Markscheme

May 2016

Chemistry

Higher level

Paper 3

27 pages

General Marking Instructions

Assistant Examiners (AEs) will be contacted by their team leader (TL) through RM™ Assessor, by e-mail or telephone – if through RM™ Assessor or by e mail, please reply to confirm that you have downloaded the markscheme from IBIS. The purpose of this initial contact is to allow AEs to raise any queries they have regarding the markscheme and its interpretation. AEs should contact their team leader through RM™ Assessor or by e-mail at any time if they have any problems/queries regarding marking. For any queries regarding the use of RM™ Assessor, please contact emarking@ibo.org.

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Subject Details: Chemistry HL Paper 3 Markscheme

Mark Allocation

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 <u>underlined</u> 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. "ECF acceptable" will be displayed in the "Notes" column.

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		*ozone:* yes because it absorbs IR ✓ *oxygen:* no because it does not absorb IR ✓		**2**
	b	i	*Any value in the range:* 1300–1500 ✓	*(It is in fact 1403 using the same measurement technique as that used to get the data in the table).*	**1**
	b	ii	CCl_4 is symmetrical/dipoles of C–Cl bonds cancel out ***OR*** fluorine/F more electronegative ❬than chlorine/Cl❭ ***OR*** C–F bond more polar ❬than C–Cl bond❭ ✓ ❬vector❭ sum of bond polarities in CCl_3F non-zero/greater than that in CCl_4 ***OR*** dipoles of ❬three❭ C–Cl bonds do not cancel the dipole of C–F bond ✓	*Accept suitable diagrams.*	**2**
	b	iii	GWP increases as IR intensity increases ✓	*Accept converse statements.*	**1**
	b	iv	no relationship **and** CO_2 and CCl_4/CF_4 are non-polar/have zero dipole moment (but) have very different integrated IR intensities ✓	*Accept a plot or sketch with a comment that "changes along x-axis produce random changes along y-axis".*	**1**
	b	v	❬data from table such as integrated IR and GWP indicate that they❭ contribute significantly to global warming ✓ persistent in atmosphere ✓ cause ozone depletion ✓ development ❬of refrigerants❭ inadvertently caused problems ✓		**2 max**

(continued)

Question			Answers	Notes	Total
2.	**a**		carefully dissolve pellets/handle concentrated solution as corrosive/ reaction exothermic ✓ pour/add ❬the concentrated solution❭ to a ❬1.00 dm^3❭ <u>volumetric flask</u> ✓ volumetric flask has low uncertainty in measurement ✓ fill up to line/mark/1 dm^3 with ❬dionized/distilled❭ water when at room temperature ***OR*** fill up to line/mark/1 dm^3 with ❬dionized/distilled❭ water mixing the solution ❬homogeneously❭ ✓		**2 max**
	b	**i**	blue to green/yellow ✓		**1**
	b	**ii**	equivalence point has been exceeded/too much acid has been added ✓ calculated concentration increased ***OR*** uncertainty increased ✓		**2**
	c		temperature of NaOH solution changed during experiment ***OR*** intensity of colour difficult to detect ✓	*Accept any valid hypothesis.*	**1**

(continued)

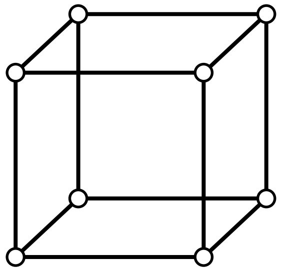
Section B

Option A — Materials

Question			Answers	Notes	Total
3.	a		$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(l) + 3CO_2(g)$ ✓		1
	b		*Fe_2O_3:* paramagnetic **and** unpaired electrons present so magnetic moments do not cancel out ✓ *Al_2O_3:* diamagnetic **and** electrons are all paired so magnetic moments cancel out ✓	*Award **[1]** for "Fe_2O_3 paramagnetic and Al_2O_3 diamagnetic".*	2
	c		$n(e) = \frac{2.00 \times 10^6}{96500} = 20.7$ ❮mol❯ ***OR*** $n(Al) = \frac{1}{3} n(e) = 6.91$ ❮mol❯ ✓ $m(Al) = 6.91 \times 26.98 = 186$ ❮g❯ ✓	*Award **[2]** for correct final answer.*	2
	d	i	collisions between electrons and positive ions/metal atoms/metal lattice ✓		1
	d	ii	metal II is a superconductor ✓ passing electrons ❮slightly❯ deform lattice/displace positive ions **and** couple/form Cooper pairs/condense with other electrons ✓ energy propagates along the lattice in wave-like manner/as phonons ✓ Cooper pair/electron condensate moves through lattice freely ***OR*** phonons are ❮perfectly❯ elastic/cause no energy loss ✓		3 max

