Markscheme

November 2024

Chemistry

Higher level

Paper 3

34 pages

Subject details: Chemistry higher level paper 3 Markscheme

Candidates are required to answer **ALL** questions in Section A **[15 marks]** and all questions from **ONE** option in Section B **[30 marks]**.
Maximum total = **[45 marks]**.

1. Each row in the "Question" column relates to the smallest subpart of the question.
2. The maximum mark for each question subpart is indicated in the "Total" column.
3. Each marking point in the "Answers" column is shown by means of a tick (✓) at the end of the marking point.
4. A question subpart may have more marking points than the total allows. This will be indicated by "**max**" written after the mark in the "Total" column. The related rubric, if necessary, will be outlined in the "Notes" column.
5. An alternative word is indicated in the "Answers" column by a slash (***/***). Either word can be accepted.
6. An alternative answer is indicated in the "Answers" column by "***OR***". Either answer can be accepted.
7. An alternative markscheme is indicated in the "Answers" column under heading **ALTERNATIVE 1** *etc*. Either alternative can be accepted.
8. Words inside chevrons **« »** in the "Answers" column are not necessary to gain the mark.
9. Words that are underlined are essential for the mark.
10. The order of marking points does not have to be as in the "Answers" column, unless stated otherwise in the "Notes" column.
11. If the candidate's answer has the same "meaning" or can be clearly interpreted as being of equivalent significance, detail and validity as that in the "Answers" column then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by ***OWTTE*** (or words to that effect) in the "Notes" column.
12. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.
13. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. When marking, indicate this by adding **ECF** (error carried forward) on the script.
14. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the "Notes" column.
15. If a question specifically asks for the name of a substance, do not award a mark for a correct formula unless directed otherwise in the "Notes" column. Similarly, if the formula is specifically asked for, do not award a mark for a correct name unless directed otherwise in the "Notes" column.
16. If a question asks for an equation for a reaction, a balanced symbol equation is usually expected, do not award a mark for a word equation or an unbalanced equation unless directed otherwise in the "Notes" column.
17. Ignore missing or incorrect state symbols in an equation unless directed otherwise in the "Notes" column.

Section A

Question			Answers	Notes	Total
1.	**a**	**i**	gradient = $\frac{0.010}{5} = 0.0020$ ✓ [mercury ion] = 0.0020 x *t* /months«μg Hg g^{-1} $month^{-1}$» ✓	*Accept gradient in the range "0.0019-0.0021"* ***OR*** *"1/500" for M1.* *Accept "y = 0.0020 x" for M2.*	**2**
1.	**a**	**ii**	*Any one of:* rate of uptake equals rate of metabolism/excretion ✓ all «binding» sites/fish «muscles» occupied/saturated ✓	*Accept "equilibrium «between [CH_3Hg^+] in water and [CH_3Hg^+] in muscle»".* *Accept "fish have matured/stopped growing so maximum concentration reached"* ***OR*** *"fish reached maximum capacity to absorb".*	**1 max**
1.	**a**	**iii**	«methylmercury is fat soluble/lipophilic» easier to pass through «cell» membranes ***OR*** «methylmercury more» readily found in nature/ecosystem «than mercury» ***OR*** «methylmercury more» soluble in water/muscle tissue «than mercury» ✓	*Do* ***not*** *accept "ionic"* ***OR*** *"polar" alone.* *Do* ***not*** *penalize references to solid Hg.* *Accept "forms ion-dipole with water" but* ***not*** *"forms hydrogen bond with water."*	**1**
1.	**b**	**i**	«3.723 x 0.0052 =» 0.019 «μg» ✓	*Ignore uncertainty values.*	**1**
1.	**b**	**ii**	«0.0001/0.0052 x 100%=» 2 «%» ✓		**1**

(continued…)

(Question 1 continued)

Question			Answers	Notes	Total
1.	**c**		*Any two of:* mass/length/size/age of fish/time in lake ✓ species/type of fish ✓ water-content of muscle tissue ✓ depth/area «in lake» where captured ✓ part/tissue of fish «sample taken from»✓ how tissue/CH_3Hg^+ is extracted✓ «water» temperature «when captured»✓	*Apply list principle (LP).* *Do **not** accept "mass of muscle sample" **OR** "same fish" alone **OR** "pH".*	**2 max**

Question			Answers	Notes	Total
2.	**a**		*Before heating:* displace oxygen/air ***OR*** avoid combustion/reaction/explosion of hydrogen ✓ *Until product has cooled:* prevent oxidation «of copper back to copper oxide» ***OR*** ensure reaction is complete ✓	*Accept "prevent «further» reaction of copper oxide with carbon dioxide/CO_2 **OR** moisture «in air»" OR "without continuous flow of H_2 reduction may be incomplete" OR "ensure only H_2 gas in reaction tube" for M1.*	**2**

