

Markscheme

November 2019

Chemistry

Standard level

Paper 3

33 pages

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Subject Details: Chemistry SL Paper 3 Markscheme**Mark Allocation**

Candidates are required to answer **ALL** questions in Section A [**15 marks**] and all questions from **ONE** option in Section B [**20 marks**].
Maximum total = [**35 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		best-fit smooth curve ✓	<i>Do not accept a series of connected lines that pass through all points OR any straight line representation.</i>	1
1.	b	i	tangent drawn at time zero ✓ g day ⁻¹ ✓ 0.16 ✓	<p><i>Accept other reasonable units for initial rate eg, mol dm⁻³ s⁻¹, mol dm⁻³ min⁻¹, g s⁻¹ OR g min⁻¹.</i></p> <p><i>M3 can only be awarded if the value corresponds to the correct unit given in M2.</i></p> <p><i>Accept values for the initial rate for M3 in the range:</i> <i>0.13 – 0.20 g day⁻¹ OR</i> <i>1.5 × 10⁻⁶ g s⁻¹ – 2.3 × 10⁻⁶ g s⁻¹ OR</i> <i>7.5 × 10⁻⁸ – 1.2 × 10⁻⁷ mol dm⁻³ s⁻¹ OR</i> <i>4.5 × 10⁻⁶ – 6.9 × 10⁻⁶ mol dm⁻³ min⁻¹</i> <i>OR 9.0 × 10⁻⁵ – 1.4 × 10⁻⁴ g min⁻¹ OR</i> <i>a range based on any other reasonable unit for rate.</i></p> <p><i>Ignore any negative rate value.</i></p> <p><i>Award [2 max] for answers such as 0.12/0.11 g day⁻¹, incorrectly obtained by using the first two points on the graph (the average rate between t = 0 and 1 day).</i></p> <p><i>Award [1 max] for correctly calculating any other average rate.</i></p>	3

(continued...)

(Question 1b continued)

Question			Answers	Notes	Total
1.	b	ii	acid used up OR acid is the limiting reactant ✓ concentration of acid decreases OR less frequent collisions ✓	Award [1 max] for "surface area decreases" if the idea that "CaCO ₃ is used up/acts as the limiting agent" is conveyed for M1. Do not accept "reaction reaches equilibrium" for M2.	2

(continued...)

(Question 1b continued)

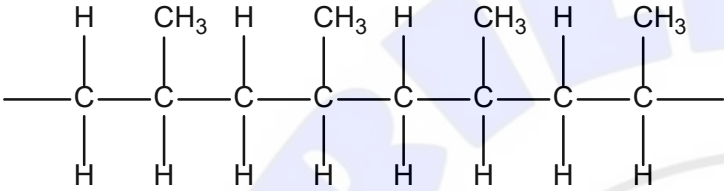
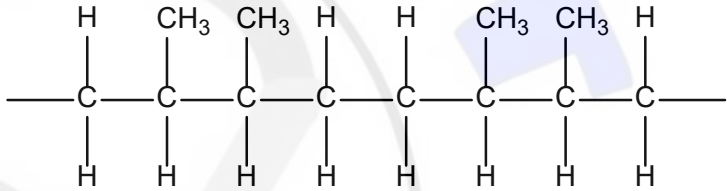
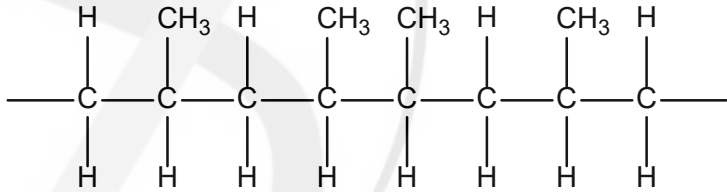
Question			Answers	Notes	Total
1.	b	iii	surface area not uniform OR limestone pieces do not have same composition/source OR limestone absorbed water «which increased mass» OR acid removed from solution when limestone removed OR «some» calcium sulfate deposited on limestone lost OR pieces of paper towel may have stuck to limestone OR beakers not covered/evaporation OR temperature not controlled ✓	Accept “acids impure”. Accept “«limestone» contains impurities”. Accept “loss of limestone when dried” OR “loss of limestone due to crumbling when removed from beaker”.	1
1.	c	i	sulfuric acid is diprotic/contains two H ⁺ «while nitric acid contains one H ⁺ »/releases more H ⁺ «so reacts with more limestone» OR higher concentration of protons/H ⁺ ✓	Ignore any reference to the relative strengths of sulfuric acid and nitric acid. Accept “sulfuric acid has two hydrogens «whereas nitric has one»”. Accept “dibasic” for “diprotic”.	1
1.	c	ii	calcium sulfate remained/deposited on limestone «in sulfuric acid» OR reaction prevented/stopped by slightly soluble/deposited layer of calcium sulfate ✓	Answer must refer to calcium sulfate.	1

