N18/4/CHEMI/HP3/ENG/TZ0/XX/M

Markscheme

November 2018

Chemistry

Higher level

Paper 3

33 pages

Section A

Question			Answers	Notes	Total
1.	a		NO_2/NO/NO_x/HNO_3/gas is poisonous/toxic/irritant ✓	*Accept formula or name.* *Accept "HNO_3 is corrosive" **OR** "poisonous/toxic gases produced".* *Accept "reaction is harmful/hazardous".*	**1**
1.	b		*Slope (gradient):* 40 ✓ *Equation:* absorbance = 40 × concentration ***OR*** $y = 40x$ ✓	*Accept any correct relationship for slope such as* $\frac{1.00}{0.025}$. *Award **[2]** if equation in M2 is correct.*	**2**
1.	c		orange is opposite blue **«**in the colour wheel**»** ***OR*** the complementary colour **«**blue**»** is seen/transmitted ✓ 585–647 **«**nm would be absorbed**»** ✓	 *Accept any value or range within 550–680 **«**nm**»** for M2.*	**2**

Question			Answers	Notes	Total
1.	d		dilute 1.00 cm^3 **«**of the standard solution with water**»** to 100 cm^3 ***OR*** dilute sample of standard solution **«**with water**»** 100 times ✓ **«**graduated/volumetric**»** pipette/pipet ✓ volumetric flask ✓	*Accept any 1:100 ratio for M1.* *Accept "mix 1 cm^3 of the standard solution with 99 cm^3 of water" for M1.* *Do **not** accept "add 100 cm^3 of water to 1.00 cm^3 of standard solution" for M1.* *Accept "burette/buret" for M2.* *Accept "graduated/measuring flask" for M3 but **not** "graduated/measuring cylinder", "conical/Erlenmeyer flask".*	**3**
1.	e	i	concentration of copper = 0.0080 **«**mol dm^{-3}**»** ✓ mass of copper in 250.0 cm^3 = **«**0.0080 mol dm^{-3} × 0.2500 dm^3 × 63.55 g mol^{-1} =**»** 0.127 **«**g**»** ***OR*** mass of brass in 1 dm^3 = **«**4 × 0.200 g =**»** 0.800 g ***AND*** $[Cu^{2+}]$ = **«**0.0080 mol dm^{-3} × 63.55 g mol^{-1} =**»** 0.5084 g dm^{-3} ✓ **«**% copper in this sample of brass = $\frac{0.127}{0.200} \times 100$ =**»** 64 **«**%**»** ***OR*** **«**% copper in this sample of brass = $\frac{0.5084}{0.800} \times 100$ =**»** 64 **«**%**»** ✓	*Accept any value in range 0.0075–0.0085 **«**mol dm^{-3}**»** for M1.* *Accept annotation on graph for M1.* *Award **[3]** for correct final answer.* *Accept "65 **«**%**»**".*	**3**
1.	e	ii	two ✓	*Do **not** apply ECF from 1(e)(i).*	**1**

Question			Answers	Notes	Total
1.	f	i	«since it is greater than 60 %» it will reduce the presence of bacteria «on door handles» ✓		1
1.	f	ii	resistant to corrosion/oxidation/rusting ***OR*** low friction surface «so ideal for connected moving components» ✓	*Accept "hard/durable", "«high tensile» strength", "unreactive", "malleable" or any reference to the appearance/ colour of brass (eg "gold-like", "looks nice" etc.).* *Do **not** accept irrelevant properties, such as "high melting/boiling point", "non-magnetic", "good heat/electrical conductor", "low volatility", etc.* *Do **not** accept "ductile".*	1
1.	g		precipitate/copper(I) iodide/CuI makes colour change difficult to see ***OR*** release of I_2/iodine from starch-I_2 complex is slow so titration must be done slowly ✓		1

Section B

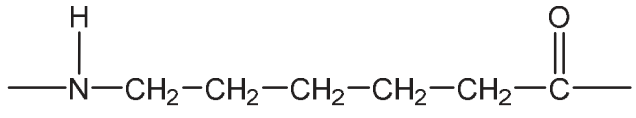
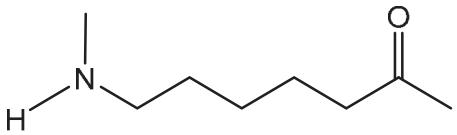
Option A — Materials

