

Markscheme

May 2019

Chemistry

Standard level

Paper 3

24 pages

No part of this product may be reproduced in any form or by any electronic or mechanical means, including information storage and retrieval systems, without written permission from the IB.

Additionally, the license tied with this product prohibits commercial use of any selected files or extracts from this product. Use by third parties, including but not limited to publishers, private teachers, tutoring or study services, preparatory schools, vendors operating curriculum mapping services or teacher resource digital platforms and app developers, is not permitted and is subject to the IB's prior written consent via a license. More information on how to request a license can be obtained from <http://www.ibo.org/contact-the-ib/media-inquiries/for-publishers/guidance-for-third-party-publishers-and-providers/how-to-apply-for-a-license>.

Aucune partie de ce produit ne peut être reproduite sous quelque forme ni par quelque moyen que ce soit, électronique ou mécanique, y compris des systèmes de stockage et de récupération d'informations, sans l'autorisation écrite de l'IB.

De plus, la licence associée à ce produit interdit toute utilisation commerciale de tout fichier ou extrait sélectionné dans ce produit. L'utilisation par des tiers, y compris, sans toutefois s'y limiter, des éditeurs, des professeurs particuliers, des services de tutorat ou d'aide aux études, des établissements de préparation à l'enseignement supérieur, des fournisseurs de services de planification des programmes d'études, des gestionnaires de plateformes pédagogiques en ligne, et des développeurs d'applications, n'est pas autorisée et est soumise au consentement écrit préalable de l'IB par l'intermédiaire d'une licence. Pour plus d'informations sur la procédure à suivre pour demander une licence, rendez-vous à l'adresse <http://www.ibo.org/fr/contact-the-ib/media-inquiries/for-publishers/guidance-for-third-party-publishers-and-providers/how-to-apply-for-a-license>.

No se podrá reproducir ninguna parte de este producto de ninguna forma ni por ningún medio electrónico o mecánico, incluidos los sistemas de almacenamiento y recuperación de información, sin que medie la autorización escrita del IB.

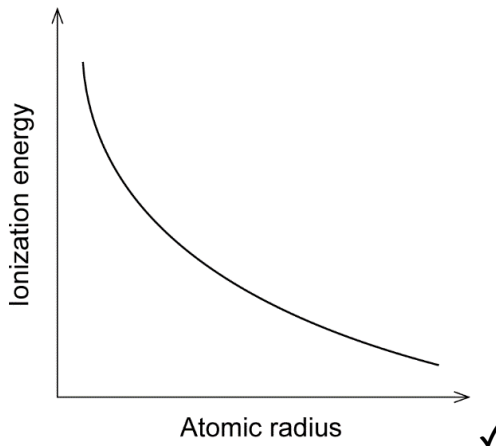
Además, la licencia vinculada a este producto prohíbe el uso con fines comerciales de todo archivo o fragmento seleccionado de este producto. El uso por parte de terceros —lo que incluye, a título enunciativo, editoriales, profesores particulares, servicios de apoyo académico o ayuda para el estudio, colegios preparatorios, desarrolladores de aplicaciones y entidades que presten servicios de planificación curricular u ofrezcan recursos para docentes mediante plataformas digitales— no está permitido y estará sujeto al otorgamiento previo de una licencia escrita por parte del IB. En este enlace encontrará más información sobre cómo solicitar una licencia: <http://www.ibo.org/es/contact-the-ib/media-inquiries/for-publishers/guidance-for-third-party-publishers-and-providers/how-to-apply-for-a-license>.

Section A

Question			Answers	Notes	Total
1.	a		group 18/noble gases ✓ smallest difference between melting and boiling points OR weakest intermolecular forces «in that period» ✓	<i>Accept “group 17/halogens”.</i>	2
1.	b	i	density increases «to a maximum in the transition elements» AND then decreases ✓		1
1.	b	ii	actinoids AND density increases down all groups «due to large increase in atomic mass for small increase in atomic volume» OR actinoids AND «much» greater atomic mass with similar type of bonding OR actinoids AND density «of actinoids» atomic number 90 to 95 is greater than corresponding lanthanoids ✓	<i>Accept “actinoids AND on graph actinoids have «much» greater density than lanthanoids”.</i>	1

(continued...)