(continued…)

(Question 2 continued)

Question			Answers	Notes	Total
2.	**b**	**i**	mass of «reduction tube and» copper oxide/sample before «heating»✓ mass of «reduction tube and» sample/copper/Cu after «reduction/heating» ✓	*Apply LP.* *Do **not** accept mass of water as not a practical method.* *Accept weight for mass.* *Accept "mass before heating" for M1* *Accept "mass after heating" for M2*	**2**
2.	**b**	**ii**	subtract mass of sample/copper/Cu «following reduction» from mass of copper oxide ✓	*Accept "difference between masses before and after reduction."* *Mark can be scored based on part bi of this question.*	**1**

(continued…)

(Question 2 continued)

Question			Answers	Notes	Total
2.	**c**		incomplete reduction/reaction/not all oxygen removed ***OR*** copper re-oxidized ***OR*** oxide was partly reduced before analysis ***OR*** impurities in sample ✓ repeat «heating in presence of H_2» until mass of product is constant ***OR*** heat for a longer time ***OR*** use a higher temperature ***OR*** increase surface area «of copper oxide» ✓	*Accept "sample wasn't heated/cooled long enough" for M1.* *Do **not** accept "not all oxygen burned" for M1.* *Improvement in M2 must be related to error identified in M1.* *Accept "handle/weigh product/copper/Cu metal in oxygen-free atmosphere" for M2.* *Accept "reduce distance between tube and heat source" for M2.*	**2**

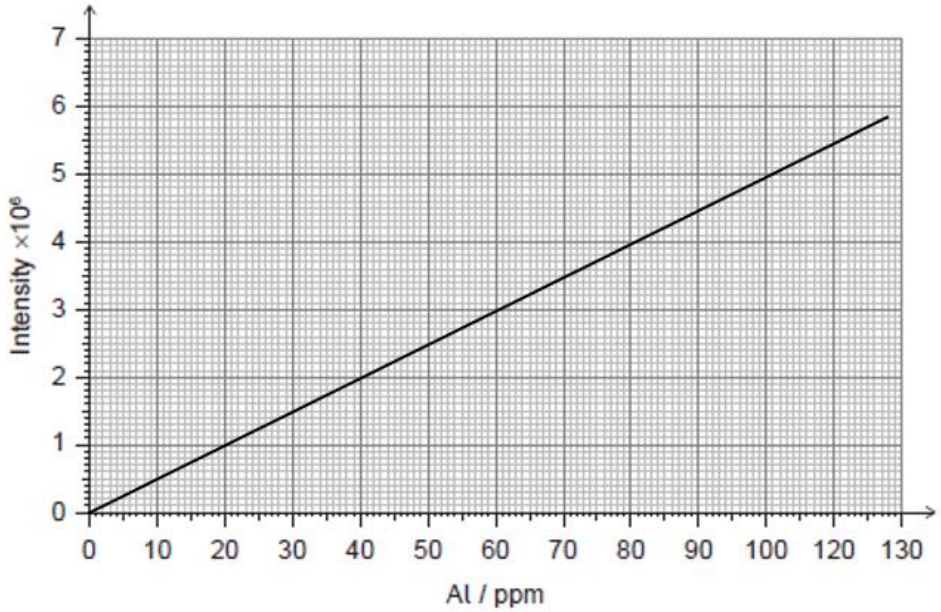
Section B

Option A — Materials

Question			Answers	Notes	Total
3.	**a**	**i**	*Any two of:* lowers the melting point «of alumina» ✓ lowers energy/electricity «consumption» ✓ lowers operating temperature ✓ improves conductivity ✓ acts as a solvent ✓	*Do **not** accept "lowers melting point of aluminium".* *Do **not** accept "lowers boiling point".*	**2 max**
3.	**a**	**ii**	*Bonding:* $\Delta\chi$ = 1.8 ***AND*** average χ = 2.5 ✓ ionic ***AND*** polar covalent ✓ *Electrical conductivity:* non/poor conductor/insulator✓	*Accept "50 to 60% ionic **AND** 40 to 50% polar covalent" **OR** any answer in the range given for M2.*	**3**

(continued…)

(Question 3 continued)

Question			Answers	Notes	Total
3.	**b**		 straight line through origin **AND** coordinate 40, 2 x 10^6 ✓		**1**

(continued…)

(Question 3 continued)