Question			Answers	Notes	Total
2.	**a**		$\Delta\chi = 0.7$ ***AND*** average $\chi = 1.7$ ✓ bonding between metallic and ionic ***OR*** more than one type of bonding present ***OR*** bond type difficult to determine as close to several regions/several types/named bonding types **«***eg* ionic and covalent *etc.***»** ***OR*** bond is mostly covalent **«**based on % covalent scale on diagram**»** ***OR*** bond has **«** $\frac{0.7}{3.2} \times 100 =$**»** 22% ionic character ✓	*Accept "EN" for "χ".* *Accept "bond is ionic but close to several regions/several types/other named bonding type(s) (eg covalent, metallic and covalent etc.)".* *Do **not** accept just "bond is ionic".* *Accept any value for % ionic character in range 15–24% or % covalent character in range 76–85%.*	**2**

Question			Answers	Notes	Total
2.	b		*Thermoplastic polymer:* PMA ***AND*** **«**weak**»** intermolecular forces/IMFs/London/dispersion/van der Waals/vdW/dipole-dipole forces **«**between layers/chains**»** ***OR*** PMA ***AND*** no/few cross-links **«**between layers/chains**»** ✓ *Thermosetting polymer:* Bakelite® ***AND*** **«**strong**»** covalent bonds **«**between layers/chains**»** ***OR*** Bakelite® ***AND*** extensive cross-links **«**between layers/chains**»** ✓	*Do **not** accept "hydrogen bonding" for M1.* *Award **[1 max]** for correct reasons for both polymer classes even if named polymers are incorrectly classified.*	**2**
2.	c		pores/cavities/channels/holes/cage-like structures **«**in zeolites**»** have specific shape/size ✓ only reactants **«**with appropriate size/geometry**»** fit inside/go through/are activated/can react ✓		**2**
2.	d	i	amino ***AND*** carboxyl ✓	*Do **not** accept "carbonyl", "hydroxyl".*	**1**

(continued...)

(Question 2d continued)

Question			Answers	Notes	Total
2.	**d**	**ii**	 / –NH(CH$_2$)$_5$CO– /  ✓	*Continuation bonds at NH and CO are required for mark.* *Ignore any brackets and n.*	**1**
2.	**d**	**iii**	*Name and reason:* PET/PETE ***AND*** peak for C=O **«**at 1700–1750 cm^{-1}**»** ✓ *RIC:* 1 ✓	*Accept "PET/PETE **AND** peak for C–O **«**at 1050–1410 cm^{-1}**»**" for M1.* *Accept "PET/PETE **AND** peak(s) for COO" for M1.* *Accept name or abbreviation for polymer.* *No ECF for M2.*	**2**

3.	**a**		positive ions/cations/Pb^{2+} ***OR*** free electrons ✓	*Accept "ions" **OR** "charged species/particle".*	**1**

Question			Answers	Notes	Total
3.	b	i	$[Pb^{2+}] = 0.50 \times 10^{-6}/5.0 \times 10^{-7}$ «g dm^{-3}» ✓ $[Pb^{2+}]$ «$= \frac{0.50 \times 10^{-6}\ g\ dm^{-3}}{207.20\ g\ mol^{-1}}$» $= 2.4 \times 10^{-9}$ «mol dm^{-3}» ✓	*Award **[2]** for correct final answer.*	**2**
3.	b	ii	«$K_{sp} = 1.43 \times 10^{-20}$» ***ALTERNATIVE 1:*** «$Q = [Pb^{2+}]\ [OH^-]^2 = 2.4 \times 10^{-9} \times (1.0 \times 10^{-2})^2$» $= 2.4 \times 10^{-13}$ ✓ $Q > K_{sp}$ ***AND*** precipitate will form ***OR*** $2.4 \times 10^{-13} > 1.43 \times 10^{-20}$ ***AND*** precipitate will form ✓ ***ALTERNATIVE 2:*** critical $[Pb^{2+}]$ for hydroxide solution «$= \frac{K_{sp}}{[OH^-]^2} = \frac{1.43 \times 10^{-20}}{(1.0 \times 10^{-2})^2}$» $= 1.4 \times 10^{-16}$ ✓ initial concentration > critical concentration ***AND*** precipitate will form ***OR*** $2.4 \times 10^{-9} > 1.4 \times 10^{-16}$ ***AND*** precipitate will form ✓ *If value given is used:* ***ALTERNATIVE 3:*** «$Q = [Pb^{2+}]\ [OH^-]^2 = 2.4 \times 10^{-4} \times (1.0 \times 10^{-2})^2$» $= 2.4 \times 10^{-8}$ ✓ $Q > K_{sp}$ ***AND*** precipitate will form ***OR*** $2.4 \times 10^{-8} > 1.43 \times 10^{-20}$ ***AND*** precipitate will form ✓		**2**