(Question 1b continued)

Question			Answers	Notes	Total
1.	b	iii	<p>Alternative 1:</p> <p>«metals with» low densities oxidize easier ✓</p> <p>«metals with» low melting points oxidize easier ✓</p> <p>Alternative 2:</p> <p>in s-block «metals with» high densities oxidize easier</p> <p>OR</p> <p>in s-block «metals with» low melting points oxidize easier ✓</p> <p>in d-block «metals with» low densities oxidize easier</p> <p>OR</p> <p>in d-block «metals with» low melting points oxidize easier ✓</p>	<p>Award [1 max] for “s-block metals more easily oxidized” OR “s-block metals have lower melting points” OR “s-block metals have lower densities”.</p> <p>Accept “have greater activity” for “oxidize easier”.</p>	2
1.	b	iv	 <p style="text-align: center;">Atomic radius ✓</p>	<p>Accept any negative sloping line.</p> <p>Do not award mark if line touches either axis.</p>	1

Question			Answers	Notes	Total
2.	a	i	100 «s» ✓	Accept 90 to 100 s.	1
2.	a	ii	highest recorded temperature OR when rate of heat production equals rate of heat loss ✓	Accept “maximum temperature”. Accept “completion/end point of reaction”.	1
2.	b	i	Maximum temperature: 73 «°C» ✓ Assumption: «temperature reached if» reaction instantaneous OR «temperature reached if reaction occurred» without heat loss ✓	Accept “rate of heat loss is constant” OR “rate of temperature decrease is constant”.	2
2.	b	ii	Any one of: copper(II) sulfate AND mass/amount of zinc is independent variable/being changed. OR copper(II) sulfate AND with zinc in excess there is no independent variable «as amount of copper(II) sulfate is fixed» ✓ copper(II) sulfate AND having excess zinc will not yield different results in each trial ✓ zinc AND results can be used to see if amount of zinc affects temperature rise «so this can be allowed for» ✓ zinc AND reduces variables/keeps the amount reacting constant ✓		1 max

(continued...)

(Question 2b continued)

Question			Answers	Notes	Total						
2.	b	iii	<table border="1"> <thead> <tr> <th>Value</th> <th>Assumption</th> </tr> </thead> <tbody> <tr> <td>$m = 25.00 \text{ g}$</td> <td> density of solution is 1.000 g cm^{-3}/same as water OR 25.00 cm^3 solution has a mass of 25.00 g OR mass of zinc/reactant is negligible OR mass of contents was 25.00 g ✓ </td> </tr> <tr> <td>$c = 4.18 \text{ J g}^{-1} \text{ K}^{-1}$</td> <td> specific heat of solution is $4.18 \text{ J g}^{-1} \text{ K}^{-1}$ /same as water OR zinc/calorimeter/beaker/thermometer absorbs no heat ✓ </td> </tr> </tbody> </table>	Value	Assumption	$m = 25.00 \text{ g}$	density of solution is 1.000 g cm^{-3} /same as water OR 25.00 cm^3 solution has a mass of 25.00 g OR mass of zinc/reactant is negligible OR mass of contents was 25.00 g ✓	$c = 4.18 \text{ J g}^{-1} \text{ K}^{-1}$	specific heat of solution is $4.18 \text{ J g}^{-1} \text{ K}^{-1}$ /same as water OR zinc/calorimeter/beaker/thermometer absorbs no heat ✓	Accept "copper(II) sulfate/zinc sulfate" for "solution".	2
			Value	Assumption							
			$m = 25.00 \text{ g}$	density of solution is 1.000 g cm^{-3} /same as water OR 25.00 cm^3 solution has a mass of 25.00 g OR mass of zinc/reactant is negligible OR mass of contents was 25.00 g ✓							
$c = 4.18 \text{ J g}^{-1} \text{ K}^{-1}$	specific heat of solution is $4.18 \text{ J g}^{-1} \text{ K}^{-1}$ /same as water OR zinc/calorimeter/beaker/thermometer absorbs no heat ✓										
lower/less exothermic/less negative AND heat loss/some heat not accounted for OR lower/less exothermic/less negative AND mass of reaction mixture greater than 25.00 g OR greater/more exothermic /more negative AND specific heat of solution less than water ✓	Accept "temperature is lower" instead of "heat loss". Accept "similar to theoretical value AND heat losses have been compensated for". Accept "greater/more exothermic/more negative AND linear extrapolation overestimates heat loss".	1									

