

Markscheme

May 2019

Chemistry

Higher level

Paper 3

34 pages

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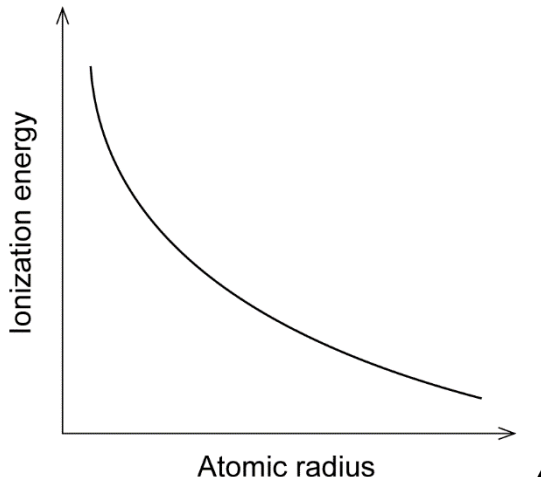
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Section A

Question			Answers	Notes	Total
1.	a		group 18/noble gases ✓ smallest difference between melting and boiling points OR weakest intermolecular forces «in that period» ✓	Accept “group 17/halogens”.	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 ✓	Accept “actinoids AND on graph actinoids have «much» greater density than lanthanoids”.	1

(Continued...)

(Question 1b continued)

Question			Answers	Notes	Total
1.	b	iii	<p>Alternative 1: «metals with» low densities oxidize easier ✓ «metals with» low melting points oxidize easier ✓</p> <p>Alternative 2: in s-block «metals with» high densities oxidize easier OR in s-block «metals with» low melting points oxidize easier ✓</p> <p>in d-block «metals with» low densities oxidize easier OR 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. 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 ✓										
2.	b	iv	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		ionic ✓		1
3.	b	i	red ✓		1
3.	b	ii	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	iii	ICP-MS ✓	Accept “MS/mass spectrometry”.	1
3.	c		$n = \frac{m}{M_r} = \frac{0.694}{6.94} = 0.100 \text{ «mol»}$ $\text{« } t = \frac{0.100 \text{ mol} \times 96\,500 \text{ C mol}^{-1}}{2.00 \text{ C s}^{-1}} \text{ »}$ 4830 «s» ✓	Accept “4820” OR “4825 «s»”. Award [2] for correct final answer.	2

(continued...)

(Question 3 continued)

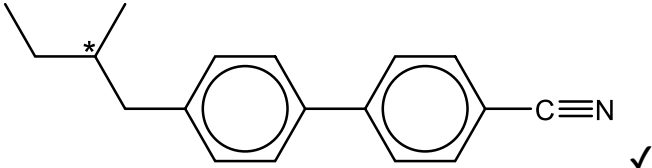
Question			Answers	Notes	Total
3.	d	i	creation of mirror image/opposing magnetic field of external field «below critical temperature/T of superconductor» OR expulsion of magnetic field from superconductor «below critical temperature/T» ✓		1
3.	d	ii	<i>Any three of:</i> positive ions/cations in lattice are attracted to passing electron ✓ lattice is distorted «by this passing electron» ✓ creates «local» regions of increased positive charge ✓ second electron is attracted to deformation AND a coupling occurs ✓		3 max
3.	e		mass of Li in unit cell = $2 \times \frac{6.94 \text{ g mol}^{-1}}{6.02 \times 10^{23} \text{ mol}^{-1}} \Rightarrow 2.31 \times 10^{-23} \text{ g}$ ✓ volume of unit cell = $(3.51 \times 10^{-8} \text{ cm})^3 \Rightarrow 4.32 \times 10^{-23} \text{ cm}^3$ ✓ «density = $\frac{2.31 \times 10^{-23} \text{ g}}{4.32 \times 10^{-23} \text{ cm}^3} \Rightarrow 0.535 \text{ g cm}^{-3}$ » ✓	Award [3] for correct final answer.	3

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 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	<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>	<p><i>Accept “does not contain dioxin ring” for M1.</i></p>	2

(continued...)