Question			Answers	Notes	Total
3.	c		«Faraday's constant, $F = 9.65 \times 10^4$ C mol^{-1} and 1 A = 1 C s^{-1}» Q «$= 0.0500\text{ mol} \times 2 \times 96500\text{ C mol}^{-1}$» $= 9650$ «C» ✓ t «$= \frac{Q}{I} = \frac{9650\text{ C}}{1.34\text{ C s}^{-1}} \approx 7200\text{ s}$ so $\frac{7200\text{ s}}{60 \times 60\text{ s h}^{-1}}$» $= 2.00$ «hours» ✓	*Award **[2]** for correct final answer.*	**2**
3.	d	i	*Any one of:* two «or more» lone/non-bonding pairs on different atoms ***OR*** two «or more» atoms/centres that act as Lewis bases ✓ form «at least» two coordination/coordinate bonds ***OR*** «at least» two atoms can form coordination/coordinate bonds ✓	*Reference to "on **DIFFERENT** atoms" required.* *Accept "dative «covalent» bond" for "coordination/coordinate bond".*	**1 max**
3.	d	ii	increase in entropy ***OR*** $\Delta S > 0$/ΔS positive ✓	*Accept "$\Delta G < 0$" but **not** "$\Delta H < 0$".*	**1**

Question			Answers	Notes	Total
4.	a		*Any two of:* cloudy/foggy/hazy phase «at first melting point» ✓ clear liquid phase «at second melting point/higher temperature» ✓ two «different» melting points ***OR*** new phase observed over a wide temperature range ✓	*Accept "exhibit both liquid and solid properties at the same time" for M3.*	**2 max**
4.	b		***ALTERNATIVE 1:*** «bulky/long» C_5H_{11}/R/alkyl «group/chain» ***AND*** prevents molecules from packing closer together «to form solid state» ✓ ***ALTERNATIVE 2:*** biphenyl «fragment»/two benzene rings/two aromatic rings ***AND*** «makes molecule» rigid/rod-shaped ✓	*Accept "rigid/rod-shaped molecule, so aligns with other molecules" for* ***ALTERNATIVE 2****.*	**1**
4.	c		«average» oxidation state of C in C_6H_{12}/cyclohexane = –2 ***AND*** in CNTs = 0 ***OR*** oxidation state of C in CNTs is higher than in C_6H_{12}/cyclohexane ***OR*** loss of H's/hydrogens ✓ «oxidation at» positive/+ «electrode»/anode ✓	*Accept "oxidation number" for "oxidation state".*	**2**

Question			Answers	Notes	Total
5.	**a**	**i**	face-centred cube/fcc ***OR*** cubic close packed/ccp ✓		**1**
5.	**a**	**ii**	$\frac{1}{2}$ **«**atom per face**»** × 6 **«**faces per cube**»** = 3 **«**atoms**»** ***AND*** $\frac{1}{8}$ **«**atom per corner**»** × 8 **«**corners per cube**»** = 1 **«**atom**»** ✓ **«**atoms per unit cell = 3 + 1 =**»** 4 ✓	*Award **[1 max]** for "4" without working shown.*	**2**
5.	**b**		**«**4 atoms per unit cell**»** mass of 4 atoms **«**$= 4 \times \frac{196.97\ \text{g mol}^{-1}}{6.02 \times 10^{23}\ \text{mol}^{-1}}$ **»** 1.31×10^{-21} **«**g**»** ✓ volume of unit cell **«**$= (4.08 \times 10^{-8})^3\ \text{cm}^3$**»** $= 6.79 \times 10^{-23}$ **«**cm^3**»** ✓ density = **«** $\frac{1.31 \times 10^{-21}\ \text{g}}{6.79 \times 10^{-23}\ \text{cm}^3}$ **»** = 1.93×10^1/19.3 **«**g cm^{-3}**»** ✓	*Award **[3]** for correct final answer.*	**3**

Option B — Biochemistry

Question			Answers	Notes	Total
6.	a		catabolism «of food/nutrients» ***OR*** «cellular» respiration ✓	*Accept "ATP" but **not** "burning of food/nutrients".*	1
6.	b		not enough sunlight/UV light «for synthesis of vitamin D in the skin» ✓		1
6.	c		cannot be metabolized/broken down ***OR*** not biodegradable ***OR*** accumulates in lipid/fat tissues ✓ increased concentration as one species feeds on another «in the food chain» ✓		2