Section B

Option A — Materials

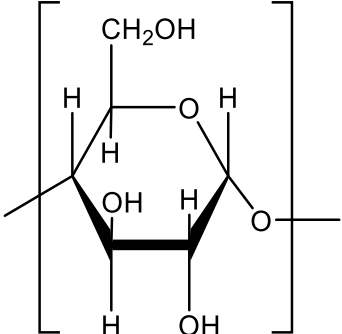
Question			Answers	Notes	Total
3.	a	i	ionic ✓		1
3.	a	ii	lithium has an unpaired electron ✓ all electrons in lithium hydride are paired ✓	Award [1 max] for correct electron configurations of Li AND Li ⁺ AND H ⁺ without discussion of pairing.	2
3.	b	i	emission spectra of both « ⁶ Li and natural Li» give same colour/produce same «range of» wavelengths OR they have same electron transitions/same nuclear charge ✓	Accept “the spectra are almost identical”.	1
3.	b	ii	ICP-MS ✓	Accept “MS/mass spectrometry”.	1
3.	c		$n = \frac{m}{M_r} = \frac{0.694}{6.94} = 0.100 \text{ «mol»} \checkmark$ $\text{« } t = \frac{0.100 \text{ mol} \times 96\,500 \text{ C mol}^{-1}}{2.00 \text{ C s}^{-1}} = \text{»}$ 4830 «s» ✓	Accept “4820” OR “4825 «s»”. Award [2] for correct final answer.	2

Question			Answers	Notes	Total
4.	a		<p><i>Any two of:</i></p> <p>heterogeneous catalyst is in different phase than reactants AND homogeneous catalyst in same phase ✓</p> <p>homogeneous catalysts chemically change/react and are reformed at end of reaction</p> <p>OR</p> <p>reactants adsorb onto heterogenous catalyst and products desorb ✓</p> <p>heterogeneous catalysts are more easily removed than homogenous catalysts ✓</p> <p>heterogeneous catalysts can function at higher temperatures ✓</p> <p>homogeneous catalysts are «generally» more selective ✓</p> <p>homogeneous catalysts offer a broader range of reactions ✓</p>	<p><i>Accept “state” for “phase”.</i></p> <p><i>Accept “heterogeneous catalyst provides a surface to activate reaction”.</i></p>	2 max
4.	b		<p>elastomers bend under force «and return to original form when force is released»</p> <p>OR</p> <p>elastomers make tyre more flexible ✓</p> <p>allows greater contact with road ✓</p>		2
4.	c	i	<p>does not contain heterocyclic ring with 2 oxygen atoms</p> <p>OR</p> <p>middle ring has only 1 oxygen atom ✓</p> <p>produces similar toxic effects to dioxins ✓</p>	<i>Accept “does not contain dioxin ring” for M1.</i>	2
4.	c	ii	<p>taken up by plants, which are eaten by animals «and then further dispersed»</p> <p>OR</p> <p>passed on in food chain ✓</p>	<i>Accept “do not break down and can be remobilised as dust”.</i>	1

