8823 –6109M

Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

November 2023

Chemistry

Higher level

Paper 3

39 pages

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	i	concentration «of vitamin C» ✓	*Do **not** accept "vitamin C" alone.* *Do **not** accept "pasteurization".*	1
1.	a	ii	187 **«**µg cm^{-3}**»** ✓	*Accept values in the range of 180–200 **«**µg cm^{-3}**».***	1
1.	a	iii	**«**average rate = 40 µg cm^{-3}/ 56 days =**»** 0.71 **«**µg cm^{-3} day^{-1}**»** ✓	*Accept values in the range of 0.62–0.73 **«**µg cm^{-3} day^{-1}**».*** *Ignore negative sign.*	1
1.	a	iv	no ***AND*** **«**average**»** gradients of both lines are the same ***OR*** no ***AND*** both lose 35-40 **«**µg cm^{-3}**»** **«**in 56 days**»** ***OR*** no ***AND*** same concentration change «in time period» ✓	*Accept "yes **AND** a mention of the «slightly» different concentration «for the same time period»".* *Accept "yes **AND** pasteurization has slightly lower/different rate".* *Accept "no **AND** same trend".*	1

Question			Answers	Notes	Total
1.	a	v	pasteurized ***AND*** same «absolute» uncertainty divided by smaller value ✓	*Accept numerical examples.* *Accept converse argument.* *Accept "error" for "uncertainty".* *Accept answers where the deduction may be inferred via any reasonably expressed mathematical perspective eg. "pasteurized **AND** larger percent uncertainty as it has lower concentration of vitamin C".*	**1**
1.	b	i	UV/ultraviolet ✓		**1**
1.	b	ii	white «crystal»/colourless «solution» ***AND*** does not absorb in visible/400–700 «nm» «region» ✓		**1**
1.	b	iii	«does not reach pathogens as UV» is absorbed by other chemicals/vitamin C/sugars/vitamins/aromatic ring/suspended particles ***OR*** absorption coefficient affected by turbidity ***OR*** «does not reach pathogens as» viscosity/density varies «affecting depth of light penetration» ✓	*Accept "orange juice is not transparent «as it contains some fibre and oils», hence UV will not penetrate it".* *Do **not** accept "UV waves too small to eliminate bacteria/make an impact".* *Do **not** accept arguments based on why other wavelengths would be effective.*	**1**

Question			Answers	Notes	Total
1.	b	iv	*Any two of:* lower temperature ✓ seal under vacuum / put in a sealed container / absence of air/oxygen / store under a protective atmosphere/an inert gas ✓ add antioxidant/reducing agent ✓ store in dark **«**bottles**»** / limit exposure to UV/ultraviolet/light ✓	*Accept "pasteurize" if answer to 1a iv is yes.* *Accept correct compound for antioxidant **OR** reducing agent.* *Do **not** accept just "adding additives'".*	**2 max**
1.	c		yes ***AND*** correlation coefficient is –0.7 «which is a moderate correlation» ***OR*** yes ***AND*** orange is an outlier ***OR*** no ***AND*** orange has the greatest concentration of vitamin C and intermediate pH ✓	*Accept "yes/no **AND** any **valid reason** supporting the correlation or not, either mathematically **OR** qualitatively outlined from the data".* *Do **not** accept "yes/no **AND** negative/weak/moderate/strong correlation" alone.* *Do **not** accept "yes **AND** correlation coefficient is –0.7 and therefore weak".*	**1**
1.	d	i	iodate/IO_3^-«aq» ✓		**1**

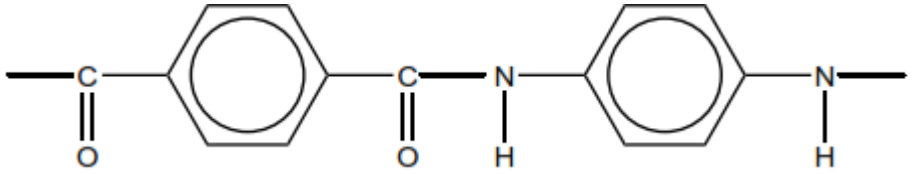
Question			Answers	Notes	Total
1.	d	ii	equivalence point was not reached ***OR*** reaction «between iodine and ascorbic acid» is slow/not complete ***OR*** stirring not sufficient ✓	*Accept "iodine evaporated".* *Do **not** accept "iodine oxidized".* *Do **not** accept "I_2 turned to $2I^-$".*	**1**
1.	d	iii	lower/decrease ✓	*Accept "as end point increases, concentration of vitamin C increases" and vice-versa.* *Do **not** accept general definitions of an end point.*	**1**
1.	d	iv	«starch-iodine complex is» same colour **«**as blueberry juice**»** ***OR*** end point colour obscured ✓	*Do **not** accept "cannot determine end point" without reference to colour.*	**1**