(Question 4 continued)

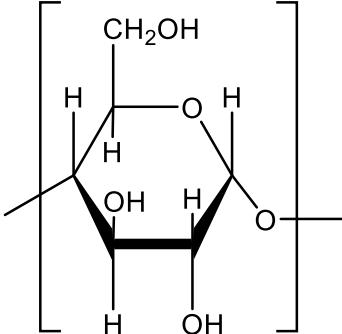
Question		Answers	Notes	Total
4.	d	addition AND not two different functional groups reacting OR addition AND formed by breaking one bond of the carbon-carbon double bonds OR addition AND empirical formula of monomer equals empirical formula of polymer OR addition AND no atoms removed/all atoms accounted for/no loss of water/ammonia/inorganic by-product/small molecules OR addition AND atom economy/efficiency is 100 % OR addition AND there is only one «reaction» product ✓		1
4.	e	Any one of: high content of raw materials in product/high atom economy ✓ use of low toxic chemicals/catalysts/materials/solvents ✓ renewable feedstock/raw materials ✓ use of renewable/clean/low carbon energy source ✓ high safety standards ✓ increase energy efficiency ✓ waste recycling ✓	Accept other reasonable answers.	1 max

Question		Answers	Notes	Total
5.	a			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>	<p><i>Accept “weak intermolecular forces break AND behaves as fluid/liquid”.</i></p>	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

Question			Answers	Notes	Total
7.	a		entropy increases «and the reaction proceeds to the right» ✓ more species / free molecules are formed OR more ways of distributing energy ✓		2
7.	b		six ✓		1

Option B — Biochemistry

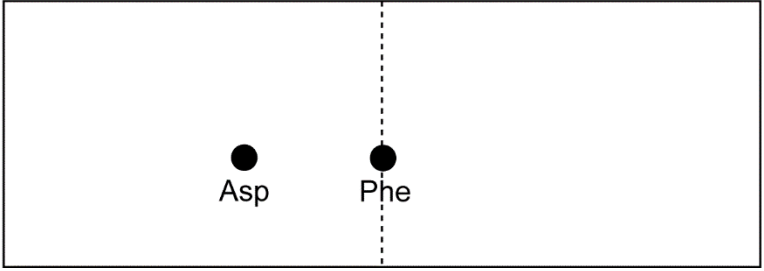
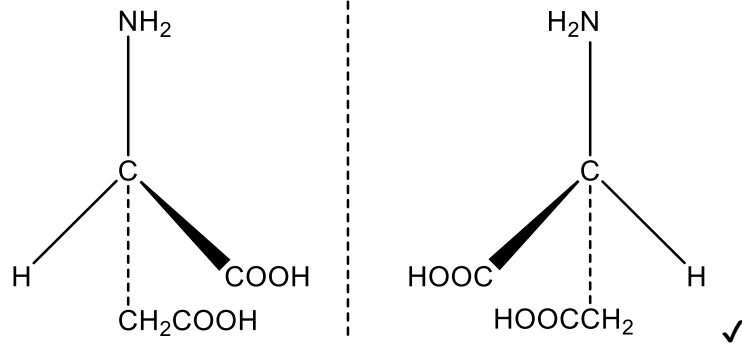
Question		Answers	Notes	Total
8.	a	 <p>continuation bonds AND -O attached to just one end AND both H atoms on end carbons must be on the same side ✓</p> <p>Type of linkage: glycosidic ✓</p>	<p>Square brackets not required. Ignore "n" if given. Mark may be awarded if a polymer is shown but with the repeating unit clearly identified.</p> <p>Accept "ether".</p>	2
8.	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
8.	c	$q = \llcorner mc\Delta T = 975\text{ g} \times 4.18\text{ J g}^{-1}\text{ K}^{-1} \times 15.0\text{ K} \Rightarrow 61\,100\text{ «J»} / 61.1\text{ «kJ»} \checkmark$ $\llcorner \text{heat per gram} = \frac{61.1\text{ kJ}}{3.49\text{ g}} \Rightarrow 17.5\text{ «kJ g}^{-1}\text{»} \checkmark$	<p>Award [2] for correct final answer.</p>	2

(continued...)