Question		Answers	Notes	Total
5.	a	nitrile ✓	Accept "cyano".	1
5.	b	<p><i>Low temperature:</i> intermolecular forces prevent molecules moving AND solid/«normal» crystal formation ✓</p> <p><i>High temperature:</i> «above a critical temperature» disrupts alignment of molecules AND behaves as fluid/liquid ✓</p>	Accept "weak intermolecular forces break AND behaves as fluid/liquid".	2

Question		Answers	Notes	Total
6.	a	<p><i>Structure:</i> giant covalent/network covalent ✓</p> <p><i>Bonding:</i> each carbon covalently bonded to 3 other carbons OR each bond has order of 1.5</p>	<p>Accept “cylindrical/tube shaped”.</p> <p>Accept “has delocalized electrons” OR “has sp^2 hybridization”.</p>	2
6.	b	<p><i>Any one of:</i> 3D electrodes ✓ catalysts ✓ biosensors ✓ molecular stents ✓ body armour ✓ synthetic muscles ✓ micro transistors/circuitry/capacitors/electrodes ✓ reinforcing phase in a matrix/composite material «such as concrete» ✓ micro antenna ✓ stealth technology ✓ water/air filtration ✓ solar cells ✓ tennis racquets ✓ microelectronic circuits ✓</p>	<p>Do not accept just general answers such as “medicine” or “defence”.</p>	1 max

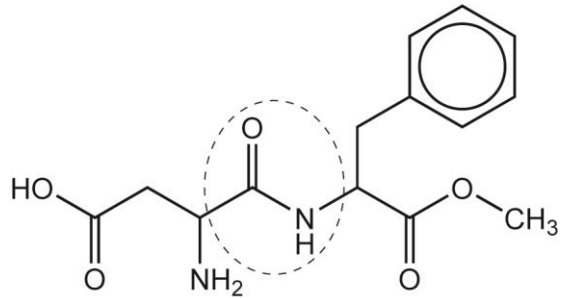
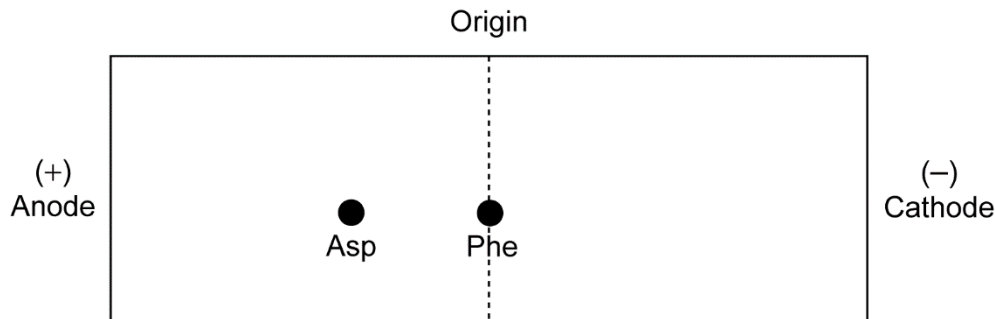
Option B — Biochemistry

Question		Answers	Notes	Total
7.	a	 <p>continuation bonds AND -O- attached to just one end AND both H-atoms on end carbons must be on the same side ✓</p> <p>Type of linkage: glycosidic ✓</p>	<p>Square brackets not required. Ignore "n" if given. Mark may be awarded if a polymer is shown but with the repeating unit clearly identified.</p> <p>Accept "ether".</p>	2
7.	b	$(C_6H_{10}O_5)_n(s) + nH_2O(l) \rightarrow nC_6H_{12}O_6(aq)$ ✓	<p>Accept "(n-1)H₂O". Do not award mark if "n" not included.</p>	1
7.	c	$q = mc\Delta T = 975 \text{ g} \times 4.18 \text{ J g}^{-1} \text{ K}^{-1} \times 15.0 \text{ K} \Rightarrow 61\,100 \text{ «J»} / 61.1 \text{ «kJ»} \checkmark$ $\text{«heat per gram} = \frac{61.1 \text{ kJ}}{3.49 \text{ g}} \Rightarrow 17.5 \text{ «kJ g}^{-1}\text{»} \checkmark$	<p>Award [2] for correct final answer.</p>	2

(continued...)