(continued)

(Question 3 continued)

Question			Answers	Notes	Total
	e	i	 ✓ ❬coordination number =❭ 6 ✓		2
	e	ii	❬Bragg equation, $n = 1$❭ ❬$d = \frac{8.80 \times 10^{-11}}{2 \times \sin(13.0)} =$❭ 1.96×10^{-10} ❬m❭ ✓		1

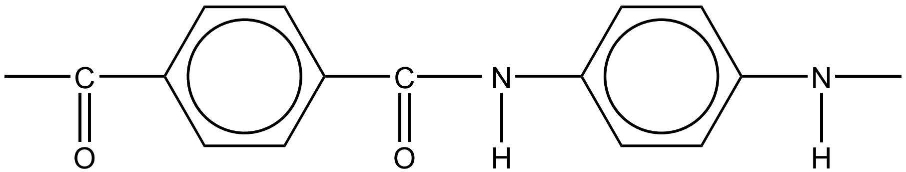
4.	**a**		possible toxicity ❬of small (airborne) particles❭ ***OR*** unknown health effects ***OR*** immune system/allergy concerns ***OR*** uncertain impact on environment ✓		1
	b		***EITHER*** pores/cavities/channels/holes ❬in zeolites❭ have specific shape/size ✓ only reactants that fit inside go through/are activated/can react ✓ ***OR*** zeolites have cage-like structure/are porous ✓ only reactants with appropriate size/geometry fit inside **and** go through/are activated/can react ✓		2

(continued)

(Question 4 continued)

Question			Answers	Notes	Total
	c		*Catalyst:* iron/Fe ***OR*** iron❮0❯ ❮penta❯ carbonyl/$Fe(CO)_5$ ✓ *Conditions:* high temperature/ 900–1600 °C **and** high pressure/10–100 atm ✓		**2**

5.			ceramics have a giant ionic/covalent structure ✓ metals contain lattice of positive metal ions in sea of delocalized electrons ✓		**2**

6.	**a**		❮CN group❯ makes molecule polar ✓ alignment/orientation of molecules can be controlled by electric field ✓		**2**
	b	**i**	 / —$COC_6H_4CONHC_6H_4NH$— ✓	*Continuation bonds are necessary for the mark.*	**1**
	b	**ii**	H bonds form between chains ❮from NH of one chain to CO of the next❯ ✓		**1**

(continued)

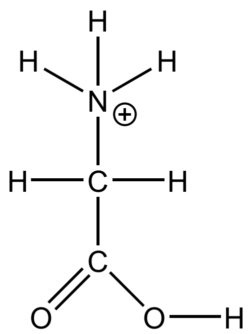
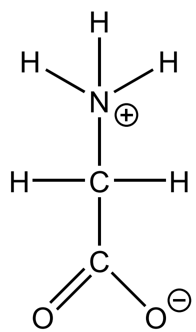
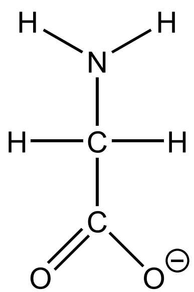
Question			Answers	Notes	Total
7.	a		plasticizer molecules fit between chains ***OR*** increase space between chains ✓ weaken intermolecular forces ✓		**2**
	b		does not degrade ❮so large volume in landfill❯ ✓ concerns about resource waste ✓ incineration produces dioxins/toxic compounds ✓		**1 max**