(Question 8 continued)

Question		Answers	Notes	Total
8.	d	<p>Any two of:</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>Accept “starch” for “carbohydrate” throughout.</p> <p>Do not accept “carbohydrates are broken down/hydrolyzed”.</p>	2 max

Question		Answers	Notes	Total
9.	a	<p>Name:</p> <p>amide/amido/carboxamide ✓</p>	<p>Accept “peptide bond/linkage”.</p>	2

Question		Answers	Notes	Total
9.	b	<p style="text-align: center;">Origin</p>  <p><i>Phe</i>: must be on the origin ✓ <i>Asp</i>: any position on the left/anode/+ side ✓</p>		2
9.	c			1

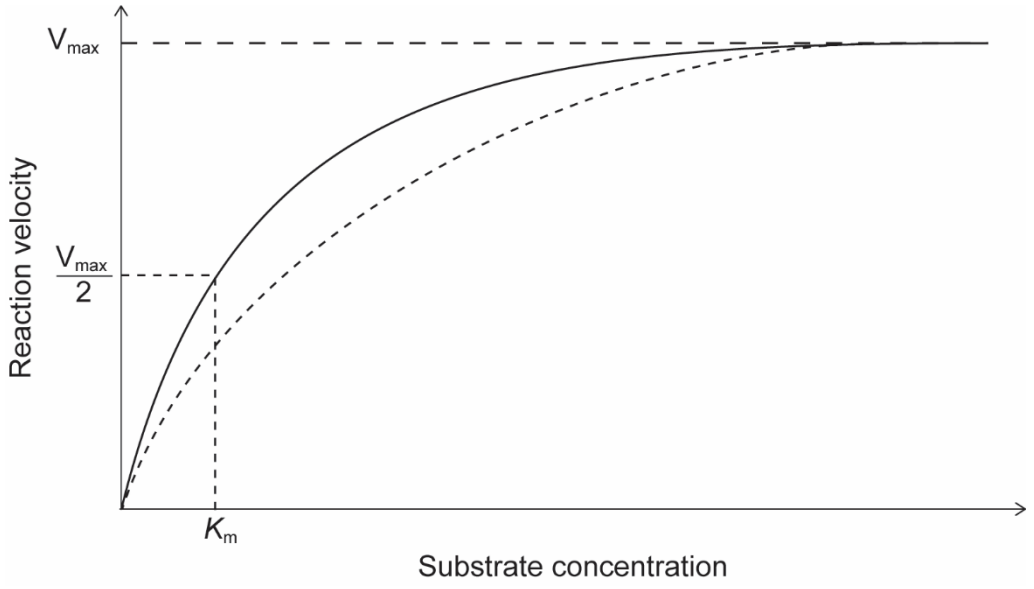
Question		Answers	Notes	Total
10.	a	<p>coconut oil has higher content of lauric/short-chain «saturated» fatty acids</p> <p>OR</p> <p>cocoa butter has higher content of stearic/palmitic/longer chain «saturated» fatty acids ✓</p> <p>longer chain fatty acids have greater surface area/larger electron cloud ✓</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 melting points of saturated and unsaturated fats.</i></p>	3
10.	b	$ \begin{array}{c} \text{H}_2\text{C}-\text{O}-\overset{\text{O}}{\parallel}{\text{C}}-(\text{CH}_2)_{10}\text{CH}_3 \\ \\ \text{HC}-\text{O}-\overset{\text{O}}{\parallel}{\text{C}}-(\text{CH}_2)_{16}\text{CH}_3 + 3\text{H}_2\text{O} \\ \\ \text{H}_2\text{C}-\text{O}-\overset{\text{O}}{\parallel}{\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 10 continued)

Question		Answers	Notes	Total
10.	c	<p>Any one 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>		1 max