Section B

Option A — Materials

Question			Answers	Notes	Total
2.	**a**		base ***AND*** **«**hydride ion is a**»** proton/H^+ acceptor ✓	*Accept appropriate equation.*	**1**
2.	**b**		*Any two of:* large surface area ✓ cage-like structure ✓ inexpensive ✓ plentiful ✓ higher selectivity **«**for calcium ions over sodium ions**»** ✓ non-toxic ✓	*Do **not** accept "environmentally friendly" alone.*	**2 max**

Question			Answers	Notes	Total
3.	**a**		«dipole» influenced by an «external» electric field ✓ change orientation ✓		**2**
3.	**b**		*Good conductors along the tube:* pi/delocalized electrons move freely «within electron cloud along tube» ***OR*** atoms bonded/in contact ✓ *Poor conductors across the width of the tube:* pi/delocalized electrons/electron cloud does not extend across walls/tubes ***OR*** atoms not bonded ✓		**2**
3.	**c**		*Any three of:* spark ✓ «produces some» free e^- ***AND*** Ar^+ «gaseous ions» ✓ charged particles oscillate back and forth ✓ using alternating/high frequency current ***OR*** «oscillating» electromagnetic/magnetic field ***OR*** high frequency radiowaves ✓ collisions create more plasma/Ar^+ and e^- ✓		**3 max**

<table>
<tr><th colspan="3">Question</th><th>Answers</th><th>Notes</th><th>Total</th></tr>
<tr><td>3.</td><td>d</td><td>i</td><td>
<table>
<tr><th></th><th>Physical properties</th><th>Example</th></tr>
<tr><td>Extensive covalent cross-links:</td><td>hard/rigid/high melting point/cannot be reshaped/more brittle/higher heat resistance ✓</td><td>«thermoset» Bakelite/HDPE/epoxies/ polyurethane ✓</td></tr>
<tr><td>Few covalent cross-links:</td><td>flexible/able to return to shape/can be recycled ✓</td><td>«thermoplastics» rubber/PVC/polystyrene/nylon/ polypropene/polyethene ✓</td></tr>
</table>
</td><td>Accept any correct example. eg. billiard balls for thermoset.
Accept “resins” for thermoset.
Accept other valid examples.
Accept “polyester” for either thermoset or thermoplastic for both.
Do not accept same physical property argument for both eg. higher mp for thermoset, lower mp for thermoplastics.</td><td>4</td></tr>
<tr><td>3.</td><td>d</td><td>ii</td><td> 

✓</td><td>Continuation bonds are necessary for the mark. Ignore any brackets.
Ignore “n” for repeating brackets.</td><td>1</td></tr>
</table>

Question			Answers	Notes	Total
3.	**d**	**iii**	protonation of oxygen **«**in the hydrogen bonds**»** ***OR*** hydrolysis of amide linkage ✓ breaks hydrogen bonds/cross-links ✓	*Accept "protonation of nitrogen".*	**2**
3.	**d**	**iv**	3 ***AND*** contains hazardous chemicals/chlorine ***OR*** 4 ***AND*** single use plastic bags clog recycling machinery ***OR*** 6 ***AND*** difficult to melt/breaks down/energy intensive ***OR*** 7 ***AND*** can be mixture/does not melt ✓	*Accept "expense involved" as a reason for any of the stated RIC.* *Accept any specific valid example.* *Accept "7* ***AND*** *can represent a wide variety of plastics" only if a specific plastic and issue are stated.*	**1**

