Cambridge Assessment
International Education

Interactive

Interactive Example Candidate Responses
Paper 22 (May/June 2016), Question 1

Cambridge International AS & A Level
Chemistry 9701

Version 1.0

Cambridge Pathway

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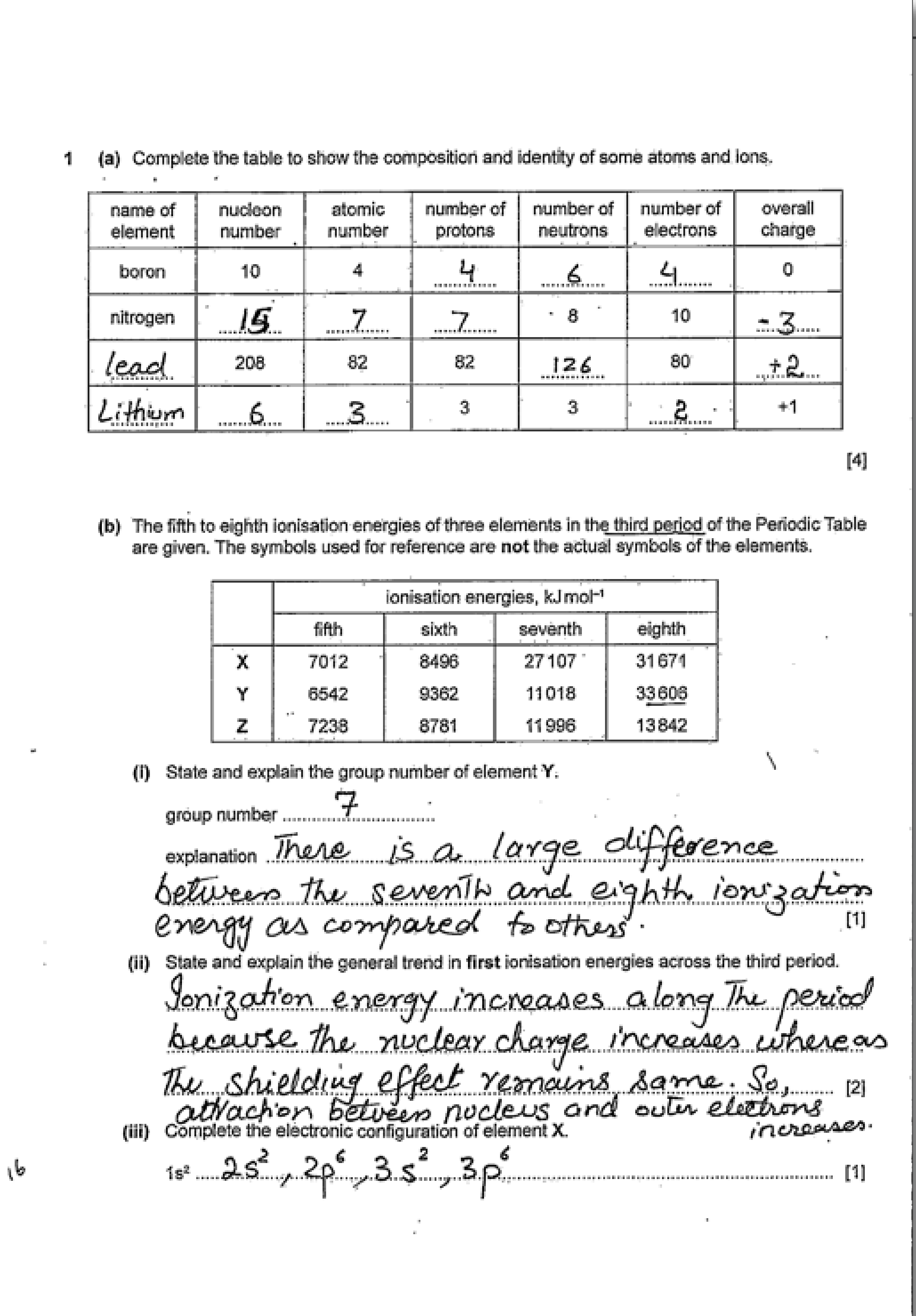

1 (a) Complete the table to show the composition and identity of some atoms and ions.

name of element	nucleon number	atomic number	number of protons	number of neutrons	number of electrons	overall charge
boron	10	4	4	6	4	0
nitrogen	15	7	7	8	10	-3
lead	208	82	82	126	80	+2
Lithium	6	3	3	3	2	+1

[4]

(b) The fifth to eighth ionisation energies of three elements in the third period of the Periodic Table are given. The symbols used for reference are **not** the actual symbols of the elements.

	ionisation energies, kJ mol⁻¹			
	fifth	sixth	seventh	eighth
X	7012	8496	27 107	31 671
Y	6542	9362	11 018	33 606
Z	7238	8781	11 996	13 842

(i) State and explain the group number of element **Y**.

group number ....7........

explanation There is a large difference between the seventh and eighth ionization energy as compared to others. [1]

(ii) State and explain the general trend in **first** ionisation energies across the third period.

Ionization energy increases along the period because the nuclear charge increases whereas the shielding effect remains same. So, attraction between nucleus and outer electrons increases. [2]

(iii) Complete the electronic configuration of element **X**.

16

$1s^2$ $2s^2, 2p^6, 3s^2, 3p^6$ [1]

Your Mark

1(a)

1(b)(i)

1(b)(ii)

1(b)(iii)

1(c)(i)

1(c)(ii)

Q1 Mark scheme

(a)(i)

name of element	nucleon number	atomic number	number of protons	number of neutrons	number of electrons	overall charge	
boron	10	5	5	5	5	0	[1]
nitrogen	15	7	7	8	10	-3	[1]
lead	208	82	82	126	80	+2	[1]
lithium	6	3	3	3	2	+1	[1]

[4]

(a)(ii) Group 17 / VII / 7

AND

big (owtte) increase / big difference / big gap / big jump / jump in increase / jump in difference after 7th IE **[1]**

(b) increases across period due to increasing attraction (of nucleus for electrons) [1]

due to increasing nuclear charge / atomic / proton number AND constant / similar shielding / same (outer) shell / energy level [1]

[2]

(c) $1s^2 2s^2 2p^6 3s^2 3p^4$ **[1]**

(100 – 99.76 – 0.04=) 0.2 **[1]**

$$\frac{0.2x + (99.76 \times 16) + (0.04 \times 17)}{100} = 16.0044$$ [1]

x = 18 [1]

[2]

[Total: 11]

EXAMINER COMMENTS

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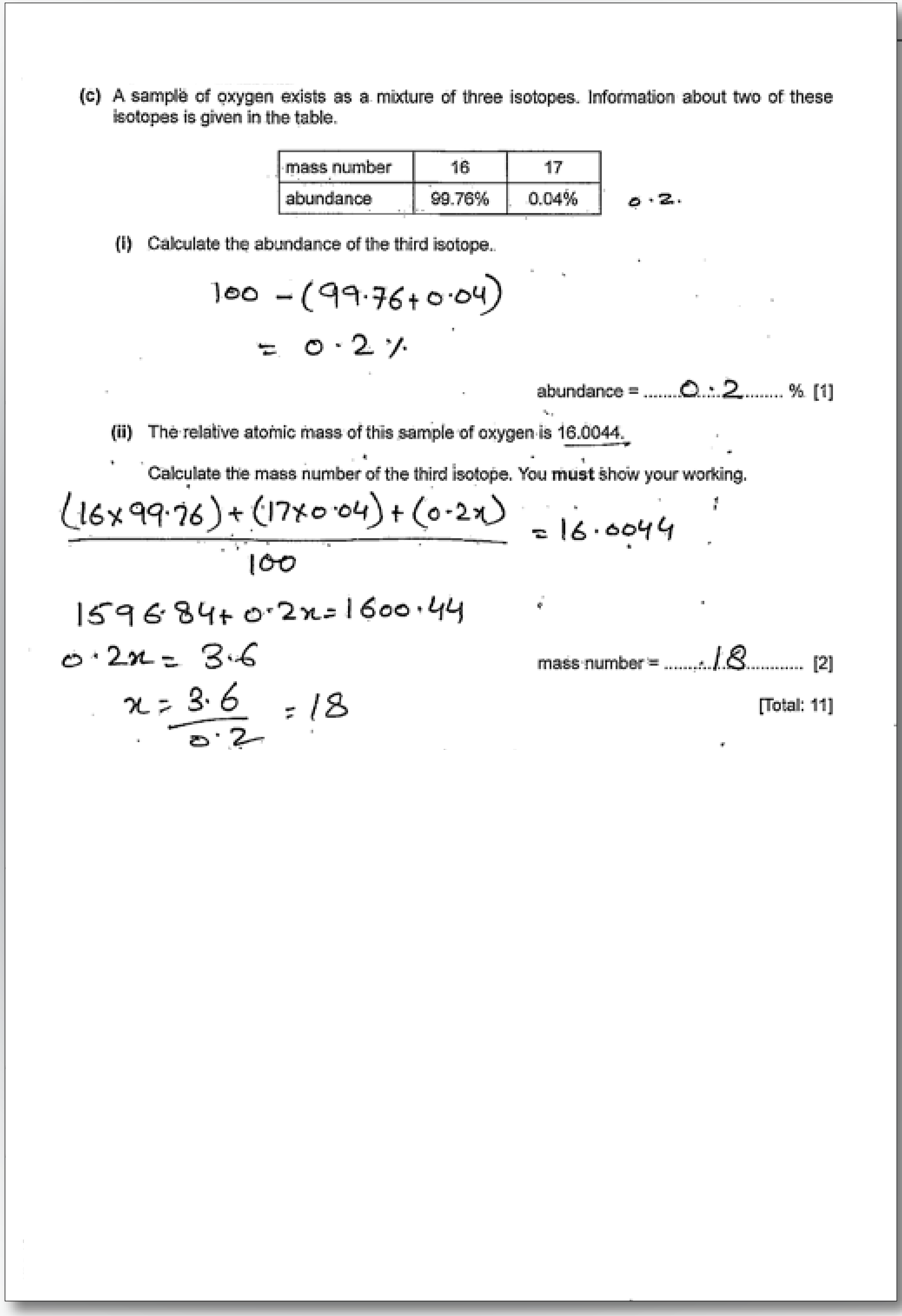

(c) A sample of oxygen exists as a mixture of three isotopes. Information about two of these isotopes is given in the table.

mass number	16	17
abundance	99.76%	0.04%

0·2·

(i) Calculate the abundance of the third isotope.

$100 - (99.76 + 0.04)$

$= 0.2\,\%$

abundance = ...0.2........ % [1]

(ii) The relative atomic mass of this sample of oxygen is 16.0044.

Calculate the mass number of the third isotope. You **must** show your working.

$$\frac{(16 \times 99.76) + (17 \times 0.04) + (0.2x)}{100} = 16.0044$$

$1596.84 + 0.2x = 1600.44$

$0.2x = 3.6$

$x = \frac{3.6}{0.2} = 18$

mass number = ...18........ [2]

[Total: 11]

Your Mark

1(a) ☐

1(b)(i) ☐

1(b)(ii) ☐

1(b)(iii) ☐

1(c)(i) ☐

1(c)(ii) ☐

Q1 Mark scheme

(a)(i)

name of element	nucleon number	atomic number	number of protons	number of neutrons	number of electrons	overall charge	
boron	10	5	5	5	5	0	[1]
nitrogen	15	7	7	8	10	-3	[1]
lead	208	82	82	126	80	+2	[1]
lithium	6	3	3	3	2	+1	[1]

[4]

(a)(ii)	Group 17 / VII / 7 AND big (owtte) increase / big difference / big gap / big jump / jump in increase / jump in difference after 7th IE	[1]
(b)	increases across period due to increasing attraction (of nucleus for electrons) due to increasing nuclear charge / atomic / proton number AND constant / similar shielding / same (outer) shell / energy level	[1] [1] **[2]**
(c)	$1s^2 2s^2 2p^6 3s^2 3p^4$	[1]
	(100 – 99.76 – 0.04=) 0.2	[1]
	$\frac{0.2x + (99.76 \times 16) + (0.04 \times 17)}{100} = 16.0044$ x = 18	[1] [1] **[2]** **[Total: 11]**

EXAMINER COMMENTS

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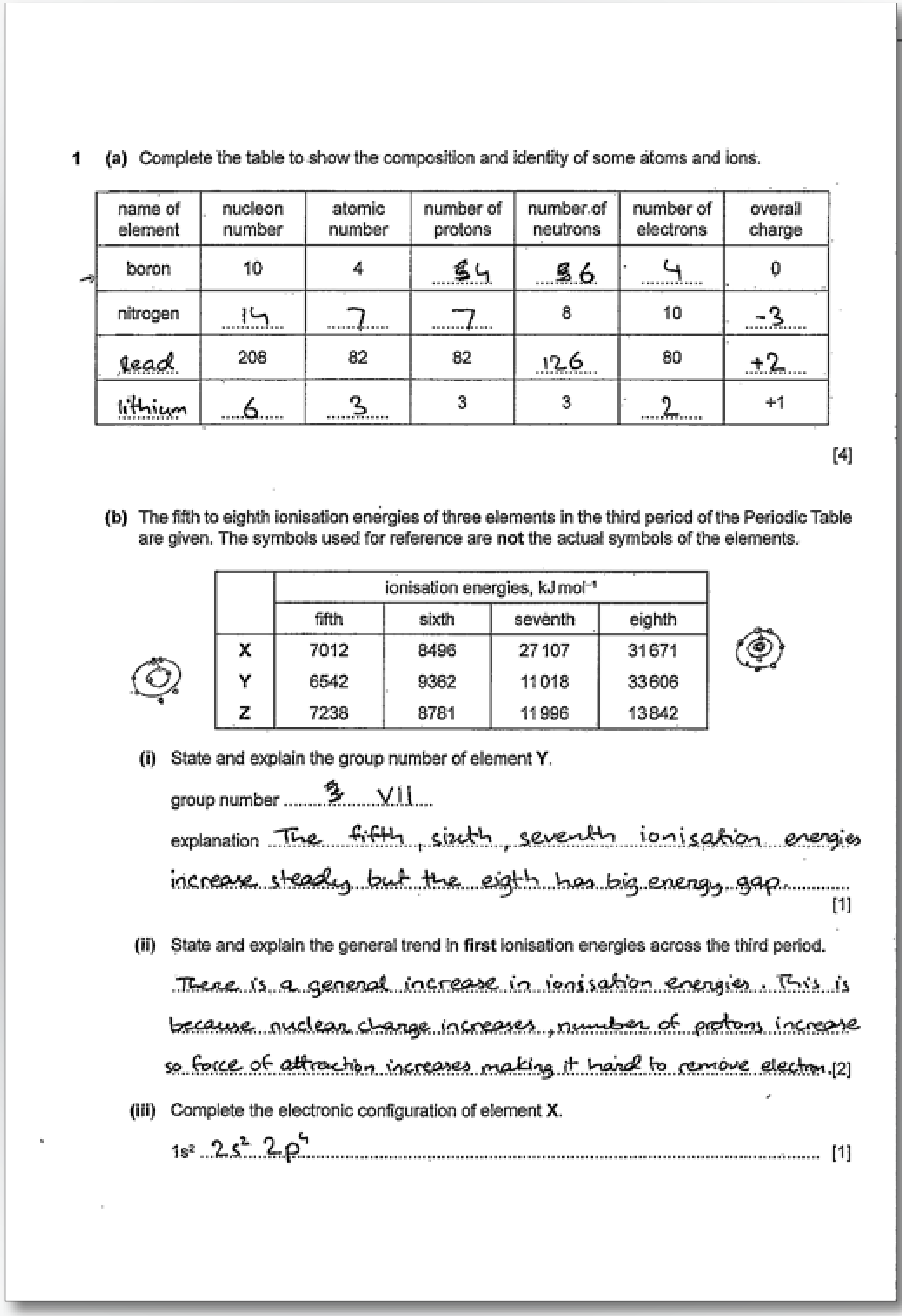


1 (a) Complete the table to show the composition and identity of some atoms and ions.

name of element	nucleon number	atomic number	number of protons	number of neutrons	number of electrons	overall charge
boron	10	4	~~5~~4	~~5~~6	4	0
nitrogen	14	7	7	8	10	-3
lead	208	82	82	126	80	+2
lithium	6	3	3	3	2	+1

[4]

(b) The fifth to eighth ionisation energies of three elements in the third period of the Periodic Table are given. The symbols used for reference are **not** the actual symbols of the elements.

	ionisation energies, kJ mol⁻¹			
	fifth	sixth	seventh	eighth
X	7012	8496	27 107	31 671
Y	6542	9362	11 018	33 606
Z	7238	8781	11 996	13 842

(i) State and explain the group number of element Y.

group number ~~3~~ VII

explanation The fifth, sixth, seventh ionisation energies increase steady but the eigth has big energy gap. [1]

(ii) State and explain the general trend in **first** ionisation energies across the third period.

There is a general increase in ionisation energies. This is because nuclear charge increases, number of protons increase so force of attraction increases making it haird to remove electron. [2]

(iii) Complete the electronic configuration of element X.

$1s^2$ $2s^2$ $2p^4$ [1]

Your Mark

1(a)

1(b)(i)

1(b)(ii)

1(b)(iii)

1(c)(i)

1(c)(ii)

Q1 Mark scheme

(a)(i)

name of element	nucleon number	atomic number	number of protons	number of neutrons	number of electrons	overall charge
boron	10	5	5	5	5	0
nitrogen	15	7	7	8	10	-3
lead	208	82	82	126	80	+2
lithium	6	3	3	3	2	+1

[1] [1] [1] [1]

[4]

(a)(ii) Group 17 / VII / 7

AND

big (owtte) increase / big difference / big gap / big jump / jump in increase / jump in difference after 7th IE **[1]**

(b) increases across period due to increasing attraction (of nucleus for electrons) [1]

due to increasing nuclear charge / atomic / proton number AND constant / similar shielding / same (outer) shell / energy level [1]

[2]

(c) $1s^2 2s^2 2p^6 3s^2 3p^4$ **[1]**

(100 − 99.76 − 0.04=) 0.2 **[1]**

$$\frac{0.2x + (99.76 \times 16) + (0.04 \times 17)}{100} = 16.0044$$ [1]

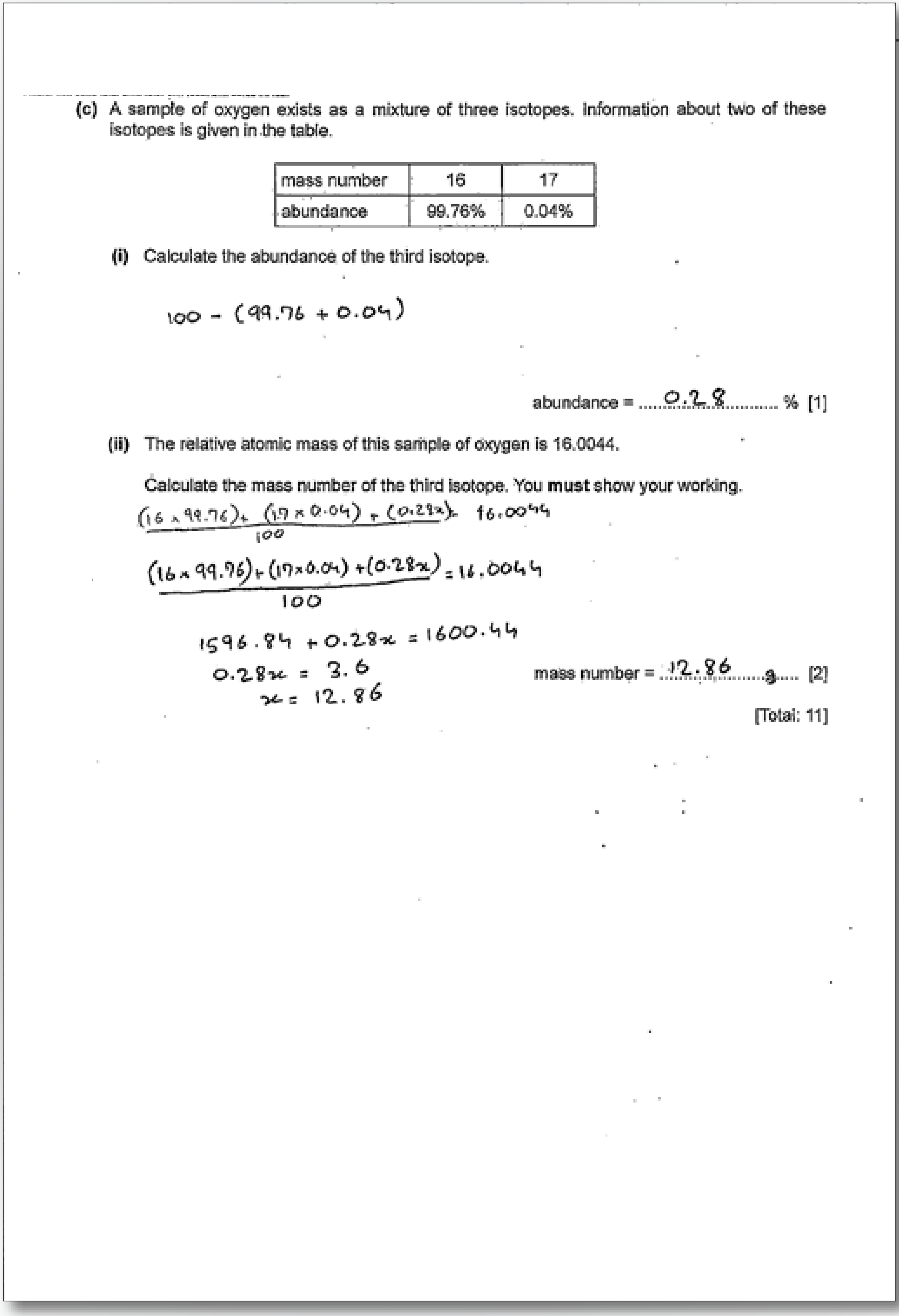
x = 18 [1]

[2]

[Total: 11]

EXAMINER COMMENTS

MARK SCHEME



(c) A sample of oxygen exists as a mixture of three isotopes. Information about two of these isotopes is given in the table.

mass number	16	17
abundance	99.76%	0.04%

(i) Calculate the abundance of the third isotope.

$100 - (99.76 + 0.04)$

abundance = ...0.28........... % [1]

(ii) The relative atomic mass of this sample of oxygen is 16.0044.

Calculate the mass number of the third isotope. You **must** show your working.