Question		Answers	Notes	Total
11.	a	<p>400–424 «nm» absorption band/violet AND 424–490 «nm» absorption band/blue ✓</p> <p>complementary/opposite colour observed</p> <p>OR</p> <p>yellow/orange observed ✓</p>	Accept “400–500 «nm» absorption band” for M1.	2
11.	b	extends energy absorption spectrum «for photosynthesis» ✓		1

12.	a	i	 <p>Reaction velocity</p> <p>Substrate concentration</p> <p>V_{max}</p> <p>$\frac{V_{max}}{2}$</p> <p>K_m</p> <p>✓</p>	<p><i>Line must start at origin, to the right of original line and bending toward the same V_{max}.</i></p>	1
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(continued...)

(Question 12 continued)

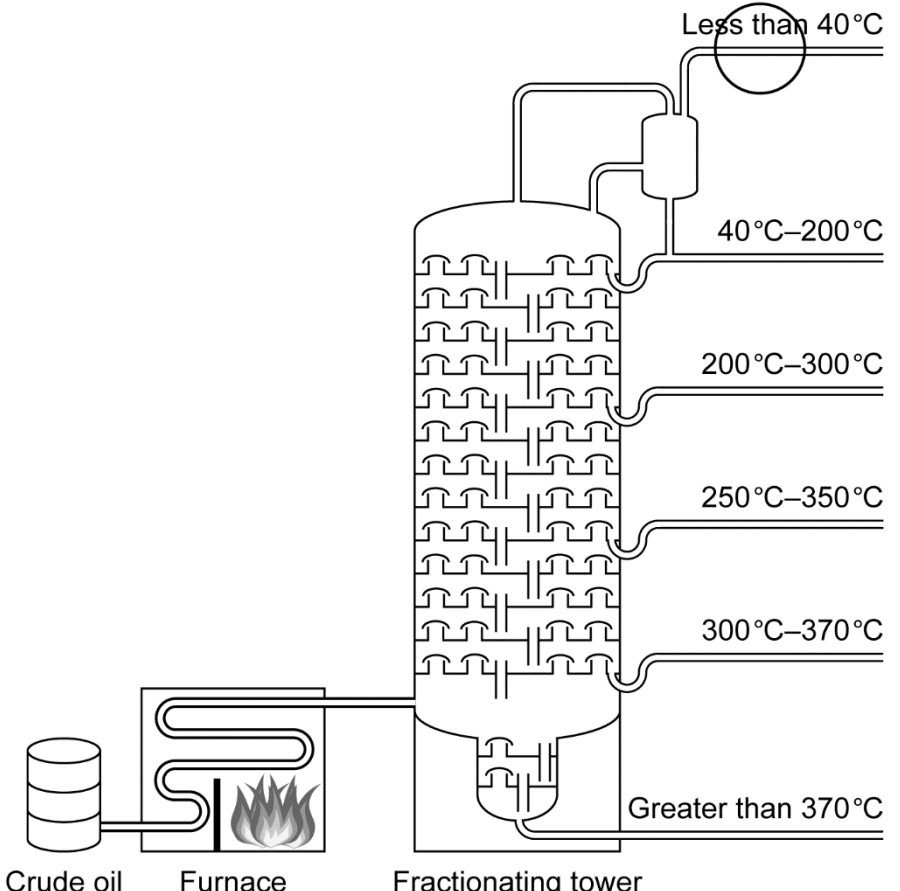
Question			Answers	Notes	Total
12.	a	ii	<p>K_m is higher /same V_{max} reached at higher [substrate] ✓</p> <p>slower reaction rate</p> <p>OR</p> <p>gives time to excrete/eliminate methanol ✓</p>		2
12.	b		<p>«$\text{pH} = \text{p}K_a + \log \frac{[\text{HPO}_4^{2-}]}{[\text{H}_2\text{PO}_4^-]} / 6.10 = 7.20 + \log \frac{[\text{HPO}_4^{2-}]}{[\text{H}_2\text{PO}_4^-]} \text{»}$</p> <p>$\log \frac{[\text{HPO}_4^{2-}]}{[\text{H}_2\text{PO}_4^-]} = \text{«}6.10 - 7.20 \text{»} -1.10$</p> <p>OR</p> <p>$\frac{[\text{HPO}_4^{2-}]}{[\text{H}_2\text{PO}_4^-]} = \text{«}10^{-1.10} \text{»} 0.079 \checkmark$</p> <p>$\text{NaH}_2\text{PO}_4 : \text{Na}_2\text{HPO}_4 = 12.6 : 1 \checkmark$</p>	Award [2] for correct final answer.	2