Question			Answers	Notes	Total
3.	**c**		«in Al alloy» different sizes of ions/particles ***OR*** Ni atoms disrupt regular structure ✓ prevent layers from slipping/sliding ✓	*Accept diagram representing lattice with different sized atoms/circles for M1.* *Difficulty sliding should be explained for M2.*	**2**
3.	**d**	**i**	electrophile **AND** Lewis acid ✓		**1**
3.	**d**	**ii**	*Any one of:* efficiency/only use small quantities ✓ selectivity ***OR*** produce the desired product ✓ ability to work in mild/severe conditions ✓ low environmental impact ***OR*** low toxicity ✓ long lifetime ***OR*** resistance to poisoning ✓ cost effective/economical ✓ easily separated/recovered ✓	*Apply LP.*	**1 max**

(continued…)

(Question 3 continued)

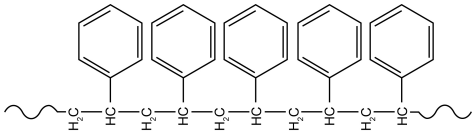
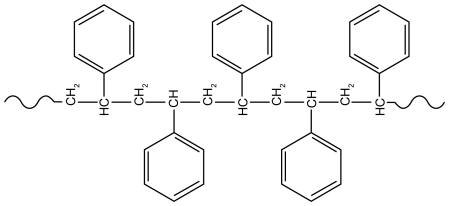
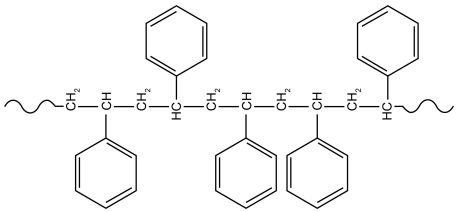
Question			Answers	Notes	Total
3.	**e**	**i**	1/2**«**atom per face**»** x 6 **«**faces per cube**»** = 3 **«**atoms**»** ***AND*** 1 / 8 **«**atom per corner**»** x 8 **«**corners per cube**»** = 1 **«**atom**»** ✓ **«**atoms per unit cell = 3 + 1 =**»** 4 ✓	*Award **[1 max]** for correct answer without working.*	**2**
3.	**e**	**ii**	**«**4 atoms per unit cell**»** mass of 4 atoms «= 4 x 26.98 g mol^{-1} ÷ 6.02 x 10^{23} mol^{-1} =» 1.79 x 10^{-22} «g» ✓ volume of unit cell «= $(4.05 \times 10^{-8})^3$ =» 6.64 x 10^{-23} «cm^3» ✓ density «=1.79 x 10^{-22} g ÷ 6.64 x $10^{-23}$$cm^3$ =» 2.70 «g cm^{-3}» ✓	*Accept alternate methods of doing calculation.* *Award **[3]** for correct final answer.*	**3**

Question			Answers	Notes	Total
4.	**a**		hydrocarbon/carbon-containing gas/compound ✓	*Accept "ethanol" **OR** specific gaseous hydrocarbons **OR** carbon monoxide/dioxide/CO/CO_2*	**1**
4.	**b**		*Obtained using CVD:* heat/vaporize compound/hydrocarbon/carbon-containing gas «mixed with inert gas» ✓ *Formed into CNT:* hydrocarbon/carbon compound decomposes «to form carbon nanotubes» ✓		**2**

(continued…)

(Question 4 continued)

Question			Answers	Notes	Total
4.	**c**		both have covalent bonds «in molecule» ✓ CNT has «weaker» London/dispersion/instantaneous dipole-induced dipole forces «between fibres» ***AND*** Kevlar has «strong» hydrogen bonds «between strands of polymers» ✓ CNT only C-C bonds ***AND*** Kevlar C-H/C-N/C-O/N-H/C=C/other covalent bonds ✓	*Accept polar «and nonpolar» covalent in Kevlar but «only» nonpolar covalent in CNT.*	**3**

Question			Answers	Notes	Total
5.	**a**		 isotactic  neither  atactic ✓	[Source: Kathy L. Singfield, Ashley J. Rowe. Experiment to Teach Multiple Melting Phenomena in Semicrystalline Polymers Using Differential Scanning Calorimetry. *World Journal of Chemical Education*. Vol. 9, No. 3, 2021, pp. 68–76. https://pubs.sciepub.com/wjce/9/3/1 Licensed under CC BY 4.0 https://creativecommons.org/licenses/by/4.0/. Image adapted.]	**1**

(continued…)

(Question 5 continued)