$\frac{(16 \times 99.76) + (17 \times 0.04) + (0.28x)}{100} = 16.0044$

$\frac{(16 \times 99.76) + (17 \times 0.04) + (0.28x)}{100} = 16.0044$

$1596.84 + 0.28x = 1600.44$

$0.28x = 3.6$

$x = 12.86$

mass number = ...12.86.........g.... [2]

[Total: 11]

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Your Mark

1(a) ☐

1(b)(i) ☐

1(b)(ii) ☐

1(b)(iii) ☐

1(c)(i) ☐

1(c)(ii) ☐

Q1 **Mark scheme**

(a)(i)

name of element	nucleon number	atomic number	number of protons	number of neutrons	number of electrons	overall charge	
boron	10	5	5	5	5	0	[1]
nitrogen	15	7	7	8	10	-3	[1]
lead	208	82	82	126	80	+2	[1]
lithium	6	3	3	3	2	+1	[1]

[4]

(a)(ii) Group 17 / VII / 7

AND

big (owtte) increase / big difference / big gap / big jump / jump in increase / jump in difference after 7th IE **[1]**

(b) increases across period due to increasing attraction (of nucleus for electrons) [1]

due to increasing nuclear charge / atomic / proton number AND constant / similar shielding / same (outer) shell / energy level [1]

[2]

(c) $1s^2 2s^2 2p^6 3s^2 3p^4$ **[1]**

(100 – 99.76 – 0.04=) 0.2 **[1]**

$\frac{0.2x + (99.76 \times 16) + (0.04 \times 17)}{100} = 16.0044$ [1]

x = 18 [1]

[2]

[Total: 11]

EXAMINER COMMENTS

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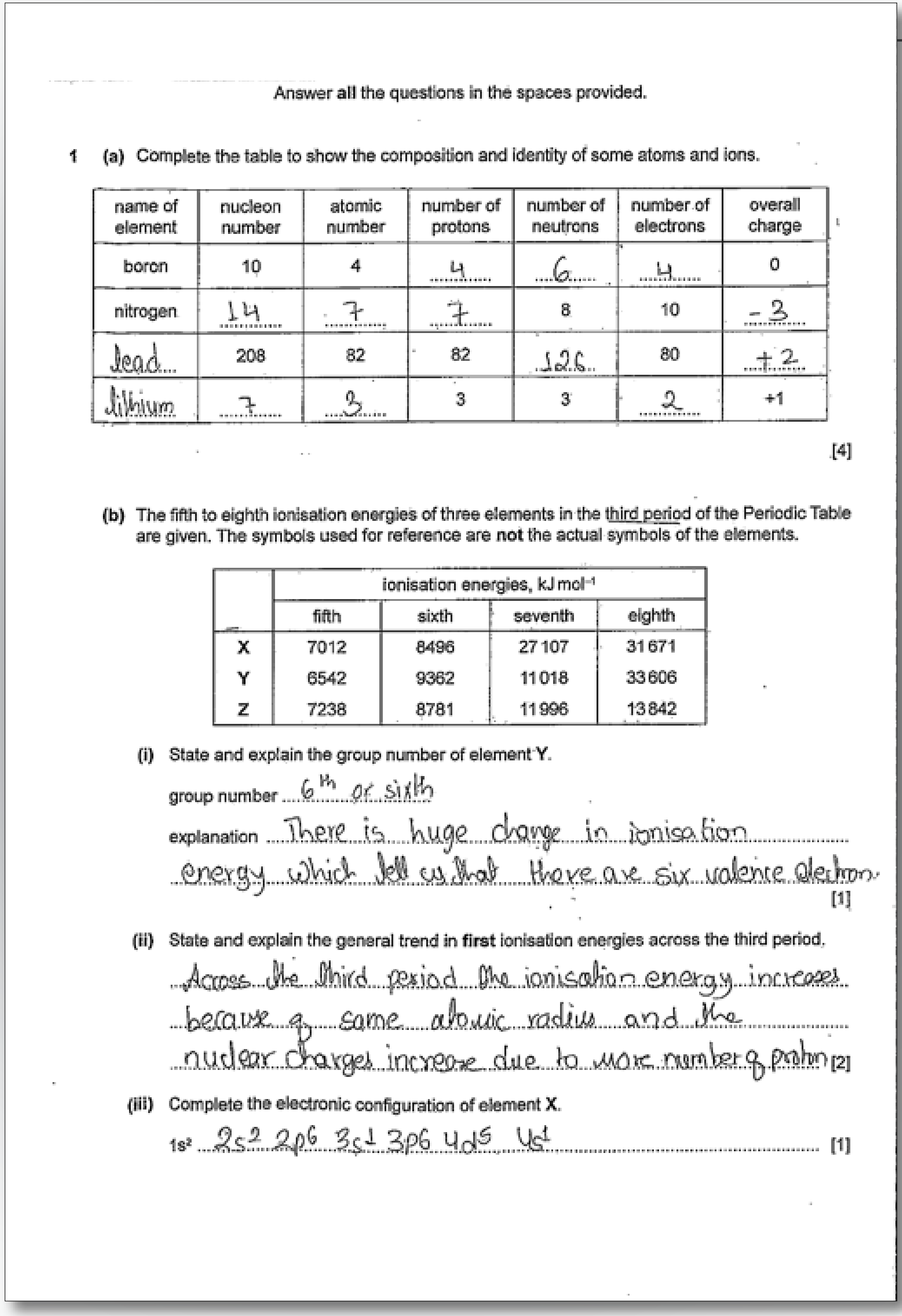

Answer **all** the questions in the spaces provided.

1 (a) Complete the table to show the composition and identity of some atoms and ions.

name of element	nucleon number	atomic number	number of protons	number of neutrons	number of electrons	overall charge
boron	10	4	4	6	4	0
nitrogen	14	7	7	8	10	-3
lead	208	82	82	126	80	+2
lithium	7	3	3	3	2	+1

[4]

(b) The fifth to eighth ionisation energies of three elements in the third period of the Periodic Table are given. The symbols used for reference are **not** the actual symbols of the elements.

	ionisation energies, kJ mol^{-1}			
	fifth	sixth	seventh	eighth
X	7012	8496	27 107	31 671
Y	6542	9362	11 018	33 606
Z	7238	8781	11 996	13 842

(i) State and explain the group number of element **Y**.

group number 6th or sixth

explanation There is huge change in ionisation energy which tell us that there are six valence electron. [1]

(ii) State and explain the general trend in **first** ionisation energies across the third period.

Across the third period the ionisation energy increases because of same atomic radius and the nuclear charges increase due to more number of proton [2]

(iii) Complete the electronic configuration of element **X**.

1s² 2s² 2p⁶ 3s¹ 3p6 4d⁵ 4s¹ [1]

Your Mark

1(a)

1(b)(i)

1(b)(ii)

1(b)(iii)

1(c)(i)

1(c)(ii)

Q1 Mark scheme

(a)(i)

name of element	nucleon number	atomic number	number of protons	number of neutrons	number of electrons	overall charge	
boron	10	5	5	5	5	0	[1]
nitrogen	15	7	7	8	10	-3	[1]
lead	208	82	82	126	80	+2	[1]
lithium	6	3	3	3	2	+1	[1]

[4]

(a)(ii) Group 17 / VII / 7
AND
big (owtte) increase / big difference / big gap / big jump / jump in increase / jump in difference after 7th IE **[1]**

(b) increases across period due to increasing attraction (of nucleus for electrons) [1]

due to increasing nuclear charge / atomic / proton number AND constant / similar shielding / same (outer) shell / energy level [1]

[2]

(c) $1s^22s^22p^63s^23p^4$ **[1]**

(100 – 99.76 – 0.04=) 0.2 **[1]**

$$\frac{0.2x + (99.76 \times 16) + (0.04 \times 17)}{100} = 16.0044$$ [1]

x = 18 [1]

[2]

[Total: 11]

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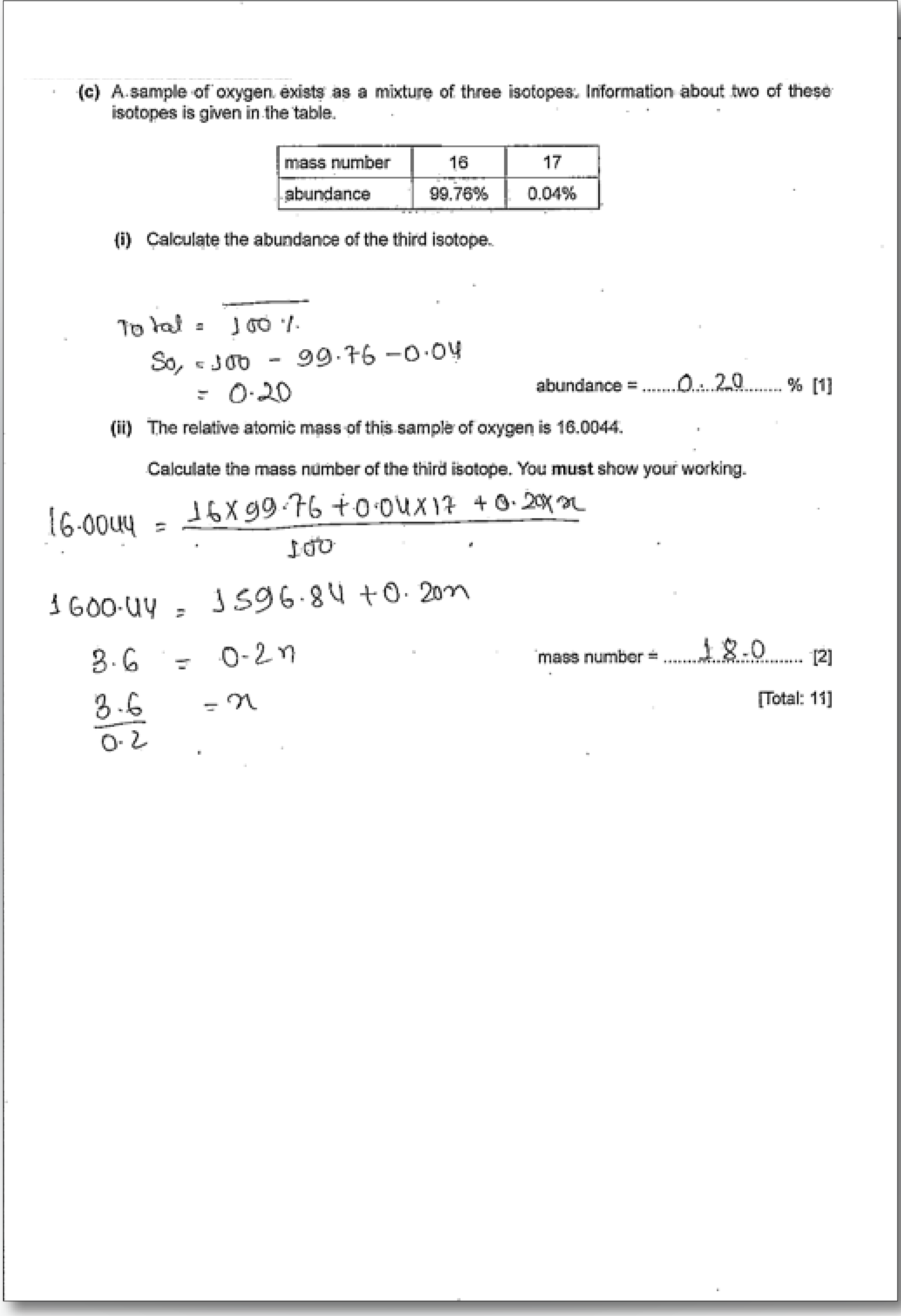

(c) A sample of oxygen exists as a mixture of three isotopes. Information about two of these isotopes is given in the table.

mass number	16	17
abundance	99.76%	0.04%

(i) Calculate the abundance of the third isotope.

Total = $\overline{100\ \%}$

So, = 100 − 99.76 − 0.04

= 0.20

abundance = ...0.20........ % [1]

(ii) The relative atomic mass of this sample of oxygen is 16.0044.

Calculate the mass number of the third isotope. You **must** show your working.

$$16.0044 = \frac{16 \times 99.76 + 0.04 \times 17 + 0.20 \times x}{100}$$

$$1600.44 = 1596.84 + 0.20x$$

$$3.6 = 0.2x$$

$$\frac{3.6}{0.2} = x$$

mass number = ...18.0........ [2]

[Total: 11]

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Your Mark

1(a) ☐

1(b)(i) ☐

1(b)(ii) ☐

1(b)(iii) ☐

1(c)(i) ☐

1(c)(ii) ☐

Q1 Mark scheme

(a)(i)

name of element	nucleon number	atomic number	number of protons	number of neutrons	number of electrons	overall charge	
boron	10	5	5	5	5	0	[1]
nitrogen	15	7	7	8	10	-3	[1]
lead	208	82	82	126	80	+2	[1]
lithium	6	3	3	3	2	+1	[1]

[4]

(a)(ii)	Group 17 / VII / 7 AND big (owtte) increase / big difference / big gap / big jump / jump in increase / jump in difference after 7th IE **[1]**
(b)	increases across period due to increasing attraction (of nucleus for electrons) [1] due to increasing nuclear charge / atomic / proton number AND constant / similar shielding / same (outer) shell / energy level [1] **[2]**
(c)	$1s^22s^22p^63s^23p^4$ **[1]**
	(100 – 99.76 – 0.04=) 0.2 **[1]**
	$\frac{0.2x + (99.76 \times 16) + (0.04 \times 17)}{100} = 16.0044$ [1] x = 18 [1] **[2]** **[Total: 11]**

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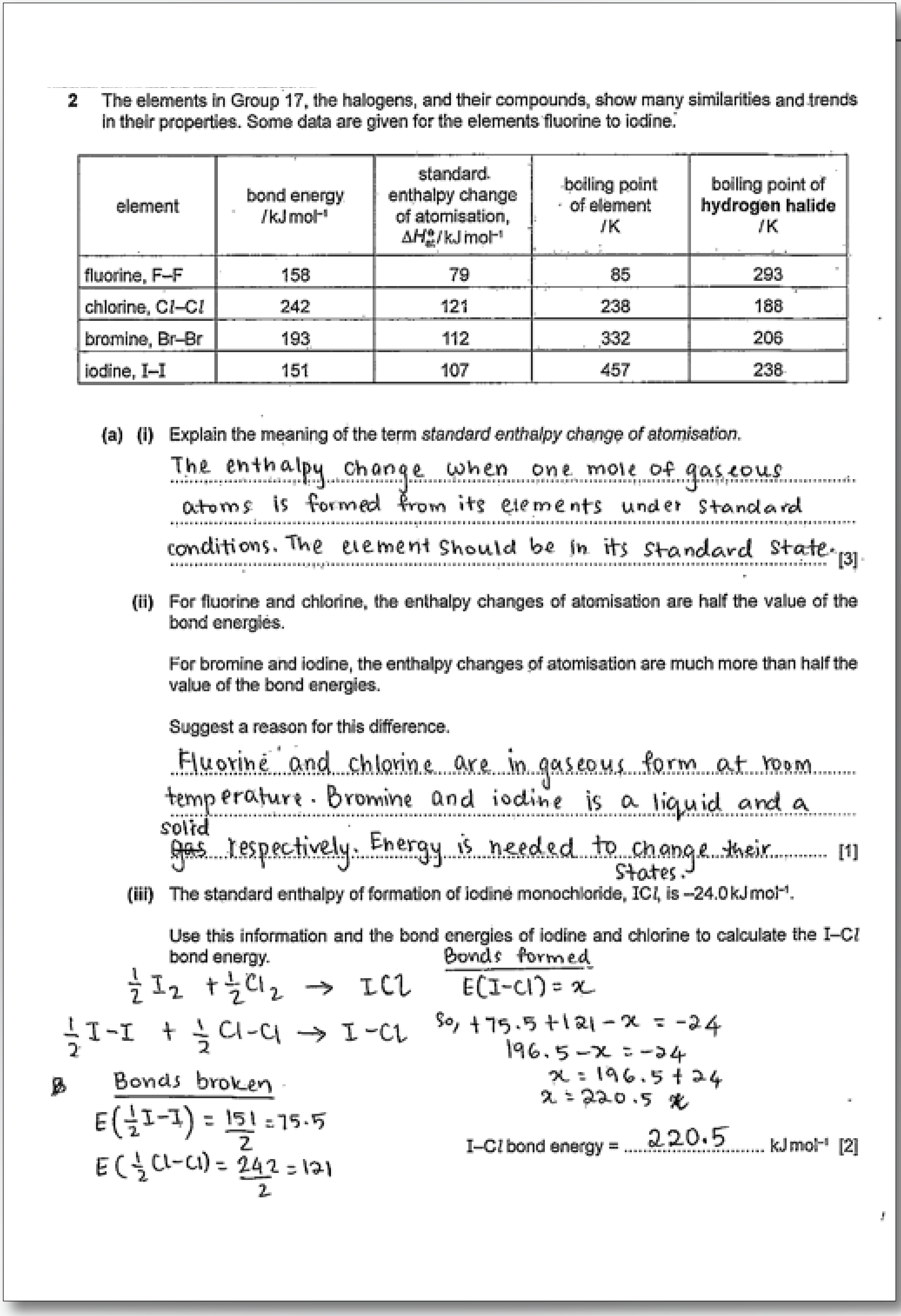

2 The elements in Group 17, the halogens, and their compounds, show many similarities and trends in their properties. Some data are given for the elements fluorine to iodine.

element	bond energy /kJ mol⁻¹	standard enthalpy change of atomisation, ΔH°_{at}/kJ mol⁻¹	boiling point of element /K	boiling point of hydrogen halide /K
fluorine, F–F	158	79	85	293
chlorine, C*l*–C*l*	242	121	238	188
bromine, Br–Br	193	112	332	206
iodine, I–I	151	107	457	238

(a) (i) Explain the meaning of the term *standard enthalpy change of atomisation*.

The enthalpy change when one mole of gaseous atoms is formed from its elements under standard conditions. The element should be in its standard state. [3]

(ii) For fluorine and chlorine, the enthalpy changes of atomisation are half the value of the bond energies.

For bromine and iodine, the enthalpy changes of atomisation are much more than half the value of the bond energies.

Suggest a reason for this difference.

Fluorine and chlorine are in gaseous form at room temperature. Bromine and iodine is a liquid and a ~~gas~~ solid respectively. Energy is needed to change their states. [1]

(iii) The standard enthalpy of formation of iodine monochloride, IC*l*, is –24.0 kJ mol⁻¹.

Use this information and the bond energies of iodine and chlorine to calculate the I–C*l* bond energy.

$\frac{1}{2}I_2 + \frac{1}{2}Cl_2 \rightarrow ICl$

$\frac{1}{2}I-I + \frac{1}{2}Cl-Cl \rightarrow I-Cl$

Bonds broken

$E(\frac{1}{2}I-I) = \frac{151}{2} = 75.5$

$E(\frac{1}{2}Cl-Cl) = \frac{242}{2} = 121$

Bonds formed

$E(I-Cl) = x$

So, $+75.5 + 121 - x = -24$

$196.5 - x = -24$

$x = 196.5 + 24$

$x = 220.5$

I–C*l* bond energy = 220.5 kJ mol⁻¹ [2]

Your Mark

2(a)(i) ☐

2(a)(ii) ☐

2(a)(iii) ☐

2(b)(i) ☐

2(b)(ii) ☐

2(c)(i) ☐

2(c)(ii) ☐

2(c)(iii) ☐

2(c)(iv) ☐

2(d)(i) ☐

2(d)(ii) ☐

Q2	**Mark scheme**
(a)(i)	enthalpy / energy / heat change when one mole of <u>gaseous atoms</u> is produced [1] from the element in its standard state [1] under standard conditions [1] **[3]**
(a)(ii)	fluorine and chlorine are gases / bromine liquid and iodine solid OR as ΔH_{at} for bromine / iodine also includes changes of state **[1]**
(a)(iii)	($\frac{1}{2}Cl_2 + \frac{1}{2}I_2 \rightarrow ICl$) $\Delta H_f = (\frac{1}{2}E(Cl_2) + \frac{1}{2}E(I_2)) - E(ICl)$ OR $E(ICl) = (151 / 2) + (242 / 2) + 24$ [1] $E(ICl) = (+)\ 220.5 / 221$ [1] **[2]**
(b)(i)	stronger / more / greater id–id / London / dispersion forces [1] due to increasing numbers of electrons [1] **[2]**
(b)(ii)	(intermolecular forces in HF are) hydrogen bonds [1] (which are) stronger (than vdW) / more energy needed to separate molecules [1] OR HF much more polar / F much more electronegative [1] Intermolecular forces in HF stronger (than in HC*l*, HBr, HI) [1] **[2]**
(c)(i)	**P** = iodine / I_2 /I; **Q** = chlorine / Cl_2 / C*l* **[1]**
(c)(ii)	weaker H–**P** than H–**Q** bond ORA / easier /less energy to break H–**P** than H–**Q** ORA [1] due to greater distance / shielding of nucleus from bond pair ORA [1] **[2]**
(c)(iii)	2H**P** (or 2HI) → (or) H_2 + $\mathbf{P}_2$ (or I_2) **[1]**
(c)(iv)	$Ag^+(aq) + \mathbf{Q}^-(aq)$ (or Cl^-) → $Ag\mathbf{Q}(s)$ (or $AgCl(s)$) [1] $Ag\mathbf{Q}(s)$ / $AgCl(s) + NH_3(aq) \rightarrow Ag(NH_3)_2^+(aq) + \mathbf{Q}^-(aq)$ / $Cl^-(aq)$ [1] **[2]**
(d)(i)	no of C*l* increases <u>by one</u> each time / matches group number [1] due to increasing number of valence/outer(most/shell) electrons / oxidation number / valency (of Mg, A*l* , Si) [1] **[2]**
(d)(ii)	$MgCl_2\ (+aq) \rightarrow Mg^{2+} + 2Cl^-$ [1] $AlCl_3 + 6H_2O \rightarrow Al(H_2O)_6^{3+} + 3Cl^-$ / $Al(H_2O)_5(OH)^{2+} + H^+ + 3Cl^-$ [1] $SiCl_4 + 2H_2O \rightarrow SiO_2 + 4H^+ + 4Cl^-$ [1] **[3]** **[Total:21]**

EXAMINER COMMENTS

MARK SCHEME

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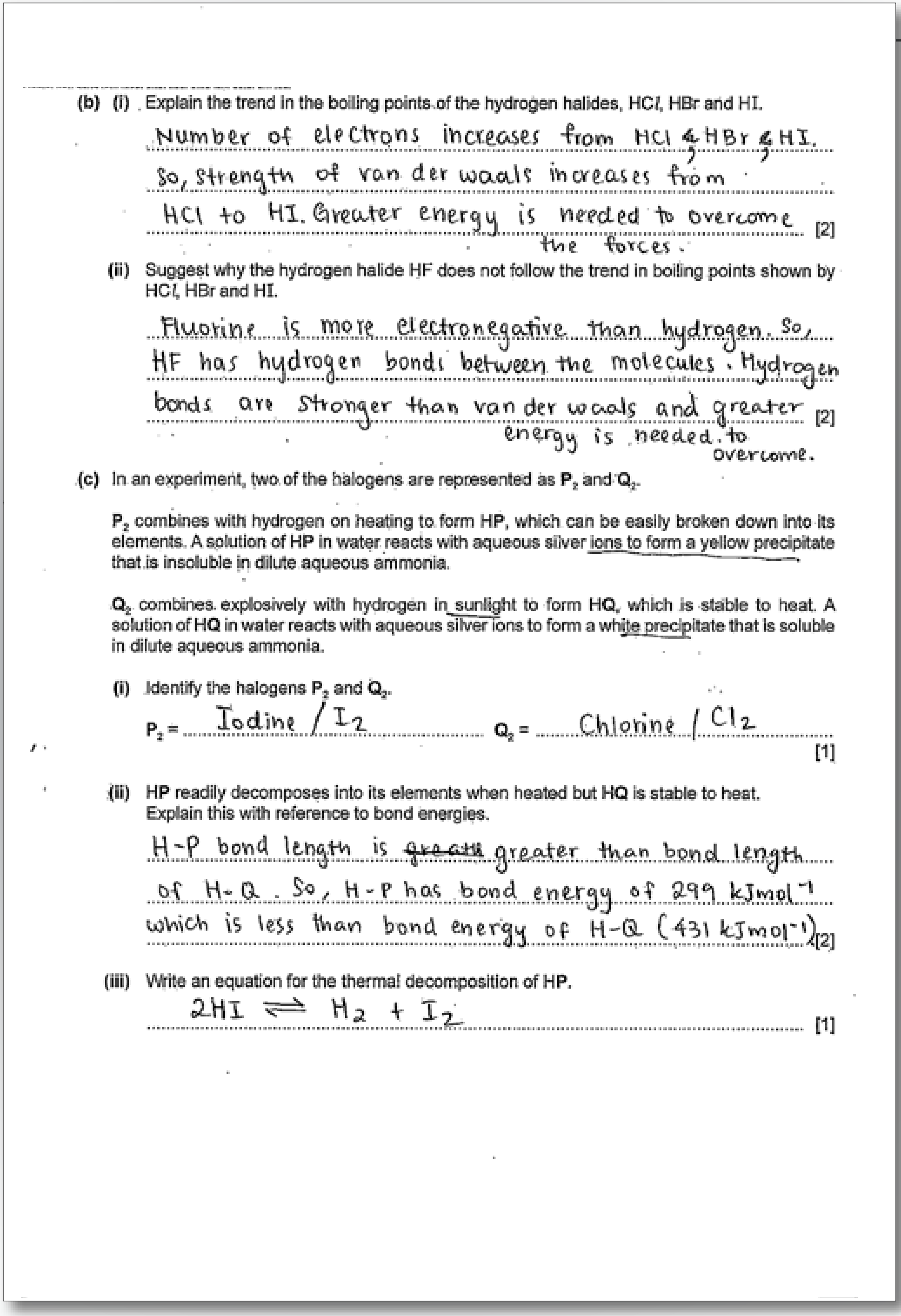

(b) (i) Explain the trend in the boiling points of the hydrogen halides, HC*l*, HBr and HI.

