	Total
14.	a		<p>«irreversibly» binds/bond to enzyme /transpepidadase 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 cell cannot reproduce ✓</p>	<p>Award [1 max] for “interferes with cell wall production.” 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
14.	b	i	 <p>3 C atoms and N atom must be included in circle ✓</p>	<p>Accept</p> 	1

(continued...)

(Question 14 continued)

Question			Answers	Notes	Total
14.	b	ii	<p>Any one of: ring is «sterically» strained/breaks up/opened OR amide/amido group «in rings» is «highly» reactive OR bond angles 90° instead of 109.5°/109°/120° OR angles less than 109.5°/109°/120°/tetrahedral/trigonal planar/triangular planar ✓</p>	<p>Mark can be scored in part (a) of this question.</p>	1 max
14.	c		<p>Functional group in both structures: Any one of: amido ✓ ether ✓ carbonyl ✓</p> <p>Functional group in zanamivir only: Any one of: hydroxyl ✓ carboxyl ✓</p>	<p>Apply List Principle</p> <p>Accept “amide/carboxamide” for M1. Accept “alkenyl/alkene” for M1. Accept “amino/amine” for M1.</p> <p>Accept “hydroxyl/alcohol” but not “hydroxide” for “hydroxyl” for M2. Accept “imine” OR “guanidino” for M2.</p>	2 max

Question			Answers	Notes	Total
15.	a	i	<p>«temporarily» binds to/blocks opioid/pain receptors in brain/CNS ✓</p> <p>prevents transmission of pain impulses in the brain/CNS «without depressing the CNS» ✓</p>	<p><i>Reference must be made to the brain/CNS once only for both marks.</i></p>	2
15.	a	ii	<p>Any two of:</p> <p>releases dopamine/endorphins «that the person craves»</p> <p>OR</p> <p>gives a feeling of pleasure/euphoria «that the person craves» ✓</p> <p>alters the structure of brain cells</p> <p>OR</p> <p>alters the way brain works «so that it only works normally when the opiates are present» ✓</p> <p>«once addicted» withdrawal symptoms occur without continual use ✓</p>		2 max
15.	b		<p>body's response to drug is reduced «when drug is used repeatedly»</p> <p>OR</p> <p>more of the drug needs to be taken to achieve the original/same effect ✓</p>	<p><i>Accept "body adapts/gets used to the continuous presence of drug".</i></p>	1

(continued...)

(Question 15 continued)

Question		Answers	Notes	Total
15.	c	anticoagulant/reduces blood clotting/blood thinner OR prevents cardiovascular disease/stroke/CVA OR reduces fever/antipyretic OR anti- inflammatory ✓	Apply List Principle Accept “prevents/reduces risk of heart attack” OR “prevent heart disease” OR “may reduce colon/colorectal cancer”.	1
15.	d	«increased» risk of stomach bleeding/ulcers OR «increased» risk of duodenal bleeding/ulcers ✓	Apply List Principle Accept “«increased» risk of liver damage”. Do not accept “synergistic effect” alone.	1

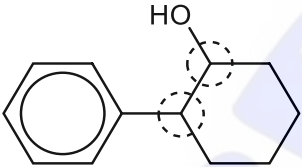
Question		Answers	Notes	Total
16.	a	« $n(\text{NaHCO}_3) = \frac{2.320}{84.01}$ and $n(\text{Na}_2\text{CO}_3) = \frac{0.500}{105.99}$ » $n(\text{NaHCO}_3) = 0.0276$ «mol» AND $n(\text{Na}_2\text{CO}_3) = 0.0047$ «mol» ✓ $n(\text{HCl}) \llcorner = 0.0276 + 2 \times 0.0047 \llcorner = 0.0370$ «mol» ✓	Award [2] for correct final answer. Accept 0.0371 «mol» for [2] .	2

(continued...)