(Question 7 continued)

Question		Answers	Notes	Total
7.	d	<p><i>Any two of:</i></p> <p>carbohydrate grains swell/break plastic into smaller pieces ✓</p> <p>inclusion of carbohydrate makes the plastic more hydrophilic/water soluble ✓</p> <p>carbohydrates are broken down/hydrolysed/digested by bacteria/micro-organisms ✓</p> <p>plastic becomes more accessible to bacteria as holes/channels are created in it ✓</p> <p>«presence of» carbohydrate weakens intermolecular/London/dispersion forces between polymer chains in the plastic ✓</p>	<p><i>Accept “starch” for “carbohydrate” throughout.</i></p> <p><i>Do not accept carbohydrates are broken down/hydrolyzed.</i></p>	2 max

Question		Answers	Notes	Total
8.	a	 <p><i>Name:</i> amide/amido/carboxamide ✓</p>	<p>Accept "peptide bond/linkage".</p>	2
8.	b	 <p><i>Phe:</i> must be on the origin ✓ <i>Asp:</i> any position on the left/anode/+ side ✓</p>		2

Question		Answers	Notes	Total
9.	a	<p>coconut oil has higher content of lauric/short-chain «saturated» fatty acids</p> <p>OR</p> <p>cocoa butter has higher content of stearic/palmitic/longer chain «saturated» fatty acids ✓</p> <p>longer chain fatty acids have greater surface area/larger electron cloud ✓</p> <p>stronger London/dispersion/instantaneous dipole-induced dipole forces «between triglycerides of longer chain saturated fatty acids» ✓</p>	<p><i>Do not accept arguments that relate to the melting points of saturated and unsaturated fats.</i></p>	3
9.	b	$ \begin{array}{c} \text{O} \\ \parallel \\ \text{H}_2\text{C} - \text{O} - \text{C} - (\text{CH}_2)_{10}\text{CH}_3 \\ \\ \text{HC} - \text{O} - \text{C} - (\text{CH}_2)_{16}\text{CH}_3 + 3\text{H}_2\text{O} \\ \\ \text{O} \\ \parallel \\ \text{H}_2\text{C} - \text{O} - \text{C} - (\text{CH}_2)_{16}\text{CH}_3 \end{array} $ $ \xrightarrow{\text{H}^+/\text{heat}} \text{CH}_3(\text{CH}_2)_{10}\text{COOH} + 2\text{CH}_3(\text{CH}_2)_{16}\text{COOH} + $ $ \begin{array}{c} \text{H} \\ \\ \text{H} - \text{C} - \text{OH} \\ \\ \text{H} - \text{C} - \text{OH} \\ \\ \text{H} - \text{C} - \text{OH} \\ \\ \text{H} \end{array} $ <p>correct products ✓</p> <p>correctly balanced ✓</p>		2

(continued...)

(Question 9 continued)

Question		Answers	Notes	Total
9.	c	<p>Any two of:</p> <p>«increased risk of» coronary/heart disease ✓</p> <p>«increased risk of» stroke ✓</p> <p>«increased risk of» atherosclerosis ✓</p> <p>«increased risk of type-2» diabetes ✓</p> <p>increase in LDL cholesterol ✓</p> <p>decrease in HDL cholesterol ✓</p> <p>«increased risk of» obesity ✓</p>		2 max