Question			Answers	Notes	Total
5.	**b**	**i**	BP2 ***AND*** «long» alkyl/C_5H_{11} «group/chain» prevents close packing ***OR*** BP2 ***AND*** «long» alkyl/C_5H_{11} «group/chain» cause molecules to align ✓	*Accept "BP2 **AND** more polar".* *Do **not** accept any reference to rigid/rod-shaped.* *Accept "tail" for "long alkyl group."*	**1**
5.	**b**	**ii**	neither «BP1 nor BP2» contain a dioxin ring ***OR*** «BP1 and BP2 have» no oxygen/O ***OR*** «BP1 and BP2 are» not heterocyclic compounds «in contrast to dioxins». ✓		**1**
5.	**b**	**iii**	BP1 ***AND*** *Any one of:* contains chlorine/Cl «and BP2 does not» ✓ can produce chlorinated dioxins on combustion «and BP2 will produce less toxic combustion products» ✓ more likely to produce persistent organic pollutants/POP ✓ act on cell receptors «and BP2 does not» ✓	*Do **not** accept just polychlorinated biphenyl/PCB with no further explanation*	**1 max**

Question			Answers	Notes	Total
6.	**a**		$\bullet O_2^-(aq) + H_2O_2(aq) \rightarrow \bullet OH(aq) + OH^-(aq) + O_2(g)$ ✓	*Penalize missing **OR** misplaced radical (on H) once per paper.*	**1**
6.	**b**		*Step one:* $Fe^{2+}(aq) + H_2O_2(aq) \rightarrow Fe^{3+}(aq) + \bullet OH(aq) + OH^-(aq)$ ✓ *Step two:* $Fe^{3+}(aq) + \bullet O_2^-(aq) \rightarrow Fe^{2+}(aq) + O_2(g)$ ✓	*Award **[1]** for showing Fe^{2+} being consumed and regenerated but wrong equation.* *Penalize missing **OR** misplaced radical (on H) once per paper.*	**2**
6.	**c**		only Cu^{2+} ions exhibit variable oxidation states ***OR*** Cd^{2+} ions do not exhibit variable oxidation states ***AND*** Cu^{2+} can be reduced to Cu^+ and oxidized back ✓		**1**
6.	**d**		chelation ✓	*Apply LP.* *Accept "diet in essential minerals «to aid removal of Cd/cadmium from binding sites»".* *Do **not** accept precipitation or adsorption.*	**1**

Option B — Biochemistry

Question			Answers	Notes	Total
7.	**a**		condensation ✓	*Accept "esterification".* *Accept "nucleophilic substitution/S_N".*	**1**
7.	**b**	**i**	***ALTERNATIVE 1:*** 2 C=C bonds / 2 carbon to carbon double bonds ✓ mass of iodine per mole of acid = «2 x 253.80 g mol^{-1} =» 507.6 «g mol^{-1}» ✓ iodine number «=$\frac{507.6\ g\ mol^{-1}}{280.50\ g\ mol^{-1}} \times 100$ » = 181 ✓ ***ALTERNATIVE 2:*** 2 C=C bonds / 2 carbon to carbon double bonds ✓ «$\frac{100\ g}{280.50\ g\ mol^{-1}} \times 2$ » = 0.713 mol of I_2 «reacts with 100 g» ✓ Iodine number «= 0.713 mol x 253.80 g mol^{-1} » = 181 ✓	*Award **[3]** for correct final answer.*	**3**
7.	**b**	**ii**	straighter chain/fewer kinks in chain/more regular structure ✓ chains pack more closely together ✓ stronger London/dispersion/instantaneous dipole-induced dipole forces «between molecules» ✓	*Accept "greater surface area/electron density" **OR** "fewer carbon-carbon/C=C bonds" **OR** "less unsaturated" for M1* *Accept "stronger van der Waals'/vdW forces" for M3.* *Do **not** accept arguments based on size/molar mass/molecular mass of molecules alone.*	**3**

(continued…)

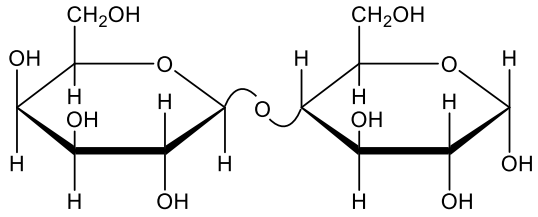
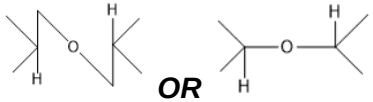
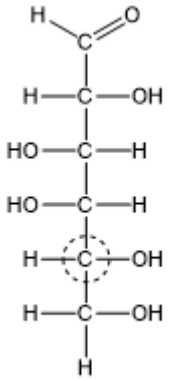
(Question 7 continued)

Question			Answers	Notes	Total
7.	**b**	**iii**	trans-fats produced ✓ *Any one of:* «trans-fats» difficult to metabolize/excrete ***OR*** «trans-fats» accumulate in body ✓ increased levels of LDL «cholesterol» ***OR*** decreased levels of HDL «cholesterol» ***OR*** increased LDL to HDL ratio ✓	*Do **not** award mark for "contains more LDL" **OR** "contains less HDL", they increase or decrease levels in the body.*	**2 max**