8.	a		$Fe^{3+} + O_2^- \rightarrow Fe^{2+} + O_2$ ✓ $Fe^{2+} + H_2O_2 \rightarrow Fe^{3+} + \bullet OH + OH^-$ ✓	*Award **[1]** for the net equation $H_2O_2 + O_2^- \rightarrow HO\bullet + OH^- + O_2$* *Accept the OH radical without the radical sign.*	**2**
	b		$K_{sp} = [Zn^{2+}][OH^-]^2 = 3 \times 10^{-17}$ $[OH^-] = 2[Zn^{2+}]$ ✓ $4[Zn^{2+}]^3 = 3 \times 10^{-17}$ ❮$[Zn^{2+}] = \sqrt[3]{7.5 \times 10^{-18}}$ =❯ 2×10^{-6} ❮$mol\,dm^{-3}$❯ ✓	*Award **[2]** for correct final answer.* *Award **[1]** for 5.5×10^{-9} or 6×10^{-9} ❮$mol\,dm^{-3}$❯.*	**2**

(continued)

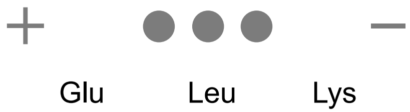
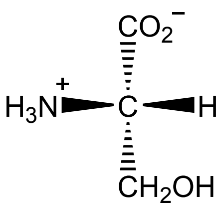
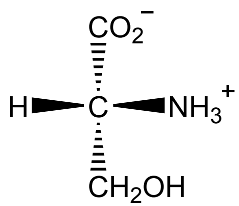
Option B — Biochemistry

Question			Answers	Notes	Total
9.	**a**	**i**	alkenyl ✓	*Accept alkene.*	**1**
	a	**ii**	fused ring structure ***OR*** three 6-membered rings and a 5-membered ring ***OR*** four-ring ❬steroidal❭ backbone ✓		**1**
	b		medical uses of steroids ❬under physician supervision❭ ***OR*** detection of banned substances has/can be improved ***OR*** understanding the health hazards is improved ✓	*Accept any medicalized specific use.*	**1**

10.	**a**		pH 1.0:  ✓ pH 6.0:  ✓ pH 11.0:  ✓	*Charges must be shown in structure for mark.* *Penalize repeated mistakes once.*	**3**

(continued)

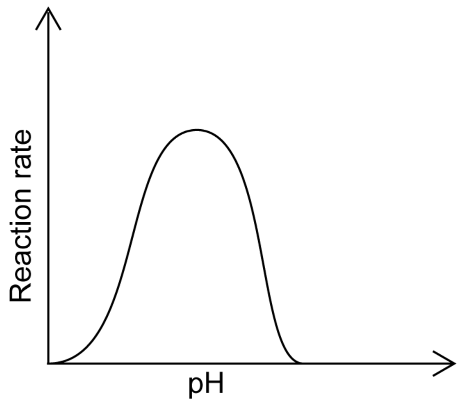
(Question 10 continued)

Question			Answers	Notes	Total
	b	i	 ✓✓	*Award **[2]** for correct order.* *Award **[1]** for Leu in center if order is incorrect.*	**2**
	b	ii	6 ✓	*Accept correct concepts expressed in other ways.*	**1**
	c	i	 **and**  ✓	*Accept un-ionized or zwitterionic forms.* *Accept any other correct representation which clearly indicates 3-dimensional structure at chiral center.* *Accept Fisher projections with the chiral carbon atom represented by crossing lines or shown as C.*	**1**
	c	ii	L ✓		**1**