Number of electrons increases from HCl & HBr & HI. So, strength of van der waals increases from HCl to HI. Greater energy is needed to overcome the forces. [2]

(ii) Suggest why the hydrogen halide HF does not follow the trend in boiling points shown by HC*l*, HBr and HI.

Fluorine is more electronegative than hydrogen. So, HF has hydrogen bonds between the molecules. Hydrogen bonds are Stronger than van der waals and greater energy is needed to overcome. [2]

(c) In an experiment, two of the halogens are represented as P_2 and Q_2.

P_2 combines with hydrogen on heating to form HP, which can be easily broken down into its elements. A solution of HP in water reacts with aqueous silver ions to form a yellow precipitate that is insoluble in dilute aqueous ammonia.

Q_2 combines explosively with hydrogen in sunlight to form HQ, which is stable to heat. A solution of HQ in water reacts with aqueous silver ions to form a white precipitate that is soluble in dilute aqueous ammonia.

(i) Identify the halogens P_2 and Q_2.

P_2 = Iodine / I_2 Q_2 = Chlorine / Cl_2 [1]

(ii) HP readily decomposes into its elements when heated but HQ is stable to heat. Explain this with reference to bond energies.

H-P bond length is ~~greate~~ greater than bond length of H-Q. So, H-P has bond energy of 299 kJmol⁻¹ which is less than bond energy of H-Q (431 kJmol⁻¹) [2]

(iii) Write an equation for the thermal decomposition of HP.

$2HI \rightleftharpoons H_2 + I_2$ [1]

Your Mark

2(a)(i) ☐

2(a)(ii) ☐

2(a)(iii) ☐

2(b)(i) ☐

2(b)(ii) ☐

2(c)(i) ☐

2(c)(ii) ☐

2(c)(iii) ☐

2(c)(iv) ☐

2(d)(i) ☐

2(d)(ii) ☐

Q2	Mark scheme
(a)(i)	enthalpy / energy / heat change when one mole of gaseous atoms is produced [1] from the element in its standard state [1] under standard conditions [1] **[3]**
(a)(ii)	fluorine and chlorine are gases / bromine liquid and iodine solid OR as ΔH_{at} for bromine / iodine also includes changes of state **[1]**
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(c)(i)	**P** = iodine / I_2 /I; **Q** = chlorine / Cl_2 / C*l* **[1]**
(c)(ii)	weaker H–**P** than H–**Q** bond ORA / easier /less energy to break H–**P** than H–**Q** ORA [1] due to greater distance / shielding of nucleus from bond pair ORA [1] **[2]**
(c)(iii)	2H**P** (or 2HI) → (or) H_2 + $\mathbf{P}_2$ (or I_2) **[1]**
(c)(iv)	$Ag^+(aq) + \mathbf{Q}^-(aq)$ (or Cl^-) $\rightarrow Ag\mathbf{Q}(s)$ (or $AgCl(s)$) [1] $Ag\mathbf{Q}(s) / AgCl(s) + \cancel{N}H_3(aq) \rightarrow Ag(NH_3)_2^+(aq) + \mathbf{Q}^-(aq) / Cl^-(aq)$ [1] **[2]**
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EXAMINER COMMENTS

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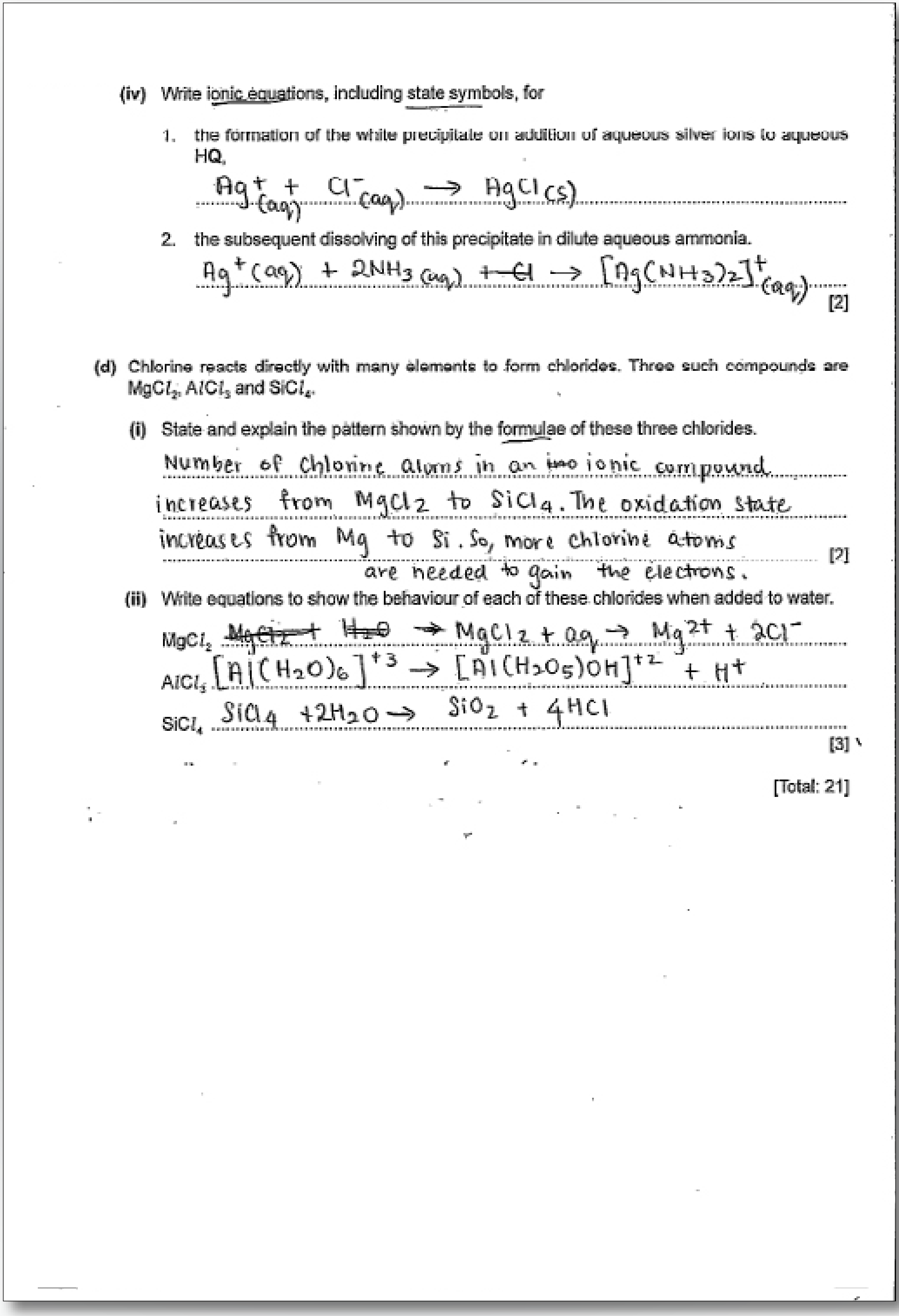

(iv) Write ionic equations, including state symbols, for

1. the formation of the white precipitate on addition of aqueous silver ions to aqueous HQ,

$Ag^{+}_{(aq)} + Cl^{-}_{(aq)} \rightarrow AgCl_{(s)}$

2. the subsequent dissolving of this precipitate in dilute aqueous ammonia.

$Ag^{+}(aq) + 2NH_{3\,(aq)}$ ~~+ Cl~~ $\rightarrow [Ag(NH_3)_2]^{+}_{(aq)}$ [2]

(d) Chlorine reacts directly with many elements to form chlorides. Three such compounds are $MgCl_2$, $AlCl_3$ and $SiCl_4$.

(i) State and explain the pattern shown by the formulae of these three chlorides.

Number of chlorine atoms in an ~~ino~~ ionic compound increases from $MgCl_2$ to $SiCl_4$. The oxidation state increases from Mg to Si. So, more chlorine atoms are needed to gain the electrons. [2]

(ii) Write equations to show the behaviour of each of these chlorides when added to water.

$MgCl_2$ ~~$MgCl_2$ +~~ ~~H_2O~~ $\rightarrow MgCl_2 + aq \rightarrow Mg^{2+} + 2Cl^-$

$AlCl_3$ $[Al(H_2O)_6]^{+3} \rightarrow [Al(H_2O_5)OH]^{+2} + H^+$

$SiCl_4$ $SiCl_4 + 2H_2O \rightarrow SiO_2 + 4HCl$

[3]

[Total: 21]

Your Mark	
2(a)(i)	
2(a)(ii)	
2(a)(iii)	
2(b)(i)	
2(b)(ii)	
2(c)(i)	
2(c)(ii)	
2(c)(iii)	
2(c)(iv)	
2(d)(i)	
2(d)(ii)	

Q2	Mark scheme
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EXAMINER COMMENTS

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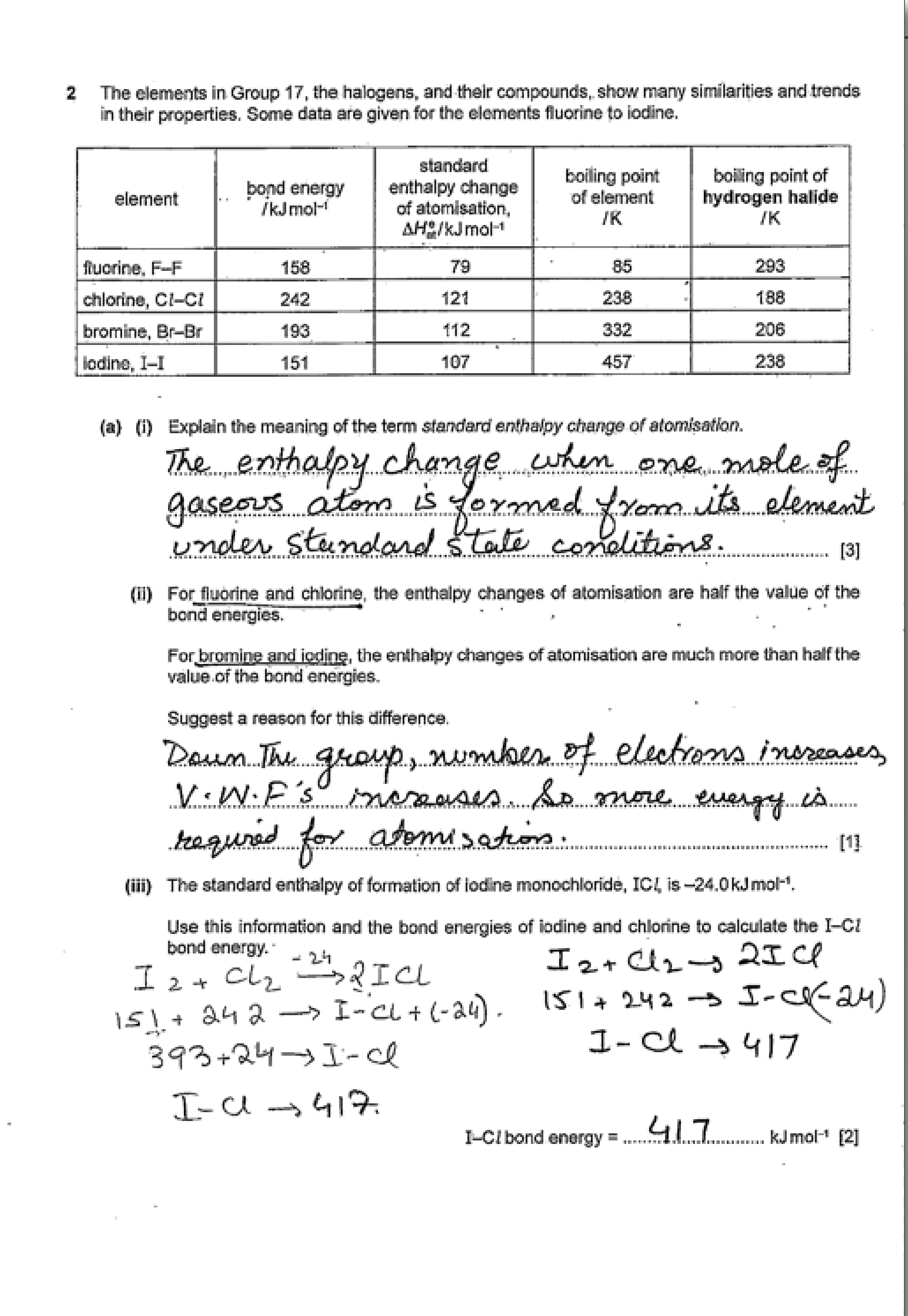

2 The elements in Group 17, the halogens, and their compounds, show many similarities and trends in their properties. Some data are given for the elements fluorine to iodine.

element	bond energy /kJ mol⁻¹	standard enthalpy change of atomisation, $\Delta H^{\ominus}_{at}$/kJ mol⁻¹	boiling point of element /K	boiling point of hydrogen halide /K
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bromine, Br–Br	193	112	332	206
iodine, I–I	151	107	457	238

(a) (i) Explain the meaning of the term *standard enthalpy change of atomisation*.

The enthalpy change when one mole of gaseous atom is formed from its element under standard state conditions. [3]

(ii) For fluorine and chlorine, the enthalpy changes of atomisation are half the value of the bond energies.

For bromine and iodine, the enthalpy changes of atomisation are much more than half the value of the bond energies.

Suggest a reason for this difference.

Down The group, number of electrons increases, V.W.F's increases. So more energy is required for atomisation. [1]

(iii) The standard enthalpy of formation of iodine monochloride, IC*l*, is –24.0 kJ mol⁻¹.

Use this information and the bond energies of iodine and chlorine to calculate the I–C*l* bond energy.

$I_2 + Cl_2 \xrightarrow{-24} 2ICl$

$151 + 242 \longrightarrow I\text{-}Cl + (-24).$

$393 + 24 \longrightarrow I\text{-}Cl$

$I\text{-}Cl \longrightarrow 417.$

$I_2 + Cl_2 \rightarrow 2ICl$

$151 + 242 \rightarrow I\text{-}Cl(-24)$

$I\text{-}Cl \rightarrow 417$

I–C*l* bond energy = 417 kJ mol⁻¹ [2]

Your Mark

2(a)(i) ☐

2(a)(ii) ☐

2(a)(iii) ☐

2(b)(i) ☐

2(b)(ii) ☐

2(c)(i) ☐

2(c)(ii) ☐

2(c)(iii) ☐

2(c)(iv) ☐

2(d)(i) ☐

2(d)(ii) ☐

Q2	Mark scheme
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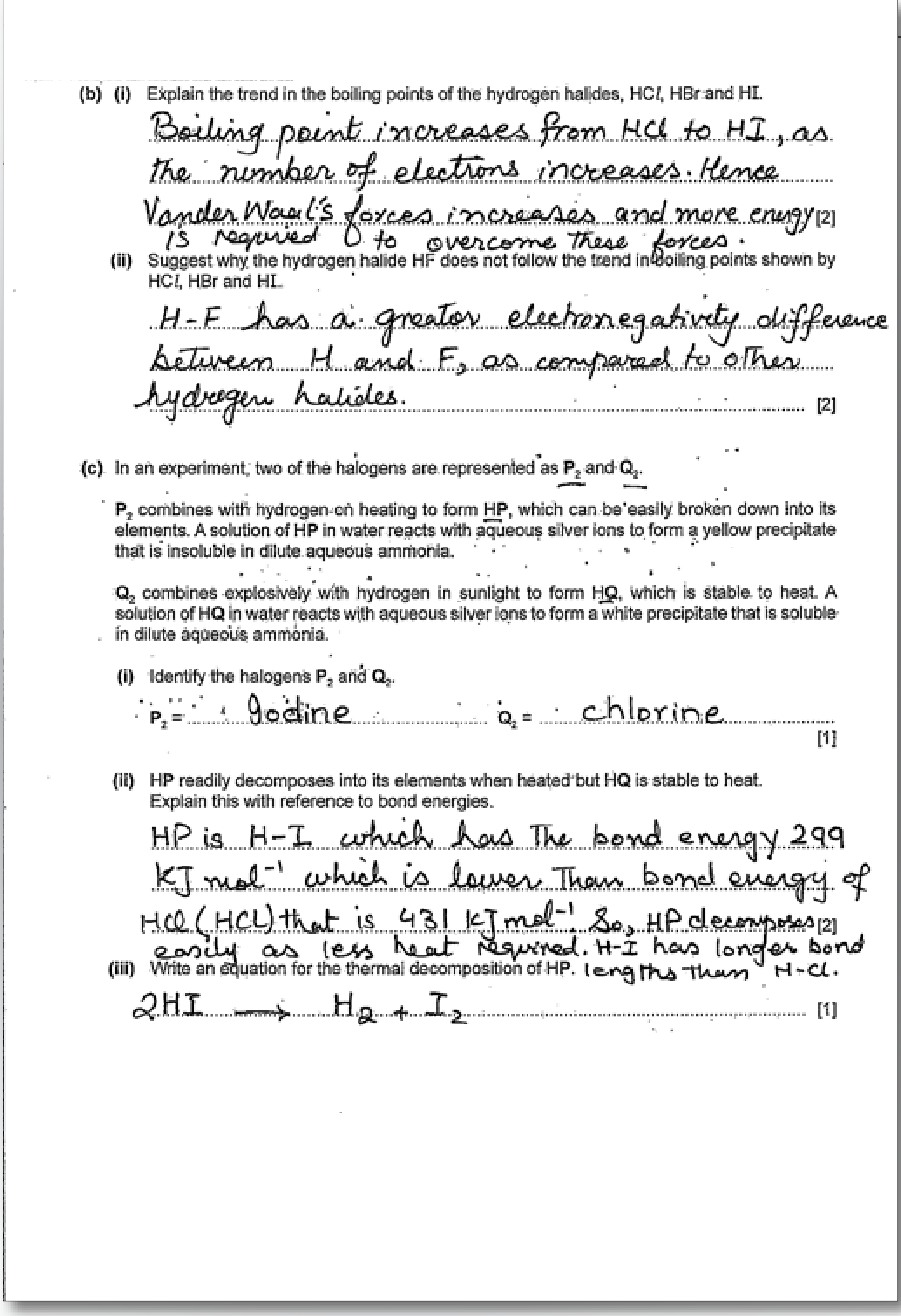

(b) (i) Explain the trend in the boiling points of the hydrogen halides, HC*l*, HBr and HI.

Boiling point increases from HCl to HI, as the number of electrons increases. Hence Vander Waal's forces increases and more energy is required to overcome these forces. [2]

(ii) Suggest why the hydrogen halide HF does not follow the trend in boiling points shown by HC*l*, HBr and HI.

H-F has a greator electronegativity difference between H and F, as compared to other hydrogen halides. [2]

(c) In an experiment, two of the halogens are represented as P_2 and Q_2.

P_2 combines with hydrogen on heating to form HP, which can be easily broken down into its elements. A solution of HP in water reacts with aqueous silver ions to form a yellow precipitate that is insoluble in dilute aqueous ammonia.

Q_2 combines explosively with hydrogen in sunlight to form HQ, which is stable to heat. A solution of HQ in water reacts with aqueous silver ions to form a white precipitate that is soluble in dilute aqueous ammonia.

(i) Identify the halogens P_2 and Q_2.

P_2 = Iodine Q_2 = chlorine [1]

(ii) HP readily decomposes into its elements when heated but HQ is stable to heat. Explain this with reference to bond energies.

HP is H-I which has The bond energy 299 KJ mol^{-1} which is lower Than bond energy of HCl (HCL) that is 431 KJ mol^{-1}. So, HP decomposes easily as less heat required. H-I has longer bond lengths than H-Cl. [2]

(iii) Write an equation for the thermal decomposition of HP.