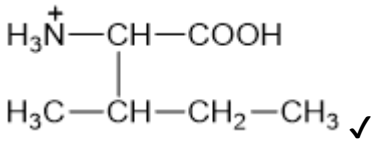
Question			Answers	Notes	Total
4.	a		copper/Cu«s» lost when drying cathode ***OR*** copper/Cu«s» falls from cathode to bottom of beaker «during electrolysis» ✓	*Answer must specify electrode.*	**1**
4.	b		«$\frac{0.296\,\text{g}}{63.55\,\text{g mol}^{-1}} = 4.66 \times 10^{-3}\,\text{mol Cu}$» «2 mol e^- for every mole Cu» = 9.32×10^{-3} «mol e^-» ✓ «$\frac{900.0\,\text{C}}{9.32 \times 10^{-3}\,\text{mol e}^-}$ = » 96,600 «C mol^{-1}» / 9.66 x 10^4 «C mol^{-1}» ✓	*Accept 96,613 «C mol^{-1}».* *Do **not** accept 96,500 «C mol^{-1}».* *Award **[2]** for correct final answer.*	**2**
4.	c		K_{sp} =$[Cu^{2+}] \times [OH^-]^2$ ***OR*** «$[Cu^{2+}]$ = » $\frac{2.2 \times 10^{-20}}{(1.0 \times 10^{-4})^2}$ ✓ «$[Cu^{2+}]$ = » 2.2×10^{-12} «mol dm^{-3}» ✓	*Award **[2]** for correct final answer.*	**2**
4.	d		non-bonding/lone pair electrons on S ***AND*** N ✓ bond to «empty» d-orbital of copper «ion»/Cu^{2+} ✓ forms two «coordination» bonds «to Cu^{2+}» ✓	*Accept O in place of either S or N for M1.* *Do **not** accept three coordination bond formation (since bidentate) involving S, N and O for M3.*	**3**

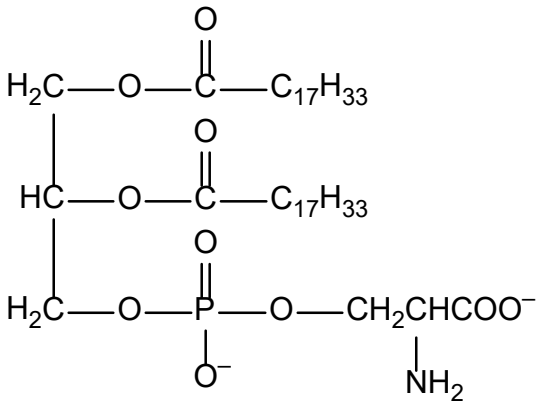
Question			Answers	Notes	Total
5.	**a**		Type 1 has sharp transition **«**to superconducting**»** ***AND*** Type 2 has gradual transition ***OR*** Type 1 has lower critical temperature/T_c ***OR*** Type 1 **«**most**»** metals ***AND*** Type 2 alloys/metal oxide ceramics/perovskites/composites ✓		**1**
5.	**b**		*Any three of:* **«**moving**»** electron attracts **«**nearby**»** positive charges/ions/cations ✓ creates **«**local**»** regions of increased positive charge ✓ positive charge/field attracts second electron **«**with opposite spin**»** ✓ two electrons form a Cooper pair ✓ **«**all**»** Cooper pairs **«**in sample**»** interact/form **«**electron**»** condensate ✓ **«**electron**»** condensate/Cooper pairs move/flow **«**through sample**»** freely/without resistance ✓		**3 max**

Option B — Biochemistry

Question			Answers	Notes	Total
6.	**a**		covalent **«**bonding**»** ***OR*** peptide «bond» ***OR*** amide «bond» ✓	*Do **not** accept "amino acid sequence".*	**1**

Question			Answers	Notes	Total
6.	b	i	*Any three of:* break down/hydrolyse polypeptide **«**to amino acids using HCl**»** ✓ sample spotted on paper/stationary phase ***AND*** solvent moves up the paper ***OR*** continuous cycles of adsorption and desorption/dissolution ***OR*** analyte moves when in solvent ***AND*** does not move when on paper ✓ components «in mixture» have different attractions to mobile phase ***AND*** stationary phase/paper ***OR*** «amino acids» separated based on solubilities in/affinity to the two phases ***OR*** separated based on polarities/polar attractions/molar masses «of amino acids» ✓ developed with ninhydrin/reagent/locating agent ***OR*** identified with ultraviolet/UV «light» ✓ calculate R_f /retention factor of each spot ***OR*** compare R_f /retention factor to known values ✓	*No marks awarded for separation based on electrophoresis.* *R_f/retention factor must be stated explicitly.*	**3 max**

Question			Answers	Notes	Total
6.	b	ii	 ✓	*Positive charge **must** be on N for mark.* *Penalize incorrect bond connectivity or missing hydrogens once only in Option B.*	**1**
6.	c		«0.5000 = 0.3826 × [protein] – 0.0015» «[protein] =» 1.311 «mg cm^{-3}» ✓		**1**