Question			Answers	Notes	Total
7.	a		«triplet» sequence/«specific» order of «nitrogenous» bases ***OR*** codon ✓		**1**
7.	b		*Any one of:* long-term «health» effects unknown ✓ can cause allergic reactions ✓ possible transfer of genetic material to other/wild species ✓ concern that power over farming is concentrated in hands of multinationals ***OR*** dependent on multinationals ✓ labelling differences between countries «means informed choice not possible» ✓	*Accept "outcrossing".*	**1 max**

Question			Answers	Notes	Total
8.	a		hydrogen bonding ✓ between C=O and H–N «groups» ✓	*Accept a diagram which shows hydrogen bonding for M1 and shows the interaction between O of C=O and H of NH for M2.* *Accept "between amido/amide/carboxamide" but **not** "between amino/amine" for M2.*	**2**
8.	b		*Enzyme action:* *Any two of:* substrate binds to active site ✓ weakens bonds in substrate ✓ lowers activation energy ***OR*** provides alternate pathway ✓ increases rate of reaction ***OR*** acts as catalyst ✓ substrate specific ✓ *Limitation:* *Any one of:* temperature dependent ✓ pH dependent ✓ can be sensitive to heavy metal ions ✓ sensitive to denaturation ✓ can be inhibited ✓ substrate specific ✓	*Accept "favourable orientation/conformation of the substrate «enforced by enzyme»" for M1.* *Do **not** accept "substrate specific" as both an enzyme action and a limitation.*	**3 max**

Question			Answers	Notes	Total
8.	c		<table><tr><th></th><th>Action of inhibitor</th><th>Effect on V_{max}</th><th>Effect on K_m</th></tr><tr><td>Non-competitive</td><td>allosteric site occupied ***OR*** active site shape changed ✓</td><td>lower ***AND***</td><td>no effect ✓</td></tr><tr><td>Competitive</td><td>active site occupied ✓</td><td>no effect ***AND***</td><td>greater ✓</td></tr></table>	*Award **[1]** for each action.* *Award **[1]** for **any two** effects stated correctly.* *Award **[2 max]** if both actions and effects are switched to incorrect inhibitor types.*	**4**

9.	a		***ALTERNATIVE 1:*** 4 C=C bonds/4 carbon to carbon double bonds ✓ mass of iodine per mole of acid = «4 × 253.80 g mol^{-1} =» 1015.2 «g mol^{-1}» ✓ iodine number «= $\frac{1015.2\ g\ mol^{-1}}{276.46\ g\ mol^{-1}} \times 100$» = 367 ✓ ***ALTERNATIVE 2:*** 4 C=C bonds/4 carbon to carbon double bonds ✓ « $\frac{100\ g}{276.46\ g\ mol^{-1}} \times 4$ =» 1.447 mol of I_2 «reacts with 100 g» ✓ iodine number «= 1.447 mol × 253.80 g mol^{-1}» = 367 ✓	*Award **[3]** for correct final answer.*	**3**

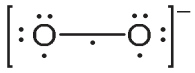
Question			Answers	Notes	Total
9.	b		*Any two of:* **«**structural**»** components of cell membranes ✓ energy storage/utilization ✓ **«**thermal/electrical**»** insulation ✓ transport **«**of lipid-soluble molecules**»** ✓ hormones/chemical messengers ✓	*Accept other specific functions, such as "prostaglandin/cytokine/bile acid synthesis", "cell differentiation/growth", "myelination", "storage of vitamins/biomolecules", "signal transmission", "protection/padding of organs", "precursors/starting materials for the biosynthesis of other lipid".*	**2 max**
9.	c		*Any one of:* atherosclerosis/cholesterol deposition **«**in artery walls**»** ✓ heart/cardiovascular disease ✓ stroke ✓	*Accept "arteries become blocked/ walls become thicker".*	**1 max**

Question			Answers	Notes	Total
10.	**a**		**«**1,4-**»**glycosidic ✓	*Do **not** accept "glucosidic".*	**1**
10.	**b**		H and OH are reversed/in different positions on C-4 ✓	*C-4 must be specified.* *Do **not** penalize if reference is made to H and OH above and below ring/in alpha and beta positions on C-4 incorrectly.*	**1**
10.	**c**	**i**	*Starch*: α**«**-glucose/links**»** ***AND*** *Cellulose*: β**«**-glucose/links**»** ✓	*Accept "Starch: coiled/spiral structure **OR** cross-links **AND** Cellulose: uncoiled **OR** straight chains/linear polymer **OR** no/few cross-links".*	**1**
10.	**c**	**ii**	*Any two of:* helps food pass through intestine ***OR*** adds bulk/dietary fibre ✓ reduces appetite ***OR*** helps prevent obesity ✓ prevents constipation ***OR*** reduces risk of hemorrhoids/diverticulosis/Crohn's disease/irritable bowel syndrome/bowel cancer ✓		**2 max**