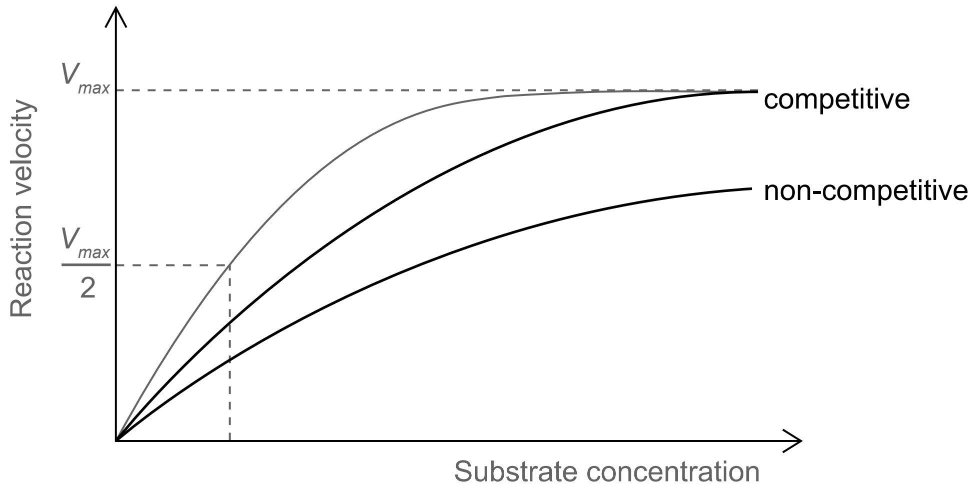
11.	**a**		$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ ✓		**1**
	b		$n(C_6H_{12}O_6)\left\langle = \frac{15.0}{180.18}\right\rangle = 0.0833$ **❮**mol**❯** ✓ **❮**energy $= 0.0833 \times 2803 =$**❯** 233 **❮**kJ**❯** ✓	*Award **[2]** for correct final answer.*	**2**

(continued)

(Question 11 continued)

Question			Answers	Notes	Total
	c		*Two advantages:* renewable resource ✓ broken down by bacteria or other organisms ✓ reduce plastic waste ✓ reduce use of petrochemicals ✓ *Two disadvantages:* require use of land ❮crop production❯ ✓ increase use of fertilizers and pesticides ❮pollutants❯ ***OR*** eutrophication ✓ might breakdown before end of use ✓ release of methane/greenhouse gas during degradation ✓	*Any two for **[2 max]**.* *Any two for **[2 max]**.*	**4 max**
	d		 bell shaped curve as shown in example above ✓		**1**

(continued)

<table>
<tr><th colspan="3">Question</th><th>Answers</th><th>Notes</th><th>Total</th></tr>
<tr><td>12.</td><td>a</td><td></td><td>

graph showing competitive inhibitor eventually reaching V_{max} ✓

graph showing non competitive inhibitor not reaching V_{max} ✓</td><td>Curves must be labeled and should not cross given curve.
Penalize one mark if curves cross.</td><td>2</td></tr>
<tr><td></td><td>b</td><td></td><td>$\log\frac{(3.70\times10^{-3})}{(2.60\times10^{-3})} = 0.153$ ✓
‹4.76 + 0.153 =› 4.91 ✓</td><td>Accept 4.9.
Award [2] for correct final answer.
Accept other methods of calculation.</td><td>2</td></tr>
</table>

<table>
<tr><td>13.</td><td>a</td><td></td><td>A and D have few polar/hydroxyl/OH groups ‹but C has many of those›
OR
A and D have hydrocarbon/six-membered carbon rings ‹but C has heterocyclic/five-membered ring› ✓
OR
A and D have long hydrocarbon chains ✓</td><td>Accept other valid similarities and differences.</td><td>1</td></tr>
<tr><td></td><td>b</td><td></td><td>0.50 and chlorophyll b ✓</td><td></td><td>1</td></tr>
</table>

(continued)

Question			Answers	Notes	Total
14.	**a**		low CO_2 level causes more oxygen to be bound to the heme ✓ high pH causes more oxygen to be bound to the heme ✓ low temperature more oxygen to be bound to the heme ✓ high organic phosphates/2,3-BPG/DPG which can bind to heme and increases affinity for oxygen ✓ CO decreases saturation/binds to active site/competitive inhibitor ✓	*Accept reverse statements for mark.*	**3 max**
	b		contains two gamma units ❮instead of the two beta units found in adults❯ ***OR*** differs slightly in amino acid sequence ❮from the two beta units found in adults❯ ✓ less sensitive to inhibitors/2,3-BPG/DPG ✓ receives O_2 from ❮partly deoxygenated❯ blood so must work at low pO_2 ✓	*Accept reverse statements for mark.*	**2 max**