Question			Answers	Notes	Total
8.	**a**	**i**	proteins are charged at certain pH/pI ✓ attracted to electrode of opposite charge ***OR*** small/lighter/higher charged species travel further in gel ✓	*Do **not** penalize reference to amino acids instead of proteins.* *Do **not** accept answers related to DNA.*	**2**
8.	**a**	**ii**	electrostatic/ionic/ion-dipole attraction ✓ hydrogen bonding ✓		**2**

(continued…)

(Question 8 continued)

Question			Answers	Notes	Total
8.	**b**	**i**	 ✓	*Award mark if hydrogens are drawn as shown and rings are connected with a single oxygen.* *Accept a straight line across the middle with the oxygen atom,*  ***OR***	**1**
8.	**b**	**ii**	carbonyl ✓ hydroxyl ✓	*Accept "aldehyde" for M1* *Accept "alcohol"* ***OR*** *"hydroxy" but* ***not*** *"hydroxide" for M2.*	**2**
8.	**b**	**iii**	 ✓	*Accept circle that includes H and OH on C5.*	**1**

(continued…)

(Question 8 continued)

Question			Answers	Notes	Total
8.	**c**		*Any two of:* lactose/substrate binds to active site ✓ weakens «glycosidic/ether» bond in substrate ✓ lowers activation energy/E_a ***OR*** provides alternate pathway✓ increases rate of reaction ***OR*** acts as catalyst ✓ lactose/substrate specific ✓	*Accept "favorable orientation/conformation of the substrate «enforced by enzyme»" for M1.*	**2 max**

Question			Answers	Notes	Total
9.	**a**		lipid soluble so dissolves in body tissues/not excreted ✓ may be toxic/have adverse effects in high concentrations/excess ✓		**2**
9.	**b**	**i**	highly conjugated system ***OR*** many alternating single and double bonds ***OR*** many delocalized electrons ✓ «strong» absorption of some/specific wavelengths/colours/visible light ✓		**2**

(continued…)

(Question 9 continued)

Question			Answers	Notes	Total
9.	**b**	**ii**	carotene/compound is oxidized ***OR*** carotene/compound undergoes oxidative rancidity ✓ «visible light» provides energy making carotene unstable ***OR*** «visible light» produces radicals ✓	*Accept "visible light causes carotenes change configuration/from cis to trans" for M1.* *Accept "visible light promotes electrons an excited state making molecule unstable" for M2.*	**2**

Question			Answers	Notes	Total
10.	**a**	**i**	«[CPK] in diluted sample = 75 x 10^{-6} mol dm^{-3} » «[CPK] in undiluted sample =» 75 x 10^{-5} / 7.5 x 10^{-4} mol dm^{-3} ✓	*Accept answers in the range 73-77 x* 10^{-5} / 7.3-7.7 x 10^{-4} *mol* dm^{-3}*.*	**1**
10.	**a**	**ii**	[CPK] = 75 x 10^{-6} «mol dm^{-3}» ***AND*** A = 0.50 ***OR*** [CPK] = 75 x 10^{-5} «mol dm^{-3}» ***AND*** A = 5.0 ✓ «$\varepsilon = \frac{A}{l \times c} = \frac{0.50}{0.100\ dm \times 7.5 \times 10^{-5}\ mol\ dm^{-3}}$ = » 6.7 x 10^{4} «dm^2 mol^{-1} » ***OR*** «$\varepsilon = \frac{A}{l \times c} = \frac{0.50}{1.00\ cm \times 7.5 \times 10^{-5}\ mol\ dm^{-3}}$ = » 6.7 x 10^{3} «dm^3 cm^{-1} mol^{-1} » ✓	*Award **[2]** for correct final answer.* *Accept "6666.6* «dm^3 cm^{-1} mol^{-1} »".	**2**

Question			Answers	Notes	Total
11.			«host selectively» bond/binds to caesium/Cs/Cs^+/metal «ion» ***OR*** complementary chemical structure of host molecule and metal «ion» ✓ «supramolecule/host and caesium» anchored/filtered/precipitated ✓	*Do **not** accept "specifically bind" for M1 as this is rare for synthetic host molecule.* *Do **not** accept "trap" for M1.* *Accept "supramolecule removed" for M2.* *Do **not** accept "removed" by itself for M2.*	**2**

