M17/4/CHEMI/HP3/ENG/TZ2/XX/M

Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

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Chemistry

Higher level

Paper 3

41 pages

International Baccalaureate®
Baccalauréat International
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Section A

Question			Answers	Notes	Total
1.	a		«$\frac{\sum(\text{renewables} + \text{hydroelectricity} + \text{nuclear})}{\text{total}}$» «$\left(\frac{8800 - 7200}{12600}\right) \times 100 =$» 13 «%» ✓	*Accept range of "11–16 %".*	1
1.	b		«$18000 = 0.54x - 2000$» $x = 37037$ «million tonnes of CO_2» ✓ «$\frac{32.00}{44.01} \times 37037 = 26930$» 27000/2.7 x 10^4 «million tonnes of O_2» ✓	*Accept "37000* «million tonnes of CO_2»*" for M1.* *Award **[2]** for correct final answer with two significant figures.* *Award **[1]** for non rounded answers in range 26903–26936* «million tonnes of O_2»**.**	2
1.	c	i	increase in «atmospheric» pressure ***OR*** increase in [O_2 (g)]/concentration of O_2 (g) ***OR*** decrease in [O_2 (aq)]/concentration of O_2 (aq) ***OR*** decrease in temperature ✓	*Accept "increase in volume of oceans «due to polar ice cap melting»" **OR** "consumption of O_2 in oceans/O_2 (aq) «by living organisms»".* *State symbols required for oxygen concentration.*	1

(continued…)

(Question 1c continued)

Question			Answers	Notes	Total
1.	**c**	**ii**	summer in one station while winter in other ***OR*** stations are at different latitudes ✓ oxygen dissolves better in colder water ✓	*Accept "opposite seasons «in each hemisphere»".* *Do **not** accept "different locations with different temperatures" **OR** "stations are in different hemispheres".*	**2**
1.	**c**	**iii**	«$(\frac{209400}{209460} - 1) \times 10^6 =$» $-$ 286.5 «per meg» ✓	*The nitrogen cancels so is not needed in the calculation.* *Negative sign required for mark.*	**1**
1.	**c**	**iv**	decrease in $[O_2]$/concentration of O_2 ***OR*** increasing combustion of fossil fuels «consumes more O_2 so $[O_2]$/concentration of O_2 decreases» ***OR*** warmer oceans/seas/water «as oxygen dissolves better in colder water» ***OR*** deforestation ✓	*Accept "decrease in level of O_2".* *Accept "increasing CO_2 production «consumes more O_2 so $[O_2]$/concentration of O_2 decreases»".* *Do **not** accept "decrease in amount of O_2" **OR** "increase in greenhouse gases".*	**1**

Question			Answers	Notes	Total
2.	a		mass/*m* of lighter before ***AND*** after the experiment ✓ volume of gas/V_{gas} **«**collected in the cylinder**»** ✓ **«**ambient**»** pressure/*P* **«**of the room**»** ✓ temperature/*T* ✓	*Accept "change in mass of lighter".* *Accept "weight" for "mass".* *Accept "volume of water displaced".* *Do **not** accept just "mass of lighter/gas".* *Do **not** accept "amount" for "volume" or "mass".*	**4**
2.	b	i	*Any two of:* pressure of gas not equalized with atmospheric/room pressure ✓ too large a recorded volume **«**of gas produces a lower value for molar mass of butane**»** ***OR*** cylinder tilted ✓ difficult to dry lighter **«**after experiment**»** ***OR*** higher mass of lighter due to moisture ***OR*** smaller change in mass but same volume **«**produces lower value for molar mass of butane**»** ✓ using degrees Celcius/°C instead of Kelvin/K for temperature ✓	*Accept "vapour pressure of water not accounted for" **OR** "incorrect vapour pressure of water used" **OR** "air bubbles trapped in cylinder". Do **not** accept "gas/bubbles escaping «the cylinder»" or other results leading to a larger molar mass.* *Accept "lighter might contain mixture of propane and butane".* *Do **not** accept only "human errors" **OR** "faulty equipment" (without a clear explanation given for each) or "mistakes in calculations".*	**2 max**

(continued…)

(Question 2b continued)

Question			Answers	Notes	Total
2.	**b**	**ii**	record vapour pressure of water **«**at that temperature**»** ***OR*** equalize pressure of gas in cylinder with atmospheric/room pressure ***OR*** tap cylinder before experiment **«**to dislodge trapped air**»** ***OR*** collect gas using a «gas» syringe/eudiometer/narrower/more precise graduated tube ***OR*** collect gas through tubing **«**so lighter does not get wet**»** ***OR*** dry lighter **«**before and after experiment**»** ***OR*** hold «measuring**»** cylinder vertical **OR** commence experiment with cylinder filled with water ✓	*Accept "adjust cylinder **«**up or down**»** to ensure water level inside cylinder matches level outside".* *Accept "repeat experiment/readings **«**to eliminate random errors**»**".* *Accept "use pure butane gas".*	**1**