Question			Answers	Notes	Total
7.	a		 phosphodiester correctly drawn ✓ both ester groups correctly drawn ✓	*Accept protonated phosphate/serine.* *Accept phosphodiester located in top or centre position also.* *Penalize incorrect bond connectivity or missing hydrogens once only in Option B.* *Do **not** accept R, unless specifically identified.*	**2**
7.	b	i	stearic acid ***AND*** stronger London/dispersion/«instantaneous» induced dipole-induced dipole forces ✓ saturated/no C=C bond ***OR*** molecules pack closer together ***OR*** no kinks in the chain ✓	*Accept "stearic acid **AND** stronger intermolecular/van der Waals/vdW forces" for M1.* *Accept "greater surface area/electron density" for M2.* *Do **not** accept "no double bond" alone.* *Do **not** accept arguments based on size/molar mass/molecular mass of molecule.* *Do **not** award ECF for linoleic acid in M2.*	**2**

Question			Answers	Notes	Total
7.	b	ii	*Advantage:* increased melting point ***OR*** decreased rate of oxidation ***OR*** longer shelf life ***OR*** spreadability ***OR*** less expensive/more profitable ✓ *Disadvantage:* formation of trans fats ***OR*** may increase levels of low-density lipoprotein/LDL ***OR*** increased risk of atherosclerosis/cholesterol deposition ***OR*** increased risk of heart attack/stroke cardiovascular/heart disease/CHD ✓	*Do **not** accept converse of a stated advantage as a disadvantage.* *Accept answers around hydrogenation process and industry for Disadvantage such as "use of «potentially toxic» metals as catalysts", "«explosive» hydrogen", "energy demand" etc.* *Accept "bad cholesterol" for LDL.*	**2**

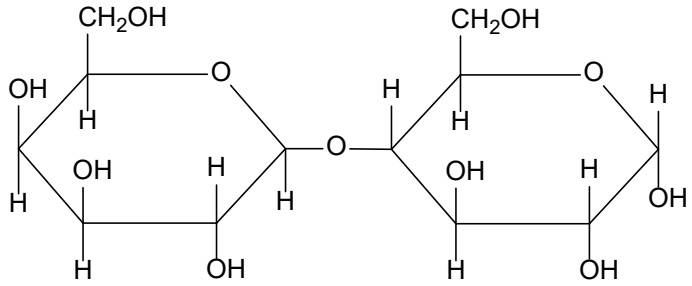
<table>
<tr><th colspan="3">Question</th><th>Answers</th><th>Notes</th><th>Total</th></tr>
<tr><td>7.</td><td>c</td><td></td><td>
<table>
<tr><th></th><th>Hydrolytic</th><th>Oxidative</th></tr>
<tr><td>Site of reactivity</td><td>ester «group»/
-OCO-</td><td>C=C/carbon to carbon double bond/alkene</td></tr>
<tr><td>Conditions that favour reaction</td><td>«high» moisture
OR
acid «conditions»
OR
enzymes/lipases/
bacteria</td><td>ultraviolet/
UV/light
OR
metal ions
OR
O_2/oxygen/
air</td></tr>
</table>
✓✓
</td><td>Award [1] for any two correct answers.

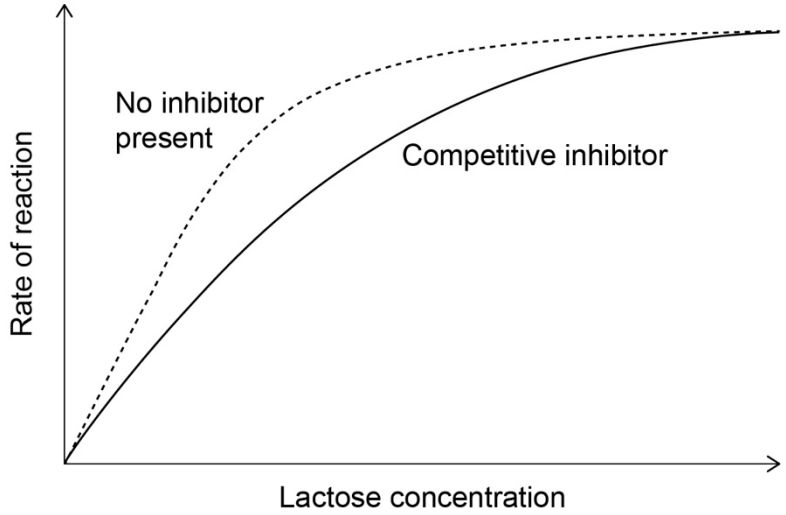
Award [2] for all four correct.

Do not accept “temperature change/heat” as a condition.

Do not accept “double bond” alone for site of oxidative rancidity.