Question			Answers	Notes	Total
2.	a	i	<p>Ethanal using Pt/C: decreases ✓</p> <p>Carbon dioxide using PtRu/C: «generally» increases AND then decreases ✓</p>	<p>Accept “no clear trend/pattern” OR “increases and decreases” OR “increases, reaches a plateau and «then» decreases” for M2.</p>	2
2.	a	ii	<p>From ethanol to ethanal: -2 to -1 OR +1/increases by 1 ✓</p> <p>From ethanol to carbon dioxide: -2 to +4 OR +6/increases by 6 ✓</p>	<p>Do not accept 2- to 1-.</p> <p>Do not accept 2- to 4+.</p> <p>Do not penalize incorrect notation twice.</p> <p>Penalize incorrect oxidation state value of carbon in ethanol once only.</p>	2
2.	a	iii	ethanal < ethanoic acid < carbon dioxide ✓	<p>Accept formulas.</p> <p>No ECF from 2a ii calculations.</p>	1
2.	b		Pt/platinum/PtC AND highest yield of CO ₂ «at all voltages» ✓	ECF from 2a iii.	1

Section B

Option A — Materials

Question		Answers	Notes	Total																					
3.	a	<p>reactant(s) adsorb onto active sites/surface ✓</p> <p>«reactant» bonds weakens «and products are desorbed» ✓</p>	<p>Do not accept “absorb” for “adsorbs” for M1. Accept “bonds to” for “adsorb” for M1.</p> <p>Accept “bonds break/stretch «and products are desorbed»” for M2</p> <p>Award [1 max] for “lowers activation energy”.</p>	2																					
3.	b	<p>Any one of the following:</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 50%; text-align: center;"><i>Heterogeneous catalysts</i></th> <th style="width: 10%; text-align: center;">AND</th> <th style="width: 40%; text-align: center;"><i>Homogeneous catalysts</i></th> </tr> </thead> <tbody> <tr> <td>«solution of» different phase/state to reactants</td> <td style="text-align: center;"> </td> <td>same phase/state as reactants ✓</td> </tr> <tr> <td>do not change</td> <td style="text-align: center;"> </td> <td>react and are regenerated ✓</td> </tr> <tr> <td>do not form intermediate/activated complex</td> <td style="text-align: center;"> </td> <td>form intermediate/activated complex ✓</td> </tr> <tr> <td>reactions at higher temperatures</td> <td style="text-align: center;"> </td> <td>reactions at lower temperatures ✓</td> </tr> <tr> <td>less selective</td> <td style="text-align: center;"> </td> <td>more selective ✓</td> </tr> <tr> <td>recovery easier/cheaper</td> <td style="text-align: center;"> </td> <td>recovery more difficult/expensive ✓</td> </tr> </tbody> </table>	<i>Heterogeneous catalysts</i>	AND	<i>Homogeneous catalysts</i>	«solution of» different phase/state to reactants		same phase/state as reactants ✓	do not change		react and are regenerated ✓	do not form intermediate/activated complex		form intermediate/activated complex ✓	reactions at higher temperatures		reactions at lower temperatures ✓	less selective		more selective ✓	recovery easier/cheaper		recovery more difficult/expensive ✓	<p>Accept “heterogeneous adsorb reactants and homogeneous” but do not accept “absorb” for “adsorb”.</p> <p>Accept “heterogeneous have active sites and homogeneous do not”.</p>	1 max
<i>Heterogeneous catalysts</i>	AND	<i>Homogeneous catalysts</i>																							
«solution of» different phase/state to reactants		same phase/state as reactants ✓																							
do not change		react and are regenerated ✓																							
do not form intermediate/activated complex		form intermediate/activated complex ✓																							
reactions at higher temperatures		reactions at lower temperatures ✓																							
less selective		more selective ✓																							
recovery easier/cheaper		recovery more difficult/expensive ✓																							
3.	c	<p>high temperature used ✓</p> <p>oxygen/O₂ reacts with carbon/C</p> <p>OR</p> <p>carbon dioxide/CO₂ can form ✓</p>		2																					