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

Question		Answers	Notes	Total
14.	a	organism whose genetic material/DNA has been altered by genetic engineering techniques «involving transferring DNA between species» ✓	Accept "any living organism that possesses a novel combination of genetic material obtained through the use of modern biotechnology".	1
14.	b	<p>Any one of:</p> <p>increased resistance to pests/micro-organisms ✓</p> <p>increased shelf-life of food ✓</p> <p>increased nutritional value ✓</p> <p>greater crop yield ✓</p> <p>greater tolerance of crops to adverse climatic/soil/growing condition ✓</p>		1 max

Option C — Energy

Question			Answers	Notes	Total
15.	a		« $\frac{891 \text{ kJ mol}^{-1}}{16.05 \text{ g mol}^{-1}} = 55.5 \text{ kJ g}^{-1} \Rightarrow 55.5 \text{ «MJ kg}^{-1}\text{» } \checkmark$ »		1
15.	b	i	«55.5 MJ × 58 % ⇒ 32.2 «MJ» ✓»		1
15.	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

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

(continued...)

(Question 15 continued)

Question			Answers	Notes	Total
15.	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
15.	d	ii	methane is less abundant AND has a greater effect «per mol» ✓		1

Question			Answers	Notes	Total
16.	a	i	${}^{235}\text{U} + {}^1_0\text{n} \rightarrow {}^{144}\text{Ba} + {}^{89}\text{Kr} + 3{}^1_0\text{n} \checkmark$		1
16.	a	ii	greater binding energy per nucleon in products than reactants \checkmark	Accept "mass of products less than mass of reactants" OR "mass converted to energy/ $E = mc^2$ ".	1
16.	a	iii	« $\Delta m = \text{mass of reactants} - \text{mass of products}$ » $\Delta m = \langle 234.99346 - 143.89223 - 88.89788 - (2 \times 1.00867) \rangle = 0.18601 \text{ «amu» } \checkmark$ $\Delta m = \langle 0.18601 \text{ amu} \times 1.66 \times 10^{-27} \text{ kg amu}^{-1} \rangle = 3.09 \times 10^{-28} \text{ «kg» } \checkmark$ $E = \langle mc^2 = 3.09 \times 10^{-28} \text{ kg} \times (3.00 \times 10^8 \text{ m s}^{-1})^2 \rangle = 2.78 \times 10^{-11} \text{ «J» } \checkmark$	Award [3] for correct final answer.	3
16.	b		mass/amount/quantity required so that «on average» each fission/reaction results in a further fission/reaction \checkmark at least one of the «3» neutrons produced must cause another reaction \checkmark	Accept "minimum mass of nuclear fuel needed for the reaction to be self-sustaining".	2
16.	c		$\lambda \left(= \frac{\ln 2}{t_{\frac{1}{2}}} = \frac{\ln 2}{3.15} \right) = 0.220 \text{ «min}^{-1}\text{» } \checkmark$ $t \left(= -\frac{1}{\lambda} \ln \frac{N}{N_0} = -\frac{\ln 0.1}{0.220} \right) = 10.5 \text{ «min» } \checkmark$	Award [2] for correct final answer.	2