Do not accept “enzymes” for oxidative rancidity.</td><td>2</td></tr>
</table>

Question			Answers	Notes	Total
8.	a	i	 glycosidic link ✓ orientation of all bonds ***AND*** correct atoms ✓	*M1 is scored for C-O-C in glycosidic link.* *Do **not** penalize for position of hydrogens in glycosidic link.* *Penalize incorrect bond connectivity or missing hydrogens once only in Option B.*	**2**
8.	a	ii	condensation «reaction» ✓		**1**

Question			Answers	Notes	Total
8.	b	i	 curve to right of original ***AND*** curve ends at same V_{max} ✓		**1**
8.	b	ii	increase ***AND*** substrate must outcompete inhibitor ***OR*** increase ***AND*** inhibitor blocks active site/prevents substrate from reaching active site ✓	*Reference to mechanism of action of competitive inhibitor required for mark*.	**1**
8.	c		rickets ***OR*** osteoporosis/weak bones/osteomalacia ✓		**1**

Question			Answers	Notes	Total
9.	a		chemicals found in an organism/environment/organic substances that are foreign/not normally present ✓	*Do **not** accept an answer based around the biomagnification of the xeonbiotic.*	1
9.	b		«both» selectively bind/bond ***OR*** «both can» bond non-covalently ***OR*** reversible ✓	*Do **not** accept "specifically bind" as this is rare for synthetic host molecules.*	1
9.	c		removal of radioactive isotope/Cs-137/heavy metals ***OR*** removal of aromatic amines ***OR*** removal of N-nitroso compounds ***OR*** removal of PCB's/polychlorinated biphenyls ***OR*** removal of dioxins ✓	*Accept "removal of radioactive caesium/material".* *Accept "removal of caesium".* *Accept other reasonable example.* *Do **not** accept "removal of plastic".*	1

Question			Answers	Notes	Total
10.	**a**		red ✓ «wavelength of maximum absorbance» 530 «nm»/green ***AND*** shows complementary colour ✓	*Accept any value in the range 520–540 «nm» in M2.*	**2**
10.	**b**		conjugated system is changed «in basic pH due to deprotonation» ✓ absorbs different wavelength «in basic pH» ***OR*** appears different colour «in basic pH» ✓	*Award **[1 max]** for "protonation/deprotonation".*	**2**

Question			Answers	Notes	Total
11.	**a**		*Any two of:* RNA has ribose ***AND*** DNA has deoxyribose ✓ RNA contains uracil/U ***AND*** DNA contains thymine/T ✓ RNA is a single strand ***AND*** DNA is a double helix ✓	*Accept "strand/helix".* *Accept "RNA forms an A-helix **AND** DNA forms a B-helix".*	**2 max**
11.	**b**		larger set of data ✓	*Accept other valid reason not related to improved technology, such as improved algorithms, changes in legal requirements etc.*	**1**

Option C — Energy

Question			Answers	Notes	Total
12.	**a**		energy needed to separate «a nucleus into» protons and neutrons/nucleons ***OR*** energy released when nucleus formed **«**from protons and neutrons**»** ✓		**1**
12.	**b**	**i**	mass defect = $\sum$(p + n) – ^{2}H ***OR*** **«**mass defect =**»** 1.672622 × 10^{-27} **«**kg**»** + 1.674927 × 10^{-27} **«**kg**»** – 3.343583 × 10^{-27} **«**kg**»** = 3.966 × 10^{-30} **«**kg**»** ✓ «nuclear binding energy = Δmc^2 = 3.966 × 10^{-30} kg × (3.00 × 10^8)^2 =**»** 3.57 x10^{-13} **«**J**»** ✓	*Award **[2]** for correct final answer.*	**2**
12.	**b**	**ii**	4 × binding energy per nucleon (BEN) ^{4}He – (2 × BEN ^{2}H + 3 × BEN ^{3}H) ***OR*** 4 × 7.1 **«**MeV**»** – (2 × 1.1 **«**Mev**»** + 3 × 2.8 **«**MeV**»**) ✓ **«**28.4 – 2.2 – 8.4 =**»** 17.8 **«**MeV**»** ✓	*Accept answers in range 17.4–18.2 **«**MeV**»**.* *Award **[2]** for correct final answer.* *Do **not** penalize a negative sign.* *Award **[1 max]** in range 2.9-3.5 **«**MeV**».***	**2**
12.	**c**	**i**	**«**$\frac{193.4\ \text{MeV} \times 1.60 \times 10^{-19}\ \text{MJ MeV}^{-1} \times 6.02 \times 10^{23}\ \text{mols}^{-1}}{235\ \text{g mol}^{-1}}$ **=»** 7.93 × 10^4 **«**MJ g^{-1}**»** ✓		**1**