Option C — Energy

Question			Answers	Notes	Total
15.	**a**	**i**	2,2-dimethylbutane ***OR*** 2,3-dimethylbutane ***OR*** 3-methylpentane ***OR*** 2-methylpentane ***OR*** cyclohexane ***OR*** methylcyclopentane ***OR*** benzene ✓	*Accept names or formulas.*	**1**
	a	**ii**	increased branching ***OR*** tertiary free radicals are more stable ***OR*** higher octane rating ✓		**1**
	b	**i**	$\left\langle \frac{5470}{114.26} = \right\rangle 47.9 \left\langle \text{kJ g}^{-1} \right\rangle$ ✓		**1**

(continued)

(Question 15 continued)

Question			Answers	Notes	Total
	b	ii	*Advantage:* ethanol does not produce particulates ***OR*** ethanol has high octane rating ***OR*** ethanol is renewable ✓ *Disadvantage:* ❬but❭ reduces efficiency ❬as ethanol has lower specific energy❭ ***OR*** ethanol is more volatile ❬than octane or its isomers❭ ***OR*** land that could be used for food production used to produce crops for ethanol ✓		**2**
	c		$2C(s) + 2H_2O(g) \rightarrow CH_4(g) + CO_2(g)$ ***OR*** $3C(s) + 2H_2O(g) \rightarrow CH_4(g) + 2CO(g)$ ✓		**1**

16.	**a**		*Reagent:* methanol/CH_3OH ***OR*** ethanol/C_2H_5OH ✓ *Catalyst:* strong acid ***OR*** strong base ✓	*Accept any strong acid such as sulfuric acid/H_2SO_4.* *Accept any strong base such as sodium hydroxide/NaOH.*	**2**

(continued)

(Question 16 continued)

Question			Answers	Notes	Total
	b		different solutions can be compared ***OR*** best ideas can be shared to arrive at global/local solutions ***OR*** acceleration of research ❮discoveries become available to everyone❯ ***OR*** improved confidence ❮statistical data can be compared/combined❯ ***OR*** money/effort/time is not wasted duplicating work others have already done ✓		**1**

17.	**a**		${}^{232}_{90}Th + {}^{12}_{6}C \rightarrow {}^{240}_{96}Cm + 4\,{}^{1}_{0}n$ ✓	*Accept* $^{232}Th + {}^{12}C \rightarrow {}^{240}Cm + 4n$.	**1**
	b	**i**	❮$\lambda = \dfrac{\ln 2}{7.038 \times 10^{8}}$ =❯ 9.849×10^{-10} ❮years❯$^{-1}$ ✓		**1**
	b	**ii**	❮3 half-lives, so❯ 2.11×10^{9} ❮years❯ ✓		**1**
	b	**iii**	produces free radicals ✓ ❮initiates chain reactions that can❯ damage DNA ***OR*** ❮initiates chain reactions that can❯ damage cells ***OR*** ❮DNA damage causes❯ mutations/cancer/apoptosis/cell death/weakening of immune system ✓	*Accept other negative biochemical and/or medical effects.*	**2**
	c	**i**	mass of helium-4 nucleus $= 4 \times 1.66 \times 10^{-27} = 6.64 \times 10^{-27}$ ❮kg❯ ***OR*** mass of nucleons $= 2 \times 1.672622 \times 10^{-27} + 2 \times 1.674927 \times 10^{-27} = 6.695098 \times 10^{-27}$ ❮kg❯ ✓ ❮mass defect $= 6.695098 \times 10^{-27} - 6.64 \times 10^{-27}$ =❯ 5.51×10^{-29} / 0.06×10^{-27} / 6×10^{-29} ❮kg❯ ✓	*Award **[2]** for correct final answer.*	**2**

(continued)

(Question 17 continued)

Question			Answers	Notes	Total
	c	ii	binding energy $= \dfrac{\Delta m \times c^2}{\text{nucleons}} = \dfrac{6 \times 10^{-29} \times (3.00 \times 10^8)^2}{4}$ $= 1 \times 10^{-12}$ ❮kJ nucleon^{-1}❯ ✓	*The use of 5.51×10^{-29} and 5.00×10^{-29} will respectively give 1.23×10^{-12} and 1.13×10^{-12}.*	**1**