Question			Answers	Notes	Total
11.	a		binding of oxygen/O_2 **«**to one active site**»** affects shape of Hb/other active sites ***OR*** binding of one oxygen/O_2 **«**molecule**»** affects binding of other oxygen/O_2 **«**molecules**»** ✓ increasing affinity of Hb to oxygen/O_2 ***OR*** enhanced binding of **«**further**»** oxygen/O_2 **«**molecules**»** ***OR*** cooperative binding ✓		**2**
11.	b		*Toxicity:* carboxyhemoglobin/Hb–CO does not readily dissociate ***OR*** CO + Hb ⇌ Hb–CO ***AND*** forward reaction favoured ***OR*** affinity of carbon monoxide/CO for hemoglobin is **«**200 times/much**»** higher than that of oxygen/O_2 ***OR*** competitive inhibitor of oxygen/O_2 binding ✓ *Treatment:* moving patient to fresh air ***OR*** **«**in severe cases**»** inhaling pure oxygen/O_2 ***OR*** high pressure oxygen/O_2 chamber ✓	*Accept "move away from carbon monoxide/CO source"* ***OR*** *"remove carbon monoxide/CO source".*	**2**

Option C — Energy

Question			Answers	Notes	Total
12.	**a**		small/lighter <u>nuclei</u> combine to form larger/heavier <u>nuclei</u> ✓ product has higher binding energy «per nucleon» ✓	*Accept binding energy curve with explanation.*	**2**
12.	**b**	**i**	converts non-fissile «^{238}U» material into fissile «^{239}Pu» material ***OR*** produces more fissile material than it consumes ✓		**1**
12.	**b**	**ii**	$^{239}Pu + {}^{1}n \rightarrow {}^{133}Xe + {}^{103}Zr + 4{}^{1}n$ ✓	*Accept equation with correct atomic numbers included.* *Accept notation for neutrons of "n".* *Accept a correctly described equation in words.*	**1**
12.	**c**		***ALTERNATIVE 1:*** «$\frac{240}{30}$ =» 8 $t_{\frac{1}{2}}$/8 half-lives «required» ✓ % remaining = «$0.50^8 \times 100$ =» 0.39 «%» ✓ ***ALTERNATIVE 2:*** λ = «$\frac{0.693}{30}$ =» 0.023 ✓ % remaining = «$100 \times e^{-0.023 \times 240}$ =» 0.39 «%» ✓	*Award **[2]** for correct final answer.*	**2**

Question			Answers	Notes	Total
12.	d	i	 ***OR***  ✓	*Accept any combination of dots, crosses and lines to represent electrons.* *Do **not** penalize missing brackets.* *Penalize missing negative charge.*	**1**
12.	d	ii	highly reactive ***OR*** start redox reactions ✓ damage/mutate DNA ***OR*** cause cancer ***OR*** damage enzymes ✓		**2**

Question			Answers	Notes	Total
13.	a		***ALTERNATIVE 1:*** $2C(s) + 2H_2O(g) \rightarrow CH_4(g) + CO_2(g)$ ✓ ***ALTERNATIVE 2:*** $C(s) + H_2O(g) \rightarrow CO(g) + H_2(g)$ ***AND*** $3H_2(g) + CO(g) \rightarrow CH_4(g) + H_2O(g)$ ✓	*Accept "$3C(s) + 2H_2O(g) \rightarrow CH_4(g) + 2CO(g)$".*	**1**
13.	b		«$\frac{141.6}{55.5}$» hydrogen/H_2 produces 2.6 times/more than twice the energy of methane/CH_4 «per mass/g» ***OR*** less mass of hydrogen/H_2 required «to produce same amount of energy» ***OR*** hydrogen/H_2 more energy efficient ✓	*Accept "hydrogen/H_2 produces «nearly» three times more energy than methane/CH_4 «per mass/g»".*	**1**
13.	c		m_{octane} «$= 72.0\,\text{dm}^3 \times 703\,\text{g dm}^{-3}$» $= 5.06 \times 10^4$ «g»/50.6 «kg» ✓ $m_{\text{carbon dioxide}}$ «$= \frac{8 \times 44.01}{114.26} \times 50.6$» $= 156$ «kg» ✓	*Award **[2]** for correct final answer.*	**2**