Question		Answers	Notes	Total
4.	a		<p>Continuation bonds must be shown.</p> <p>Ignore square brackets and "n".</p> <p>Do not accept one repeating unit in square brackets with a subscript of 4.</p> <p>Accept condensed structure provided all C to C bonds are shown and CH₃ groups on same side.</p> <p>Accept</p>  <p>OR</p>  <p>Do not accept syndiotactic (alternating orientation of the CH₃ groups).</p>	1
4.	b	<p>isotactic «has higher melting point» AND ordered chains pack more closely</p> <p>OR</p> <p>isotactic «has higher melting point» AND stronger intermolecular/London/dispersion forces ✓</p>	<p>Accept "van der Waals' forces"/"vdW".</p>	1
4.	c	<p>softens when heated «and hardens when cooled» ✓</p>		1

Question		Answers	Notes	Total
4.	d	<p>Any two of:</p> <p>collection/transportation of plastic waste ✓</p> <p>separation of different types «of plastic»</p> <p>OR</p> <p>separation of plastic from other materials ✓</p> <p>melting plastic ✓</p> <p>processing/washing/cleaning/drying/manufacture of recycled plastic ✓</p>		2 max

Question			Answers	Notes	Total
5.	a		ions of more reactive metals are harder to reduce OR more reactive metals have more negative electrode potentials ✓ electrolysis is needed/used for the most reactive metals OR carbon is used to reduce metal oxides of intermediate reactivity/less reactive than carbon OR heating ore is sufficient for less reactive metals ✓	Award [1 max] for “«ease of reduction/extraction» depends on reactivity”.	2
5.	b	i	electronegativity difference = 1.8 «and average electronegativity = 2.5» ✓ 57 «%» ✓	Accept any value in the range 52–65%. Award [2] for correct final answer.	2


(continued...)

(Question 5b continued)

Question			Answers	Notes	Total
5.	b	ii	<p><i>Anode (positive electrode):</i> $2\text{O}^{2-} \rightarrow 4\text{e}^{-} + \text{O}_2(\text{g})$</p> <p>OR</p> <p>$2\text{O}^{2-} + \text{C} \rightarrow 4\text{e}^{-} + \text{CO}_2(\text{g}) \checkmark$</p> <p><i>Cathode (negative electrode):</i> $\text{Al}^{3+} + 3\text{e}^{-} \rightarrow \text{Al}(\text{l}) \checkmark$</p> <p>$\text{O}_2$ gas AND Al liquid \checkmark</p>	<p>Award [1 max] for M1 and M2 if correct half-equations are given at the wrong electrodes OR if incorrect reversed half-equations are given at the correct electrodes.</p> <p>Only state symbols of products required, which might be written as (g) and (l) in half-equations. Ignore any incorrect or missing state symbols for reactants.</p>	3

Question		Answers	Notes	Total
6.	a	molecules point/align in same direction/orientation OR molecules have directional order ✓ molecules are randomly distributed OR molecules are not in a layered arrangement OR molecules do not have positional order ✓	<i>Accept suitable diagram for M1 and M2.</i>	2
6.	b	molecules align with field ✓		1