Section B

Option A — Materials

Question			Answers	Notes	Total
3.	**a**		reinforcing «phase» ✓ «embedded in» matrix «phase» ✓		**2**
3.	**b**		<table><tr><th></th><th>Physical or chemical</th><th>Bottom up or top down</th></tr><tr><td>Lithography</td><td>physical</td><td>top down</td></tr><tr><td>Metal coordination</td><td>chemical</td><td>bottom up</td></tr></table> ✓✓	*Award **[2]** for all 4, **[1]** for 2 or 3 correct.*	**2**
3.	**c**	**i**	100% ✓	*Accept "almost 100%" if a catalyst is referred to.*	**1**
3.	**c**	**ii**	addition ***AND*** no atoms removed/all atoms accounted for/no loss of water/ammonia/inorganic by-product/small molecules ***OR*** addition ***AND*** there is only one «reaction» product ✓		**1**
3.	**c**	**iii**	amido ***OR*** amino ✓	*Accept "amide/carboxamide/carbamoyl" for "amido".* *Accept "amine" for "amino".* *Accept "carbonyl".*	**1**

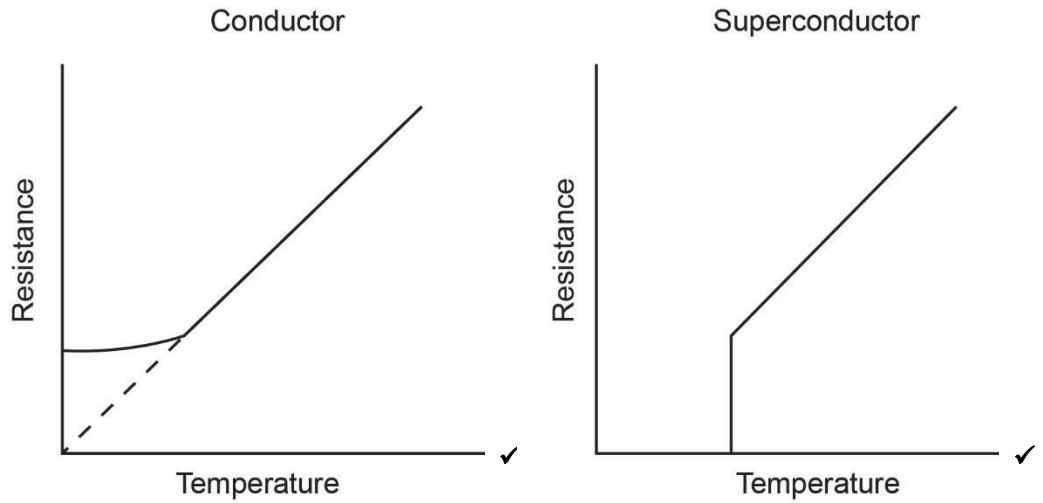
Question			Answers	Notes	Total
4.	a		HCl/hydrogen chloride ✓	*Accept "hydrochloric acid".*	1
4.	b		forms four/six/several/multiple coordinate/coordination bonds **«**to a central metal ion**»** ***OR*** is a polydentate/tetradentate/hexadentate ligand ✓ forms more stable complex/stronger bonds with central metal ion ***OR*** increases entropy/*S* by releasing smaller **«**monodentate ligand**»** molecules previously complexed ✓ complex ions are much larger **«**and can be removed easily due to large size of chelate complexes**»** ***OR*** heavy metal ions trapped inside the ligand/become **«**biologically**»** inactive/non-toxic/harmless ✓	*Accept "dative* **«***covalent***»***" for "coordinate/coordination".* *Do* ***not*** *accept just "chelates".*	3

Question			Answers	Notes	Total
5.	a		carbon monoxide/CO adsorbs onto palladium/Pd ✓ bonds stretched/weakened/broken ***OR*** **«**new**»** bonds formed ***OR*** activation energy/E_a **«**barrier**»** lowered **«**in both forward and reverse reactions**»** ✓ products/CO_2 desorb **«**from surface of catalyst**»** ✓		**3**
5.	b	i	Fe/iron ***OR*** Zn/zinc ***OR*** Co/cobalt ***OR*** Cd/cadmium ***OR*** Cr/chromium ✓	*Accept "Mn/manganese".*	**1**

(continued…)

(Question 5b continued)

Question			Answers	Notes	Total
5.	**b**	**ii**	$Ni^{2+}(aq) + Fe(s) \rightarrow Ni(s) + Fe^{2+}(aq)$ ***OR*** $Ni^{2+}(aq) + Zn(s) \rightarrow Ni(s) + Zn^{2+}(aq)$ ***OR*** $Ni^{2+}(aq) + Co(s) \rightarrow Ni(s) + Co^{2+}(aq)$ ***OR*** $Ni^{2+}(aq) + Cd(s) \rightarrow Ni(s) + Cd^{2+}(aq)$ ***OR*** $Ni^{2+}(aq) + Cr(s) \rightarrow Ni(s) + Cr^{2+}(aq)$ ✓	*Accept "$3Ni^{2+}(aq) + 2Cr(s) \rightarrow 3Ni(s) + 2Cr^{3+}(aq)$".* *Do **not** penalize similar equations involving formation of $Fe^{3+}(aq)$, $Mn^{2+}(aq)$ **OR** $Co^{3+}(aq)$.* *Ignore Cl^- ions.* *Accept correctly balanced non-ionic equations eg, "$NiCl_2(aq) + Zn(s) \rightarrow Ni(s) + ZnCl_2(aq)$" etc.* *Do **not** allow ECF from (b) (i).*	**1**
5.	**b**	**iii**	$K_{sp} = [Ni^{2+}][OH^-]^2$ ***OR*** $5.48 \times 10^{-16} = [Ni^{2+}][10^{-3.5}]^2$ ✓ **«**$[Ni^{2+}]$ =**»** 5.48×10^{-9} **«**mol dm^{-3}**»** ✓	*Award **[2]** for correct final answer.*	**2**