Question			Answers	Notes	Total
17.	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
17.	b	i	Electrode A: $C_2H_6O(aq) + 3H_2O(l) \rightarrow 12H^+(aq) + 12e^- + 2CO_2(g)$ ✓ Electrode B: $3O_2(g) + 12H^+(aq) + 12e^- \rightarrow 6H_2O(l)$ ✓	Accept balanced equations with integer or fractional coefficients. Penalize equilibrium arrows once only.	2
17.	b	ii	<i>Name:</i> PEM/proton-exchange membrane/polymer exchange membrane/polymer electrolyte membrane ✓ <i>Function:</i> allows the passage of protons/ H^+ ions «from anode to cathode but not electrons or molecules» ✓		2
17.	b	iii	<i>Any one of:</i> water is a reactant/allows the cell to operate at a higher concentration of protons/ H^+ ions OR water is a stronger electrolyte and thus produces higher electric current ✓ less dangerous/flammable ✓		1

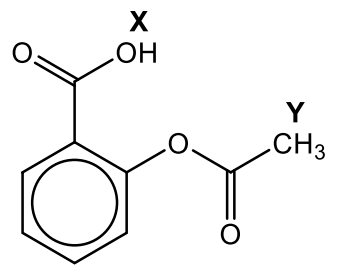
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(Question 17 continued)

Question		Answers	Notes	Total
17.	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

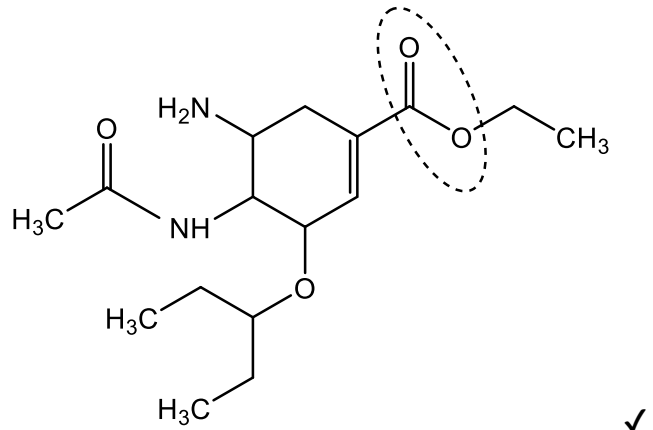
Question		Answers	Notes	Total
18.	a	<p>metal conductivity decreases AND semi-conductor conductivity increases ✓</p> <p><i>metal:</i> collisions between «already free moving» electrons/vibrating lattice ions and electrons increase ✓</p> <p><i>semi-conductor:</i></p> <p>provides sufficient energy for electrons to move to conduction band</p> <p>OR</p> <p>allows semiconductors to ionize forming freely moving electrons ✓</p>		3
18.	b	<p><i>Any one of:</i></p> <p>cheaper ✓</p> <p>uses light of lower energy ✓</p> <p>plentiful resources ✓</p> <p>renewable resources ✓</p> <p>use of nanoparticles provides large surface area exposure to sunlight ✓</p> <p>can absorb better under cloudy conditions ✓</p> <p>better conductivity ✓</p> <p>more flexible ✓</p>		1 max

Option D — Medicinal chemistry

Question			Answers	Notes	Total
19.	a		<p>Name: hydroxyl ✓</p> <p>Absorption band: 3200–3600 «cm⁻¹» ✓</p>	Accept “phenol” OR “alcohol” but not “hydroxide”.	2
19.	b	i	 <p>correct X ✓</p> <p>correct Y ✓</p>	X and Y must be near the Hs.	2
19.	b	ii	X: singlet AND Y: singlet ✓		1

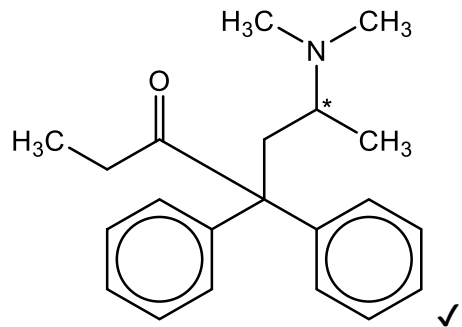
Question			Answers	Notes	Total
20.	a		«four-membered» beta-lactam ring ✓	Accept a diagram showing a structural representation of the beta-lactam ring.	1
20.	b	i	produce penicillinase/enzyme that deactivates penicillin ✓		1
20.	b	ii	side-chain changed «preserving beta-lactam ring» ✓	Accept "R group changed".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