Question			Answers	Notes	Total
12.	c	ii	specific energy ***AND*** low density ***OR*** specific energy ***AND*** a small mass occupies a large volume ✓	*Do **not** accept "specific energy **AND** gas/gaseous" alone*.	**1**
12.	d	i	${}^{235}_{92}\text{U} \rightarrow {}^{231}_{90}\text{Th} + {}^{4}_{2}\text{He}$ ✓	*Accept "α" for helium-4 species in equation.* *Do **not** penalize missing atomic numbers.* *Penalize incorrect atomic numbers.*	**1**
12.	d	ii	**Alternative 1:** «$\frac{1}{0.03125} = 2^n$» $n = 5$ «half-lives» ✓ «25.5 × 5 half-lives = » 127.5 «hours» ✓ **Alternative 2:** $t = t_{\frac{1}{2}} \times \frac{ln\left(\frac{N_0}{N}\right)}{ln\,2}$ ✓ «$25.5 \times \frac{ln\left(\frac{1.000}{0.03125}\right)}{ln\,2} =$ » 127.5 «hours» ✓	*Award **[2]** for correct final answer.*	**2**

Question			Answers	Notes	Total
13.	**a**	**i**	*Carbon dioxide:* absorbs infrared radiation/IR ✓ bending/stretching/vibration **«**of bonds**»** ✓ *Chlorophyll:* absorbs visible light ✓ electron excitation/promotion/release ✓	*Do **not** accept "traps" for "absorbs".* *Do **not** accept "reflects «green» visible light" for M3.*	**4**
13.	**a**	**ii**	*Carbon dioxide*: 10^{-4} to 10^{-6} «m» ***AND*** *Chlorophyll*: 400 to 700 «nm» ✓	*Accept any range inside the given range.* *Accept Carbon dioxide: infrared/IR **AND** Chlorophyll: visible/Vis.* *Ignore incorrect or missing units.*	**1**
13.	**b**		infrared/IR **«**radiation**»** from earth's surface absorbed **«**by bonds of greenhouse gasses**»** in the **«**lower**»** atmosphere ✓ lower amounts **«**of re-radiated IR**»** reach upper atmosphere ✓	*Do **not** accept "heat for infrared/IR" in M1.* *Do **not** accept "greenhouse gases trap infrared/IR radiation" alone for M1.*	**2**

Question			Answers	Notes	Total
13.	**c**		large surface area ***AND*** increases light absorption/chance photon will be absorbed ✓ **«**dye allows absorption of a**»** wide range of wavelengths ***OR*** dye converts most/all absorbed photons into electrons ✓		**2**

Question			Answers	Notes	Total
14.	**a**		reduction/loss of oxygen/gain of hydrogen ✓	*Accept "decomposition".*	**1**
14.	**b**		methane/CH_4 «(g)» ✓		**1**
14.	**c**		*Advantage:* *Any one of:* cleaner combustion/less soot/ash ✓ less CO_2 per unit of heat ✓ lower carbon footprint ✓ higher specific energy ✓ *Disadvantage:* *Any one of:* highly combustible/explosive ✓ emits greenhouse gas/methane/CH_4 if leaks occur ✓ lower energy density ✓ transported under pressure ✓ difficult to detect leaks ✓	*Do **not** accept converse of stated advantage for disadvantage.* *Accept "easy to transport/no need to store locally" as an advantage.* *Do **not** accept vague answers such as "less pollution" **OR** "clean fuel" **OR** "less CO_2 produced" for Advantage or "hazardous" for Disadvantage.* *Accept "odourless" as a Disadvantage.*	**2 max**

Question			Answers	Notes	Total
14.	**d**		coal more plentiful **«**than crude oil**»** ***OR*** **«**can be**»** produced from renewable source ***OR*** **«**can be**»** carbon neutral ***OR*** can undergo liquefaction to form octanes ***OR*** **«**can be**»** produced by gasification underground ***OR*** coal gasification produces other usable products/slag ✓	*Accept "easy to capture/store **«**to not release CO_2 to the atmosphere**»**.* *Accept "carbon capture as part of the process".*	**1**