Question			Answers	Notes	Total
5.	c	i	paramagnetic materials have unpaired electrons ***OR*** diamagnetic materials have all electrons «spin-»paired ✓ unpaired electrons align with an external magnetic field ***OR*** paired electrons are not influenced by magnetic field ✓	*Accept "diamagnetic materials have no unpaired electrons" for M1.*	**2**
5.	c	ii	 ✓ ✓	*Conductor:* *Accept any concave upwards curve or line showing resistance increasing with temperature. There should be a y-axis intercept. Do **not** accept x-axis intercept for conductor.* *Superconductor:* *Sharp transition with vertical line to x-axis. Greater than T_c, accept any concave upwards curve or line showing resistance increasing with temperature.*	**2**

(continued…)

(Question 5c continued)

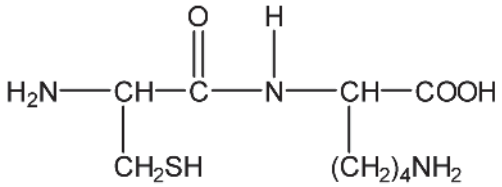
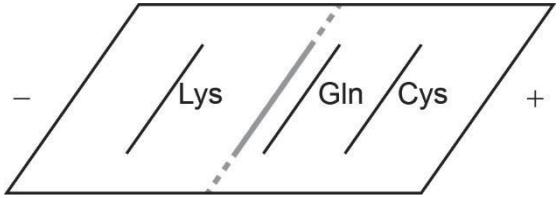
Question			Answers	Notes	Total
5.	**c**	**iii**	*Any three of*: type 1 have lower critical temperature/T_c **«**than type 2**»** ***OR*** type 2 can superconduct at higher temperatures **«**than type 1**»** ✓ type 1 are **«**elemental**»** metals ***AND*** type 2 can be alloys/composites/metal oxide ceramics/perovskites ✓ type 1 have sharp transition to superconductivity ***AND*** type 2 have more gradual transition ✓ type 1 have all **«**magnetic**»** flux expelled to normal state ***AND*** type 2 have partial penetration of flux in mixed state ✓ type 1 typically work via Cooper pairs ***AND*** type 2 may not necessarily use this mechanism ✓ magnetic fields can penetrate type 2 in the mixed state **«**in a type of Vortex**»** ***AND*** type 1 has no mixed state ✓ type 1 have one critical magnetic field/B_c ***AND*** type 2 have two/B_{c_1} and B_{c_2} ✓	*Award **[1 max]** if three correct pieces of information are given for one type only without contrasting with the other type.* *Marks may also be awarded from suitable sketch(es).* *Accept "H" for "B".*	**3 max**

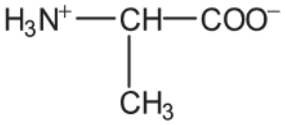
Question			Answers	Notes	Total
6.	a		*Polar molecule:* «orientation of molecule» influenced by electric field/«applied» voltage/«applied» potential «difference»/«applied» current ***OR*** can be switched on and off ✓ *Long alkyl chain:* prevents close packing of molecules ***OR*** molecules can align ***OR*** reduces the melting point of the liquid crystal/LC «phase making liquid at room temperature» ✓	*Accept "makes molecule rod-shaped" for M2.*	**2**

Question			Answers	Notes	Total
6.	b		inability to replicate calibrations below certain levels ***OR*** variation in methodology ***OR*** variation between machines calibrated with the same samples ***OR*** variation in plasma torches ***OR*** different detection limits for MS and OES ***OR*** interference from solvents/other chemicals ***OR*** inability to produce pure standards ***OR*** chance that low signal and blank are the same ✓		**1**

Question			Answers	Notes	Total
7.			HDPE ***AND*** LDPE **«**have similar IR**»** ✓ both are polyethene/polyethylene ***OR*** only branching differs ***OR*** same bonds ***OR*** same bending/stretching/vibrations ✓	*Accept "water bottle **AND** water bottle cap" for M1.*	**2**

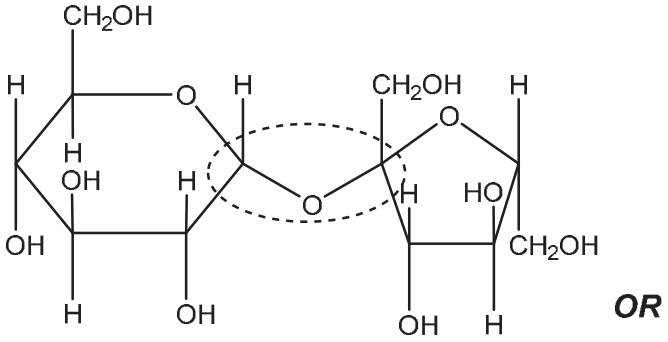
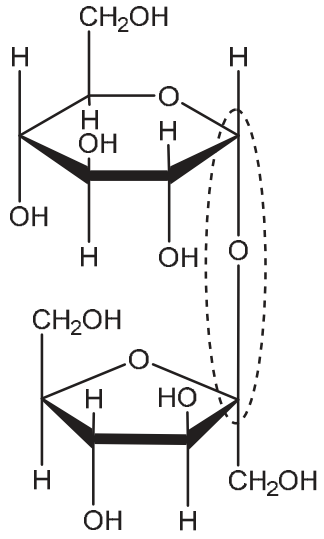
Option B — Biochemistry