$2HI \longrightarrow H_2 + I_2$ [1]

Your Mark	
2(a)(i)	
2(a)(ii)	
2(a)(iii)	
2(b)(i)	
2(b)(ii)	
2(c)(i)	
2(c)(ii)	
2(c)(iii)	
2(c)(iv)	
2(d)(i)	
2(d)(ii)	

Q2	Mark scheme	
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(d)(ii)	$MgCl_2 (+aq) \rightarrow Mg^{2+} + 2Cl^-$ $AlCl_3 + 6H_2O \rightarrow Al(H_2O)_6^{3+} + 3Cl^- / Al(H_2O)_5(OH)^{2+} + H^+ + 3Cl^-$ $SiCl_4 + 2H_2O \rightarrow SiO_2 + 4H^+ + 4Cl^-$	[1] [1] [1] **[3]** **[Total:21]**

EXAMINER COMMENTS

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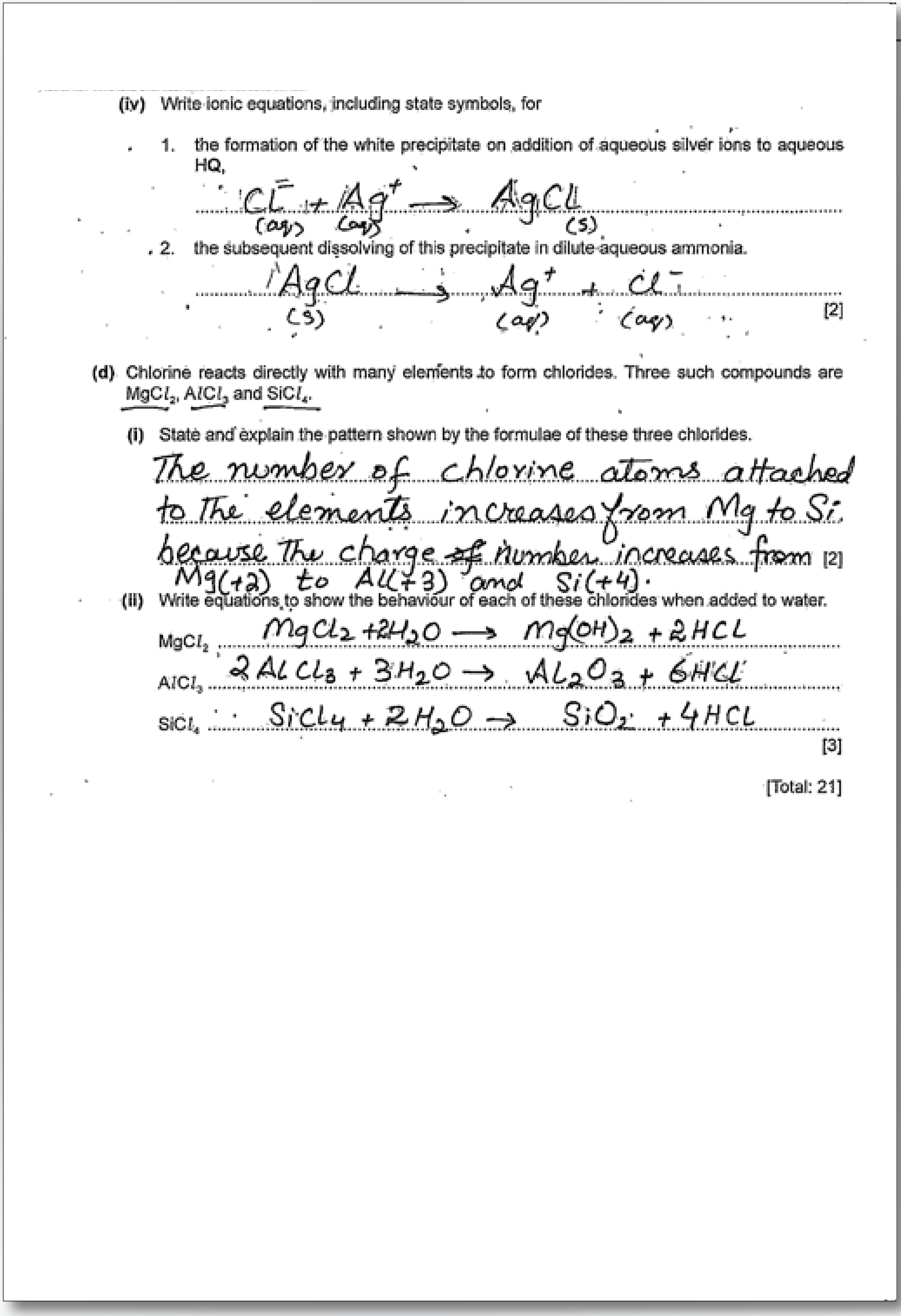

(iv) Write ionic equations, including state symbols, for

1. the formation of the white precipitate on addition of aqueous silver ions to aqueous HQ,

$Cl^-_{(aq)} + Ag^+_{(aq)} \longrightarrow AgCl_{(s)}$

2. the subsequent dissolving of this precipitate in dilute aqueous ammonia.

$AgCl_{(s)} \longrightarrow Ag^+_{(aq)} + Cl^-_{(aq)}$

[2]

(d) Chlorine reacts directly with many elements to form chlorides. Three such compounds are $MgCl_2$, $AlCl_3$ and $SiCl_4$.

(i) State and explain the pattern shown by the formulae of these three chlorides.

The number of chlorine atoms attached to The elements increases from Mg to Si. because The charge ~~of~~ number increases from Mg(+2) to Al(+3) and Si(+4). [2]

(ii) Write equations to show the behaviour of each of these chlorides when added to water.

$MgCl_2$ $MgCl_2 + 2H_2O \longrightarrow Mg(OH)_2 + 2HCL$

$AlCl_3$ $2AlCl_3 + 3H_2O \rightarrow Al_2O_3 + 6HCL$

$SiCl_4$ $SiCl_4 + 2H_2O \rightarrow SiO_2 + 4HCL$

[3]

[Total: 21]

Your Mark

2(a)(i) ☐

2(a)(ii) ☐

2(a)(iii) ☐

2(b)(i) ☐

2(b)(ii) ☐

2(c)(i) ☐

2(c)(ii) ☐

2(c)(iii) ☐

2(c)(iv) ☐

2(d)(i) ☐

2(d)(ii) ☐

Q2	Mark scheme
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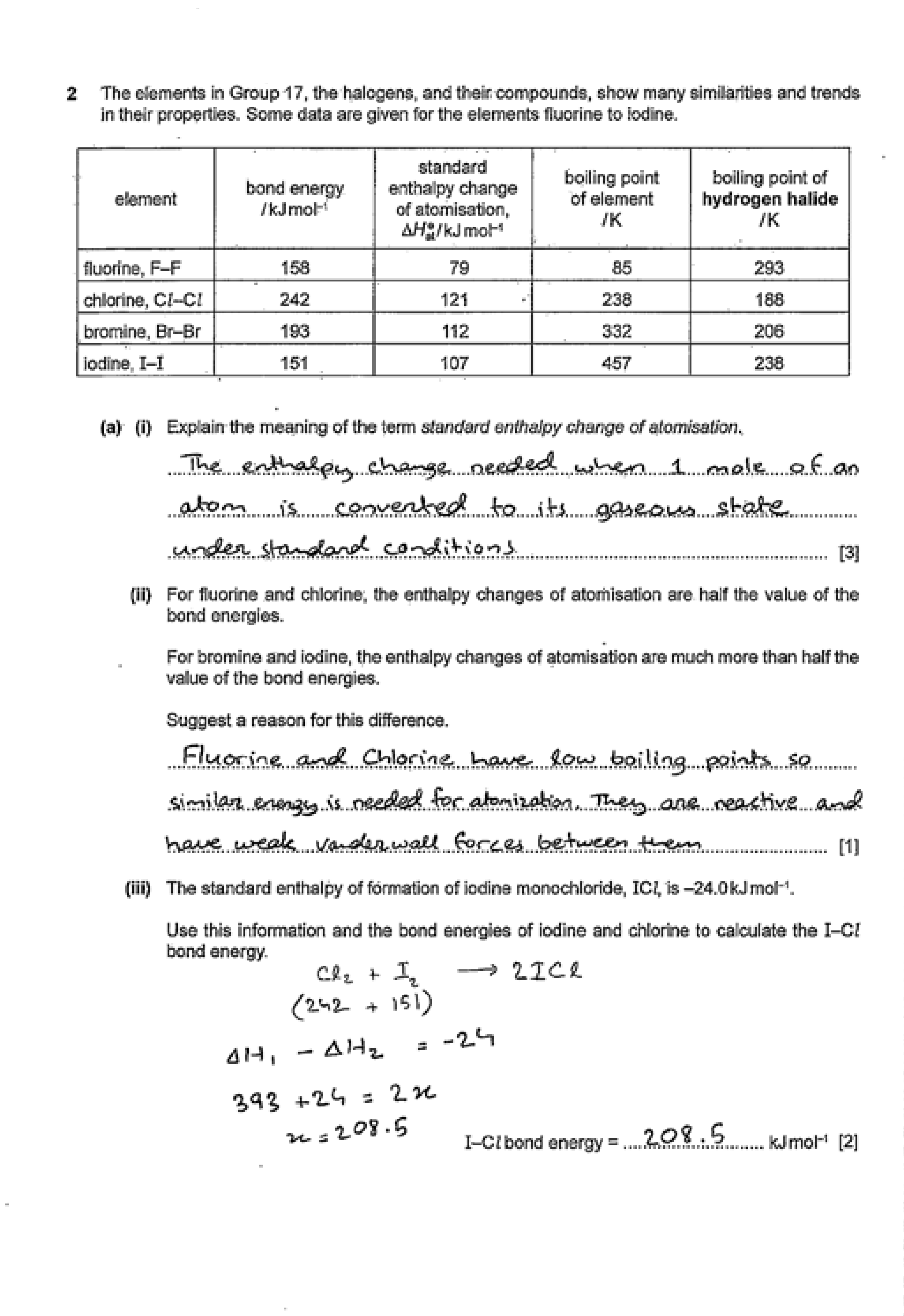

2 The elements in Group 17, the halogens, and their compounds, show many similarities and trends in their properties. Some data are given for the elements fluorine to iodine.

element	bond energy /kJ mol^{-1}	standard enthalpy change of atomisation, $\Delta H^{\ominus}_{at}$/kJ mol^{-1}	boiling point of element /K	boiling point of **hydrogen halide** /K
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bromine, Br–Br	193	112	332	206
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(a) (i) Explain the meaning of the term *standard enthalpy change of atomisation.*

The enthalpy change needed when 1 mole of an atom is converted to its gaseous state under standard conditions [3]

(ii) For fluorine and chlorine, the enthalpy changes of atomisation are half the value of the bond energies.

For bromine and iodine, the enthalpy changes of atomisation are much more than half the value of the bond energies.

Suggest a reason for this difference.

Fluorine and Chlorine have low boiling points so similar energy is needed for atomization. They are reactive and have weak vanderwall forces between them [1]

(iii) The standard enthalpy of formation of iodine monochloride, IC*l*, is –24.0 kJ mol^{-1}.

Use this information and the bond energies of iodine and chlorine to calculate the I–C*l* bond energy.

$Cl_2 + I_2 \longrightarrow 2ICl$

$(242 + 151)$

$\Delta H_1 - \Delta H_2 = -24$

$393 + 24 = 2x$

$x = 208.5$

I–C*l* bond energy = 208.5 kJ mol^{-1} [2]

Your Mark

2(a)(i)	
2(a)(ii)	
2(a)(iii)	
2(b)(i)	
2(b)(ii)	
2(c)(i)	
2(c)(ii)	
2(c)(iii)	
2(c)(iv)	
2(d)(i)	
2(d)(ii)	

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EXAMINER COMMENTS MARK SCHEME

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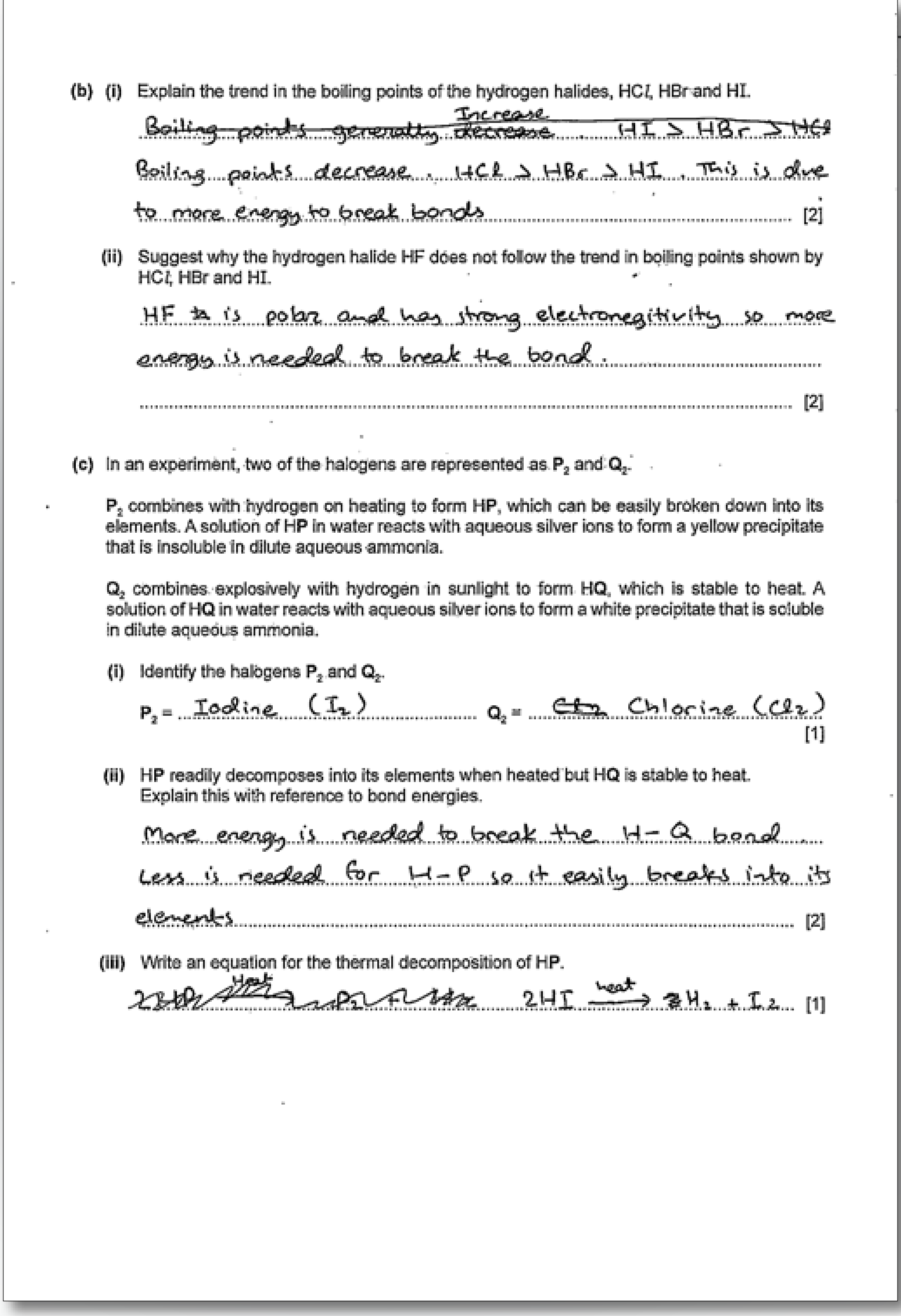

(b) (i) Explain the trend in the boiling points of the hydrogen halides, HC*l*, HBr and HI.

~~Boiling points generally decrease~~ Increase ~~HI > HBr > HCl~~

Boiling points decrease . HCl > HBr > HI . This is due

to more energy to break bonds [2]

(ii) Suggest why the hydrogen halide HF does not follow the trend in boiling points shown by HC*l*, HBr and HI.

HF ~~is~~ is polar and has strong electronegitivity so more

energy is needed to break the bond.

[2]

(c) In an experiment, two of the halogens are represented as P_2 and Q_2.

P_2 combines with hydrogen on heating to form HP, which can be easily broken down into its elements. A solution of HP in water reacts with aqueous silver ions to form a yellow precipitate that is insoluble in dilute aqueous ammonia.

Q_2 combines explosively with hydrogen in sunlight to form HQ, which is stable to heat. A solution of HQ in water reacts with aqueous silver ions to form a white precipitate that is soluble in dilute aqueous ammonia.

(i) Identify the halogens P_2 and Q_2.

P_2 = Iodine (I_2) Q_2 = ~~Cl2~~ Chlorine (Cl_2)

[1]

(ii) HP readily decomposes into its elements when heated but HQ is stable to heat. Explain this with reference to bond energies.

More energy is needed to break the H–Q bond

Less is needed for H–P so it easily breaks into its

elements [2]

(iii) Write an equation for the thermal decomposition of HP.

~~[illegible]~~ $2HI \xrightarrow{heat} H_2 + I_2$ [1]

Your Mark

2(a)(i) ☐

2(a)(ii) ☐

2(a)(iii) ☐

2(b)(i) ☐

2(b)(ii) ☐

2(c)(i) ☐

2(c)(ii) ☐

2(c)(iii) ☐

2(c)(iv) ☐

2(d)(i) ☐

2(d)(ii) ☐

Q2	Mark scheme	
(a)(i)	enthalpy / energy / heat change when one mole of <u>gaseous atoms</u> is produced from the element in its standard state under standard conditions	[1] [1] [1] **[3]**
(a)(ii)	fluorine and chlorine are gases / bromine liquid and iodine solid OR as ΔH_{at} for bromine / iodine also includes changes of state	**[1]**
(a)(iii)	($\frac{1}{2}Cl_2 + \frac{1}{2}I_2 \rightarrow ICl$) $\Delta H_f = (\frac{1}{2}E(Cl_2) + \frac{1}{2}E(I_2)) - E(ICl)$ OR $E(ICl) = (151 / 2) + (242 / 2) + 24$ $E(ICl) = (+)\ 220.5 / 221$	[1] [1] **[2]**
(b)(i)	stronger / more / greater id–id / London / dispersion forces due to increasing numbers of electrons	[1] [1] **[2]**
(b)(ii)	(intermolecular forces in HF are) hydrogen bonds (which are) stronger (than vdW) / more energy needed to separate molecules OR HF much more polar / F much more electronegative Intermolecular forces in HF stronger (than in HC*l*, HBr, HI)	[1] [1] [1] [1] **[2]**
(c)(i)	**P** = iodine / I_2 /I; **Q** = chlorine / Cl_2 / C*l*	**[1]**
(c)(ii)	weaker H–**P** than H–**Q** bond ORA / easier /less energy to break H–**P** than H–**Q** ORA due to greater distance / shielding of nucleus from bond pair ORA	[1] [1] **[2]**
(c)(iii)	2H**P** (or 2HI) → (or) H_2 + $\mathbf{P}_2$ (or I_2)	**[1]**
(c)(iv)	$Ag^+(aq) + \mathbf{Q}^-(aq)$ (or Cl^-) → $Ag\mathbf{Q}(s)$ (or $AgCl(s)$) $Ag\mathbf{Q}(s)$ / $AgCl(s) + \cancel{N}H_3(aq) \rightarrow Ag(NH_3)_2^+(aq) + \mathbf{Q}^-(aq)$ / $Cl^-(aq)$	[1] [1] **[2]**
(d)(i)	no of C*l* increases <u>by one</u> each time / matches group number due to increasing number of valence/outer(most/shell) electrons / oxidation number / valency (of Mg, A*l* , Si)	[1] [1] **[2]**
(d)(ii)	$MgCl_2\ (+aq) \rightarrow Mg^{2+} + 2Cl^-$ $AlCl_3 + 6H_2O \rightarrow Al(H_2O)_6^{3+} + 3Cl^-$ / $Al(H_2O)_5(OH)^{2+} + H^+ + 3Cl^-$ $SiCl_4 + 2H_2O \rightarrow SiO_2 + 4H^+ + 4Cl^-$	[1] [1] [1] **[3]** **[Total:21]**

EXAMINER COMMENTS

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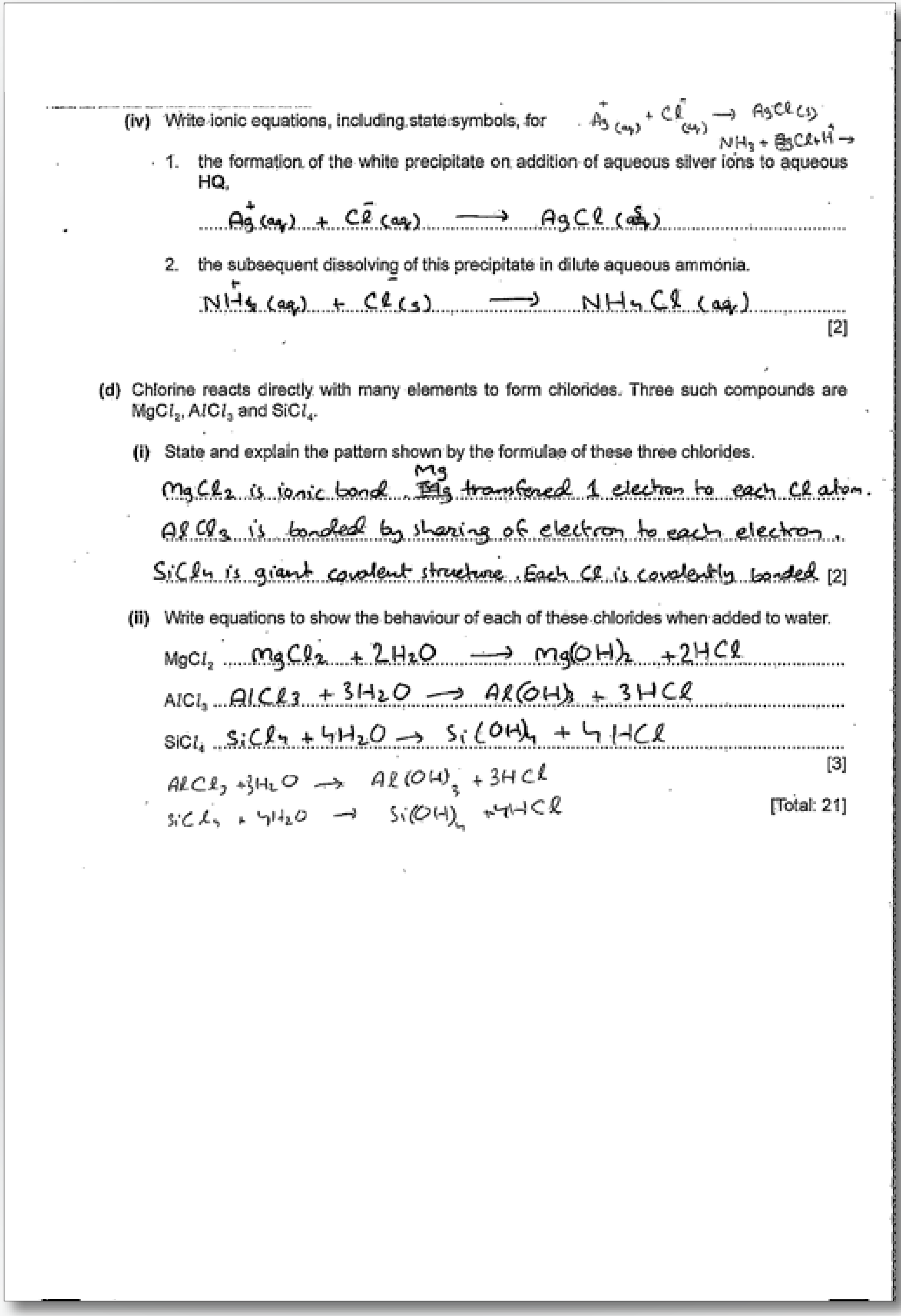

(iv) Write ionic equations, including state symbols, for $Ag^{+}_{(aq)} + Cl^{-}_{(aq)} \rightarrow AgCl_{(s)}$

$NH_3 + AgCl + H^{+} \rightarrow$

1. the formation of the white precipitate on addition of aqueous silver ions to aqueous HQ,

$Ag^{+}(aq) + Cl^{-}(aq) \longrightarrow AgCl(\overset{s}{aq})$

2. the subsequent dissolving of this precipitate in dilute aqueous ammonia.