Option B — Biochemistry

Question		Answers	Notes	Total
7.	a	 <p>amide link (eg, CONH) ✓ correct order and structure of amino acids ✓</p>	<p>Accept a skeletal formula or a full or condensed structural formula.</p> <p>Accept zwitterion form of dipeptide.</p> <p>Accept CO–NH but not CO–HN for amide link.</p>	2
7.	b	<p>«Asp isoelectric point lower than Phe and » Phe has a neutral/hydrocarbon side chain ✓ Asp side chain contains –COOH/carboxyl ✓</p>	<p>Award [1 max] for “Asp has two carboxyl/–COOH groups and Phe has one carboxyl/–COOH group”.</p> <p>Accept “Asp has an acidic side chain” for M2</p>	2

Question		Answers	Notes	Total
8.	a	enzyme denatures OR change of conformation/shape of active site OR substrate cannot bind to active site/binds less efficiently ✓	Accept "change in structure" or "substrate doesn't fit/fits poorly into active site"	1
8.	b	Any two of: acidic/basic/ionizable/COOH/carboxyl/NH ₂ /amino groups in the R groups/side chains «react» ✓ exchange/lose/gain protons/H ⁺ ✓ change in H-bonds/ionic interactions/intermolecular forces/London dispersion forces ✓	Do not accept "enzyme denatures" OR "change of conformation/tertiary structure" OR "substrate cannot bind to active site/binds less efficiently" as this was the answer to 8(a).	2 max
8.	c	breakdown of oil spills/industrial/sewage waste/plastics OR production of alternate sources of energy «such as bio diesel» OR involve less toxic chemical pathway «in industry» ✓	Accept "«enzymes in» biological detergents can improve energy efficiency".	1

Question		Answers	Notes	Total
9.	a	«one C=C bond» «1 mole iodine : 1 mole oleic acid» $\left\langle \frac{100 \times 253.80}{282.46} \Rightarrow 89.85 \text{ «g of } I_2 \text{»} \right\rangle \checkmark$	Accept 90 «g of I_2 ».	1
9.	b	atherosclerosis/cholesterol deposition «in artery walls»/increases risk of heart attack/stroke/cardiovascular disease/CHD \checkmark	Accept “arteries become blocked/walls become thicker”, “increases blood pressure”, OR “blood clots”. Do not accept “high cholesterol” OR “obesity”	1
9.	c	no kinks in chain/more regular structure OR straight chain OR no C=C/carbon to carbon double bonds OR saturated OR chains pack more closely together \checkmark stronger London/dispersion/instantaneous induced dipole-induced dipole forces «between molecules» \checkmark	Accept “greater surface area/electron density” for M1. Accept “stronger intermolecular/van der Waals’/vdW forces” for M2.	2


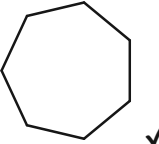
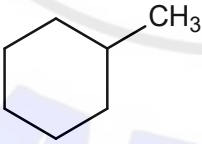
Question			Answers	Notes	Total
9.	d	i	<p><i>Similarity:</i></p> <p>«derived from» propane-1,2,3-triol/glycerol/glycerin/glycerine</p> <p>OR</p> <p>«derived from» at least two fatty acids</p> <p>OR</p> <p>contains ester linkages</p> <p>OR</p> <p>long carbon chains ✓</p> <p><i>Difference:</i></p> <p>phospholipids contain two fatty acids AND triglycerides three</p> <p>OR</p> <p>phospholipids contain phosphate/phosphato «group»/residue of phosphoric acid AND triglycerides do not ✓</p>	<p><i>Do not accept “two fatty acids as both a similarity and a difference”.</i></p> <p><i>Do not accept just “hydrocarbon/carbon chains”.</i></p> <p><i>Accept “phospholipids contain phosphorus AND triglycerides do not”.</i></p> <p><i>Accept “phospholipids are amphiphilic AND triglycerides are not” OR “phospholipids have hydrophobic tails and hydrophilic heads AND triglycerides do not”.</i></p>	2
9.	d	ii	<p>«concentrated» NaOH (aq)/sodium hydroxide</p> <p>OR</p> <p>«concentrated» HCl (aq)/hydrochloric acid</p> <p>OR</p> <p>enzymes/lipases ✓</p>	<p><i>Accept other strong acids or bases.</i></p>	1