Question			Answers	Notes	Total
8.	a		 correct order ✓ amide link ✓	*Accept CO-NH but **not** CO-HN for amide link.* *Accept a full or condensed structural formula.* *Penalize incorrect bond linkages or missing hydrogens once only in 8 (a) and 8 (c) (i).*	**2**
8.	b		 Cys and Gln move to positive electrode ***AND*** Lys to negative electrode ✓ Cys further to positive electrode than Gln ✓	*Do **not** penalize if lines are omitted or if different markings are given (eg, spots etc.), as long as relative positions are correctly indicated.* *Accept Gln on original position indicated.* *Award **[1 max]** for reverse order of amino acids.*	**2**

Question			Answers	Notes	Total
8.	c	i	 ✓	*Penalize incorrect bond linkages or missing hydrogens once only in 8 (a) and 8 (c) (i).*	**1**
8.	c	ii	«$\text{pH} = 9.87 + \log\left(\frac{0.500}{0.700}\right)$» «$= 9.87 - 0.146$» $= 9.72$ ✓	*pH can be deduced by an alternative method.*	**1**

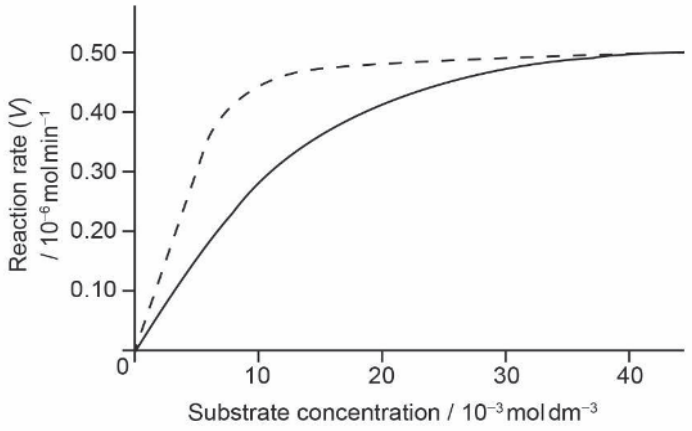
Question			Answers	Notes	Total
9.	a		stearic acid ***AND*** chain has no kinks/more regular structure ***OR*** stearic acid ***AND*** it has straight chain ***OR*** stearic acid ***AND*** no C=C/carbon to carbon double bonds ***OR*** stearic acid ***AND*** saturated ***OR*** stearic acid ***AND*** chains pack more closely together ✓ stronger London/dispersion/instantaneous induced dipole-induced dipole forces «between molecules» ✓	*Accept "stearic acid **AND** greater surface area/electron density".* *M2 can only be scored if stearic acid is correctly identified.* *Accept "stronger intermolecular/van der Waals'/vdW forces".*	**2**
9.	b		«$n(I_2) = 0.123\ dm^3 \times 0.500\ mol\ dm^{-3}$ =» 0.0615 «mol» ✓ «$m(I_2) = 0.0615\ mol \times 253.8\ g\ mol^{-1}$ =» 15.6 «g» ✓ «iodine number = $\frac{15.6\ g \times 100}{10.0\ g}$ »= 156 ✓	*Award **[3]** for correct final answer.* *Iodine number must be a whole number.* *Award **[2 max]** for 78.*	**3**

Question			Answers	Notes	Total
10.	**a**		$C_{17}H_{31}COONa$ ✓ $[(CH_3)_3NCH_2CH_2OH]OH$ ✓	*Accept "$NaC_{17}H_{31}COO$".* *Accept "$(CH_3)_3N^+CH_2CH_2OH$" **OR** "$[(CH_3)_3NCH_2CH_2OH]^+$" if positive charge is shown.* *Accept suitable names (eg, sodium linoleate, choline hydroxide etc.) **OR** correct molecular formulas.*	**2**
10.	**b**		hydrolysis ✓	*Accept "nucleophilic substitution/displacement / S_N/S_N2 / saponification".* *Do **not** accept "acid hydrolysis".*	**1**

Question			Answers	Notes	Total
11.	a		*Only in straight chain form:* carbonyl ***OR*** aldehyde ✓ *Only in ring structure:* hemiacetal ✓	*Accept functional group abbreviations (eg, CHO etc.).* *Accept "ether".*	**2**
11.	b		 ***OR***  correct link between the two monosaccharides ✓	*Correct 1,4 beta link **AND** all bonds on the 2 carbons in the link required for mark.* *Ignore any errors in the rest of the structure.* *Penalize extra atoms on carbons in link.*	**1**

Question			Answers	Notes	Total
11.	c		minimize «negative» impact on environment ***OR*** minimize waste produced ***OR*** consider atom economy ***OR*** efficiency of synthetic process ***OR*** problems of side reactions/lower yields ***OR*** control temperature «inside large reactors» ***OR*** availability of starting/raw materials ***OR*** minimize energy costs ***OR*** value for money/cost effectiveness/cost of production ✓		1