$NH_4^{+}(aq) + Cl(s) \longrightarrow NH_4Cl(aq)$

[2]

(d) Chlorine reacts directly with many elements to form chlorides. Three such compounds are $MgCl_2$, $AlCl_3$ and $SiCl_4$.

(i) State and explain the pattern shown by the formulae of these three chlorides.

$MgCl_2$ is ionic bond. ~~Mg~~ Mg transfered 1 electron to each Cl atom.

$AlCl_3$ is bonded by sharing of electron to each electron.

$SiCl_4$ is giant covalent structure. Each Cl is covalently bonded [2]

(ii) Write equations to show the behaviour of each of these chlorides when added to water.

$MgCl_2$ $MgCl_2 + 2H_2O \longrightarrow Mg(OH)_2 + 2HCl$

$AlCl_3$ $AlCl_3 + 3H_2O \longrightarrow Al(OH)_3 + 3HCl$

$SiCl_4$ $SiCl_4 + 4H_2O \rightarrow Si(OH)_4 + 4HCl$

[3]

$AlCl_3 + 3H_2O \rightarrow Al(OH)_3 + 3HCl$

$SiCl_4 + 4H_2O \rightarrow Si(OH)_4 + 4HCl$

[Total: 21]

Your Mark

2(a)(i)	☐
2(a)(ii)	☐
2(a)(iii)	☐
2(b)(i)	☐
2(b)(ii)	☐
2(c)(i)	☐
2(c)(ii)	☐
2(c)(iii)	☐
2(c)(iv)	☐
2(d)(i)	☐
2(d)(ii)	☐

Q2	Mark scheme	
(a)(i)	enthalpy / energy / heat change when one mole of gaseous atoms is produced from the element in its standard state under standard conditions	 [1] [1] [1] **[3]**
(a)(ii)	fluorine and chlorine are gases / bromine liquid and iodine solid OR as ΔH_{at} for bromine / iodine also includes changes of state	**[1]**
(a)(iii)	($\frac{1}{2}Cl_2 + \frac{1}{2}I_2 \rightarrow ICl$) $\Delta H_f = (\frac{1}{2}E(Cl_2) + \frac{1}{2}E(I_2)) - E(ICl)$ OR $E(ICl) = (151 / 2) + (242 / 2) + 24$ $E(ICl) = (+)\ 220.5 / 221$	 [1] [1] **[2]**
(b)(i)	stronger / more / greater id–id / London / dispersion forces due to increasing numbers of electrons	[1] [1] **[2]**
(b)(ii)	(intermolecular forces in HF are) hydrogen bonds (which are) stronger (than vdW) / more energy needed to separate molecules OR HF much more polar / F much more electronegative Intermolecular forces in HF stronger (than in HC*l*, HBr, HI)	[1] [1] [1] [1] **[2]**
(c)(i)	**P** = iodine / I_2 /I; **Q** = chlorine / Cl_2 / C*l*	**[1]**
(c)(ii)	weaker H–**P** than H–**Q** bond ORA / easier /less energy to break H–**P** than H–**Q** ORA due to greater distance / shielding of nucleus from bond pair ORA	[1] [1] **[2]**
(c)(iii)	2H**P** (or 2HI) → (or) H_2 + $\mathbf{P}_2$ (or I_2)	**[1]**
(c)(iv)	$Ag^{+}(aq) + \mathbf{Q}^{-}(aq)$ (or Cl^{-}) → Ag**Q**(s) (or AgC*l*(s)) Ag**Q**(s) / AgC*l*(s) + $NH_3(aq) \rightarrow Ag(NH_3)_2^{+}(aq) + \mathbf{Q}^{-}(aq) / Cl^{-}(aq)$	[1] [1] **[2]**
(d)(i)	no of C*l* increases by one each time / matches group number due to increasing number of valence/outer(most/shell) electrons / oxidation number / valency (of Mg, A*l* , Si)	[1] [1] **[2]**
(d)(ii)	$MgCl_2\ (+aq) \rightarrow Mg^{2+} + 2Cl^{-}$ $AlCl_3 + 6H_2O \rightarrow Al(H_2O)_6^{3+} + 3Cl^{-} / Al(H_2O)_5(OH)^{2+} + H^{+} + 3Cl^{-}$ $SiCl_4 + 2H_2O \rightarrow SiO_2 + 4H^{+} + 4Cl^{-}$	[1] [1] [1] **[3]** **[Total:21]**

EXAMINER COMMENTS

MARK SCHEME

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Interactive Example Candidate Responses
Paper 22 (May/June 2016), Question 3

Cambridge International AS & A Level
Chemistry 9701

Version 1.0

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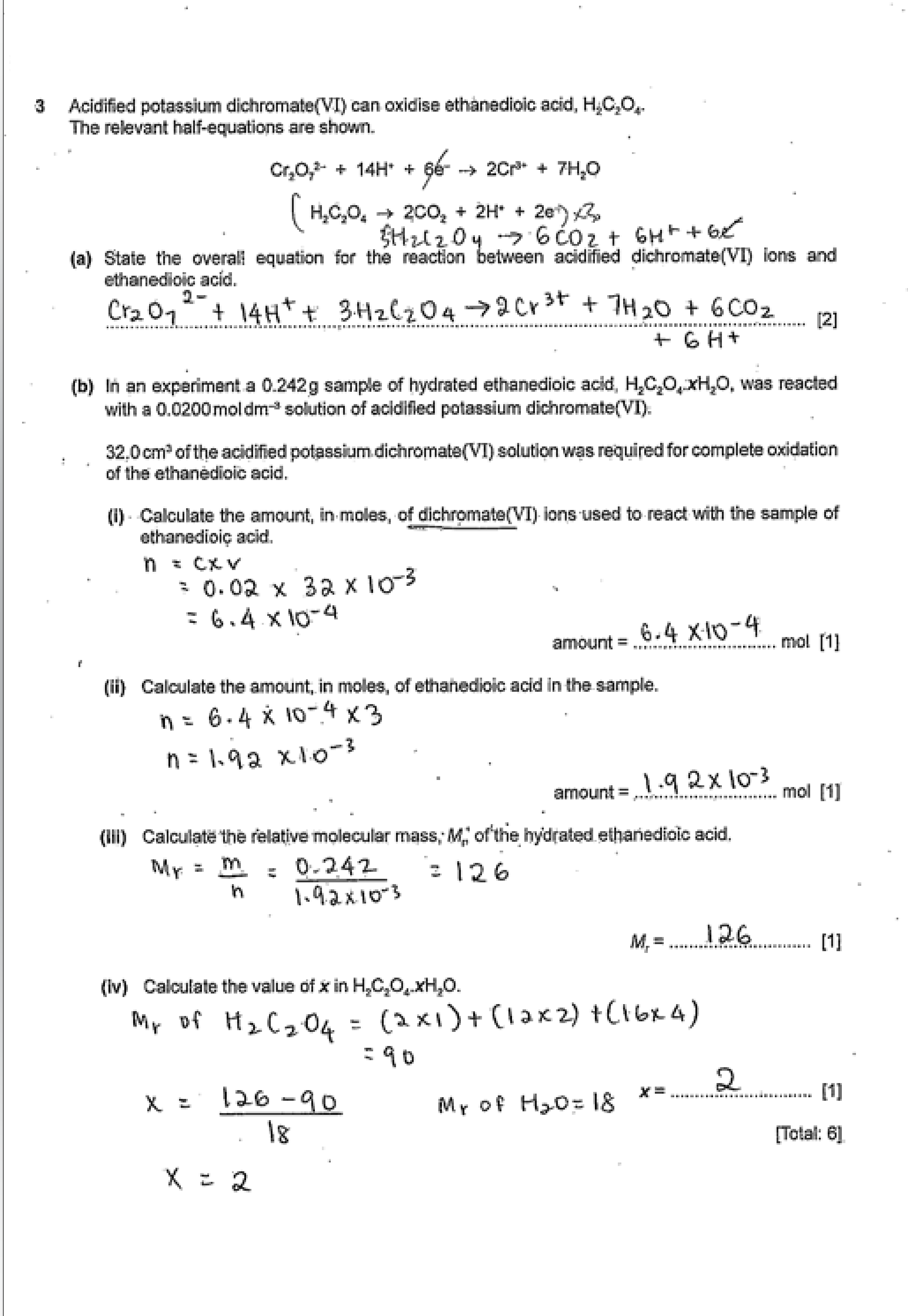

3 Acidified potassium dichromate(VI) can oxidise ethanedioic acid, $H_2C_2O_4$.
The relevant half-equations are shown.

$$Cr_2O_7^{2-} + 14H^+ + \cancel{6}e^- \rightarrow 2Cr^{3+} + 7H_2O$$

$$(H_2C_2O_4 \rightarrow 2CO_2 + 2H^+ + 2e^-) \times 3$$

$$3H_2C_2O_4 \rightarrow 6CO_2 + 6H^+ + 6e^-$$

(a) State the overall equation for the reaction between acidified dichromate(VI) ions and ethanedioic acid.

$Cr_2O_7^{2-} + 14H^+ + 3H_2C_2O_4 \rightarrow 2Cr^{3+} + 7H_2O + 6CO_2 + 6H^+$ [2]

(b) In an experiment a 0.242 g sample of hydrated ethanedioic acid, $H_2C_2O_4.xH_2O$, was reacted with a 0.0200 mol dm^{-3} solution of acidified potassium dichromate(VI).

32.0 cm^3 of the acidified potassium dichromate(VI) solution was required for complete oxidation of the ethanedioic acid.

(i) Calculate the amount, in moles, of dichromate(VI) ions used to react with the sample of ethanedioic acid.

$n = c \times v$

$= 0.02 \times 32 \times 10^{-3}$

$= 6.4 \times 10^{-4}$

amount = 6.4×10^{-4} mol [1]

(ii) Calculate the amount, in moles, of ethanedioic acid in the sample.

$n = 6.4 \times 10^{-4} \times 3$

$n = 1.92 \times 10^{-3}$

amount = 1.92×10^{-3} mol [1]

(iii) Calculate the relative molecular mass, M_r, of the hydrated ethanedioic acid.

$M_r = \frac{m}{n} = \frac{0.242}{1.92 \times 10^{-3}} = 126$

M_r = 126 [1]

(iv) Calculate the value of x in $H_2C_2O_4.xH_2O$.

M_r of $H_2C_2O_4 = (2 \times 1) + (12 \times 2) + (16 \times 4)$

$= 90$

$x = \frac{126 - 90}{18}$ M_r of $H_2O = 18$ x = 2 [1]

$x = 2$

[Total: 6]

Your Mark

3(a) ☐

3(b)(i) ☐

3(b)(ii) ☐

3(b)(iii) ☐

3(b)(iv) ☐

Q3	Mark scheme	
(a)	$Cr_2O_7^{2-} + 8H^+ + 3H_2C_2O_4 \rightarrow 2Cr^{3+} + 6CO_2 + 7H_2O$ M1 = species M2 = balancing	 [1] [1] **[2]**
(a)(i)	(0.02 × 32.0/1000 =) 6.40×10^{-4}	**[1]**
(a)(ii)	($6.4 \times 10^{-4} \times 3$ =)1.92×10^{-3}	**[1]**
(a)(iii)	(0.242 / 1.92×10^{-3} =) 126(.0)	**[1]**
(a)(iv)	(126 – 90 = 36; 36 / 18 = 2 hence) x = 2	**[1]** **[Total: 6]**

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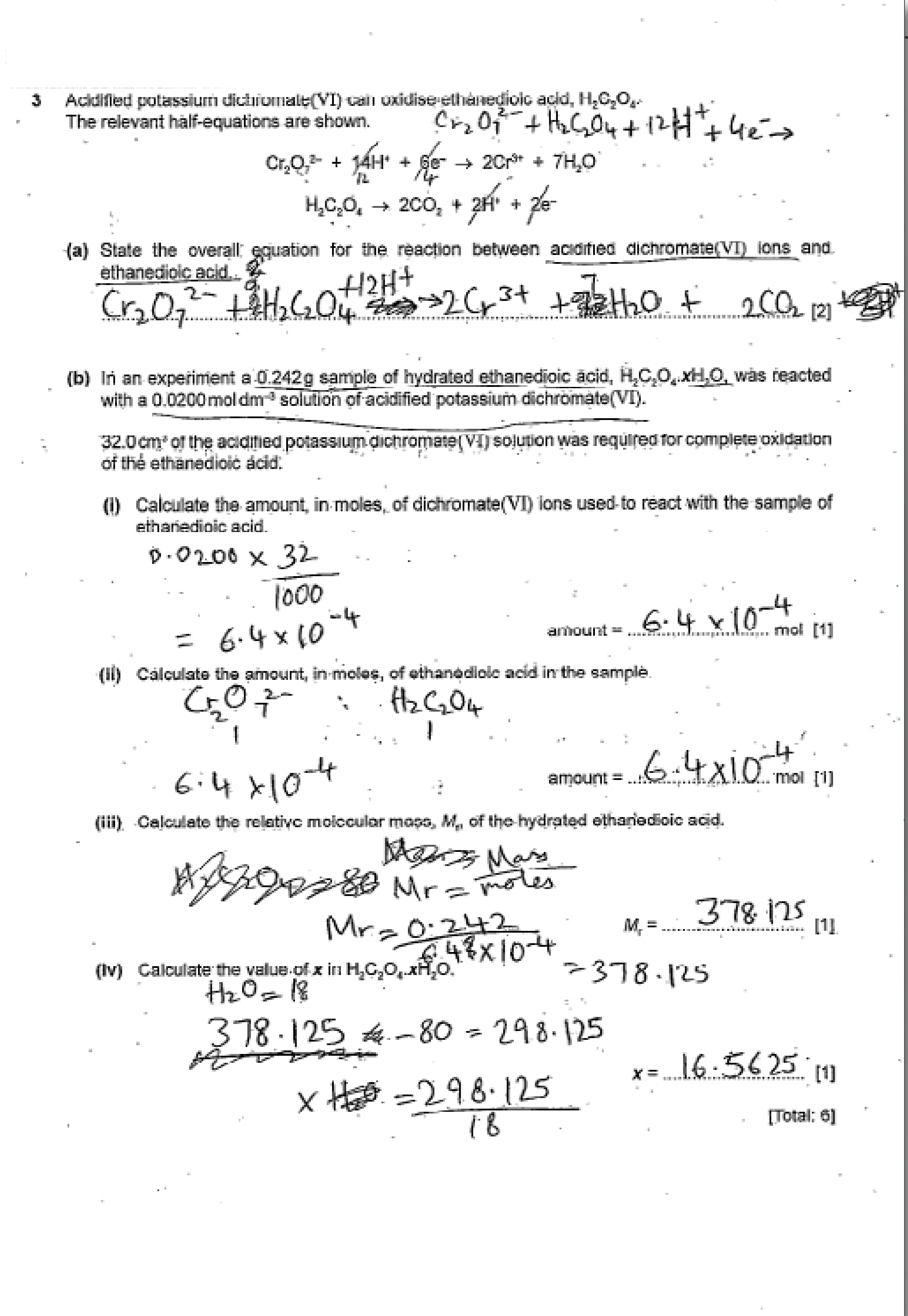


3 Acidified potassium dichromate(VI) can oxidise ethanedioic acid, $H_2C_2O_4$.
The relevant half-equations are shown. $Cr_2O_7^{2-} + H_2C_2O_4 + 12H^+ + 4e^- \rightarrow$

$$Cr_2O_7^{2-} + \underset{12}{\cancel{14}}H^+ + \underset{4}{\cancel{6}}e^- \rightarrow 2Cr^{3+} + 7H_2O$$

$$H_2C_2O_4 \rightarrow 2CO_2 + \cancel{2}H^+ + \cancel{2}e^-$$

(a) State the overall equation for the reaction between acidified dichromate(VI) ions and ethanedioic acid.

$Cr_2O_7^{2-} + H_2C_2O_4 \overset{+12H^+}{\rightarrow} 2Cr^{3+} + 7H_2O + 2CO_2$ [2]

(b) In an experiment a 0.242 g sample of hydrated ethanedioic acid, $H_2C_2O_4.xH_2O$, was reacted with a 0.0200 mol dm^{-3} solution of acidified potassium dichromate(VI).

32.0 cm^3 of the acidified potassium dichromate(VI) solution was required for complete oxidation of the ethanedioic acid.

(i) Calculate the amount, in moles, of dichromate(VI) ions used to react with the sample of ethanedioic acid.

$$\frac{0.0200 \times 32}{1000}$$

$$= 6.4 \times 10^{-4}$$

amount = 6.4×10^{-4} mol [1]

(ii) Calculate the amount, in moles, of ethanedioic acid in the sample.

$Cr_2O_7^{2-}$: $H_2C_2O_4$

1 : 1

6.4×10^{-4}

amount = 6.4×10^{-4} mol [1]

(iii) Calculate the relative molecular mass, M_r, of the hydrated ethanedioic acid.

$Mr = \frac{Mass}{moles}$

$Mr = \frac{0.242}{6.4 \times 10^{-4}} = 378.125$

M_r = 378.125 [1]

(iv) Calculate the value of x in $H_2C_2O_4.xH_2O$.

$H_2O = 18$

$378.125 - 80 = 298.125$

$x = \frac{298.125}{18}$

x = 16.5625 [1]

[Total: 6]

Your Mark

3(a)

3(b)(i)

3(b)(ii)

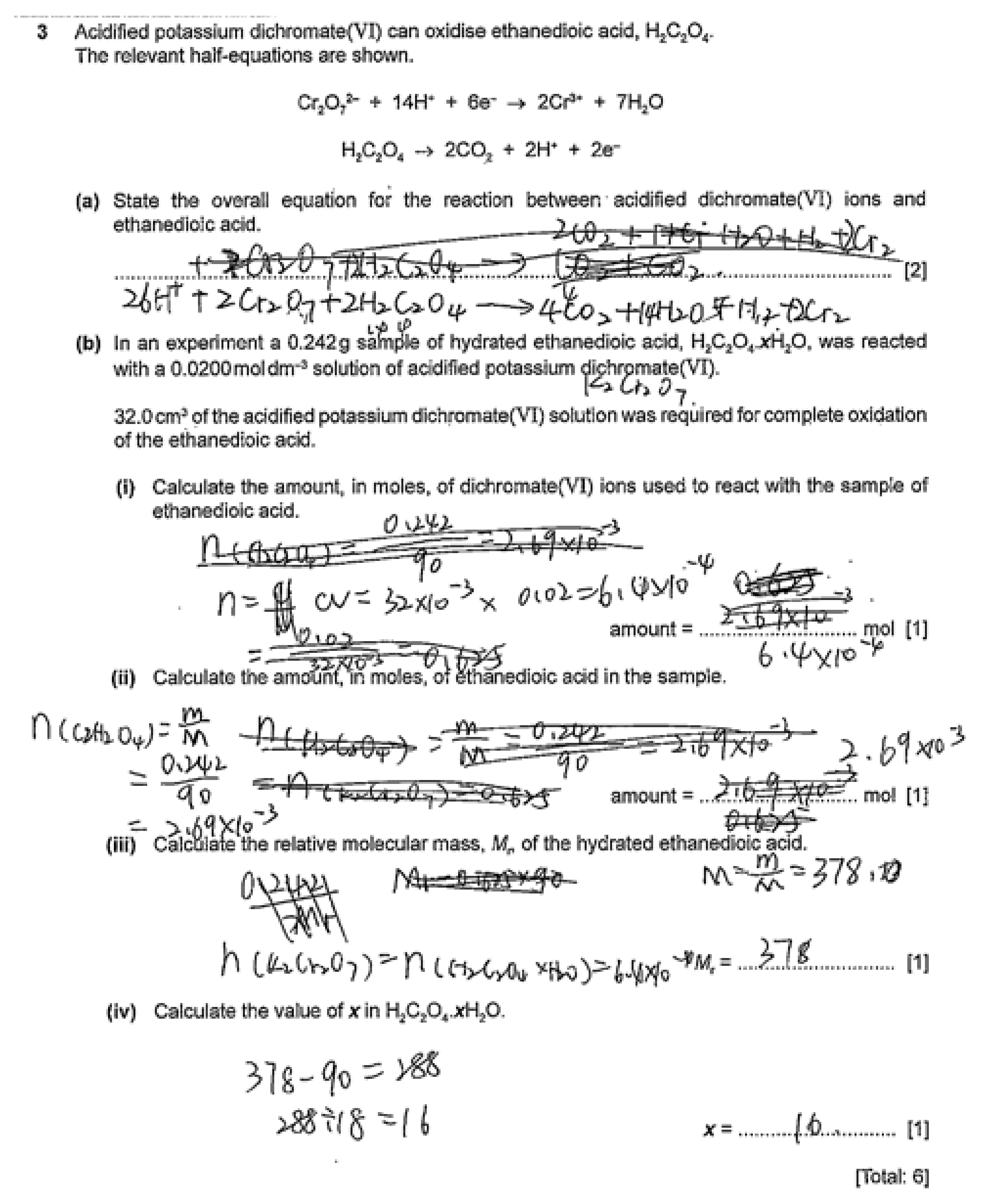
3(b)(iii)

3(b)(iv)

Q3	Mark scheme	
(a)	$Cr_2O_7^{2-} + 8H^+ + 3H_2C_2O_4 \rightarrow 2Cr^{3+} + 6CO_2 + 7H_2O$ M1 = species M2 = balancing	 [1] [1] **[2]**
(a)(i)	$(0.02 \times 32.0/1000 =)\ 6.40 \times 10^{-4}$	**[1]**
(a)(ii)	$(6.4 \times 10^{-4} \times 3 =)1.92 \times 10^{-3}$	**[1]**
(a)(iii)	$(0.242 / 1.92 \times 10^{-3} =)\ 126(.0)$	**[1]**
(a)(iv)	(126 – 90 = 36; 36 / 18 = 2 hence) $x = 2$	**[1]** **[Total: 6]**

EXAMINER COMMENTS

MARK SCHEME



3 Acidified potassium dichromate(VI) can oxidise ethanedioic acid, $H_2C_2O_4$.
The relevant half-equations are shown.

$$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$$

$$H_2C_2O_4 \rightarrow 2CO_2 + 2H^+ + 2e^-$$

(a) State the overall equation for the reaction between acidified dichromate(VI) ions and ethanedioic acid.

