Markscheme

May 2017

Chemistry

Higher level

Paper 3

Section A

Question			Answers	Notes	Total
1.	**a**		$$\left\langle\!\!\left\langle \frac{\sum(\text{renewables} + \text{hydroelectricity} + \text{nuclear})}{\text{total}} \right\rangle\!\!\right\rangle$$ $\left\langle\!\!\left\langle \left(\dfrac{8800 - 7200}{12600}\right) \times 100 = \right\rangle\!\!\right\rangle$ 13 «%» ✔	*Accept range of "11–16 %".*	**1**
1.	**b**		«$18000 = 0.54x - 2000$» $x = 37037$ «million tonnes of CO_2» ✔ «$\dfrac{32.00}{44.01} \times 37037 = 26930$» 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**

(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".*	**1.** **2**
1.	**c**	**iii**	$«(\dfrac{209400}{209460} - 1) \times 10^6 =» - 286.5$ «per meg» ✔	*The nitrogen cancels so is not needed in the calculation.* *Negative sign required for mark.*	**1.** **1**
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.** **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".*	2. **1**

Section B

Option A — Materials

Question			Answers	Notes	Total
3.	**a**		reinforcing «phase» ✓ «embedded in» matrix «phase» ✓		**2**
3.	**b**		<table><tr><td></td><td>*Physical or chemical*</td><td>*Bottom up or top down*</td></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 <u>palladium/Pd</u> ✓ 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.*	**5.** **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**
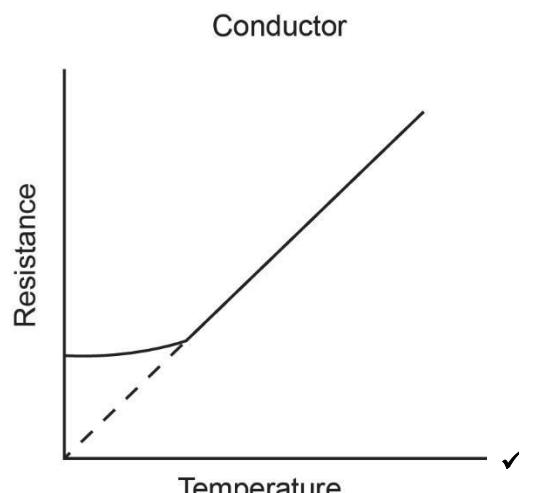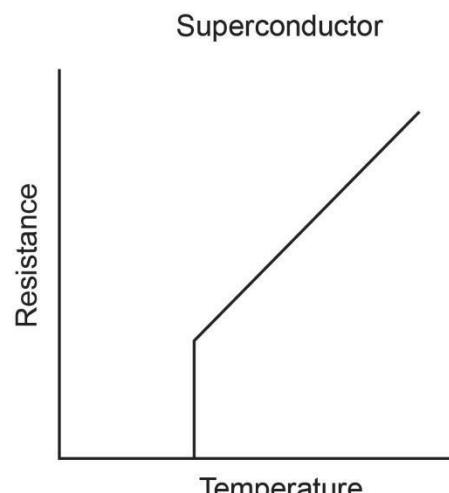
(continued…)

(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		1
			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 ✔		

| 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	H_3N^+—CH—COO$^-$ $\quad\quad\quad\;\;$ $\mid$ $\quad\quad\quad\;$ CH$_3$ $\quad\quad$ ✓	*Penalize incorrect bond linkages or missing hydrogens once only in 8 (a) and 8 (c) (i).*	1
8.	c	ii	«pH $= 9.87 + \log\left(\dfrac{0.500}{0.700}\right)$» «$= 9.87 - 0.146$» $= 9.72$ ✓	*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 <u>C</u>=<u>C</u>/<u>carbon to carbon</u> 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 × 0.500 mol dm^{-3} =» 0.0615 «mol» ✓ «$m(I_2)$ = 0.0615 mol × 253.8 g mol^{-1} =» 15.6 «g» ✓ «iodine number = $\dfrac{15.6 \text{ g} \times 100}{10.0 \text{ g}}$ »= 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**		 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**
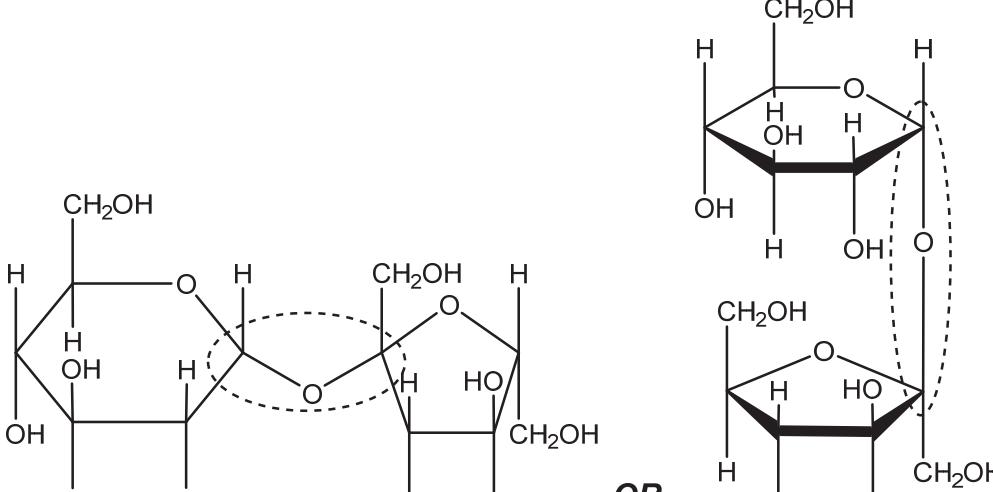
Question			Answers	Notes	Total
11.	**c**		minimize «negative» impact on environment		**1**
			OR		
			minimize waste produced		
			OR		
			consider atom economy		
			OR		
			efficiency of synthetic process		
			OR		
			problems of side reactions/lower yields		
			OR		
			control temperature «inside large reactors»		
			OR		
			availability of starting/raw materials		
			OR		
			minimize energy costs		
			OR		
			value for money/cost effectiveness/cost of production ✓		