Question			Answers	Notes	Total
12.	a		«extensive system of» conjugation/alternating single and double «carbon to carbon» bonds ***OR*** delocalized electrons «over much of the molecule» ✓	*Accept "delocalization".*	1
12.	b		*cis*«-retinal» converts to *trans*«-retinal» ***OR*** one of the C=C «fragments in retinal» changes «its configuration» from *cis* to *trans* ✓		1

Question			Answers	Notes	Total
13.	a		«K_m = [substrate] at $\frac{1}{2}$ V_{max}» 4.2×10^{-3} ✓ mol dm^{-3} ✓	*Accept answers in the range of 3.5×10^{-3} to 5.0×10^{-3} mol dm^{-3}.* *M2 can be scored independently.*	**2**
13.	b		 graph to right of curve ***AND*** finish at same V_{max} ✓	*Do **not** penalize if curve does not finish exactly at same V_{max} as long as it is close to it (since drawn curve does not flatten out completely at V_{max} = 0.50).*	**1**
13.	c		K_m is inverse measure of affinity of enzyme for a substrate / K_m is inversely proportional to enzyme activity ***OR*** high value of K_m indicates higher substrate concentration needed for enzyme saturation ***OR*** low value of K_m means reaction is fast at low substrate concentration ✓	*Idea of inverse relationship must be conveyed.* *Accept "high value of K_m indicates low affinity of enzyme for substrate/less stable ES complex/lower enzyme activity".* *Accept "low value of K_m indicates high affinity of enzyme for substrate/stable ES complex/greater enzyme activity".*	**1**

Question			Answers	Notes	Total
14.	**a**		oxygen binds to first active site **«**of deoxygenated heme**»** ***AND*** alters shape of other active sites ***OR*** cooperative binding ✓ affinity of partially oxygenated hemoglobin for oxygen increases ✓		**2**
14.	**b**		CO is a competitive inhibitor **«**of oxygen binding to hemoglobin**»** ***OR*** CO has greater affinity for hemoglobin **«**than oxygen**»** ✓ less oxygen is transported ***OR*** uptake of oxygen decreases ***OR*** causes hypoxia ✓	*Do **not** penalize "CO binds irreversibly" if included in answer.*	**2**
15.	**a**		phosphate groups **«**in nucleotides fragments are almost completely**»** ionized ✓	*Do **not** accept just "phosphate «groups»".*	**1**
15.	**b**		–CTGCCTAGT– ✓		**1**

Option C — Energy

Question			Answers	Notes	Total
16.	**a**	**i**	${}^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n}$ ✓	*Accept "n" for "${}^{1}_{0}n$".* *Accept "$^{2}H + {}^{3}H \rightarrow {}^{4}He + {}^{1}n$/n".*	**1**
16.	**a**	**ii**	higher binding energy/BE **«**per nucleon**»** for helium/products ***OR*** nucleons in products more tightly bound ✓ mass defect/lost matter converted to energy ✓	*Accept converse statement in M1.* *Accept "mass deficit" for "mass defect".*	**2**
16.	**a**	**iii**	$\Delta BE = BE(^{4}\mathrm{He}) - (BE(^{2}\mathrm{H}) + BE(^{3}\mathrm{H}))$ ***OR*** $\Delta BE = 4 \times 7.1 - (2 \times 1.1 + 3 \times 2.8)$ ✓ $= 17.8$ **«**MeV**»** ✓	*Accept answers in range 17.3 to 18.1 **«**MeV**»**.* *Award **[1 max]** for final answers in range of 3.0 to 3.4 **«**MeV**»**.* *Award **[2]** for correct final answer.*	**2**
16.	**b**		spectrometry ✓	*Accept "spectroscopy" for "spectrometry" **OR** more specific techniques such as "atomic absorption spectrometry/AAS", "astrophotometry" etc. Do **not** award mark for incorrect specific spectrometric techniques.* *Do **not** accept "spectrum".*	**1**

<table>
<tr><th colspan="3">Question</th><th>Answers</th><th>Notes</th><th>Total</th></tr>
<tr><td>17.</td><td>a</td><td></td><td>
<table>
<tr><th>Energy source</th><th>Advantage</th><th>Disadvantage</th></tr>
<tr><td>Biofuels</td><td>low carbon footprint
OR
sustainable/renewable
OR
lower emissions of CO «for biodiesel/ethanol».
OR
economic security/availability in countries without crude oil ✓</td><td>lower energy content/specific energy
OR
high cost (only if a specific example if given eg, growing corn for ethanol etc.)
OR
use agricultural resources/fertilizers/pesticides/water
OR
biodiesel has high viscosity/clogs fuel injectors
OR
less suitable in low temperatures
OR
increased NO_x emissions for biodiesel
OR
greenhouse gases/CO_2 «still/also» produced ✓</td></tr>
<tr><td>Fossil fuels</td><td>higher energy content/specific energy
OR
low cost
OR
readily accessible ✓</td><td>linked to climate change/global warming/increased release of greenhouse gases
OR
not sustainable/renewable
OR
greater pollution possibilities ✓</td></tr>
</table>
</td><td>
Do not award marks for converse statements for advantage and disadvantage.
Points related to greenhouse gases should be counted only once for the entire question.

Biofuels:
Accept “«close to» carbon neutral”, “produce less greenhouse gases/CO_2” as an advantage.

Accept “engines have to be modified if biodiesel used” as a disadvantage.