Question		Answers	Notes	Total
10.	a	hydroxyl ✓	Accept "hydroxy" but not "hydroxide". Accept "alkenyl". Do not accept formula.	1
10.	b	accumulates in fat/tissues/living organisms OR cannot be metabolized/does not break down «in living organisms» OR not excreted / excreted «very» slowly ✓ passes «unchanged» up the food chain OR increased concentration as one species feeds on another «up the food chain» ✓	Accept "lipids" for "fat".	2
10.	c	«solubility depends on forming many» H-bonds with water ✓ maltose has many hydroxyl/OH/oxygen atom/O «and forms many H-bonds» ✓	Reference to "with water" required. Accept "hydroxy" for "hydroxyl" but not "hydroxide/OH". Reference to many/several OH groups/O atoms required for M2.	2

Option C — Energy

Question		Answers	Notes	Total
11.	a	<p>«similar specific energy and» pentane has «much» larger energy density ✓</p> <p><i>Any two for [2 max]:</i> similar number of bonds/«C and H» atoms in 1 kg «leading to similar specific energy» OR only one carbon difference in structure «leading to similar specific energy» ✓</p> <p>pentane liquid AND butane gas «at STP» ✓</p> <p>1 m³ of pentane contains greater amount/mass than 1 m³ of butane ✓</p>	<p>Accept “both are alkanes” for M2.</p> <p>Accept “pentane would be easier to transport”.</p> <p>Accept “same volume” for “1 m³” and “greater amount” for “more moles” for M4.</p>	3
11.	b	<p>«energy input => 5.54 × 10⁴ «MJ» ✓</p> <p>«efficiency = $\frac{2.41 \times 10^4 \text{ MJ}}{5.54 \times 10^4 \text{ MJ}} \times 100$ => 43.5 «%» ✓</p>	<p>Award [2] for correct final answer.</p>	2

Question		Answers	Notes	Total
12.	a	low knocking/auto-ignition OR more efficient fuel OR high compression OR more power extracted OR more air going into engine / turbocharging OR less engine damage ✓	Do not accept “pre-ignition”. Accept “less CO ₂ emissions since knocking engine uses more fuel «to produce the same power»”.	1

Question			Answers	Notes	Total
12.	b	i	<p>Any two of:</p> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> $\begin{array}{c} \text{CH}_3 \\ \\ \text{CH}_3-\text{CH}-\text{CH}_2-\text{CH}_2-\text{CH}_2-\text{CH}_3 \end{array}$ <p>✓</p> </div> <div style="text-align: center;"> $\begin{array}{c} \text{CH}_3 \\ \\ \text{CH}_3-\text{CH}_2-\text{CH}-\text{CH}_2-\text{CH}_2-\text{CH}_3 \end{array}$ <p>✓</p> </div> </div> <div style="display: flex; justify-content: space-around; margin-top: 10px;"> <div style="text-align: center;"> $\begin{array}{c} \text{CH}_3 \\ \\ \text{CH}_3-\text{CH}-\text{CH}-\text{CH}_2-\text{CH}_3 \\ \\ \text{CH}_3 \end{array}$ <p>✓</p> </div> <div style="text-align: center;"> $\begin{array}{c} \text{CH}_3 \\ \\ \text{CH}_3-\text{CH}-\text{CH}_2-\text{CH}-\text{CH}_3 \\ \\ \text{CH}_3 \end{array}$ <p>✓</p> </div> </div> <div style="display: flex; justify-content: space-around; margin-top: 10px;"> <div style="text-align: center;"> $\begin{array}{c} \text{CH}_3 \\ \\ \text{CH}_3-\text{C}-\text{CH}_2-\text{CH}_2-\text{CH}_3 \\ \\ \text{CH}_3 \end{array}$ <p>✓</p> </div> <div style="text-align: center;"> $\begin{array}{c} \text{CH}_3 \quad \text{CH}_3 \\ \quad \\ \text{CH}_3-\text{C}-\text{CH}-\text{CH}_3 \\ \\ \text{CH}_3 \end{array}$ <p>✓</p> </div> </div> <div style="display: flex; justify-content: space-around; margin-top: 10px;"> <div style="text-align: center;"> $\begin{array}{c} \text{CH}_3 \\ \\ \text{CH}_3-\text{CH}_2-\text{C}-\text{CH}_2-\text{CH}_3 \\ \\ \text{CH}_3 \end{array}$ <p>✓</p> </div> <div style="text-align: center;">  <p>✓</p> </div> </div> <div style="display: flex; justify-content: space-around; margin-top: 10px;"> <div style="text-align: center;">  <p>✓</p> </div> <div style="text-align: center;">  <p>✓</p> </div> </div>	<p>Accept skeletal formulas or full or condensed structural formulas.</p> <p>Accept any other branched cycloalkane that contains 7 carbons.</p> <p>Do not accept any alkenes.</p> <p>Penalize missing hydrogens or bond connectivities once only in Option C.</p> <p>Accept hydrogen as the second product if the first product is toluene or a cycloalkane.</p>	<p>2 max</p>