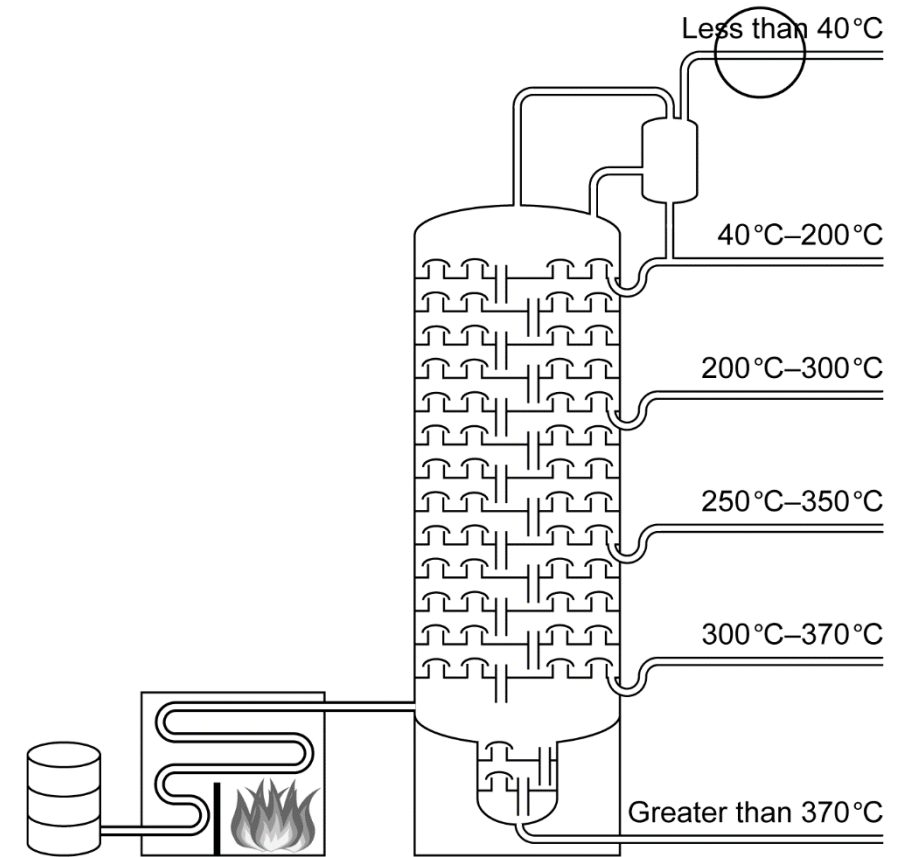
Question		Answers	Notes	Total
10.		<p><i>ascorbic acid</i>: many hydroxyl/OH groups AND <i>retinol</i>: few/one hydroxyl/OH group OR</p> <p><i>ascorbic acid</i>: many hydroxyl/OH groups AND <i>retinol</i>: long hydrocarbon chain ✓</p> <p><i>ascorbic acid</i>: «many» H-bond with water OR</p> <p><i>retinol</i>: cannot «sufficiently» H-bond with water ✓</p>	Do not accept "OH/hydroxide".	2

Option C — Energy

Question			Answers	Notes	Total
11.	a		$\frac{891\text{kJmol}^{-1}}{16.05\text{gmol}^{-1}} = 55.5\text{kJg}^{-1} \Rightarrow 55.5\text{ «MJ kg}^{-1}\text{» } \checkmark$		1
11.	b	i	«55.5 MJ × 58 % ⇒ 32.2 «MJ» ✓		1
11.	b	ii	<p><i>Reason for higher efficiency:</i> no heat/energy loss in producing steam OR no need to convert chemical energy of the fuel into heat and then heat into mechanical energy OR direct conversion of «gravitational» potential energy to mechanical energy ✓</p> <p><i>Reason for decreased use:</i> limited supply of available hydroelectric sites OR rapid growth of electrical supply in countries with little hydroelectric potential OR not building «new hydroelectric» dams because of environmental concerns ✓</p>	<p>Accept “less energy lost as heat” but do not accept “no energy lost”.</p> <p>Accept “new/alternative/solar/wind power sources «have taken over some of the demand»”.</p> <p>Accept “lower output from existing stations due to limited water supplies”.</p>	2

(continued...)