Fossil Fuels:
Accept specific pollution examples (eg, oil spills, toxic substances released when burning crude oil, etc.) as a disadvantage.
</td><td>4</td></tr>
</table>

Question			Answers	Notes	Total
17.	b	i	«specific energy =» 142 ✓ kJ g^{-1} ✓	*Accept other correct values with the correct corresponding units.* *M2 can be scored independently.*	2
17.	b	ii	large volumes of hydrogen required ***OR*** hydrogen has lower energy density ✓ not easily transportable «form» as it is a gas ***OR*** heavy containers required to carry ***AND*** compress/regulate «hydrogen» ***OR*** high energy/cost required to compress hydrogen to transportable liquid form ***OR*** atmospheric pollution may be generated during production of hydrogen ***OR*** hydrogen fuel cells do not work at very low temperatures ***OR*** highly flammable when compressed/difficult to extinguish fires ***OR*** leaks not easy to detect ***OR*** high cost of production ***OR*** lack of filling stations/availability to consumer «in many countries» ✓	*Accept "«hydrogen combustion contributes to» knocking in engines"* ***OR*** *"modified engine required" for M2.* *Accept "explosive" but not "more dangerous" for M2.*	2

Question			Answers	Notes	Total
17.	c	i	*Anode (negative electrode):* $CH_3OH\,(aq) + H_2O\,(l) \rightarrow 6H^+\,(aq) + 6e^- + CO_2\,(g)$ ✓ *Cathode (positive electrode):* $\frac{3}{2}\,O_2\,(g) + 6H^+\,(aq) + 6e^- \rightarrow 3H_2O\,(l)$ ✓	*Award **[1 max]** for correct equations at wrong electrode.* *Accept "e" for "e^-".* *Accept "$O_2\,(g) + 4H^+\,(aq) + 4e^- \rightarrow 2H_2O\,(l)$".*	**2**
17.	c	ii	allows H^+/ions pass through/diffuse/move **«**from anode to cathode but not electrons or small molecules**»** ✓	*Accept "acts as a salt bridge".*	**1**
17.	c	iii	H^+/ions pass through/diffuse/move from anode/negative electrode «through membrane» to cathode/positive electrode ✓ H^+/ions used to reduce oxygen at cathode/positive electrode ✓	*Oxygen must be mentioned for M2.*	**2**

<table>
<tr><th colspan="3">Question</th><th>Answers</th><th>Notes</th><th>Total</th></tr>
<tr><td>18.</td><td>a</td><td>i</td><td>
<table>
<tr><th>Type of radiation</th><th>Region</th></tr>
<tr><td>Incoming radiation from sun</td><td>A «and B»</td></tr>
<tr><td>Re-radiated from Earth's surface</td><td>B</td></tr>
<tr><td>Absorbed by CO_2 in the atmosphere</td><td>B ✓</td></tr>
</table>
</td><td>Accept “B” alone for incoming radiation from sun.

All three correct answers necessary for mark.</td><td>1</td></tr>
<tr><td>18.</td><td>a</td><td>ii</td><td><u>both</u> between 400–700 «nm» ✓
β-carotene at higher wavelength than retinal ✓</td><td>Accept any wavelength within the 400-700 nm visible region range for M1 and any higher wavelength for β-carotene within the same region for M2.</td><td>2</td></tr>
<tr><td>18.</td><td>b</td><td>i</td><td>$CO_2\,(aq) + H_2O\,(l) \rightleftharpoons H_2CO_3\,(aq)$ ✓</td><td>State symbols AND equilibrium sign required for mark in (b) (i) only.
Accept “$CO_2\,(aq) + H_2O\,(l) \rightleftharpoons H^+\,(aq) + HCO_3^-\,(aq)$”
OR
“$CO_2(aq) + H_2O(l) \rightleftharpoons 2H^+(aq) + CO_3^{2-}(aq)$”.</td><td>1</td></tr>
</table>

(continued…)

(Question 18b continued)

Question			Answers	Notes	Total
18.	**b**	**ii**	$CO_2\,(aq) + H_2O\,(l) \rightleftharpoons 2H^+\,(aq) + CO_3^{2-}\,(aq)$ ***OR*** $CO_2\,(aq) + H_2O\,(l) \rightleftharpoons H^+\,(aq) + HCO_3^-\,(aq)$ ***OR*** $H_2CO_3\,(aq) + H_2O\,(l) \rightleftharpoons H_3O^+\,(aq) + HCO_3^-\,(aq)$ ***OR*** $H_2CO_3\,(aq) \rightleftharpoons H^+\,(aq) + HCO_3^-\,(aq)$ ***OR*** $H_2CO_3\,(aq) + 2H_2O\,(l) \rightleftharpoons 2H_3O^+\,(aq) + CO_3^{2-}\,(aq)$ ***OR*** $H_2CO_3\,(aq) \rightleftharpoons 2H^+\,(aq) + CO_3^{2-}\,(aq)$ ✓ equilibrium shifts to the right causing increase in $[H_3O^+]/[H^+]$ **«**thereby decreasing pH**»** ✓	*Equilibrium sign needed in (b) (ii) but penalize missing equilibrium sign once only in (b) (i) and (ii).* *Do **not** accept "$CO_2\,(aq) + H_2O\,(l) \rightleftharpoons H_2CO_3\,(aq)$" unless equation was not given in b (i).*	**2**