Option C — Energy

Question			Answers	Notes	Total
12.	**a**	**i**	${}^{2}_{1}H + {}^{3}_{1}H \rightarrow {}^{4}_{2}He + {}^{1}_{0}n$ ✓	*Accept equations without atomic numbers but **not** incorrect atomic numbers.* *Accept "D for deuterium" and "T for tritium" including mass numbers.* *Do **not** accept N for n.* *Accept values on the right side of the symbols if consistent.*	**1**
12.	**a**	**ii**	helium/product has higher binding energy «per nucleon» than «the average of binding energies per nucleon for» reactants/deuterium and tritium ✓ mass deficit/defect converted to energy ✓	*Accept "binding energy of ^{4}He is higher than the sum of binding energies of ^{2}H and ^{3}H" for M1.* *Accept "binding energy is released as heat" for M2.* *Do **not** accept just "mass converted to energy" alone.*	**2**
12.	**b**		*Δm= (mass of reactants-mass of products)* Δm = «6.01512 + 1.00867 – 3.01605 – 4.00260 =» 0.00514 «amu» ✓ Δm = «0.00514 amu x 1.66×10^{-27} kg amu^{-1}=» 8.53×10^{-30} «kg» ✓ E = «mc^2 = 8.53×10^{-30} «kg» x $(3.00 \times 10^{8}$ m $s^{-1})^2$ =» 7.68×10^{-13} «J» ✓	*Award **[3]** for correct final answer.*	**3**

Question			Answers	Notes	Total
12.	**c**		electrons/atoms/ions/elements absorb «specific» photons/frequencies/wavelength/energies «and jump to higher levels» ✓ «continuous» spectrum is missing this frequency/wavelength ***OR*** «absorbed» frequency/wavelength of light is re-radiated in all directions ✓	*Accept correctly annotated diagram.* *Accept: "gasses in sun's atmosphere for element" in M1.* *Accept "black lines seen «in continuous spectrum» where photons absorbed" for M2.*	**2**

Question			Answers	Notes	Total
13.	**a**		UV has higher energy/shorter wavelength «for use on ISS» ✓ UV is absorbed «by O_3» in the atmosphere ***OR*** only a little/small percentage «of UV light» reaches the earth's surface ✓		**2**

(continued…)

(Question 13 continued)

Question			Answers	Notes	Total
13.	**b**		«1.3 watts m^{-2} X 3 =» 3.9 «watts» ✓ «3.9 watts x 20 % =» 0.78 «W» ✓	*Accept range of "3.6-4.2* «*watts*»" *for M1.* *Accept range of "0.72-0.84* «W»" *for M2.* *Accept range of "0.24-0.28* «W»" *for M2 if M1 is missing.*	2
13.	**c**		change in polarity/dipole ✓ bonds stretch/bend ***OR*** bond length/O-H distance changes ***OR*** bond angle/H-O-H angle changes ✓ different vibrations/vibrational modes absorb different wavelengths ✓	*Accept "bonds/molecules vibrate" for M2.* *Accept "molecules stretch"* ***OR*** *"molecules bend" for M2.* *Accept appropriate diagrams.*	**3**

(continued…)

(Question 13 continued)

Question			Answers	Notes	Total
13.	**d**		highly conjugated system ***OR*** many alternating single and double bonds ***OR*** many delocalized electrons ✓		**1**
13.	**e**	**i**	*Any two of:* cheaper ***OR*** ease of fabrication ✓ use light of lower energy/lower frequency/longer wavelength ✓ absorb wider range of wavelengths ✓ dye converts most/all absorbed photons into electrons ✓ plentiful /renewable resources **«**to construct DSSC cells**»** ✓ 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**»** ✓ use of nanoparticles provides large surface area exposure to sunlight/sun/light ✓ can absorb better under cloudy/low light conditions ✓ better conductivity ✓ more flexible ✓	*Apply LP.* *Accept "more efficient".*	**2 max**
13.	**e**	**ii**	transfer electrons to external circuit/from electrolyte to anode. ✓	*Accept "provide large surface area".* *Accept "provides substrate to adsorb the dye molecules".*	**1**

(continued…)

(Question 13 continued)

Question			Answers	Notes	Total
13.	**e**	**iii**	Anode: $3I^-(aq) \longrightarrow I_3^-(aq) + 2e^-$ ✓ Cathode: $I_3^-(aq) + 2e^- \longrightarrow 3I^-(aq)$ ✓	*Award **[1 max]** for correct equations at wrong electrodes.* *Award **[1 max]** for using I_2*	**2**

Question			Answers	Notes	Total
14.	**a**	**i**	$C_8H_{18}(l) + 12.5\ O_2(g) \rightarrow 8CO_2(g) + 9H_2O(g)$ ✓ «1 x 8(44.01) ÷ 114.26 =» 3.081«kg CO_2 produced» ✓	*Accept equation with whole number coefficients.* *Award **[2]** for correct final answer.* *Accept "3.09 «kg CO_2 produced»" if whole numbers are used for molar mass.*	**2**
14.	**a**	**ii**	CO_2 «produced by burning ethanol» captured by crops «via photosynthesis» ✓	*Do **not** accept just "renewable" **OR** "carbon neutral" alone"*	**1**
14.	**b**		*Any one of:* «alkali» scrubbers ✓ react with CaO to produce carbonate ✓	*Apply LP.* *Accept "use as a feedstock" **OR** "convert to syngas".* *Do **not** accept carbon fixation/capture.*	**1 max**