Question			Answers	Notes	Total
14.	a		*Advantage:* renewable «energy source» ***OR*** does not produce greenhouse gases ***OR*** can be installed «almost» anywhere ***OR*** low maintenance costs ✓ *Disadvantage:* widely dispersed/not concentrated «form of energy» ***OR*** geography/weather/seasonal dependent ***OR*** not available at night ***OR*** energy storage is difficult/expensive ***OR*** toxic/hazardous materials used in production ***OR*** concerns about space/aesthetics/environment where installed ***OR*** need to be «constantly» cleaned ✓	*Accept "can be used for passive/active heating", "can be converted to electric energy".* *Accept any specific greenhouse gas name or formula for "greenhouse gases".* *Accept "solar cells require large areas", "solar cell manufacture produces pollution/greenhouse gases", "higher cost of solar cells «compared with traditional sources such as fossil fuels or hydroelectric»".*	**2**

Question			Answers	Notes	Total
14.	b	i	high viscosity ✓	*Accept "low volatility", just "viscous/viscosity"* ***OR*** *"does not flow easily".*	1
14.	b	ii	convert to esters of monoatomic alcohols ***OR*** react with short-chain alcohols **«**in the presence of acid or base**»** ✓	*Accept "convert to shorter **«**carbon chain**»** esters"* ***OR*** *"transesterification".* *Accept specific alcohols, such as methanol or ethanol.*	1
14.	c		carbon dioxide/CO_2 more/most abundant **«**GHG than methane/CH_4**»** ***OR*** carbon dioxide/CO_2 has **«**much**»** longer atmospheric life **«**than methane/CH_4**»** ✓ methane/CH_4 **«**much**»** better/more effective at absorbing IR radiation **«**than carbon dioxide/CO_2**»** ***OR*** methane/CH_4 has a greater greenhouse factor **«**than carbon dioxide/CO_2**»** ***OR*** methane/CH_4 has a greater global warming potential/GWP **«**than carbon dioxide/CO_2**»** ✓	*Accept "carbon dioxide/CO_2 contributes more to global warming **«**than methane/CH_4**»**".*	2
14.	d		$CO_2\,(g) + H_2O\,(l) \rightleftharpoons H^+(aq) + HCO_3^-\,(aq)$ ***OR*** $CO_2\,(g) \rightleftharpoons CO_2\,(aq)$ ***AND*** $CO_2\,(aq) + H_2O\,(l) \rightleftharpoons H^+(aq) + HCO_3^-\,(aq)$ ✓ **«**increasing $[CO_2\,(g)]$**»** shifts equilibrium/reaction to right ***AND*** pH decreases ✓	*Accept "$H_2CO_3\,(aq)$" for "$CO_2\,(aq) + H_2O\,(l)$".* *Equilibrium arrows required for M1.* *State symbols required for* $CO_2\,(g) \rightleftharpoons CO_2\,(aq)$ *equation only for M1.* *Accept "concentration of H^+/$[H^+]$ increases **AND** pH decreases" for M2.*	2

Question			Answers	Notes	Total
15.	**a**		«redox» reaction in rechargeable battery is reversible «but not in a primary cell» ***OR*** secondary cells need to be charged before use ***OR*** secondary cells have greater rate of self-discharge ✓	*Accept "primary cells cannot be recharged/reused", "primary cells can be used only once"* ***OR*** *"lithium batteries may explode".*	**1**
15.	**b**		*Anode (negative electrode):* $Li\ (graphite) \rightarrow Li^+\ (electrolyte) + e^-$ ***OR*** $LiC_6\ (s) \rightarrow 6C\ (s) + Li^+\ (electrolyte) + e^-$ ✓ *Cathode (positive electrode):* $Li^+\ (electrolyte) + e^- + MnO_2\ (s) \rightarrow LiMnO_2\ (s)$ ***OR*** $Li^+\ (electrolyte) + e^- + NiO_2\ (s) \rightarrow LiNiO_2\ (s)$ ***OR*** $Li^+\ (electrolyte) + e^- + CoO_2\ (s) \rightarrow LiCoO_2\ (s)$ ***OR*** $2Li^+\ (electrolyte) + 2e^- + 2CoO_2\ (s) \rightarrow Co_2O_3\ (s) + Li_2O\ (s)$ ✓	*Accept "polymer" for "electrolyte".* *Award* ***[1 max]*** *if electrodes are reversed.* *Do* ***not*** *accept "CO" for "Co".*	**2**