~~$Cr_2O_7 + H_2C_2O_4 \rightarrow CO_2 + CO_2$~~ ~~$2CO_2 + H_2O + H_2 + Cr_2$~~ [2]

$26H^+ + 2Cr_2O_7 + 2H_2C_2O_4 \longrightarrow 4CO_2 + 14H_2O + H_2 + 2Cr_2$

(b) In an experiment a 0.242 g sample of hydrated ethanedioic acid, $H_2C_2O_4.xH_2O$, was reacted with a 0.0200 mol dm^{-3} solution of acidified potassium dichromate(VI). $K_2Cr_2O_7$

32.0 cm^3 of the acidified potassium dichromate(VI) solution was required for complete oxidation of the ethanedioic acid.

(i) Calculate the amount, in moles, of dichromate(VI) ions used to react with the sample of ethanedioic acid.

~~$n(H_2C_2O_4) = \frac{0.242}{90} = 2.69\times10^{-3}$~~

$n = cv = 32\times10^{-3} \times 0.02 = 6.4\times10^{-4}$

~~$= \frac{0.02}{32\times10^{-3}} = 0.625$~~

amount = ~~0.625~~ ~~2.69×10^{-3}~~ 6.4×10^{-4} mol [1]

(ii) Calculate the amount, in moles, of ethanedioic acid in the sample.

$n(C_2H_2O_4) = \frac{m}{M}$ ~~$n(H_2C_2O_4) = \frac{m}{M} = \frac{0.242}{90} = 2.69\times10^{-3}$~~

$= \frac{0.242}{90}$ ~~$= n(K_2Cr_2O_7) = 0.625$~~

$= 2.69\times10^{-3}$

amount = ~~2.69×10^{-3}~~ ~~0.625~~ 2.69×10^{-3} mol [1]

(iii) Calculate the relative molecular mass, M_r, of the hydrated ethanedioic acid.

$M = \frac{m}{n} = 378.10$

$n(K_2Cr_2O_7) = n(H_2C_2O_4 \cdot xH_2O) = 6.4\times10^{-4}$ M_r = 378 [1]

(iv) Calculate the value of x in $H_2C_2O_4.xH_2O$.

$378 - 90 = 288$

$288 \div 18 = 16$

x = 16 [1]

[Total: 6]

Your Mark

3(a) ☐

3(b)(i) ☐

3(b)(ii) ☐

3(b)(iii) ☐

3(b)(iv) ☐

Q3	Mark scheme	
(a)	$Cr_2O_7^{2-} + 8H^+ + 3H_2C_2O_4 \rightarrow 2Cr^{3+} + 6CO_2 + 7H_2O$ M1 = species M2 = balancing	 [1] [1] **[2]**
(a)(i)	$(0.02 \times 32.0/1000 =)\ 6.40 \times 10^{-4}$	**[1]**
(a)(ii)	$(6.4 \times 10^{-4} \times 3 =)\ 1.92 \times 10^{-3}$	**[1]**
(a)(iii)	$(0.242 / 1.92 \times 10^{-3} =)\ 126(.0)$	**[1]**
(a)(iv)	(126 – 90 = 36; 36 / 18 = 2 hence) x = 2	**[1]** **[Total: 6]**

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Paper 22 (May/June 2016), Question 4

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Chemistry 9701

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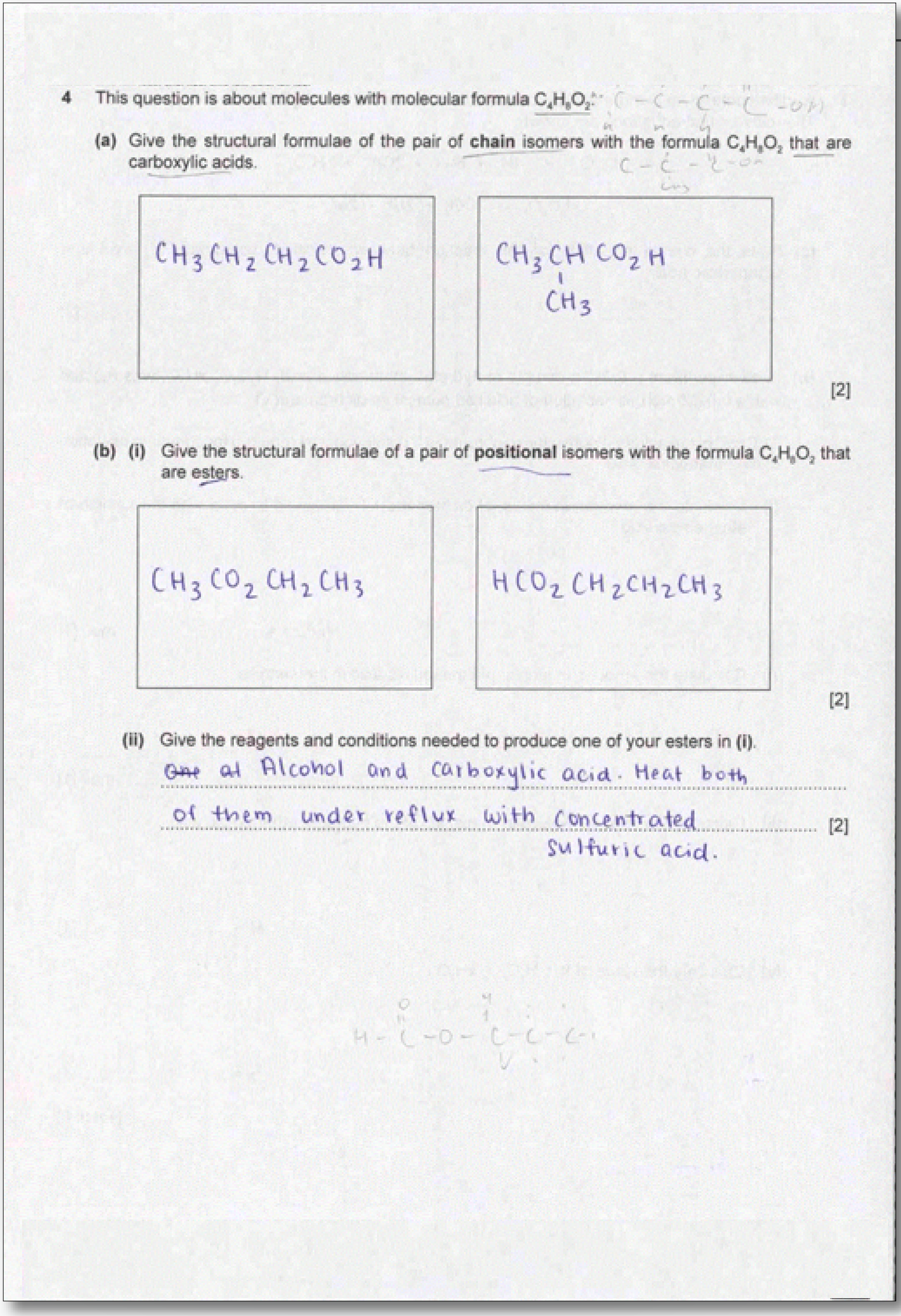

4 This question is about molecules with molecular formula $C_4H_8O_2$.

(a) Give the structural formulae of the pair of **chain** isomers with the formula $C_4H_8O_2$ that are carboxylic acids.

$CH_3CH_2CH_2CO_2H$

$CH_3\underset{\substack{|\\ CH_3}}{C}HCO_2H$

[2]

(b) (i) Give the structural formulae of a pair of **positional** isomers with the formula $C_4H_8O_2$ that are esters.

$CH_3CO_2CH_2CH_3$

$HCO_2CH_2CH_2CH_3$

[2]

(ii) Give the reagents and conditions needed to produce one of your esters in (i).

~~One~~ al Alcohol and carboxylic acid. Heat both of them under reflux with concentrated sulfuric acid. [2]

Your Mark

4(a) ☐

4(b)(i) ☐

4(b)(ii) ☐

4(c) ☐

Q4	Mark scheme
(a)	$CH_3CH_2CH_2COOH$ [1] $(CH_3)_2CHCOOH$ / $CH_3CH(CH_3)COOH$ [1] **[2]**
(b)(i)	Two from 1. $CH_3CH_2COOCH_3$ 2. $CH_3COOCH_2CH_3$ 3.$HCOOCH_2CH_2CH_3$ **[max 2]**
(b)(ii)	icorrect acid + alcohol for either ester [1] 1. methanol + propanoic acid 2. ethanol + ethanoic acid 3. propan-1-ol + methanoic acid (conc)H_2SO_4 / (conc)H_3PO_4 AND heat / warm / reflux; [1] **[2]**
(c)	Peak at 1710–1750 (for ester) due to C(=)O [1] Peak at 1500–1680 (for **X**) due to C(=)C / alkene [1] Peak at 3200–3650 (for **X**) due to (alcohol) O(–)H [1] **[3]** **[Total: 9]**

EXAMINER COMMENTS MARK SCHEME

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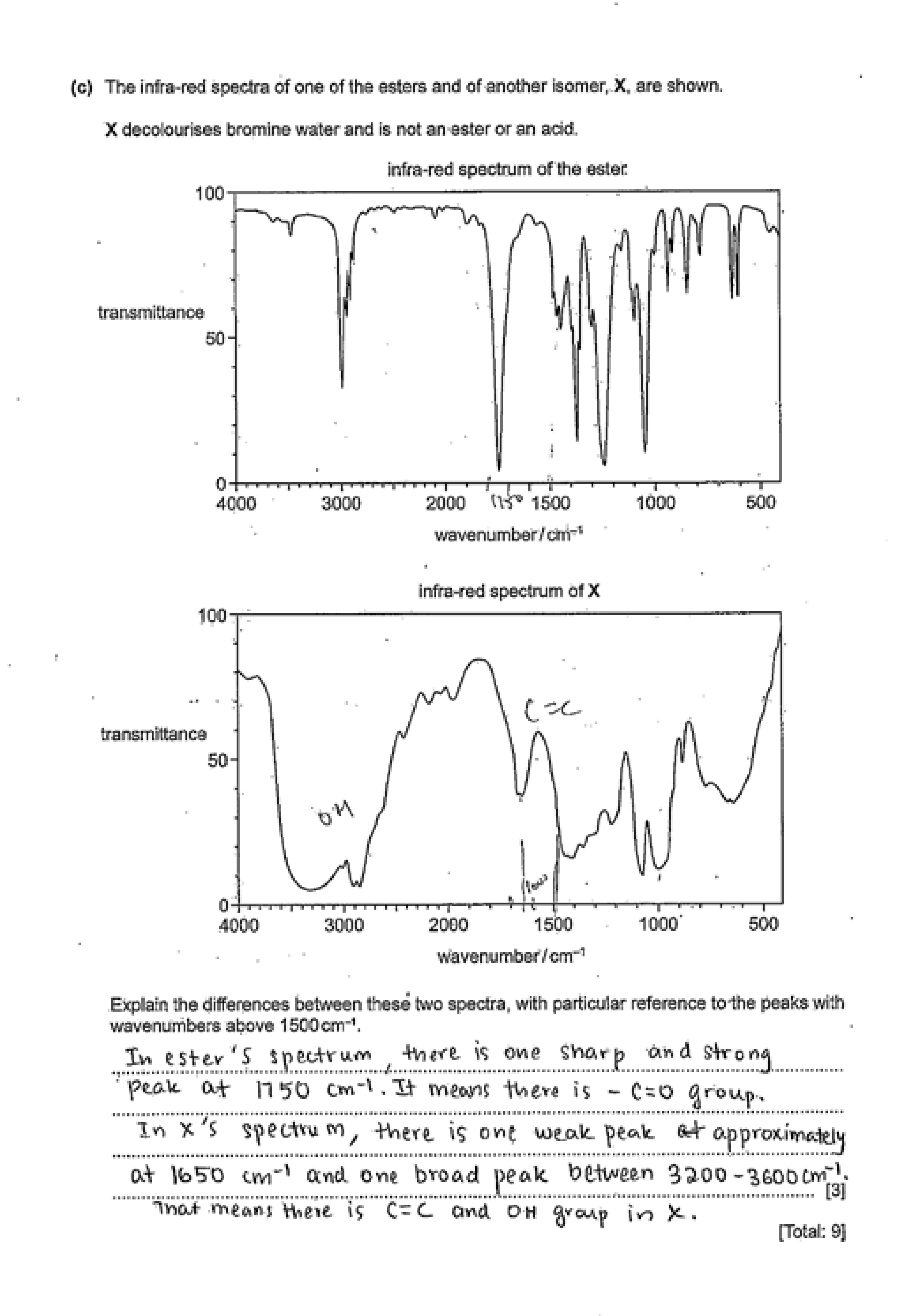

(c) The infra-red spectra of one of the esters and of another isomer, **X**, are shown.

X decolourises bromine water and is not an ester or an acid.

Explain the differences between these two spectra, with particular reference to the peaks with wavenumbers above 1500 cm^{-1}.

In ester's spectrum, there is one sharp and strong peak at 1750 cm^{-1}. It means there is - C=O group.

In X's spectrum, there is one weak peak ~~at~~ approximately at 1650 cm^{-1} and one broad peak between 3200-3600 cm^{-1}.

That means there is C=C and OH group in X.

[3]

[Total: 9]

Your Mark

4(a) ☐

4(b)(i) ☐

4(b)(ii) ☐

4(c) ☐

Q4	Mark scheme	
(a)	$CH_3CH_2CH_2COOH$	[1]
	$(CH_3)_2CHCOOH$ / $CH_3CH(CH_3)COOH$	[1]
		[2]
(b)(i)	Two from 1. $CH_3CH_2COOCH_3$ 2. $CH_3COOCH_2CH_3$ 3. $HCOOCH_2CH_2CH_3$	
		[max 2]
(b)(ii)	icorrect acid + alcohol for either ester 1. methanol + propanoic acid 2. ethanol + ethanoic acid 3. propan-1-ol + methanoic acid	[1]
	(conc)H_2SO_4 / (conc)H_3PO_4 AND heat / warm / reflux;	[1]
		[2]
(c)	Peak at 1710–1750 (for ester) due to C(=)O	[1]
	Peak at 1500–1680 (for **X**) due to C(=)C / alkene	[1]
	Peak at 3200–3650 (for **X**) due to (alcohol) O(–)H	[1]
		[3]
		[Total: 9]

EXAMINER COMMENTS

MARK SCHEME

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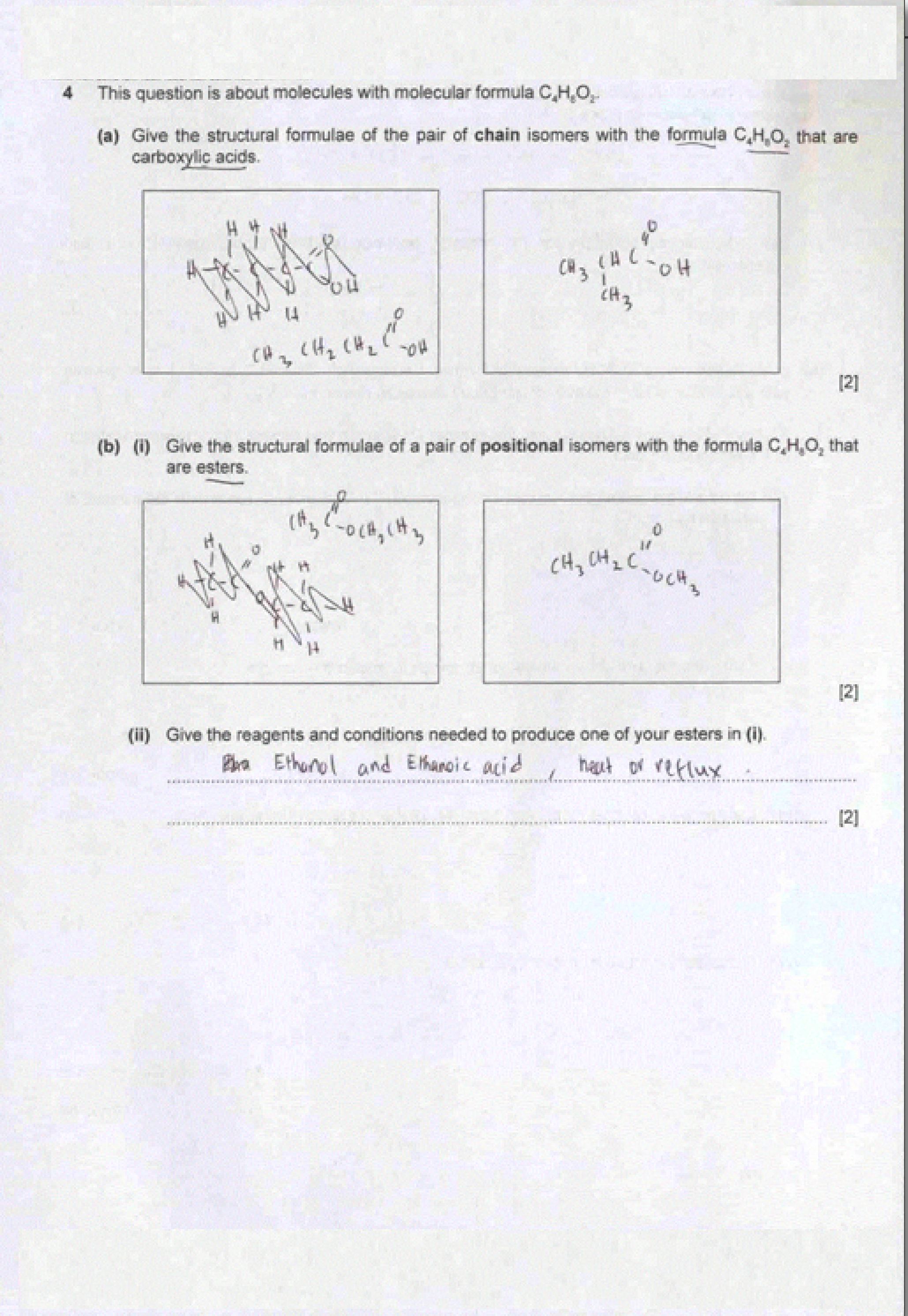

4 This question is about molecules with molecular formula $C_4H_8O_2$.

(a) Give the structural formulae of the pair of **chain** isomers with the formula $C_4H_8O_2$ that are carboxylic acids.

$CH_3CH_2CH_2\overset{O}{\overset{\|}{C}}-OH$

$CH_3\underset{CH_3}{\underset{|}{CH}}\overset{O}{\overset{\|}{C}}-OH$

[2]

(b) (i) Give the structural formulae of a pair of **positional** isomers with the formula $C_4H_8O_2$ that are esters.

$CH_3\overset{O}{\overset{\|}{C}}-OCH_2CH_3$

$CH_3CH_2\overset{O}{\overset{\|}{C}}-OCH_3$

[2]

(ii) Give the reagents and conditions needed to produce one of your esters in (i).

Ethanol and Ethanoic acid , heat or reflux .

[2]

Your Mark

4(a) ☐

4(b)(i) ☐

4(b)(ii) ☐

4(c) ☐

Q4	Mark scheme	
(a)	$CH_3CH_2CH_2COOH$ $(CH_3)_2CHCOOH$ / $CH_3CH(CH_3)COOH$	[1] [1] **[2]**
(b)(i)	Two from 1. $CH_3CH_2COOCH_3$ 2. $CH_3COOCH_2CH_3$ 3. $HCOOCH_2CH_2CH_3$	**[max 2]**
(b)(ii)	icorrect acid + alcohol for either ester 1. methanol + propanoic acid 2. ethanol + ethanoic acid 3. propan-1-ol + methanoic acid (conc)H_2SO_4 / (conc)H_3PO_4 AND heat / warm / reflux;	[1] [1] **[2]**
(c)	Peak at 1710–1750 (for ester) due to C(=)O Peak at 1500–1680 (for **X**) due to C(=)C / alkene Peak at 3200–3650 (for **X**) due to (alcohol) O(–)H	[1] [1] [1] **[3]** **[Total: 9]**

EXAMINER COMMENTS

MARK SCHEME

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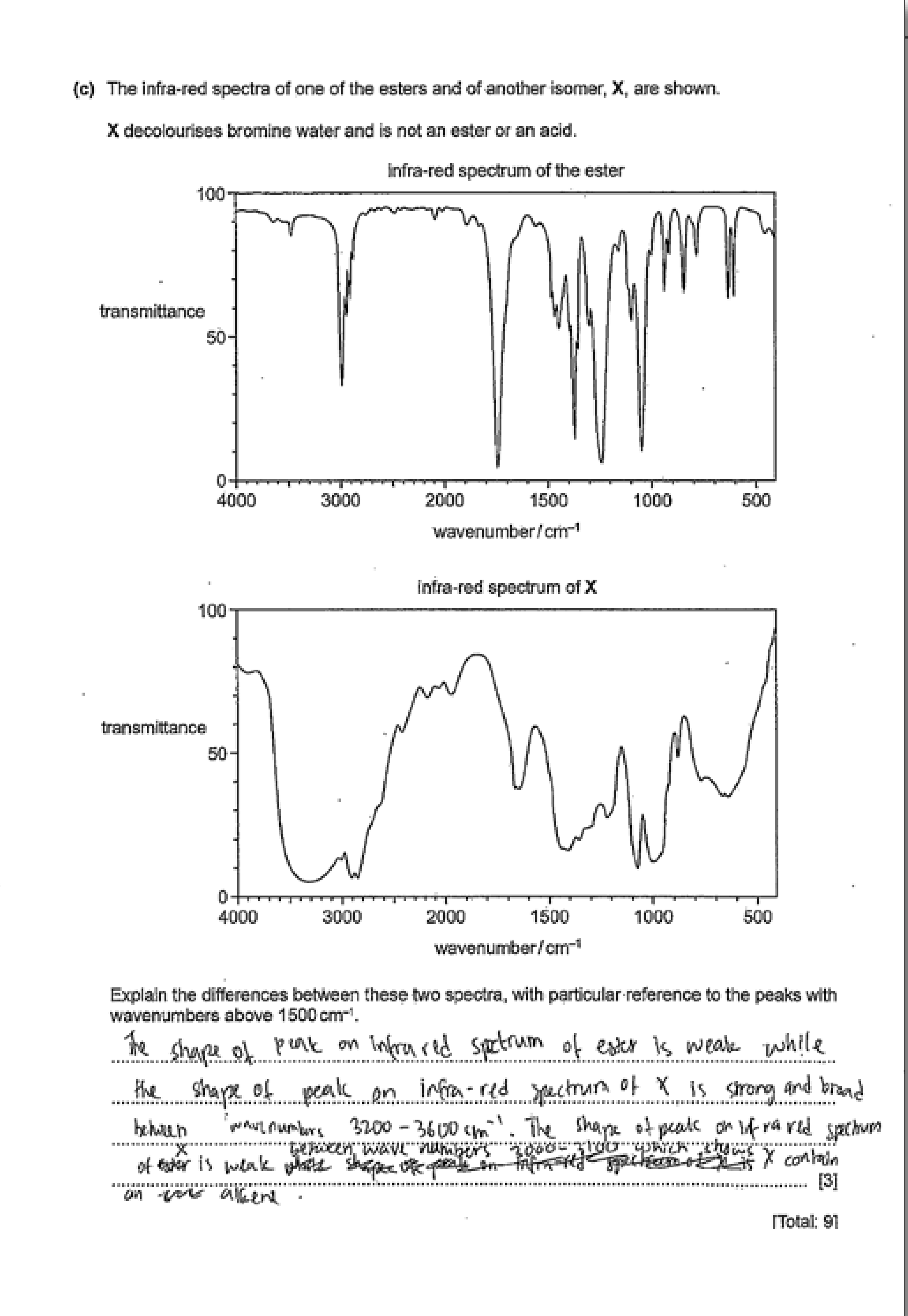

(c) The infra-red spectra of one of the esters and of another isomer, **X**, are shown.