Question			Answers	Notes	Total
15.	**a**		*Negative electrode (anode):* $CH_3COO^-(aq) + 2H_2O(l) \rightarrow 2CO_2(g) + 7H^+(aq) + 8e^-$ ✓ *Positive electrode (cathode):* $O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$ ✓	*Award **[1 max]** for correct half-equations at wrong electrodes.* *Accept any correct fractional or multiple coefficients.* *Ignore equilibrium sign.*	**2**
15.	**b**		*Fuel cells:* refilled ***AND*** with fuel/hydrogen/methanol/reducing agent ✓ *Secondary cells*: recharged ***AND*** by reversing **«**chemical**»** reaction ***OR*** recharged ***AND*** by external power source ✓	*Award **[1 max]** for Fuel cells: refilled **AND** Secondary cells: recharged with no or incorrect details given.*	**2**
15.	**c**		«$E = E^\theta - \frac{RT}{nF} \ln» \frac{[Mg^{2+}]}{[Ag^+]^2}$ ***OR*** ***«****E* = 3.17 – $\frac{8.31 \times 298}{2 \times 96\,500}$ ln**»** $\frac{2.00}{(0.0100)^2}$ ✓ = **«**3.17 – 0.0128 × 9.90 = 3.17 – 0.127 =**»** 3.04 **«**V**»** ✓	*Award **[2]** for correct final answer.* *Award **[1 max]** for 3.10 «V».*	**2**

Option D — Medicinal chemistry

Question			Answers	Notes	Total
16.	**a**		*Site of action:* **«**at the**»** source/«site of» pain/injury ✓ *Mode of action:* interferes with the production of substances that cause pain/swelling/fever ***OR*** blocks the production/formation of prostaglandins ***OR*** cyclooxygenase enzyme/COX inhibition ✓		**2**
16.	**b**	**i**	**«**melts**»** over a **«**larger**»** range of temperatures ✓ observed **«**melting point**»** is lower than accepted value ✓	*Do **not** accept "different than accepted value" for M2.*	**2**
16.	**b**	**ii**	3200–3600 **«**cm^{-1}**»** ✓	*Accept any value/range within the range.*	**1**

Question			Answers	Notes	Total
16.	**c**		drugs broken down/metabolized from digestive system ***OR*** not all «of the drug is» absorbed ✓	*Accept "drugs not easily absorbed from digestive system" **OR** "oral drugs have slower absorption and distribution than IV drugs" **OR** '"drugs affected by acid" **OR** "pass through digestive system" .* *Do **not** accept "IV administration has 100% bioavailability **AND** oral administration does not" - reason must be stated.*	**1**
16.	**d**		*Any two of:* morphine has «two» hydroxyl «groups» ***AND*** diamorphine has «two» ester/ethanoate/acetate «groups» ✓ morphine is more polar than diamorphine ***OR*** groups in morphine are replaced with less polar/non-polar groups in diamorphine ✓ morphine is «more» soluble in blood «plasma» ***OR*** diamorphine is «more» soluble in lipids ***OR*** diamorphine is more soluble in non-polar environment of CNS/central nervous system than morphine ✓ diamorphine crosses the blood–brain barrier/BBB in greater concentration/more rapidly/easily ✓	*Accept "heroin" for "diamorphine".* *Accept formulas. Accept "hydroxy" for "hydroxyl" but **not** "hydroxide". Accept "acyl" for "ester «groups»".* *Do **not** accept just "diamorphine is non-polar" for M2.* *Accept "morphine soluble in water «medium»" for M3.* *Accept "fats" for "lipid".* *Do **not** accept "diamorphine crosses blood-brain barrier/BBB" alone without reference to rate or concentration.*	**2 max**

Question			Answers	Notes	Total
16.	**e**		Diamorphine ester/carbonyl **«**groups**»** ***AND*** peaks **«**around**»** 1700–1750 **«**cm^{-1}**»** ✓ absence of hydroxyl/phenol **«**groups**»** ***AND*** absence of peak **«**around**»** 3200–3600 **«**cm^{-1}**»** ✓	*Do not award mark for mentioning diamorphine alone.* *If morphine selected, no marks awarded.* *Accept any value(s) within the range.*	**2**

Question			Answers	Notes	Total
17.	a		inhibits the secretion of stomach acid/H^+ ✓ «active metabolites» bind «irreversibly» to «receptors of the» proton pump ✓	*Accept "PPI/proton pump inhibitor" for M2.* *Accept '"specific H+/K+ATPase inhibitor"' for M2.* *Do **not** accept "binds to H2/histamine receptors" for M2.* *Accept "H^+/K^+ ATPase" for "proton pump".*	**2**
17.	b		$NaHCO_3$ (aq) + HCl (aq) → H_2O (l) + CO_2 (g) + NaCl (aq) ✓	*Correct state symbols must be included.* *Accept net ionic equation.* *Do **not** accept "H_2CO_3(aq)".*	**1**
17.	c		no ***AND*** «mode of action is to» inhibit acid production ***OR*** no ***AND*** «mode of action» does not neutralize acid ✓	*Do **not** accept answers that only describe binding to H2 receptors.*	**1**
17.	d		omeprazole ***AND*** presence of aromatic ring/benzene/phenyl «H atom» ✓	*Accept identification of omeprazole (either named or drawn) with a clear indication of the presence of the proton on the aromatic ring.*	**1**