(continued...)

(Question 12b continued)

Question			Answers	Notes	Total
12.	b	ii	$ \begin{array}{c} \text{CH}_3 \\ \\ \text{CH}_3 - \text{C} - \text{CH}_2 - \text{CH}_2 - \text{CH}_3 \\ \\ \text{CH}_3 \end{array} $ /(\text{CH}_3)_3\text{CCH}_2\text{CH}_2\text{CH}_3 ✓	Accept a skeletal formula or a full or condensed structural formula. Penalize missing hydrogens or bond connectivities once only in Option C.	1

Question			Answers	Notes	Total
13.	a	i	${}^4_2\text{He} + {}^8_4\text{Be} \rightarrow {}^{12}_6\text{C} \checkmark$	<i>Do not penalize missing atomic numbers.</i>	1
13.	a	ii	<p>ALTERNATIVE 1 binding energy per nucleon is larger in carbon-12/product «than beryllium-8 and helium-4/reactants» \checkmark</p> <p>difference in «total» binding energy is released «during fusion» \checkmark</p> <p>ALTERNATIVE 2 mass of carbon-12/product «nucleus» is less than «the sum of» the masses of helium-4 and beryllium-8 «nuclei»/reactants</p> <p>OR two smaller nuclei form a larger nucleus \checkmark</p> <p>mass lost/difference is converted to energy «and released»</p> <p>OR $E = mc^2 \checkmark$</p>		2

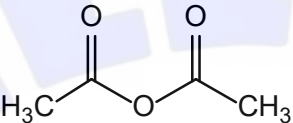
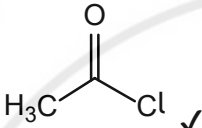
Question		Answers	Notes	Total
13.	b	<p>ALTERNATIVE 1</p> <p>3 half-lives ✓</p> <p>0.500 g «of beryllium-8 remain» ✓</p> <p>ALTERNATIVE 2</p> $m = 4.00 \left(\frac{1}{2} \right)^{\frac{2.01 \times 10^{-16}}{6.70 \times 10^{-17}}} \checkmark$ <p>0.500 g «of beryllium-8 remain» ✓</p> <p>ALTERNATIVE 3</p> $\lambda = \left\langle \frac{\ln 2}{6.70 \times 10^{-17}} \right\rangle = 1.03 \times 10^{16} \text{ «s}^{-1}\text{» } \checkmark$ $m = \left\langle 4.00 e^{-1.03 \times 10^{16} \times 2.01 \times 10^{-16}} \right\rangle \Rightarrow 0.500 \text{ «g» } \checkmark$	<p>Award [2] for correct final answer.</p>	2