X decolourises bromine water and is not an ester or an acid.

Explain the differences between these two spectra, with particular reference to the peaks with wavenumbers above 1500 cm⁻¹.

The shape of peak on infrared spectrum of ester is weak while the shape of peak on infra-red spectrum of X is strong and broad between wavenumbers 3200 – 3600 cm⁻¹. The shape of peak on infrared spectrum of ester is weak ~~while shape of peak on infrared spectrum of X is~~ between wave numbers 3000 – 3100 which shows X X contain an ~~one~~ alkene. [3]

[Total: 9]

Your Mark

4(a) ☐

4(b)(i) ☐

4(b)(ii) ☐

4(c) ☐

Q4	Mark scheme
(a)	$CH_3CH_2CH_2COOH$ [1] $(CH_3)_2CHCOOH$ / $CH_3CH(CH_3)COOH$ [1] **[2]**
(b)(i)	Two from 1. $CH_3CH_2COOCH_3$ 2. $CH_3COOCH_2CH_3$ 3. $HCOOCH_2CH_2CH_3$ **[max 2]**
(b)(ii)	icorrect acid + alcohol for either ester [1] 1. methanol + propanoic acid 2. ethanol + ethanoic acid 3. propan-1-ol + methanoic acid (conc)H_2SO_4 / (conc)H_3PO_4 AND heat / warm / reflux; [1] **[2]**
(c)	Peak at 1710–1750 (for ester) due to C(=)O [1] Peak at 1500–1680 (for **X**) due to C(=)C / alkene [1] Peak at 3200–3650 (for **X**) due to (alcohol) O(–)H [1] **[3]** **[Total: 9]**

EXAMINER COMMENTS

MARK SCHEME

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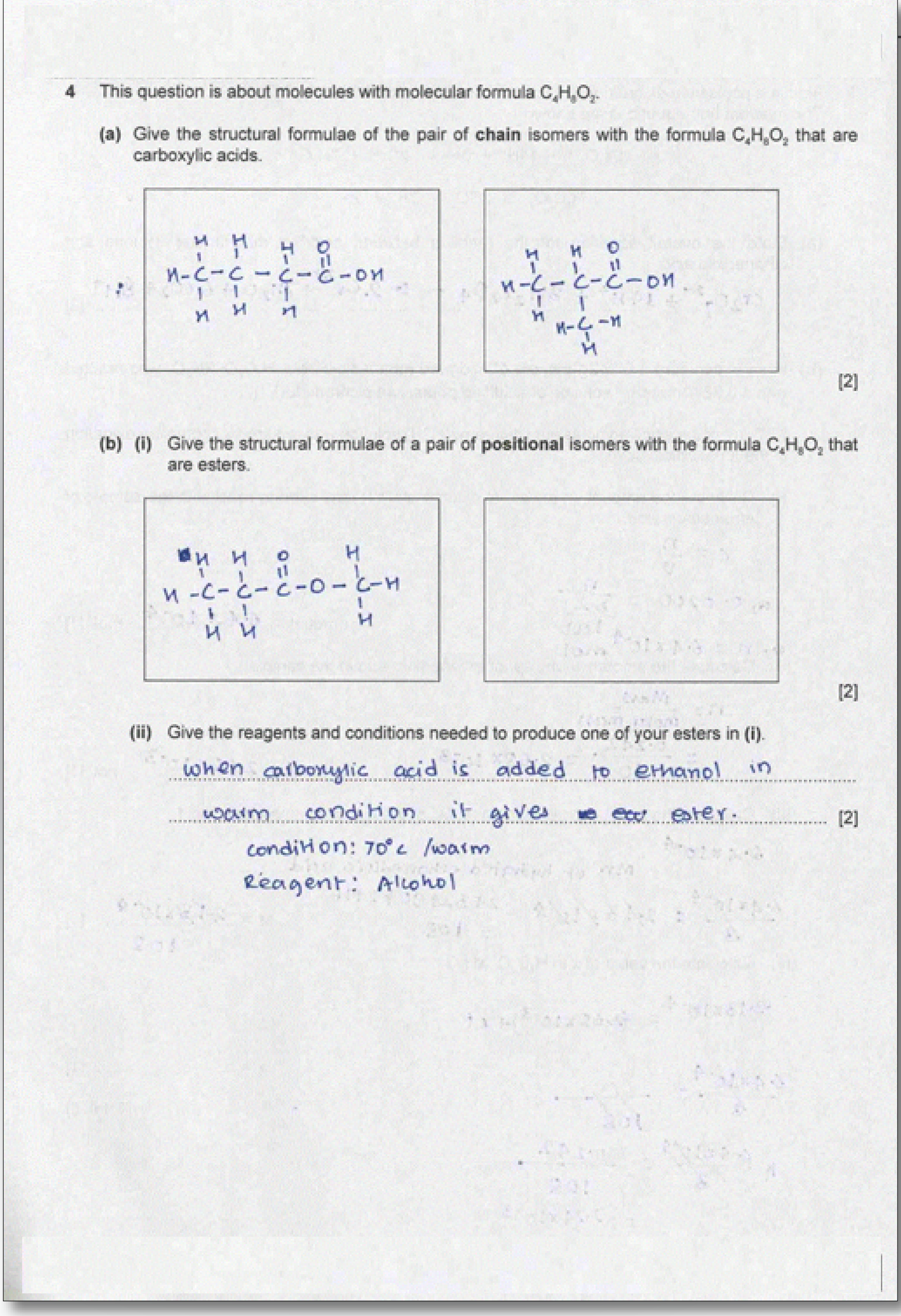

4 This question is about molecules with molecular formula $C_4H_8O_2$.

(a) Give the structural formulae of the pair of **chain** isomers with the formula $C_4H_8O_2$ that are carboxylic acids.

[2]

(b) (i) Give the structural formulae of a pair of **positional** isomers with the formula $C_4H_8O_2$ that are esters.

[2]

(ii) Give the reagents and conditions needed to produce one of your esters in **(i)**.

when carbonylic acid is added to ethanol in warm condition it gives ~~ee~~ ~~eec~~ ester. [2]

condition: 70°c /warm

Reagent: Alcohol

Your Mark

4(a) ☐

4(b)(i) ☐

4(b)(ii) ☐

4(c) ☐

Q4	**Mark scheme**
(a)	$CH_3CH_2CH_2COOH$ [1] $(CH_3)_2CHCOOH$ / $CH_3CH(CH_3)COOH$ [1] **[2]**
(b)(i)	Two from 1. $CH_3CH_2COOCH_3$ 2. $CH_3COOCH_2CH_3$ 3. $HCOOCH_2CH_2CH_3$ **[max 2]**
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(c)	Peak at 1710–1750 (for ester) due to C(=)O [1] Peak at 1500–1680 (for **X**) due to C(=)C / alkene [1] Peak at 3200–3650 (for **X**) due to (alcohol) O(–)H [1] **[3]** **[Total: 9]**

EXAMINER COMMENTS

MARK SCHEME

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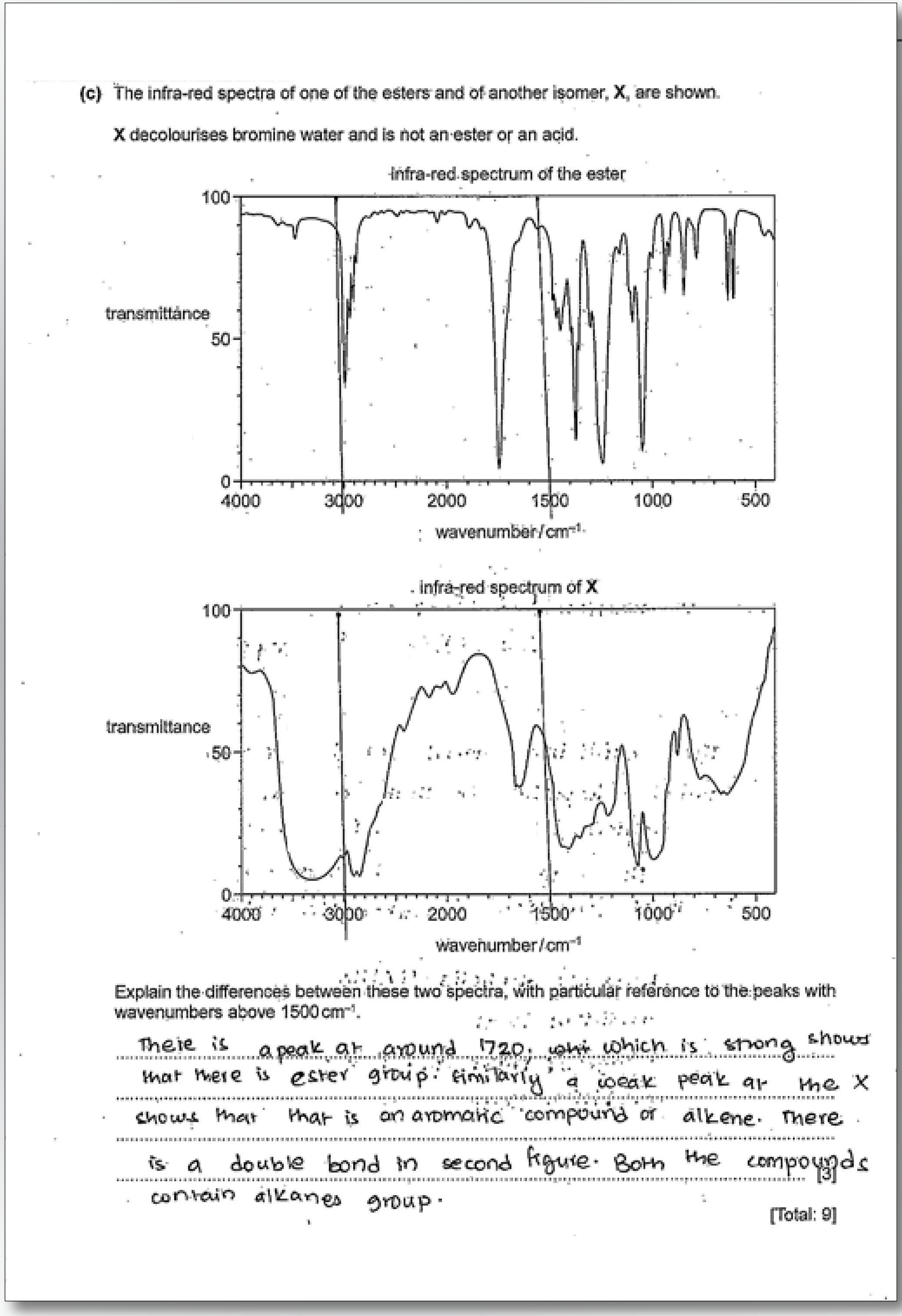

(c) The infra-red spectra of one of the esters and of another isomer, **X**, are shown.

X decolourises bromine water and is not an ester or an acid.

Explain the differences between these two spectra, with particular reference to the peaks with wavenumbers above 1500 cm⁻¹.

There is a peak at around 1720, ~~whi~~ which is strong shows that there is ester group. similarly a weak peak at the X shows that that is an aromatic compound or alkene. There is a double bond in second figure. Both the compounds contain alkanes group.

[3]

[Total: 9]

Your Mark

4(a) ☐

4(b)(i) ☐

4(b)(ii) ☐

4(c) ☐

Q4	Mark scheme
(a)	$CH_3CH_2CH_2COOH$ [1] $(CH_3)_2CHCOOH$ / $CH_3CH(CH_3)COOH$ [1] **[2]**
(b)(i)	Two from 1. $CH_3CH_2COOCH_3$ 2. $CH_3COOCH_2CH_3$ 3. $HCOOCH_2CH_2CH_3$ **[max 2]**
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(c)	Peak at 1710–1750 (for ester) due to C(=)O [1] Peak at 1500–1680 (for **X**) due to C(=)C / alkene [1] Peak at 3200–3650 (for **X**) due to (alcohol) O(–)H [1] **[3]** **[Total: 9]**

EXAMINER COMMENTS

MARK SCHEME

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International Education

Interactive

Interactive Example Candidate Responses
Paper 22 (May/June 2016), Question 5

Cambridge International AS & A Level
Chemistry 9701

Version 1.0

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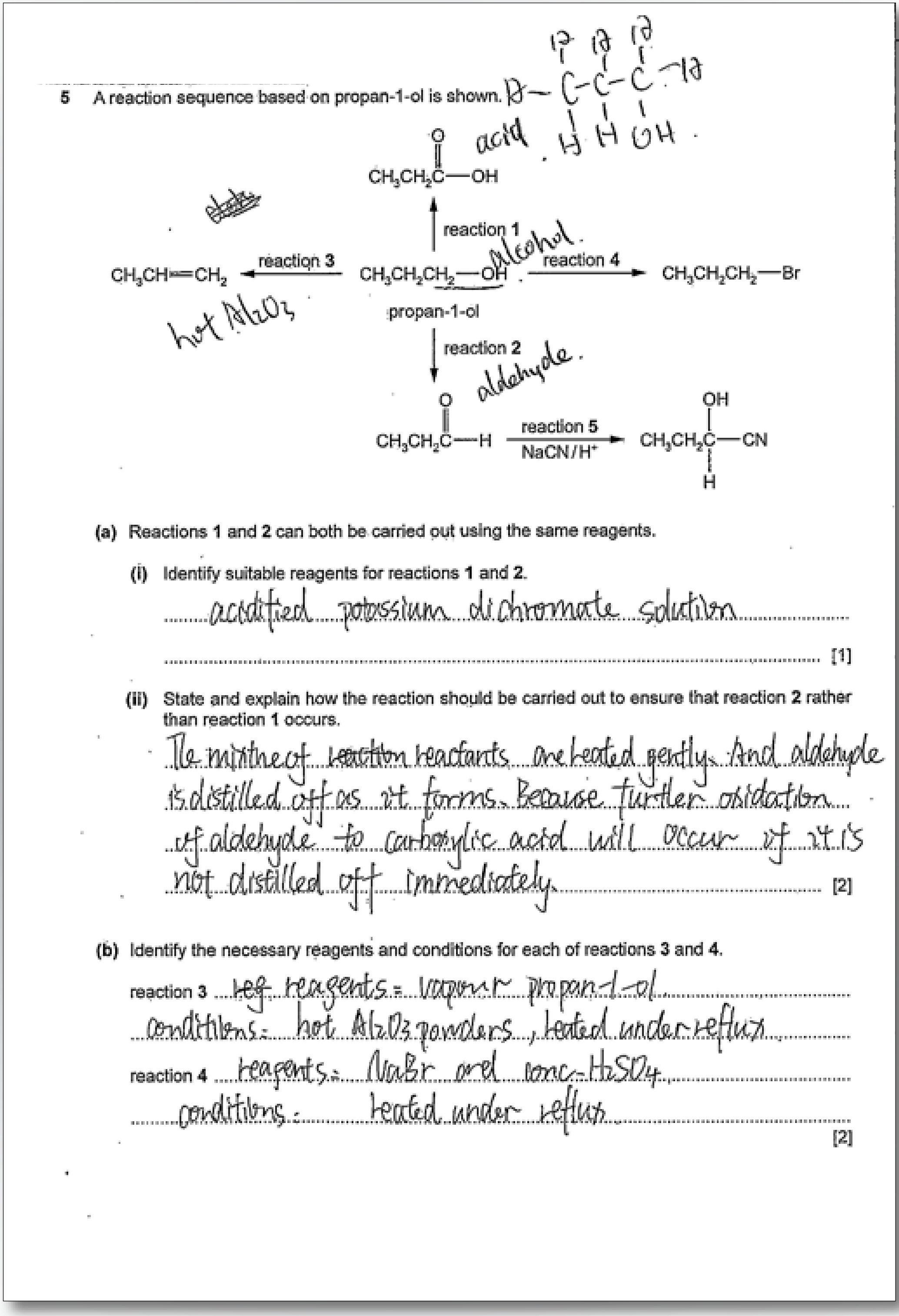


5 A reaction sequence based on propan-1-ol is shown.

(a) Reactions **1** and **2** can both be carried out using the same reagents.

(i) Identify suitable reagents for reactions **1** and **2**.

acidified potassium dichromate solution

[1]

(ii) State and explain how the reaction should be carried out to ensure that reaction **2** rather than reaction **1** occurs.

The mixture of ~~reaction~~ reactants are heated gently. And aldehyde is distilled off as it forms. Because further oxidation of aldehyde to carboxylic acid will occur if it is not distilled off immediately. [2]

(b) Identify the necessary reagents and conditions for each of reactions **3** and **4**.

reaction 3 ~~reg~~ reagents: vapour propan-1-ol

conditions: hot Al_2O_3 powders, heated under reflux

reaction 4 reagents: NaBr and conc. H_2SO_4

conditions: heated under reflux

[2]

Your Mark

5(a)(i) ☐

5(a)(ii) ☐

5(b) ☐

5(c)(i) ☐

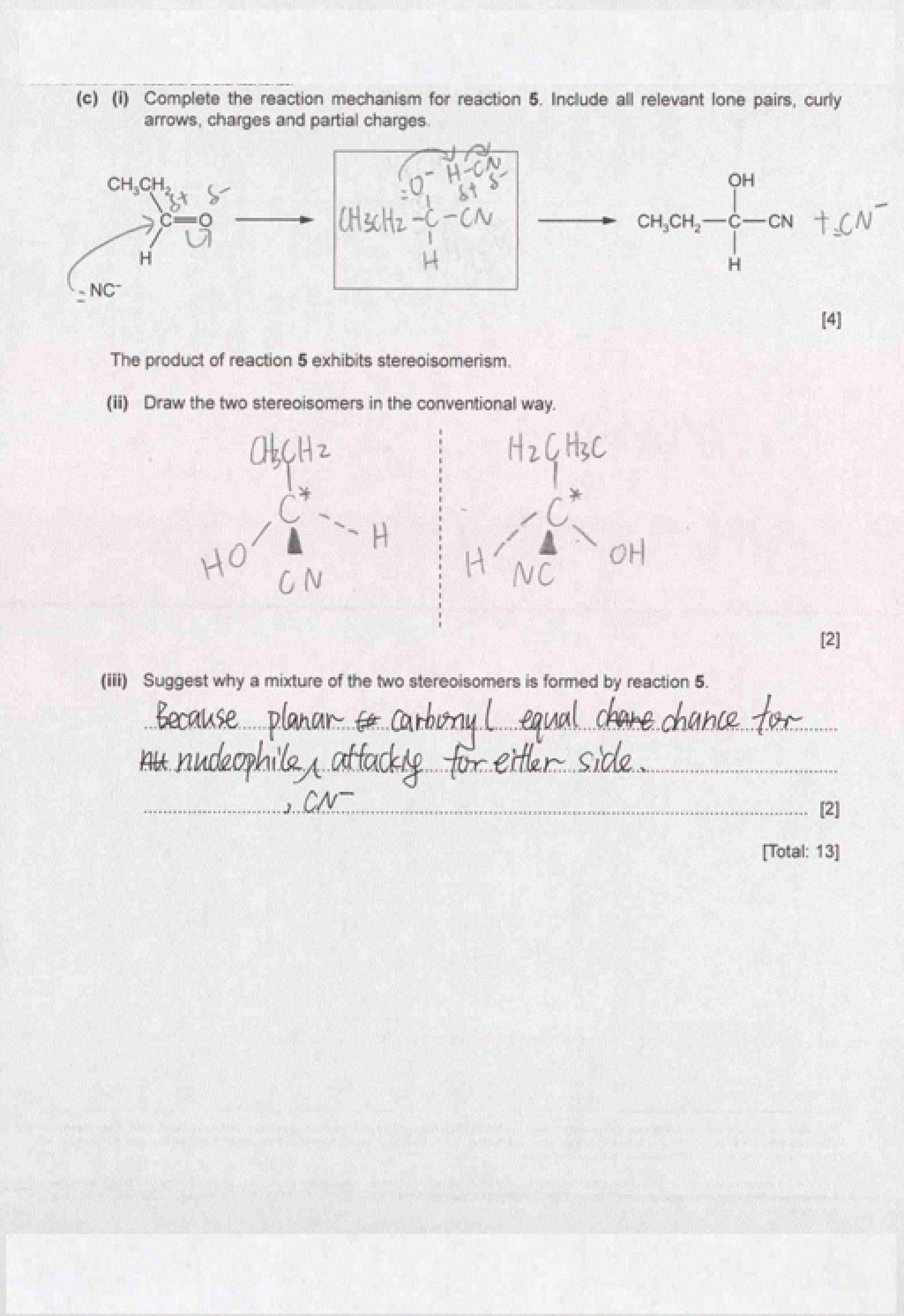
5(c)(ii) ☐

5(c)(iii) ☐

Q5	Mark scheme
(a)(i)	acidified / H^+ AND potassium / sodium dichromate **[1]**
(a)(ii)	distillation (rather than reflux) [1] (ensures aldehyde escapes) to avoid further oxidation / to avoid forming acid / as reflux causes further oxidation [1] **[2]**
(b)	reaction 3 – (conc) H2SO4 / (conc) H3PO4 or Al 2O3 / pumice / porcelain / porous pot / ceramic AND heat reaction 4 – KBr / NaBr with (conc) H2SO4 or (red)P and Br2 / PBr3 [1] AND heat [1] **[2]**

EXAMINER COMMENTS

MARK SCHEME



(c) (i) Complete the reaction mechanism for reaction **5**. Include all relevant lone pairs, curly arrows, charges and partial charges.

[4]

The product of reaction **5** exhibits stereoisomerism.

(ii) Draw the two stereoisomers in the conventional way.

[2]

(iii) Suggest why a mixture of the two stereoisomers is formed by reaction **5**.

Because planar ~~co~~ carbonyl equal ~~chane~~ chance for ~~Att~~ nucleophile, CN⁻ attacking for either side.