Question			Answers	Notes	Total
21.	a		$\text{CaCO}_3(\text{s}) + 2\text{HCl}(\text{aq}) \rightarrow \text{CO}_2(\text{g}) + \text{CaCl}_2(\text{aq}) + \text{H}_2\text{O}(\text{l})$ ✓	Accept balanced ionic equations involving "H ⁺ " or "H ₃ O ⁺ ". Do not accept "H ₂ CO ₃ ".	1
21.	b		<i>Omeprazole:</i> inhibits enzyme/«gastric» proton pump «which secretes H ⁺ ions into gastric juice» OR inhibits the H ⁺ /K ⁺ -ATPase system ✓ <i>Ranitidine:</i> inhibits/blocks H ₂ /histamine receptors «in cells of stomach lining» OR prevents histamine binding to H ₂ /histamine receptors «and triggering acid secretion» ✓	Accept "H ₂ -receptor antagonist" for M2.	2

Question			Answers	Notes	Total
22.	a	i		Accept circles that include the alkyl side chain.	1
22.	a	ii	283 ✓		1
22.	b		more soluble «in water» ✓		1
22.	c		viruses undergo «rapid» mutation ✓ mutation causes a change in viral protein OR drug no longer binds to virus ✓	Accept “rapid reproduction «allows resistant viruses to multiply»”.	2

Question		Answers	Notes	Total
23.	a	<p>«temporarily» bond/bind to «opioid» receptors in the brain/CNS ✓ block the transmission of pain impulses ✓</p>		2
23.	b	<p>«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 ✓</p>	<p><i>Award [1 max] if no statement or an incorrect statement about the blood–brain barrier.</i></p>	2

Question			Answers	Notes	Total
24.	a	i	<p>Alternative 1</p> <p>half-lives = « $\frac{24.0}{6.0}$ » ⇒ 4.0 ✓</p> <p>«N(t) (%) = 100(0.5)⁴ ⇒ 6.3 «%» ✓</p> <p>Alternative 2</p> <p>$\lambda = \left\langle \frac{\ln 2}{t_{\frac{1}{2}}} = \frac{\ln 2}{6.0} \right\rangle 0.116 \text{ hour}^{-1}$ OR $\frac{N_t}{N_0} = e^{-0.116 \times 24}$ ✓</p> <p>6.3 «%» ✓</p>	<p>Accept “6.25 «%»”.</p> <p>Award [2] for correct final answer.</p>	2
24.	a	ii	<p>$^{99}\text{Tc} \rightarrow ^{99}\text{Ru} + \beta^-$</p> <p>Ru ✓</p> <p>mass number of Ru AND beta product ✓</p>	<p>Accept “$e/e^- / {}_{-1}^0 e$” for “β^-”.</p>	2
24.	b	i	<p>small/low amounts of radiation AND for a short time ✓</p>	<p>Accept “weakly ionizing radiation” instead of “small amounts of radiation”.</p> <p>Accept “short half-lives” instead of “for a short time”.</p>	1
24.	b	ii	<p>stored in shielded containers until radiation level drops «to a safe level» ✓</p>		1
24.	c		<p>lower frequency/longer wavelength/lower energy</p> <p>OR</p> <p>does not use ionizing radiation/radionuclides ✓</p>	<p>Do not accept “does not cause cancer”.</p>	1

Question		Answers	Notes	Total
25.	a			1
25.	b	<p>«plane-»polarized light passed through sample ✓</p> <p>analyser/second polarizer determines angle of rotation of plane of plane-polarized light</p> <p>OR</p> <p>each enantiomer rotates plane «of plane-polarized light» in opposite directions «by the same angle» ✓</p>		2