(Question 11 continued)

Question			Answers	Notes	Total
11.	c	i	 <p>Crude oil Furnace Fractionating tower ✓</p> <p>[Source: Image used with kind permission of science-resources.co.uk]</p>		1
11.	c	ii	gasoline > diesel > lubricating motor oil > asphalt ✓	Accept products written in this order whether separated by >, comma, or nothing.	1

(continued...)

(Question 11 continued)

Question			Answers	Notes	Total
11.	d	i	methane is tetrahedral OR methane has zero dipole moment/is non-polar/bond polarities cancel ✓ <i>Any two of:</i> IR absorption can result in increased vibrations/bending/stretching ✓ only modes that cause change in dipole absorb IR ✓ for methane this is asymmetric bending/stretching ✓		3 max
11.	d	ii	methane is less abundant AND has a greater effect «per mol» ✓		1

Question			Answers	Notes	Total
12.	a	i	$^{235}\text{U} + {}^1_0\text{n} \rightarrow {}^{144}\text{Ba} + {}^{89}\text{Kr} + 3 {}^1_0\text{n}$ ✓		1
12.	a	ii	greater binding energy per nucleon in products than reactant ✓	Accept “mass of products less than reactants” OR “mass converted to energy/ $E = mc^2$ ”.	1
12.	b		mass/amount/quantity required so that «on average» each fission/reaction results in a further fission/reaction ✓ at least one of the «3» neutrons produced must cause another reaction ✓	Accept “minimum mass of fuel needed for the reaction to be self-sustaining”.	2
12.	c		«6.25 % = 4 half-lives, so $4 \times 3.15 \Rightarrow$ 12.6 «min» ✓		1

Question		Answers	Notes	Total
13.	a	increased AND fuels can be compressed more «before ignition» ✓	Accept “engines can be designed with higher compression ratio” OR “less chance of pre-ignition/auto-ignition/knocking occurring”.	1
13.	b	<p>Alternative 1</p> <p>$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$ / 1 mol ethanol produces 2 mol CO_2</p> <p>OR</p> <p>$C_8H_{18}(l) + 12.5O_2(g) \rightarrow 8CO_2(g) + 9H_2O(l)$ / 1 mol octane produces 8 mol CO_2 ✓</p> <p>For 1 g of fuel:</p> <p>« $\frac{1g}{46 \text{ g mol}^{-1}} \times 2 \text{ mol } CO_2(g) \Rightarrow 0.04$ «mol $CO_2(g)$» from ethanol ✓</p> <p>« $\frac{1g}{114 \text{ g mol}^{-1}} \times 8 \text{ mol } CO_2(g) \Rightarrow 0.07$ «mol $CO_2(g)$» from octane ✓</p> <p>Alternative 2</p> <p>ratio of C in ethanol:octane is 2:8, so ratio in carbon dioxide produced per mole will be 1:4 ✓</p> <p>ratio amount of fuel in 1 g = $\frac{1}{46} : \frac{1}{114} = 2.5:1$ ✓</p> <p>4 > 2.5 so octane produces more carbon dioxide</p> <p>OR</p> <p>ratio of amount of carbon dioxide = 2.5:4 = 1:1.61 so octane produces more «for combustion of same mass» ✓</p>		3

(continued...)

(Question 13 continued)