18.			$CO_2(g) + H_2O(l) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$ ***OR*** $CO_2(g) \rightleftharpoons CO_2(aq)$ **and** $CO_2(aq) + H_2O(l) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$ ✓ increasing $[CO_2]$ shifts equilibrium to right/increases $[H^+]$ ✓ pH decreases ✓	*Accept $H_2CO_3(aq)$ instead of $CO_2(aq)$.* *Do not award M1 if states of CO_2 not shown or incorrect.*	**3**

19.			bond length changes/❮asymmetric❯ stretching ***OR*** bond angle changes/bends ✓ polarity/dipole moment changes ✓	*Accept appropriate diagram.*	**2**

20.	**a**		*Negative electrode (anode):* $CH_3OH(aq) + H_2O(l) \rightarrow CO_2(g) + 6H^+(aq) + 6e^-$ ✓ *Positive electrode (cathode):* $O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$ ✓	*Accept $\frac{3}{2}O_2(g) + 6H^+(aq) + 6e^- \rightarrow 3H_2O(l)$.*	**2**

(continued)

(Question 20 continued)

Question			Answers	Notes	Total
	b		*Advantage:* produces continuous supply of electricity ❮on addition of more raw materials❯ ***OR*** does not need to be recharged ***OR*** less hazardous if broken or exposed to the environment ***OR*** weighs much less than lead-acid battery ✓ *Disadvantage:* more expensive ***OR*** needs constant supply of fuel ***OR*** methanol/ethanol fuel cells difficult to use in cold weather ***OR*** methanol/ethanol fuel cells produce carbon dioxide ***OR*** storage/transport of gases/hydrogen a problem in hydrogen fuel cell ***OR*** potentially explosive/hydrogen is flammable ✓		**2**

21.	**a**		*n-type:* ❮small amount of❯ As/Sb/group 15 element added **and** ❮extra❯ electrons ✓ *p-type:* ❮small amount of❯ Ga/In/group 13 element added **and** ❮extra electron❯ holes ✓	*Award **[1 max]** if only doping elements or only charge carriers are given.* *Accept “group 5” for “group 15”.* *Accept “group 3” for “group 13”.*	**2**

(continued)

(Question 21 continued)

Question			Answers	Notes	Total
	b		large surface area ❬increases chance photon will be absorbed❭ ✓ ❬dye allows❭ absorption of a wide range of wavelengths ***OR*** dye converts most/all absorbed photons into electrons ✓		**2**

Option D — Medicinal chemistry

Question			Answers	Notes	Total
22.	**a**		beta-lactam ring is strained ***OR*** ring breaks easily ✓ bonds covalently/interferes with the enzyme/transpeptidase that synthesizes the bacterium cell wall ✓ inhibits cross linking in bacteria cell walls ***OR*** bacteria burst ❮from high osmotic pressure❯ ***OR*** cell cannot reproduce ✓		**3**
	b		bacteria can become resistant pollute the environment ❮overuse in livestock❯ loss of useful bacteria weakening of the immune system/natural body resistance to diseases ✓	*Any **two** for **[1 max]**.*	**1**

23.	**a**		<table><tr><th>Reagent</th><th>By-product</th></tr><tr><td>$(CH_3CO)_2O$ ***OR*** CH_3COCl ***OR*** CH_3COOH ✓</td><td>CH_3COOH ***OR*** HCl ***OR*** H_2O ✓</td></tr></table>	*Award M2 if only the by-product correspond to the reagent.*	**2**

(continued)

(Question 23 continued)

Question			Answers	Notes	Total
	b		morphine has ❬two❭ hydroxyl ❬groups❭ **and** diamorphine/heroin has ❬two❭ ester ❬groups❭ ✓ morphine is more polar than diamorphine/heroin ✓ morphine does not cross the blood-brain barrier as well as diamorphine/heroin ✓ morphine is better soluble in the blood plasma while diamorphine/heroin is better soluble in lipids ✓	*Accept converse argument.* *Accept "alcohol" for "hydroxyl".*	**3 max**
	c		spectrum A is diamorphine because it has a ❬strong❭ peak at 1700–1750 cm^{-1} ***OR*** spectrum A is diamorphine because it has a C=O/carbonyl (group)/ester ✓ spectrum B is morphine because it has a ❬strong broad❭ peak at 3200–3600 cm^{-1} ***OR*** spectrum B is morphine because it has a –OH/hydroxyl (group) ✓	*Accept "alcohol" for "hydroxyl".*	**2**