<table>
<tr><th colspan="3">Question</th><th>Answers</th><th>Notes</th><th>Total</th></tr>
<tr><td>19.</td><td>a</td><td></td><td>
<table>
<tr><th>Type of solar cell</th><th>Absorption of photons</th><th>Charge separation</th></tr>
<tr><td>Silicon based</td><td>absorbs photons in the semiconducting material ✓</td><td>«valence band» electron«s»
promoted to conduction band
OR
free-moving/mobile electron«s» produced
OR
one-way flow of electron«s»
OR
«excess» electrons in one zone of semiconductor «and excess holes in another zone» ✓</td></tr>
<tr><td>DSSC</td><td>dye absorbs a photon «and injects an electron into TiO_2» ✓</td><td>redox reaction involving I^-/iodide
OR
I^-/iodide oxidized to I_3^-/triiodide
OR
I^-/iodide reduces dye
OR
I^-/iodide releases electron to dye
OR
I_3^-/triiodide reduced to I^-/iodide ✓</td></tr>
</table>
</td><td>Accept “existence of holes AND electrons at p-n junction” for M2.</td><td>4</td></tr>
</table>

Question			Answers	Notes	Total
19.	b		*Any of:* cheaper ***OR*** ease of fabrication ***OR*** use light of lower energy/lower frequency/longer wavelength ***OR*** plentiful and renewable resources «to construct DSSC cells» ***OR*** operate at lower «internal» temperatures/better at radiating heat away «since constructed with thin front layer of conductive plastic compared to glass box in photovoltaic cell» ***OR*** use of nanoparticles provides large surface area exposure to sunlight/sun/light ***OR*** can absorb better under cloudy conditions ***OR*** better conductivity ***OR*** more flexible ✓	*Accept "lower mass/lighter «so greater flexibility to integrate into windows etc.»" **OR** "greater power-conversion efficiency «with latest DSSC models»".*	**1**

Option D — Medicinal chemistry

Question			Answers	Notes	Total
20.	**a**	**i**	n(salicylic acid) = **«** $\frac{2.65\text{ g}}{138.13\text{ g mol}^{-1}}$ **=»** 0.0192 **«mol»** ***AND*** n(ethanoic anhydride) = **«** $\frac{2.51\text{ g}}{102.10\text{ g mol}^{-1}}$ **=»** 0.0246 **«mol»** ✓	*Accept integer values for molar masses in (a) (i) and (ii).*	**1**
20.	**a**	**ii**	**«**mass = 0.0192 mol × 180.17 g mol^{-1} **=»** 3.46 **«g»** ✓	*Award ECF mark **only** if limiting reagent determined in (i) has been used.*	**1**
20.	**a**	**iii**	*Any two of:* 2500–3000 **«**cm^{-1}**»** / **«**absorbance**»** due to O–H in carboxyl ✓ 1700–1750 **«**cm^{-1}**»** / **«**absorbance**»** due to C=O in carboxyl/ethanoate ✓ 1050–1410 **«**cm^{-1}**»** / **«**absorbance**»** due to C–O bond in carboxyl/ethanoate ✓	*Accept "carboxylic acid" for "carboxyl", "acetate/ester" for "ethanoate".* *Accept specific wavenumber once within indicated range.* *Do **not** award mark if reference is made to an alcohol/ether.*	**2 max**
20.	**a**	**iv**	*Any two of:* melting point ✓ mass spectrometry/MS ✓ high-performance liquid chromatography/HPLC ✓ NMR/nuclear magnetic resonance ✓ X-ray crystallography ✓ elemental analysis ✓	*Accept "spectroscopy" instead of "spectrometry" where mentioned but **not** "spectrum".* *Accept "ultraviolet **«**-visible**»** spectroscopy/UV/UV-Vis".* *Do **not** accept "gas chromatography/GC".* *Accept "thin-layer chromatography/TLC" as an alternative to "HPLC".*	**2 max**

Question			Answers	Notes	Total
20.	**b**	**i**	react with NaOH ✓	*Accept "$NaHCO_3$" **OR** "Na_2CO_3" instead of "NaOH".* *Accept chemical equation **OR** name for reagent used.*	**1**
20.	**b**	**ii**	**«**marginally**»** higher ***AND*** increase rate of dispersion ***OR*** **«**marginally**»** higher ***AND*** increase absorption in mouth/stomach **«**mucosa**»** ***OR*** **«**approximately the**»** same ***AND*** ionic salt reacts with HCl/acid in stomach to produce aspirin again ✓	*Do **not** accept "**«**marginally**»** higher **AND** greater solubility in blood".*	**1**

Question			Answers	Notes	Total
21.	**a**		*Any two of:* diamorphine has ester/ethanoate/acetate **«**groups**»** ***AND*** morphine has hydroxyl **«**groups**»** ✓ diamorphine/ester/ethanoate/acetate groups less polar ✓ diamorphine more soluble in lipids ✓	*Accept "alcohol/hydroxy" for "hydroxyl" but* ***not*** *"hydroxide".* *Accept "diamorphine non-polar".* *Accept converse statements.*	**2 max**
21.	**b**		morphine has a smaller therapeutic window ✓	*Accept converse statements.* *Accept "codeine has lower activity"* ***OR*** *"codeine has lower risk of overdose"* ***OR*** *"codeine is less potent".* *Do* ***not*** *accept "lower abuse potential for codeine"* ***OR*** *"codeine less addictive"* ***OR*** *"codeine has a lower bioavailability".*	**1**
21.	**c**	**i**	6 ✓		**1**
21.	**c**	**ii**	*Chemical shift:* 2.2–2.7 **«**ppm**»** ✓ *Splitting pattern:* quartet/q ✓		**2**