Question		Answers	Notes	Total
14.	a	$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$ ✓		1
14.	b	<p>Any two of:</p> <p>«showing strong» correlation between «atmospheric» CO₂ concentration/greenhouse gas concentration and average «global/surface/ocean» temperature ✓</p> <p>lab evidence that greenhouse gases/CO₂ absorb(s) infrared radiation ✓</p> <p>«advanced» computer modelling ✓</p> <p>ice core data ✓</p> <p>tree ring data ✓</p> <p>ocean sediments / coral reefs / sedimentary rocks data ✓</p>	<p>Do not accept “global warming” for “average temperature”.</p> <p>Do not accept “traps/reflects heat” OR “thermal energy”.</p> <p>Evidence must be outlined and connected to data.</p> <p>Accept references to other valid greenhouse gases other than carbon dioxide/CO₂ such as methane/CH₄ or nitrous oxide/N₂O.</p>	2 max
14.	c	<p>biofuel raw material/sugar/glucose formed by photosynthesis</p> <p>OR</p> <p>biofuel raw material/sugar/glucose uses up carbon dioxide during its formation</p> <p>OR</p> <p>biofuel from capturing gases from decaying of organic matter formed from photosynthesis ✓</p> <p>$6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(aq) + 6O_2(g)$ ✓</p>	Accept arguments based on material coming from plant sources consuming carbon dioxide/carbon for M1.	2
14.	d	<p>transesterification</p> <p>OR</p> <p>«nucleophilic» substitution/S_N ✓</p>		1

Option D — Medicinal chemistry

Question		Answers	Notes	Total
15.	a	<p>Any two of:</p> <p>benzene/aromatic ring ✓</p> <p>«tertiary» amino «group» ✓</p> <p>ethenylene/1,2-ethenediyl «group» ✓</p> <p>ether «group» ✓</p>	<p>Accept “phenyl” for “benzene ring” although there are no phenyl groups as the benzene ring in this compound is a part of a polycyclic structure.</p> <p>Do not accept “arene” or “benzene” alone.</p> <p>Accept “amine” for “amino «group»”.</p> <p>Accept “alkenyl/alkene/vinylene” for ethenylene/1,2-ethenediyl «group».</p>	2 max
15.	b	<p>Any three of:</p> <p>morphine has «two» hydroxyl «groups» AND diamorphine has «two» ester/ethanoate/acetate «groups» ✓</p> <p>morphine is more polar than diamorphine</p> <p>OR</p> <p>groups in morphine are replaced with less polar/non-polar groups in diamorphine ✓</p> <p>morphine is «more» soluble in blood «plasma»</p> <p>OR</p> <p>diamorphine is «more» soluble in lipids</p> <p>OR</p> <p>diamorphine is more soluble in non-polar environment of CNS/central nervous system than morphine ✓</p> <p>diamorphine crosses the blood–brain barrier/BBB «easily» ✓</p>	<p>Accept “heroin” for “diamorphine”.</p> <p>Accept formulas.</p> <p>Accept “hydroxy” for “hydroxyl” but not “hydroxide”.</p> <p>Accept “acyl” for “ester «groups»”.</p> <p>Do not accept just “diamorphine is non-polar” for M2.</p> <p>Accept “water” for blood”.</p> <p>Accept “fats” for “lipid”.</p>	3 max

Question		Answers	Notes	Total
16.	a	hydrochloric acid/HCl «(aq)» AND strong «acid» ✓		1
16.	b	$\text{MgCO}_3(\text{s}) + 2\text{HCl}(\text{aq}) \rightarrow \text{MgCl}_2(\text{aq}) + \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$ ✓	Accept ionic equation.	1
16.	c	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» OR prevents parietal cells from producing/releasing acid ✓	Do not accept “antihistamine” by itself. Accept “H ₂ -receptor antagonist/H ₂ RA” OR “blocks/inhibits action of histamine”. Accept “blocks receptors in parietal cells «from releasing/producing acid»”. Do not accept proton pump/ATPase inhibitor.	1
16.	d	«pK _a = 4.76» «pH = pK _a + log $\left(\frac{[\text{CH}_3\text{COO}^-]}{[\text{CH}_3\text{COOH}]}\right)$ » «pH = 4.76 + 0.40 ⇒ 5.16 ✓		1