Question			Answers	Notes	Total
15.	**c**		«$E = E^{\ominus} - \left(\frac{RT}{nF}\right) lnQ$» $0.19 = 0.14 - \left(\frac{8.31 \times 298}{2 \times 96500}\right) \ln \left(\frac{[Cd^{2+}]}{[1]}\right)$ ***OR*** $0.05 = -0.01283 \ln [Cd^{2+}]$ ***OR*** $\ln[Cd^{2+}] = -3.897$ ✓ $[Cd^{2+}] = 0.020$ «mol dm^{-3}» ✓	*Award **[2]** for correct final answer.*	**2**
15.	**d**	**i**	«extensive» conjugation ***OR*** «extensive» alternate single and double bonds ✓	*Accept "delocalization".*	**1**
15.	**d**	**ii**	electrons excited/released «from dye» ✓	*Accept "photooxidation/oxidizes dye".*	**1**
15.	**d**	**iii**	transfers e^- to external circuit ✓	*Accept "provides large surface area".*	**1**
15.	**d**	**iv**	$I_3^-(aq) + 2e^- \rightarrow 3I^-(aq)$ ✓	*Accept "$3I_2(aq) + 2e^- \rightarrow 2I_3^-(aq)$".*	**1**

Option D — Medicinal chemistry

Question			Answers	Notes	Total
16.	**a**		<table><tr><td></td><td>Bond angle</td></tr><tr><td>β-lactam ring</td><td>90º ✓</td></tr><tr><td>sp^2</td><td>120º ***AND***</td></tr><tr><td>sp^3</td><td>109.5º ✓</td></tr></table>	*Accept "109º".*	**2**
16.	**b**		**«**irreversibly**»** binds/bonds to enzyme/transpeptidase ***OR*** inhibits enzyme/transpeptidase **«**in bacteria**»** that produces cell walls ***OR*** prevents cross-linking of bacterial cell walls ✓ cells absorb water ***AND*** burst ***OR*** cells cannot reproduce ✓	*Accept "reacts with" for "bonds to" for M1.* *Do **not** accept "cell membrane" for "cell wall" for M1.* *Accept "cells burst due to osmotic pressure" for M2.* *Accept "bacteria" for "cells" for M2.*	**2**
16.	**c**		**«**modify**»** side-chain ✓	*Accept "**«**modify**»** R".*	**1**
16.	**d**		no cell walls ***OR*** humans do not have transpeptidase ✓		**1**

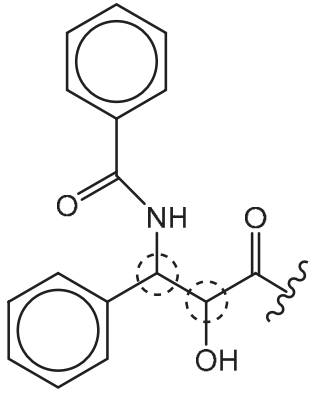
Question			Answers	Notes	Total
17.	a		blood-brain barrier is hydrophobic/non-polar/made of lipids ✓ morphine has hydroxyl/OH «groups»/is more polar ***AND*** diamorphine has ester/ethanoate/$OCOCH_3$/acetate «groups»/is less polar/is lipid soluble ✓	*Accept "fats" for "lipid(s)".* *Accept "alcohol/hydroxy" for "hydroxyl" but **not** "hydroxide".* *Accept "non-polar" for "less polar" in M2.*	**2**
17.	b		fraction/proportion/percentage of «administered dosage» that enters blood/plasma/circulation ✓	*Accept "fraction/proportion/percentage of «administered dosage» that reaches target «part of human body»".*	**1**

18.	a		***ALTERNATIVE 1:*** *Using*: $pH = pK_a + log\left(\frac{[A^-]}{[HA]}\right)$ $pK_a = 10.32$ ✓ $pH = «10.32 + \log\left(\frac{0.0200}{0.0100}\right) =» 10.62$ ✓ ***ALTERNATIVE 2:*** $[H^+] «= K_a \times \left(\frac{0.0100}{0.0200}\right)» = 2.4 \times 10^{-11}$ ✓ $pH = 10.62$ ✓	*Award **[2]** for correct final answer.* *Accept answers for M2 between 10.6 and 10.7.* *Award **[1 max]** for pH = 10.02.*	**2**