Question			Answers	Notes	Total
22.	a		blocks/binds to H2-histamine receptors **«**in cells of stomach lining**»** ***OR*** prevents histamine molecules binding to H2-histamine receptors **«**and triggering acid secretion**»** ✓	*Accept "H2 receptor antagonist".*	**1**
22.	b		$[Na_2CO_3] = \text{«}\frac{0.500\,g}{105.99\,g\,mol^{-1} \times 0.075\,dm^3}$ **=»** 0.0629 **«**mol dm^{-3}**»** ✓ **«**$pH = pK_a + \log\frac{[conj\ base]}{[conj\ acid]}$**»** «pH = 10.35 − 0.201 **=»** 10.15 ✓	*Alternative method involving K_a may be used to deduce pH in M2.* *Award **[2]** for correct final answer.*	**2**

Question			Answers	Notes	Total
23.	a		*One similarity:* both contain amido «group» ✓ *One difference:* oseltamivir contains ester «group» ***AND*** zanamivir does not ***OR*** oseltamivir contains amino «group» ***AND*** zanamivir does not «but contains a guanidino group» ***OR*** zanamivir contains carboxyl «group» ***AND*** oseltamivir does not ***OR*** zanamivir contains «several» hydroxyl «groups» ***AND*** oseltamivir does not ***OR*** oseltamivir contains ester «group» ***AND*** zanamivir contains carboxyl «group» ***OR*** oseltamivir contains ester «group» ***AND*** zanamivir contains «several» hydroxyl «groups» ✓	*Accept "both contain ether «group»" **OR** "both contain alkene/alkenyl «group»" **OR** "both contain carbonyl «group»" **OR** "both contain amino/amine «group»". Latter cannot be given in combination with second difference alternative with respect to amino group.* *Accept "amide/carboxamide/carbamoyl" for "amido".* *Accept "amine" for "amino".* *Accept "carboxylic acid" for "carboxyl".* *Accept "hydroxy/alcohol" for "hydroxyl", but **not** "hydroxide".*	**2**

Question			Answers	Notes	Total
23.	b		«negative» side-effects of medication on patient/volunteers ***OR*** effects on environment «from all materials used and produced» ***OR*** potential for abuse ***OR*** drugs may be developed that are contrary to some religious doctrines ***OR*** animal testing ***OR*** risk to benefit ratio ***OR*** appropriate consent of patient volunteers ✓		1

Question			Answers	Notes	Total
24.			*Any of:* **«**most are**»** toxic **«**to living organisms**»** ***OR*** incomplete combustion/incineration can produce toxic products/dioxins/phosgene ***OR*** carcinogenic ✓ **«**some can be**»** greenhouse gases ✓ ozone-depleting ✓ can contribute to formation of **«**photochemical**»** smog ✓ can accumulate in groundwater ***OR*** have limited biodegradability ✓ cost/hazards of disposal ✓	*Do **not** accept "harmful to the environment".* *Do **not** accept just "pollutes water".*	**1 max**

Question			Answers	Notes	Total
25.			chiral molecule/auxiliary/optically active species added/connected/attached «to non-chiral starting molecule to force reaction to follow a certain path» ✓ one enantiomer produced ***OR*** chiral auxiliary creates stereochemical condition «necessary to follow a certain pathway» ***OR*** stereochemical induction ***OR*** existing chiral centre affects configuration of new chiral centres ✓ **«**after new chiral centre created» chiral auxiliary removed «to obtain desired product**»** ✓		**3**

Question			Answers	Notes	Total
26.	**a**	**i**	more damaging than other radiation types ***OR*** very damaging to «cancer» cells ***OR*** high ionizing density «of alpha particles» ✓ absorbed within a very short range of emission ***OR*** causes little damage to surrounding tissues ✓	*Accept "high ionizing power «of alpha particles»" for M1.* *Accept "low penetrating power «of alpha particles»" for M2.*	**2**
26.	**a**	**ii**	«radioactive isotope/radionuclide/alpha-emitter» administered using carrier drug/protein/antibodies ✓		**1**
26.	**b**	**i**	beta/β «radiation» ✓		**1**
26.	**b**	**ii**	${}^{90}_{39}\text{Y} \rightarrow {}^{90}_{40}\text{Zr} + \beta$ ✓	*Accept "* ${}^{0}_{-1}e$ */e/*e^-*" **OR** "* ${}^{0}_{-1}\beta / \beta^-$*"* *Accept ECF from (b) (i) if incorrect radiation identified, eg,* ${}^{90}_{39}Y \rightarrow {}^{86}_{37}Rb + {}^{4}_{2}He$ *.*	**1**
26.	**b**	**iii**	**ALTERNATIVE 1**: «4 half-lives» 6.25 «%» ✓ **ALTERNATIVE 2**: «$N_t = N_0(0.5)^{\frac{t}{t_{1/2}}} = 100\ (0.5)^{\frac{27}{6.75}}$ =» 6.25 «%» ✓		**1**