(Question 16 continued)

Question		Answers	Notes	Total
16.	b	blocks/binds to H ₂ /histamine receptors «in cells of stomach lining» OR prevents histamine molecules binding to H ₂ /histamine receptors «and triggering acid secretion» ✓ prevents «parietal» cells/stomach lining from releasing/producing acid ✓	Accept “H ₂ -receptor antagonist/H ₂ RA” OR “blocks/inhibits action of histamine” for M1. Do not accept just “inhibits acid production” for M2.	2

Question		Answers	Notes	Total
17.	a	low activity/radioactivity AND has short half-life ✓	Accept “emits weak ionizing radiation” for “low activity/radioactivity”. Accept “exists for a short period of time” for “short half-life”.	1
17.	b	store in sealed/shielded container AND until material has decayed/becomes inactive AND then dispose «with normal waste»/in landfill/incineration ✓	Apply List Principle	1

Question		Answers	Notes	Total
18.	a		Both circles are needed for mark.	1
18.	b	<p>Any two of:</p> <p>«chiral auxiliary» is attached to «non-optically active/non-chiral» substrate ✓</p> <p>configuration of another chiral centre determined by existing chiral centre OR</p> <p>creates stereochemical condition necessary to follow a certain pathway ✓</p> <p>«chiral auxiliary» is removed «after reaction is complete» ✓</p>	Accept “stereochemical induction” for M2.	2 max
Question		Answers	Notes	Total
19.	a	${}^{223}\text{Ra} \rightarrow {}^{219}\text{Rn} + {}^4\text{He}$ <p>OR</p> ${}_{88}^{223}\text{Ra} \rightarrow {}_{86}^{219}\text{Rn} + {}_2^4\text{He} \checkmark$	<p>Accept “α” for “${}^4_2\text{He}$”.</p> <p>Penalize incorrect atomic numbers.</p>	1

(continued...)

(Question 19 continued)

Question		Answers	Notes	Total
19.	b	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}} = 0.0608$ $\frac{N}{N_0} = e^{-\lambda t} = e^{-0.0608 \cdot 30}$ <p>OR</p> $\frac{N}{N_0} = 0.5^{\frac{30}{11.4}} \checkmark$ <p>16 «%» ✓</p>	<p>Award [2] for correct final answer.</p>	<p>2</p>

(continued...)

(Question 19 continued)

Question		Answers	Notes	Total
19.	c	<p>Any two of: more damaging than other radiation types OR very damaging to «cancer cells» OR highly ionizing «alpha particles» ✓</p> <p>short range «of emission» OR causes little damage to surrounding tissues ✓</p> <p>«alpha emitter» carried to/selectively absorbed by/radiation source delivered directly to cancer cells «by antibody, carrier drug, protein» OR several sites in body can be targeted «at same time» ✓</p>	<p>Accept “high ionizing power «of alpha particles»” for M1. Accept “low penetrating power «of alpha particles»” for M2.</p>	2 max

Question		Answers	Notes	Total
20.	a	<p>1700–1750 «cm⁻¹ C=O in carboxylic acid» OR 2500–3000 «cm⁻¹ O–H in carboxylic acid» ✓</p>	Apply List Principle	1

(continued...)

(Question 20 continued)

Question			Answers	Notes	Total
20.	b	i	ethanol AND <i>Any one of:</i> three signals/environments ✓ shows splitting OR characteristic triplet-quartet pattern of ethyl group ✓ signal at ~1.3/0.9–1.0 ppm for CH ₃ ✓ signal at ~2.6/1.0–6.0 ppm for R–O–H ✓ signal at ~3.7/3.3–3.7 ppm for –CH ₂ –O–R ✓ no signal at 9.0–13.0 for RCOO–H ✓		1
20.	b	ii	doublet AND adjacent to C with one H ✓	<i>For Spanish students only due to a translation error, accept <<one>> signal between 2.2 and 2.7 ppm because the H atoms in the methyl group in ethanal are next to a C=O.</i>	1