Question			Answers	Notes	Total
15.	**a**		**«**redox**»** reaction in rechargeable battery is reversible **«**but not in a primary cell**»** ***OR*** rechargeable battery needs to be charged before use ***OR*** rechargeable battery has greater rate of self-discharge ✓	*Accept "rechargeable battery can be recharged **AND** primary cell cannot" **OR** "rechargeable battery can be used more than once/many times **AND** primary cell can be used once only".*	**1**
15.	**b**		«$E(H^+(aq)/H_2(g)) = 0 - (RT/F) \ln[H^+]^2$» «$E(H^+(aq)/H_2(g)) = -0.0591pH$ = » –0.591 «V» ✓ E(cell) «= –0.591 – (–0.76) = 0.169 V» ≈ 0.17 «V» ✓	*Award **[2]** for correct final answer.* *Award **[1 max]** for –0.17.*	**2**
15.	**c**		*Chemical natures:* further apart in redox table/activity series «used as electrodes» produces higher voltage/electrical output ✓ *Quantities:* «larger» quantity of materials increase/impact total work/length of time battery can operate ***OR*** «higher» concentrations can influence voltage/electrical output ***OR*** «higher» concentrations influence/increase total energy/voltage/electrical output ✓	*Do **not** accept "higher charge" alone for M1.*	**2**

Option D — Medicinal chemistry

Question			Answers	Notes	Total
16.	**a**	**i**	$\ll \frac{0.897 \times 180.17}{138.13} \gg =$ 1.17 «g» ✓		**1**
16.	**a**	**ii**	water ***AND*** incomplete drying/water retained in solid ***OR*** ethanoic acid ***AND*** not evaporated ✓	*Apply LP.* *Accept "ethanoic anhydride **AND** excess reagent".* *Accept "salicylic acid **AND** incomplete conversion/reaction".*	**1**
16.	**a**	**iii**	*Any three of:* dissolve in hot solvent ✓ filter/centrifuge «undissolved impurities» ✓ cool to reform crystals ✓ filter/centrifuge «purified product from dissolved impurities» ✓ rinse with cold solvent ✓	*Steps given must relate to the process of recrystallization.* *Do **not** award "filter" or "centrifuge" twice unless separate functions specified.* *Accept 'drying of final product'.* *Do **not** accept steps in the process of converting aspirin to sodium salt/soluble aspirin.*	**3 max**

(continued…)

(Question 16 continued)

Question			Answers	Notes	Total
16.	**a**	**iv**	*In both spectra:* 1050-1410 «cm^{-1} due to C−O» ***OR*** 1700-1750 «cm^{-1} due to C=O» ***OR*** 2850-3090 «cm^{-1} due to C−H» ✓ *In aspirin spectrum only:* 2500-3000 «cm^{-1} due to O−H» ***OR*** 1620–1680 « cm^{-1} due to C=C » ✓	*Apply LP.*	**2**
16.	**b**		*Aspirin:* prevents/interferes with production of prostaglandins/substances responsible for pain/swelling/fever' ✓ *Morphine:* blocks impulses within the brain /CNS ***OR*** binds to the «opioid/pain» receptors in the brain/CNS ***OR*** effective against strong pain ✓	*Award **[1 max]** for "aspirin acts at the pain source **AND** morphine acts on the brain/CNS".* *Accept "blocks COX/cyclooxygenase" for M1.* *Accept "effective against pain due to cancer/surgery/serious injury" for M2.* *Accept "sedate patients/relieve anxiety/stress associated with severe/terminal illness" for M2.* *Do **not** accept **"**blocks impulses to the brain" for M2.*	**2**

(continued…)

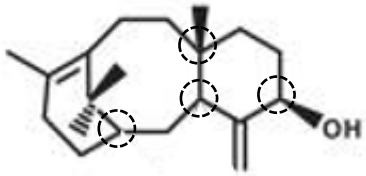
(Question 16 continued)

Question			Answers	Notes	Total
16.	**c**		*Any two of:* different functional groups ✓ affect binding between drug and receptor «sites/molecules» ***OR*** cause different solubility in lipids/blood-brain barrier/BBB ✓ codeine/diamorphine must be hydrolysed «before it can bind to opioid receptors» ✓	*Allow names or structures for M1.*	**2 max**