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 $\dfrac{1}{2}$ 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	$_1^2H + {}_1^3H \rightarrow {}_2^4He + {}_0^1n$ ✔	*Accept "n" for "$_0^1n$".* *Accept "$^2H + {}^3H \rightarrow {}^4He + {}^1n/n$".*	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	$\Delta BE = BE(^4He) - (BE(^2H) + BE(^3H))$ **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

Question			Answers			Notes	Total
17.	**a**		**Energy source**	**Advantage**	**Disadvantage**	*Do **not** award marks for converse statements for advantage and disadvantage.*	**4**
			Biofuels	low carbon footprint **OR** sustainable/renewable **OR** lower emissions of CO «for biodiesel/ethanol». **OR** economic security/availability in countries without crude oil ✔	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 ✔	*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	higher energy content/specific energy **OR** low cost **OR** readily accessible ✔	linked to climate change/global warming/increased release of greenhouse gases **OR** not sustainable/renewable **OR** greater pollution possibilities ✔	*Fossil Fuels:* *Accept specific pollution examples (eg, oil spills, toxic substances released when burning crude oil, etc.) as a disadvantage.*	

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):* $\dfrac{3}{2}\,O_2\,(g) + 6H^+\,(aq) + 6e^- \rightarrow 3H_2O\,(l)$ ✔	*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**

Question			Answers	Notes	Total
18.	a	i	<table><tr><td>**Type of radiation**</td><td>**Region**</td></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>	*Accept "B" alone for incoming radiation from sun.* *All three correct answers necessary for mark.*	1
18.	a	ii	both between 400–700 «nm» ✔ β-carotene at higher wavelength than retinal ✔	*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.*	2
18.	b	i	$CO_2 (aq) + H_2O (l) \rightleftharpoons H_2CO_3 (aq)$ ✔	*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** *"$CO_2 (aq) + H_2O (l) \rightleftharpoons 2H^+ (aq) + CO_3^{2-} (aq)$".*	1

(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**

Question			Answers	Notes	Total
19.	**a**			*Accept "existence of holes **AND** electrons at p-n junction" for M2.*	**4**

Type of solar cell	Absorption of photons	Charge separation
Silicon based	absorbs photons in the <u>semiconducting</u> material ✓	«valence band» <u>electron</u>«s» promoted to conduction band **OR** free-moving/mobile <u>electron</u>«s» produced **OR** one-way flow of <u>electron</u>«s» **OR** «excess» <u>electrons</u> in one zone of semiconductor «and excess holes in another zone» ✓
DSSC	dye absorbs a photon «and injects an electron into TiO_2» ✓	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 ✓

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	$n(\text{salicylic acid}) = \left\langle\!\!\frac{2.65\ \text{g}}{138.13\ \text{g mol}^{-1}}\!=\right\rangle 0.0192\ \langle\text{mol}\rangle$ **AND** $n(\text{ethanoic anhydride}) = \left\langle\!\!\frac{2.51\ \text{g}}{102.10\ \text{g mol}^{-1}}\!=\right\rangle 0.0246\ \langle\text{mol}\rangle$ ✔	*Accept integer values for molar masses in (a) (i) and (ii).*	1
20.	a	ii	«mass = 0.0192 mol $\times$ 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$_2$CO$_3$" 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] = $«$\dfrac{0.500\,g}{105.99\,gmol^{-1} \times 0.075\,dm^3}$ =» 0.0629 «mol dm^{-3}» ✔ «$pH = pK_a + \log \dfrac{[\text{conj base}]}{[\text{conj acid}]}$» «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	$^{90}_{39}Y \rightarrow {}^{90}_{40}Zr + \beta$ ✔	*Accept "$^{\ 0}_{-1}e$ /e/e$^-$" **OR** "$^{\ 0}_{-1}\beta$/β^-"* *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