24.	**a**		$Mg(OH)_2(s) + 2HCl(aq) \rightarrow 2H_2O(l) + MgCl_2(aq)$ ***OR*** $Mg(OH)_2(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + 2H_2O(l)$ ✓		**1**

(continued)

(Question 24 continued)

Question			Answers	Notes	Total
	b		both compounds relieve symptoms of acid reflux/ heartburn ***OR*** both compounds relieve symptoms of indigestion ✓ omeprazole stops the production of acid **and** magnesium hydroxide neutralizes the acid that is present ✓ omeprazole takes longer ❮than magnesium hydroxide❯ to provide relief ***OR*** magnesium hydroxide provides faster relief ❮than omeprazole❯ ✓ omeprazole can prevent long term damage from overproduction of acid **and** magnesium hydroxide does not prevent acid damage ✓ magnesium hydroxide affects ionic balance in the body/produces ❮many❯ side effects **and** omeprazole does not affect ionic balance/has few❮er❯ side effects ✓		**3 max**

25.	**a**		<table><tr><th>Example</th><th></th><th>Treatment</th></tr><tr><td>gowns/gloves/syringes/ needles/cotton swabs</td><td>**and**</td><td>storage ❮in shielded container❯ until isotope has decayed, then dispose as normal/non-radioactive waste ✓</td></tr><tr><td>radioactive sources/ equipment for external radiotherapy</td><td>**and**</td><td>store <u>underground</u>/bury ✓</td></tr></table>	*Award 1 mark for example **and** corresponding treatment.* *Award **[1 max]** for the two types of waste.*	**2**

(continued)

(Question 25 continued)

Question			Answers	Notes	Total
	b		${}^{216}_{84}Po \rightarrow {}^{4}_{2}He + {}^{212}_{82}Pb$ correct reactant ✓ correct alpha particle ✓	*Atomic numbers not required for mark.* *Accept α symbol.*	**2**
	c		*Advantage:* selectively kills cancer cells ✓ *Cancer treatment:* melanoma ***OR*** leukemia ***OR*** rectal ***OR*** breast ***OR*** ovarian ***OR*** prostate ***OR*** pancreatic ***OR*** cancers that spread around the body/produce metastases ✓	*Accept skin cancer.*	**2**

(continued)

(Question 25 continued)

Question			Answers	Notes	Total
	d		***EITHER*** $\lambda = \frac{\ln 2}{6.01} \approx 0.115$ ❮h^{-1}❯ ✓ ❮remaining mass $= 5.80 \times 10^{-9} \times e^{-0.115 \times 24.04} =$❯ 3.63×10^{-10} ❮g❯ ✓ ***OR*** $\frac{24.04}{6.01} = 4$ ❮half-lives❯ ✓ ❮$\frac{5.80 \times 10^{-9}}{2^4} =$❯ 3.63×10^{-10} ❮g❯ ✓	*Award **[2]** for correct final answer.*	**2**
	e		risk vs benefit ❮patient and environment❯ ***OR*** security ***OR*** cultural resistance/superstition/lack of education ✓		**1**

26.	**a**		ether ✓		**1**
	b		*Number of signals:* 3 ❮signals❯ ✓ *Relative integration:* 6:4:1 ✓	*Accept any correct ratio order.*	**2**
	c	**i**	polarimeter ✓	*Accept other alternative techniques such as "GC/HLPC/chromatography using a chiral column".*	**1**

(continued)

(Question 26 continued)

	c	**ii**	polarized light passed through sample ✓ analyser/second polarizer detects whether plane of polarization rotated ***OR*** each enantiomer will rotate plane (of plane–)polarized light differently ✓	*Accept explanation related to other alternative techniques such as GC/ HLPC/chromatography using a chiral column.*	**2**