Question			Answers	Notes	Total
18.	**a**	**i**	inhibit/bind neuraminidase **«**found on surface of influenza virus**»** ✓ prevents virus from leaving **«**host**»** cell ✓	*Accept "enzyme" for "neuraminidase".* *Do **not** award M2 if response also states "prevents virus from entering cell".*	**2**
18.	**a**	**ii**	genetic engineering of bacteria **«**to produce shikimic acid**»** ***OR*** extraction/isolation **«**of shikimic acid**»** sourced from pine needles/other sources ***OR*** suspension cultures of **«**Indian**»** sweetgum tree ✓ **«**synthesis no longer depends on**»** star anise **«**which is**»** in limited supply ***OR*** less waste/energy/**«**organic**»** solvents/steps ***OR*** improves atom economy ✓	*Accept "sourced from pine needles/other sources" **OR** "sourced from **«**Indian**»** sweetgum tree".*	**2**

Question			Answers	Notes	Total
18.	b	i	*Any two of:* ring is «sterically» strained ***OR*** angles of 90° instead of 109.5/109/120° angles ***OR*** angles smaller than 109.5/109/120°/tetrahedral/trigonal planar/triangular planar angle ✓ ring breaks up/opens/reacts «easily» ***OR*** amido/amide group «in ring» is «highly» reactive ✓ «irreversibly» binds/bonds to enzyme/transpeptidase ***OR*** inhibits enzyme/transpeptidase «in bacteria» that produces cell walls ✓ prevents transpeptidase/enzyme from catalyzing the cross-linking «in the cell wall» ***OR*** weakens bacterial cell wall ✓	*Accept arguments using correct descriptions of hybridization for M1.* *Do **not** accept "breaks/binds to cell walls" – a reference to the enzyme is needed for alternatives 1 and 2 for M3.* *Do **not** accept "cell membrane" for "cell wall" in M3 or M4.*	**2 max**
18.	b	ii	current medication ineffective ***OR*** new antibiotic/drugs must be developed ✓	*Accept "creation of superbugs".* *Do **not** accept answers related to health effects **OR** costs.*	**1**

Question			Answers	Notes	Total
19.	**a**	**i**	hair loss ***OR*** nausea ***OR*** fatigue ***OR*** loss of appetite ***OR*** sterility ***OR*** **«**localized**»** tissue damage ***OR*** secondary cancers ✓	*Accept any other valid side effect.*	**1**
19.	**a**	**ii**	low ionizing **«**power**»** ***OR*** high penetration **«**power**»** ✓	*Accept "less damage to tissue".*	**1**
19.	**a**	**iii**	${}^{177}_{71}\text{Lu} \rightarrow {}^{177}_{72}\text{Hf} + {}^{0}_{-1}\text{e}^{-}$ ✓	*Do **not** penalize missing atomic numbers.* *Penalize incorrect atomic numbers.* *Ignore the inclusion of the antineutrino,* ${}^{0}_{0}\overline{\nu}$ *.* *Accept "*β*,* β^{-}*,* ${}^{0}_{-1}\beta^{-}$*, etc." for "* ${}^{0}_{-1}\text{e}^{-}$ *".*	**1**

Question			Answers	Notes	Total
19.	**a**	**iv**	**ALTERNATIVE 1:** $\lambda = «\frac{\ln 2}{t_{\frac{1}{2}}} = \frac{\ln 2}{6.71}\text{ days} =» 0.103$ «days^{-1}» ✓ N = «$N_0 e^{-\lambda t} = 2.00\,\mu g\ e^{(-0.103\ \text{days}^{-1} \times 7\ \text{days})}$ =» 0.970 «μg» ✓ **ALTERNATIVE 2:** «$\frac{7\text{ days}}{6.71\text{ days}}$ =» 1.04 «half-lives passed» ✓ «mass remaining = 2.00 μg × $(0.5)^{1.04}$ =» 0.970 «μg» ✓	*Award **[2]** for correct final answer.* *Accept any value in range 0.968–0.972 «μg».*	**2**
19.	**b**	**i**	added/connected/attached «to substrate» ***AND*** removed «at the end of the synthesis to obtain desired product» ✓ one enantiomer produced ***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 ✓		**2**
19.	**b**	**ii**	H_2O/water ✓	*Accept OH containing a heavier isotope of hydrogen or oxygen.* *Ignore charge on H_2O.*	**1**