Question			Answers	Notes	Total
17.	**a**		*Laboratory synthesis:* natural sources not depleted/not reliant on scarce resources ***OR*** new structures can be developed to target specific sites ***OR*** higher purity/concentration ✓ *Derivation from natural sources:* provide ready-made complex organic structures «that would be difficult to synthesize» ***OR*** active compounds may be beyond synthetic techniques ***OR*** can provide semi-synthetic approach ✓	*Do **not** accept "produced faster **OR** lower cost".*	**2**

(continued…)

(Question 17 continued)

Question			Answers	Notes	Total
17.	**b**		 ✓	*Apply LP.* *Award **[1]** for two chiral carbon atoms circled in the diagram.* *Award **[0]** if any achiral carbon atoms are circled.* *Accept circle including carbon and substituents but **not** additional carbons.*	**1**
17.	**c**		«plane» polarized light passed through sample ✓ analyser/second polarizer determines angle of rotation of plane of plane-polarized light ***OR*** each enantiomer rotates plane «of plane-polarized light» in opposite directions «by the same angle» ✓		**2**

Question			Answers	Notes	Total
18.	**a**		«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**

(continued…)

(Question 18 continued)

Question			Answers	Notes	Total
18.	**b**		*Any two of:* prevents virus attaching to/entering 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 host cell» ✓ prevents release of «replicated» viruses «from host cell» ✓	*Apply LP.* *Accept "prevents synthesis of virus by host cell".* *Accept "alters RNA/DNA/genetic material of virus".* *Accept "blocks viral enzyme/reverse transcriptase"*	**2 max**

Question			Answers	Notes	Total
19.	**a**		$Ca(OH)_2(aq) + 2HCl(aq) \rightarrow CaCl_2(aq) + 2H_2O(l)$ ***OR*** $Ca(OH)_2(aq) + 2H^+(aq) \rightarrow Ca^{2+}(aq) + 2H_2O(l)$ ✓	*Accept "$OH^-(aq) + H^+(aq) \rightarrow H_2O(l)$".*	**1**
19.	**b**		$pK_a = 10.32$ ✓ pH «= $pK_a + \log\left(\frac{[A^-]}{[HA]}\right) = 10.32 + \log\left(\frac{0.015}{0.020}\right)$ » = 10.20 ✓	*Accept "10.31" for M1.* *Accept "10.19" for M2.* *Award **[2]** for correct final answer.* *Award **[1 max]** if the final answer is not to 2 decimal places.*	**2**

(continued…)

(Question 19 continued)

Question			Answers	Notes	Total
19.	**c**		blocks/binds to H2/histamine receptors «in cells of stomach lining» ***OR*** prevents histamine molecules binding to H2/histamine receptors «and triggering acid secretion» ✓ prevents «parietal» cells/stomach lining from releasing/producing acid ✓	*Do **not** accept 'proton pump inhibitor'.* *Accept "H2-receptor antagonist/H2RA" **OR** "blocks/inhibits action of histamine" for M1.* *Do **not** accept just "inhibits acid production" for M2.*	**2**

Question			Answers	Notes	Total
20.	**a**	**i**	$^{131}_{53}I \rightarrow {}^{131}_{54}Xe + {}^{0}_{-1}\beta$ ✓	*Accept β, β^-, e or e^-.* *Accept $^{131}I \rightarrow {}^{131}Xe + \beta$.* *Accept $^{131}I \rightarrow {}^{131}Xe + \beta + \nu$.* *Accept equations without atomic numbers but **not** with incorrect atomic numbers.* *Accept values on the right side if consistent.*	**1**

(continued…)

(Question 20 continued)

Question			Answers	Notes	Total
20.	**a**	**ii**	***Alternative 1:*** «$N(t) = N_0 \left(\frac{1}{2}\right)^{\frac{6.0}{8.02}}$» «$\frac{N(t)}{N_0} = 0.595$ » «% remaining =» 59.5 «%» / 60 «%» ✓ ***Alternative 2****:* «$\lambda = \frac{\ln 2}{t_{1/2}} = 0.0864$» «$N(t) = N_0 e^{-\lambda t} = e^{-0.0864 \times 6.0}$» «% remaining =» 59.5 «%» / 60 «%» ✓	*Award **[1]** for the correct final answer.*	**1**
20.	**b**		strongly ionizing radiation/interacts strongly with matter ***OR*** short path length/low penetrating power ✓	*Apply LP.* *Accept "limited damage to tissues «surrounding tumours»".*	**1**
20.	**c**		radioisotope delivered directly to «targeted» cancer cells ✓ by a carrier drug/protein/antibody/chelating agent ✓	*Accept 'several sites in body can be targeted at the same time'.*	**2**