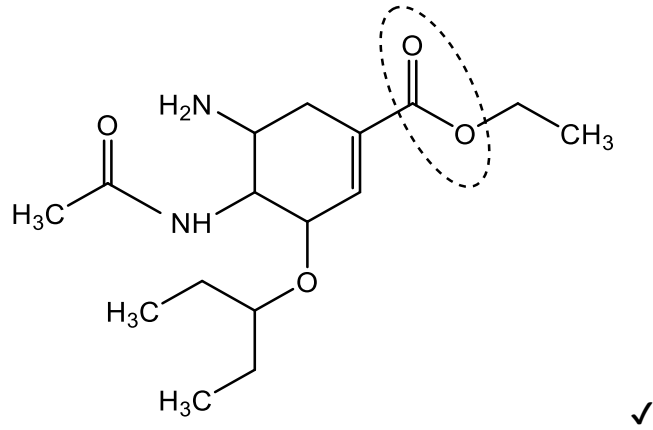
Question		Answers	Notes	Total
13.	c	use of «farm» land «for production» OR deforestation «for crop production for fuel» OR can release more NO _x «than normal fuel on combustion» ✓	<i>Ignore any reference to cost.</i>	1

Option D — Medicinal chemistry

Question			Answers	Notes	Total
14.			Name: hydroxyl ✓ Absorption band: 3200–3600 «cm ⁻¹ » ✓	Accept “phenol” OR “alcohol” but not “hydroxide”.	2

Question			Answers	Notes	Total
15.	a		«four-membered» beta-lactam ring ✓	Accept a diagram showing a structural representation of the beta-lactam ring.	1
15.	b	i	produce penicillinase/enzyme that deactivates penicillin ✓		1
15.	b	ii	side-chain changed «preserving beta-lactam ring» ✓	Accept “R group changed”.	1

Question			Answers	Notes	Total
16.	a	i	$\text{CaCO}_3(\text{s}) + 2\text{HCl}(\text{aq}) \rightarrow \text{CO}_2(\text{g}) + \text{CaCl}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) \checkmark$	<p>Accept balanced ionic equations involving "H⁺" or "H₃O⁺".</p> <p>Do not accept "H₂CO₃".</p>	1
16.	a	ii	$n \text{CaCO}_3 = \left\langle \frac{1.00 \text{ g}}{100.09 \text{ g mol}^{-1}} \right\rangle = \left\langle 0.00999 \text{ mol} \right\rangle \checkmark$ <p>volume CO₂ = «0.00999 mol × 22.7 dm³ mol⁻¹ = » 0.227 «dm³» ✓</p>	<p>Accept 0.224 «dm³» if 22.4 dm³ mol⁻¹ is used as molar volume.</p> <p>Award [2] for correct answer.</p>	2
16.	b		<p><i>Omeprazole:</i> inhibits enzyme/«gastric» proton pump «which secretes H⁺ ions into gastric juice» OR inhibits the H⁺/K⁺-ATPase system ✓</p> <p><i>Ranitidine:</i> inhibits/blocks H₂/histamine receptors «in cells of stomach lining» OR prevents histamine binding to H₂/histamine receptors «and triggering acid secretion» ✓</p>	<p>Accept "H₂-receptor antagonist" for M2.</p>	2

Question			Answers	Notes	Total
17.	a	i	 <p style="text-align: right;">✓</p>	Accept circles that include the alkyl side chain.	1
17.	a	ii	more soluble «in water» ✓		1
17.	b		viruses undergo «rapid» mutation ✓ mutation causes a change in viral protein OR drug to no longer binds to virus ✓	Accept “rapid reproduction «allows resistant viruses to multiply»”.	2

Question			Answers	Notes	Total
18.	a		«temporarily» bond/bind to «opioid» receptors in the brain/CNS ✓ block the transmission of pain impulses ✓		2
18.	b		«codeine crosses blood–brain barrier more easily» morphine has more hydroxyl/OH «groups than codeine» ✓ codeine/ether group is less polar OR hydroxyl/OH «groups in morphine» H-bond to water ✓	<i>Award [1 max] if no statement or an incorrect statement about the blood–brain barrier.</i>	2

Question			Answers	Notes	Total
19.	a		small/low amounts of radiation AND for a short time ✓	<i>Accept “weakly ionizing radiation” instead of “small amounts of radiation”. Accept “short half-lives” instead of “for a short time”.</i>	1
19.	b		stored in shielded containers until radiation drops «to a safe level» ✓		1