Question			Answers	Notes	Total
18.	b		$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$ ***OR*** $CaCO_3(s) + 2H^+(aq) \rightarrow Ca^{2+}(aq) + H_2O(l) + CO_2(g)$ ✓		**1**
18.	c		«back» titration ***OR*** thermal decomposition ***OR*** atomic absorption/AA ✓	*Accept "gravimetric analysis".* *Do **not** accept description of a technique without proper term given for the technique.*	**1**

19.			*Any two of:* prevents virus attaching to host cell ✓ alters cell's genetic material/DNA «so that virus cannot use it to multiply» ✓ blocks enzyme activity in the host cell «so that virus cannot use it to multiply» ✓ prevents removal of protein coat/capsid ✓ prevents injection of viral DNA/RNA into cell ✓ prevents release of «replicated» viruses from host cell ✓	*Accept "prevents synthesis of virus by host cell".* *Accept "alters RNA/DNA/genetic material of virus".* *Do **not** accept just "mimics nucleotides".*	**2 max**

Question			Answers	Notes	Total
20.			*Any two of:* **«**weak**»** C–Cl bonds break/produce radicals ✓ contribute to ozone depletion ✓ contribute to **«**photochemical**»** smog ✓ cause cancers ✓ damage respiratory system ✓ cause organ failure ✓ produce toxic chemicals/phosgene/dioxins ✓	*Accept "chlorinated solvents are toxic".*	**2 max**

21.	**a**		 ✓	*Do **not** penalize any other notation (eg *) used for a circle.*	**1**

Question			Answers	Notes	Total
21.	b		chiral auxiliary creates stereochemical condition necessary to follow a certain pathway ***OR*** stereochemical induction ***OR*** existing chiral centre affects configuration of new chiral centres ✓ chiral molecule/auxiliary/optically active species is used/added/connected to the starting molecule **«**to force reaction to follow a certain path**»** ***OR*** **«**after new chiral centre created**»** chiral auxiliary removed **«**to obtain desired product**»** ✓		**2**
21.	c		*Any two of:* immiscible solvents ✓ partitioning of Taxol between the two solvents ✓ Taxol more soluble in one solvent ✓ extraction carried out multiple times **«**to improve extraction**»** ✓ shaking/stirring the mixture ✓ separating the two layers ✓ evaporation of the solvent from the final solution **«**to obtain pure Taxol**»** ✓		**2 max**

Question			Answers	Notes	Total
22.	a		«alpha emitter» carried to/selectively absorbed by cancer cells «by antibody, carrier drug, protein» ✓ low penetrating power ***OR*** short range ✓	*Do **not** accept just "targets cancer cells and does not affect healthy cells".*	**2**
22.	b	i	***ALTERNATIVE 1:*** «$\frac{48}{6.0}$ =» 8 $t_{\frac{1}{2}}$ /8 half-lives «required» ✓ % remaining = «$(0.5)^8 \times 100$ =» 0.39 «%» ✓ ***ALTERNATIVE 2:*** λ = «$\frac{0.693}{6.0}$ =» 0.1155 ✓ % remaining = «$100 \times e^{-0.1155 \times 48}$ =» 0.39 «%» ✓	*Award **[2]** for correct final answer.* *Accept "0.32 «%»" in **ALTERNATIVE 2**.*	**2**
22.	b	ii	removed by excretion ✓	*Accept any method of excretion.*	**1**

Question			Answers	Notes	Total
23.	a		gas chromatography/GC ***OR*** high performance liquid chromatography/HPLC ✓	*Accept "chromatography", "TLC/thin-layer chromatography", "paper chromatography* ***OR*** *"extraction".* *Do* ***not*** *accept just "mass spectrometry/MS" but do* ***not*** *penalize any reference to MS with HPLC or GC (eg GC-MS).*	**1**
23.	b		***ALTERNATIVE 1:*** *Any two of:* **«**blow through tube of**»** acidified **«**orange**»** potassium dichromate(VI)/$K_2Cr_2O_7$/dichromate/$Cr_2O_7^{2-}$ ✓ Cr(VI)/Cr^{6+}/$Cr_2O_7^{2-}$ reduced to Cr(III)/Cr^{3+} ✓ colour changes **«**from orange**»** to green ***OR*** colour change is monitored ✓ ***ALTERNATIVE 2:*** oxygen reduced to water ***OR*** ethanol oxidized to ethanoic/acetic acid ✓ current measured ✓	*Accept "ethanol oxidized to ethanal/acetaldehyde".*	**2 max**