Question		Answers	Notes	Total
17.	a	<p>ethanoic anhydride/acetic anhydride/</p>  <p>OR</p> <p>ethanoyl chloride/acetyl chloride/</p> 	<p>Accept condensed structural formulas.</p> <p>Accept "ethanoic acid/acetic acid/CH₃COOH".</p> <p>Accept "C₄H₆O₃" OR "C₂H₃OCl".</p>	1
17.	b	<p>react with sodium hydroxide/NaOH/«strong» base</p> <p>OR</p> <p>convert to «ionic» salt ✓</p> <p>$C_6H_4(OCOCH_3)COOH(s) + NaOH(aq) \rightarrow C_6H_4(OCOCH_3)COONa(aq) + H_2O(l)$ ✓</p>	<p>Accept other suitable bases (eg, KOH/NaHCO₃/Na₂CO₃) with corresponding equation for chosen base for M2.</p> <p>Accept "CaCO₃", although calcium salicylate is not water soluble.</p> <p>Accept ionic equation.</p> <p>Award [2] for M2.</p>	2

Question		Answers	Notes	Total
18.	a	<p>Any one of: bacteria perform living functions «on their own and viruses do not without host cell» OR bacteria have cell walls «and viruses do not» OR bacteria do not have a capsid «and viruses do» OR bacteria larger than viruses OR bacteria reproduce by fission/budding «and viruses reproduce within a living host cell» OR bacteria affected by antibiotics «while viruses are not» ✓</p>	<p>Accept “bacteria have flagella/ cytoplasm/ribosome «and virus can have head/protein tail/double stranded RNA/single stranded DNA»”</p> <p>Accept “asexual reproduction” for bacteria.</p> <p>Accept other specific structural differences between bacteria and viruses, and examples of living functions that bacteria perform (such as excretion, reproduction etc.) that viruses do not.</p> <p>Accept “bacteria are living and viruses are not”</p>	1

Question		Answers	Notes	Total
18.	b	<p><i>Any two of:</i></p> <p>HIV difficult to detect/remains dormant ✓</p> <p>HIV mutates rapidly/quickly ✓</p> <p>HIV replicates rapidly/quickly ✓</p> <p>HIV destroys «T-» helper cells/white blood cells/lymphocytes</p> <p>OR</p> <p>HIV attacks immune system ✓</p> <p>HIV has several «significantly different» strains/subtypes ✓</p>	<p>Accept “virus” for “HIV”.</p> <p>Do not accept “AIDS mutates” without mention of the HIV/virus.</p> <p>Penalize the use of “AIDS” for “HIV” once only.</p> <p>Accept “HIV metabolism linked to that of host cell” OR “drugs harm host cell as well as HIV”.</p>	2 max

Question		Answers	Notes	Total
18.	c	<p>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 ✓</p> <p>ring breaks up/opens/reacts «easily» OR amido/amide group «in ring» is «highly» reactive ✓</p> <p>«irreversibly» binds/bonds to enzyme/transpeptidase OR inhibits enzyme/transpeptidase «in bacteria» that produces cell walls OR prevents cross-linking of «bacterial» cell walls ✓</p>	<p><i>Accept arguments using correct descriptions of hybridization for M1.</i></p> <p><i>Do not accept "breaks/binds to cell walls" – a reference to the enzyme is needed for alternatives 1 and 2 for M3.</i></p> <p><i>Do not accept "cell membrane" for "cell wall" for M3.</i></p>	3

Question		Answers	Notes	Total
19.	a	<p>«leads to bacterial» resistance «to antibiotics» OR destroys useful/beneficial bacteria OR useful/beneficial/less harmful bacteria replaced with «more» harmful bacteria ✓</p>	<p>Accept "affects/disturbs micro-ecosystems".</p>	1 max
19.	b	<p>Any one of: «most are» toxic «to living organisms» OR incomplete combustion/incineration can produce toxic products/dioxins/phosgene OR carcinogenic/can cause cancer ✓ accumulate in groundwater OR have limited biodegradability ✓ cost of disposal ✓</p>	<p>Do not accept "harmful to the environment". Do not accept just "pollutes water". Do not accept "hazard of disposal". Accept "ozone depletion" only if there is some reference to chlorinated solvents.</p>	1 max