[2]

[Total: 13]

Select page

HIGH MIDDLE LOW

Your Mark

5(a)(i) ☐

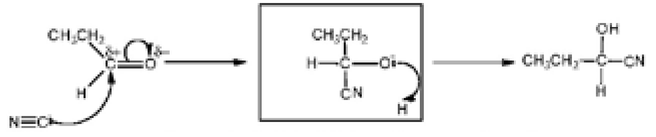
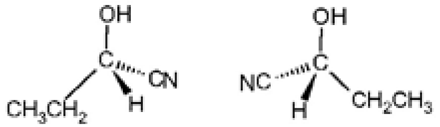
5(a)(ii) ☐

5(b) ☐

5(c)(i) ☐

5(c)(ii) ☐

5(c)(iii) ☐

Q5	**Mark scheme**	
(c)(i)	 M1 = lone pair on C of CN⁻ AND curly arrow from lone pair to carbonyl carbon M2 = dipole on C=O AND curly arrow to O from = M3 = intermediate with negative charge M4 = lone pair and curly arrow to H⁺	[1] [1] [1] [1] **[4]**
(c)(ii)		[1+1] **[2]**
(c)(iii)	attack / attach from either side / above or below / from two directions because the carbonyl / molecule is planar / trigonal / flat / because of the shape of the molecule OR product is chiral / has a chiral carbon / has a carbon attached to four different groups / has a chiral centre / is asymmetric (equal) chance of forming either (of the two optical isomers) / mechanism doesn't distinguish between the two (optical isomers) / able to form either / chance of forming / able to form 50:50 OR because the carbonyl / molecule is planar / trigonal / flat OR because of the shape of the molecule (equal) chance of forming either (of the two optical isomers) / mechanism doesn't distinguish between the two (optical isomers) / able to form either / chance of forming / able to form 50:50	[1] [1] **[2]** **[Total: 13]**

EXAMINER COMMENTS

MARK SCHEME

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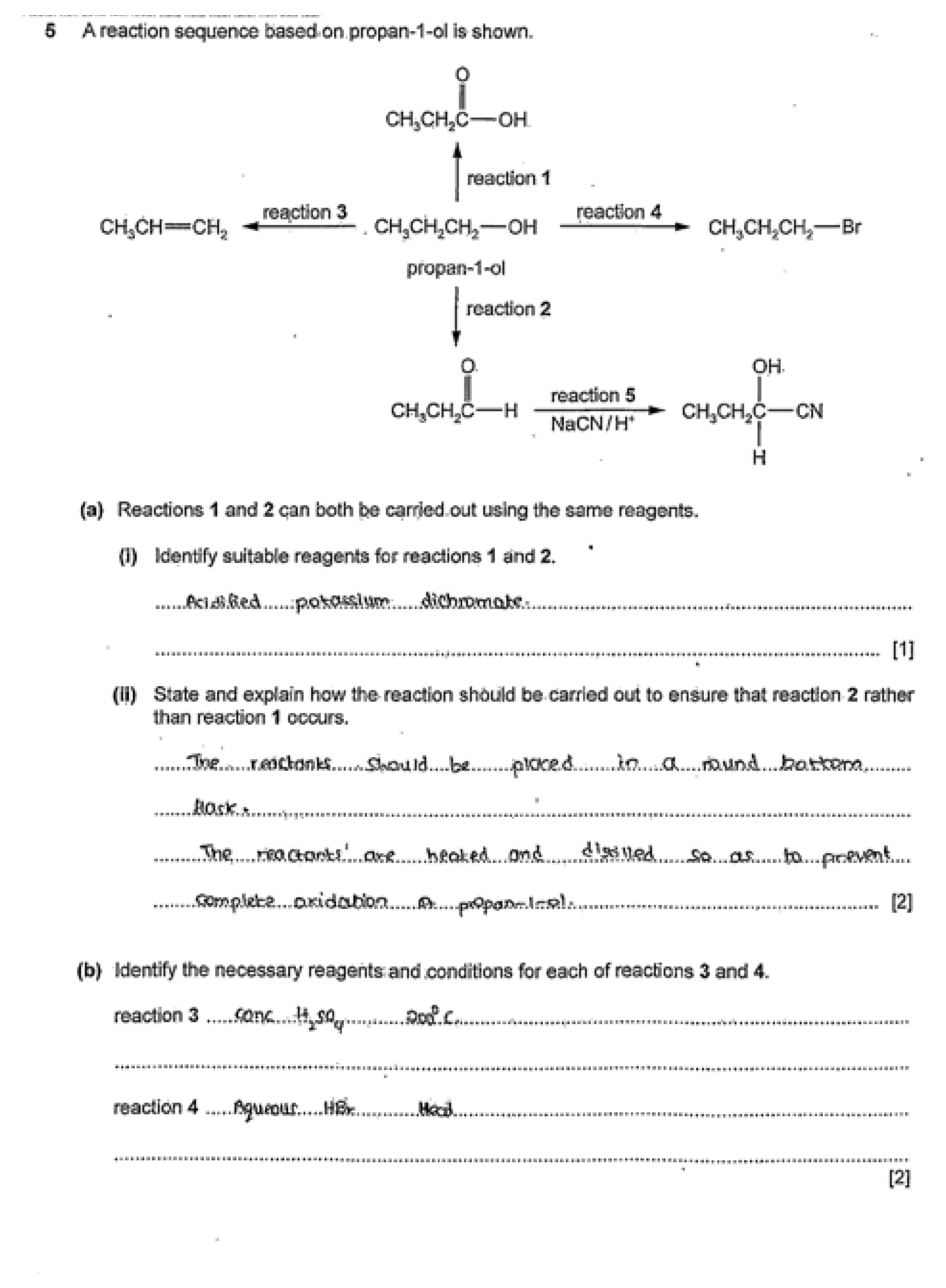

5 A reaction sequence based on propan-1-ol is shown.

(a) Reactions 1 and 2 can both be carried out using the same reagents.

(i) Identify suitable reagents for reactions 1 and 2.

Acidified potassium dichromate

[1]

(ii) State and explain how the reaction should be carried out to ensure that reaction 2 rather than reaction 1 occurs.

The reactants should be placed in a round bottom flask.

The reactants' are heated and distilled so as to prevent complete oxidation of propan-1-ol.

[2]

(b) Identify the necessary reagents and conditions for each of reactions 3 and 4.

reaction 3 conc. H_2SO_4 200°C

reaction 4 Aqueous HBr heat

[2]

Your Mark

5(a)(i) ☐

5(a)(ii) ☐

5(b) ☐

5(c)(i) ☐

5(c)(ii) ☐

5(c)(iii) ☐

Q5	**Mark scheme**	
(a)(i)	acidified / H⁺ AND potassium / sodium dichromate	**[1]**
(a)(ii)	distillation (rather than reflux) (ensures aldehyde escapes) to avoid further oxidation / to avoid forming acid / as reflux causes further oxidation	[1] [1] **[2]**
(b)	reaction 3 – (conc) H2SO4 / (conc) H3PO4 or Al 2O3 / pumice / porcelain / porous pot / ceramic AND heat reaction 4 – KBr / NaBr with (conc) H2SO4 or (red)P and Br2 / PBr3 AND heat	[1] [1] **[2]**

EXAMINER COMMENTS

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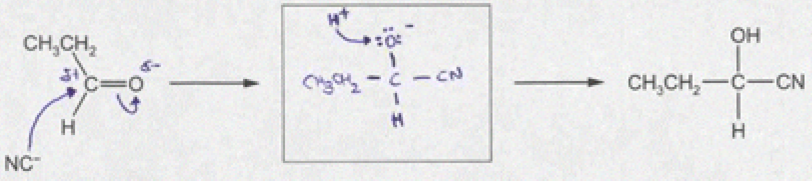
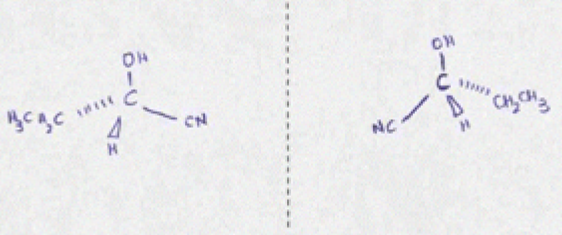
(c) (i) Complete the reaction mechanism for reaction **5**. Include all relevant lone pairs, curly arrows, charges and partial charges.



[4]

The product of reaction **5** exhibits stereoisomerism.

(ii) Draw the two stereoisomers in the conventional way.



[2]

(iii) Suggest why a mixture of the two stereoisomers is formed by reaction **5**.

The CN⁻ can do both backside or forward attack. Thus forming a product with retension configuration and another one with inversion configuration (S_N2 mechanism) [2]

[Total: 13]

Your Mark

5(a)(i) ☐

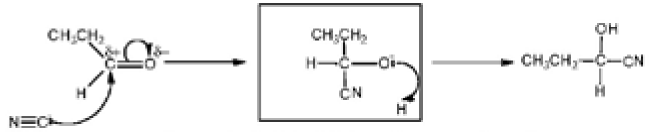
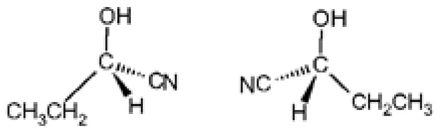
5(a)(ii) ☐

5(b) ☐

5(c)(i) ☐

5(c)(ii) ☐

5(c)(iii) ☐

Q5	Mark scheme
(c)(i)	 M1 = lone pair on C of CN^- AND curly arrow from lone pair to carbonyl carbon [1] M2 = dipole on C=O AND curly arrow to O from = [1] M3 = intermediate with negative charge [1] M4 = lone pair and curly arrow to H^+ [1] **[4]**
(c)(ii)	[1+1]  **[2]**
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EXAMINER COMMENTS

MARK SCHEME

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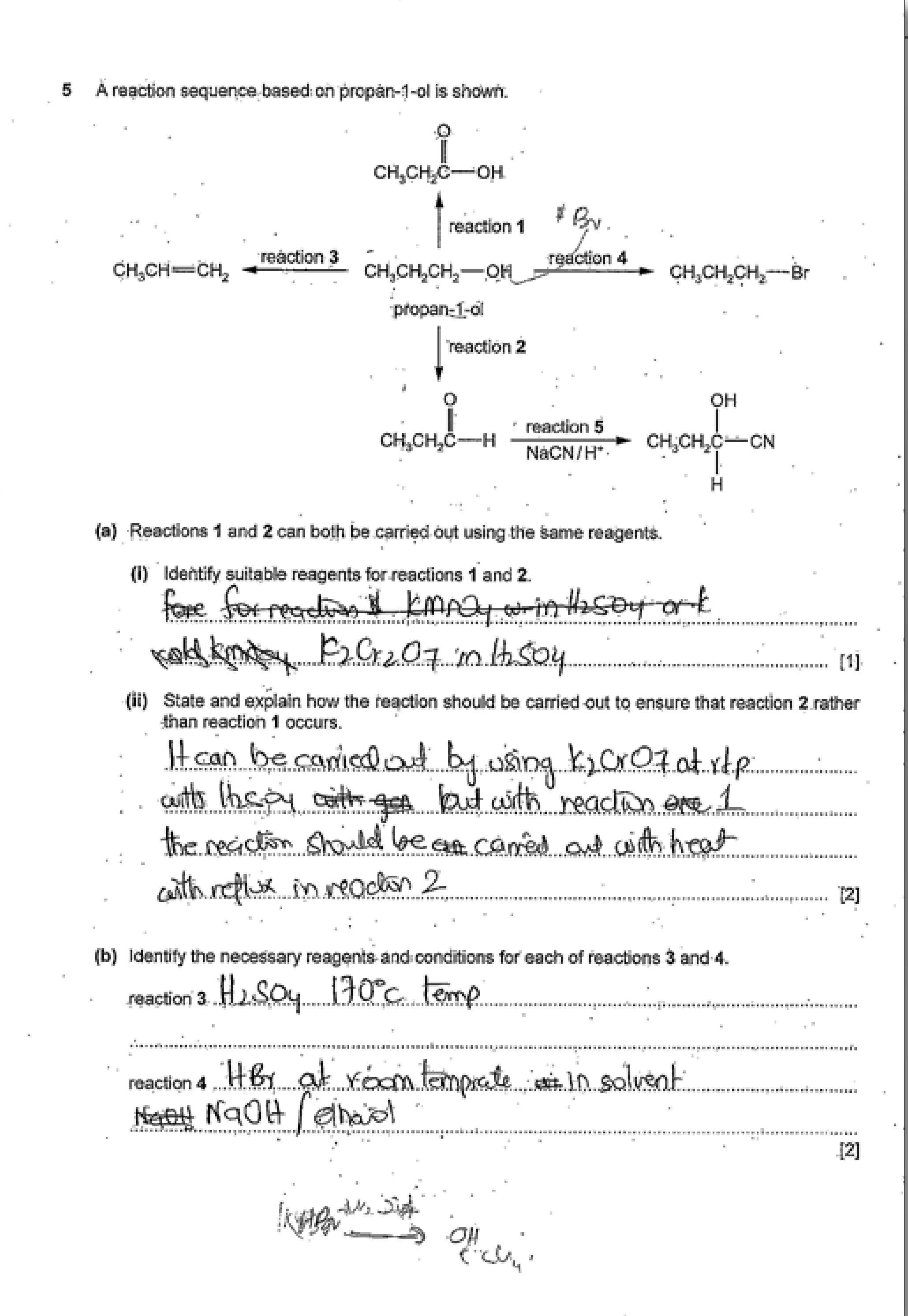


5 A reaction sequence based on propan-1-ol is shown.

(a) Reactions **1** and **2** can both be carried out using the same reagents.

(i) Identify suitable reagents for reactions **1** and **2**.

~~fore for reaction 1 $KMnO_4$ or in H_2SO_4 or t~~
~~cold $KMnO_4$~~ $K_2Cr_2O_7$ in H_2SO_4 [1]

(ii) State and explain how the reaction should be carried out to ensure that reaction **2** rather than reaction **1** occurs.

It can be carried out by using K_2CrO_7 at r.t.p
with H_2SO_4 ~~with gen~~ but with reaction ~~one~~ 1
the reaction should be ~~an~~ carried out with heat
with reflux in reaction 2 [2]

(b) Identify the necessary reagents and conditions for each of reactions **3** and **4**.

reaction **3** H_2SO_4 170°c temp

reaction **4** HBr at room temprate ~~at~~ in solvent
~~NaOH~~ NaOH / ethanol
[2]

[illegible] $\xrightarrow{H_2SO_4}$ OH [illegible]

Your Mark

5(a)(i) ☐

5(a)(ii) ☐

5(b) ☐

5(c)(i) ☐

5(c)(ii) ☐

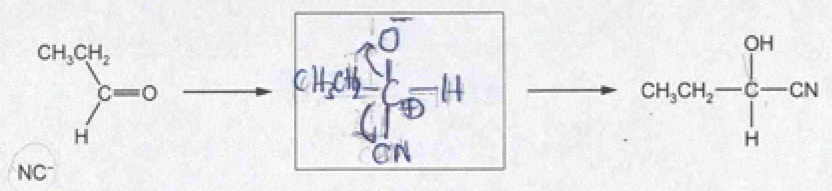
5(c)(iii) ☐

Q5	Mark scheme	
(a)(i)	acidified / H^+ AND potassium / sodium dichromate	**[1]**
(a)(ii)	distillation (rather than reflux)	[1]
	(ensures aldehyde escapes) to avoid further oxidation / to avoid forming acid / as reflux causes further oxidation	[1] **[2]**
(b)	reaction 3 – (conc) H2SO4 / (conc) H3PO4 or Al 2O3 / pumice / porcelain / porous pot / ceramic AND heat	[1]
	reaction 4 – KBr / NaBr with (conc) H2SO4 or (red)P and Br2 / PBr3 AND heat	[1] **[2]**

EXAMINER COMMENTS

MARK SCHEME

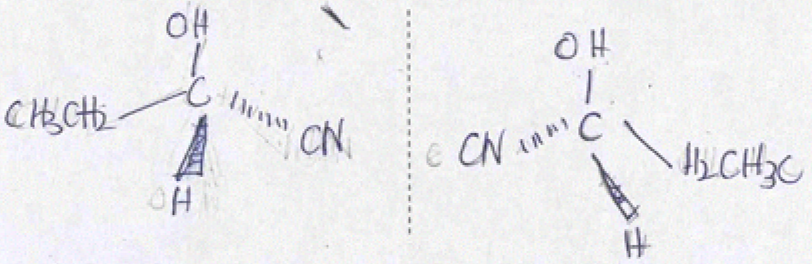
(c) (i) Complete the reaction mechanism for reaction **5**. Include all relevant lone pairs, curly arrows, charges and partial charges.



[4]

The product of reaction **5** exhibits stereoisomerism.

(ii) Draw the two stereoisomers in the conventional way.



[2]

(iii) Suggest why a mixture of the two stereoisomers is formed by reaction **5**.

It is because of the ~~[illegible]~~ carbo cation formation and the double bond has enofn electrons so ~~[illegible]~~ nucleophile addition takes place [2]

[Total: 13]

Your Mark

5(a)(i) ☐

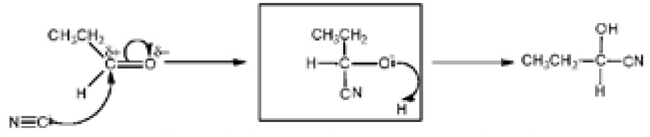
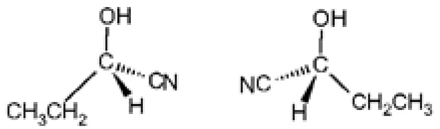
5(a)(ii) ☐

5(b) ☐

5(c)(i) ☐

5(c)(ii) ☐

5(c)(iii) ☐

Q5	**Mark scheme**
(c)(i)	 M1 = lone pair on C of CN⁻ AND curly arrow from lone pair to carbonyl carbon [1] M2 = dipole on C=O AND curly arrow to O from = [1] M3 = intermediate with negative charge [1] M4 = lone pair and curly arrow to H⁺ [1] **[4]**
(c)(ii)	[1+1]  **[2]**
(c)(iii)	attack / attach from either side / above or below / from two directions because the carbonyl / molecule is [1] planar / trigonal / flat / because of the shape of the molecule [1] OR product is chiral / has a chiral carbon / has a carbon attached to four different groups / has a chiral centre / is asymmetric (equal) chance of forming either (of the two optical isomers) / mechanism doesn't distinguish between the two (optical isomers) / able to form either / chance of forming / able to form 50:50 OR because the carbonyl / molecule is planar / trigonal / flat OR because of the shape of the molecule (equal) chance of forming either (of the two optical isomers) / mechanism doesn't distinguish between the two (optical isomers) / able to form either / chance of forming / able to form 50:50 **[2]** **[Total: 13]**

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Interactive Example Candidate Responses
Paper 33 (May/June 2016), Question 3(a)

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Chemistry 9701

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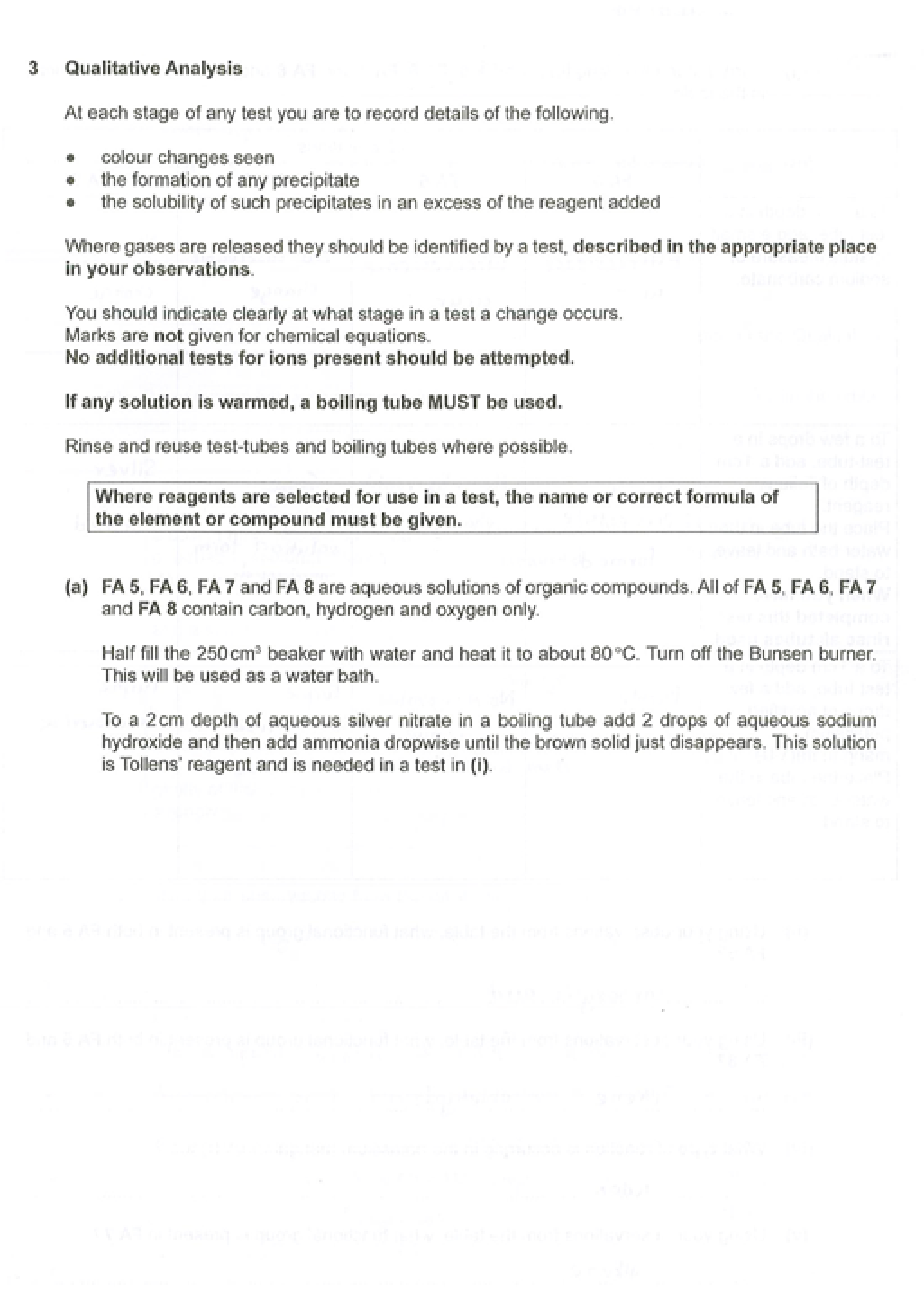


3 **Qualitative Analysis**

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations.**

You should indicate clearly at what stage in a test a change occurs.
Marks are **not** given for chemical equations.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.

Rinse and reuse test-tubes and boiling tubes where possible.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

(a) **FA 5**, **FA 6**, **FA 7** and **FA 8** are aqueous solutions of organic compounds. All of **FA 5**, **FA 6**, **FA 7** and **FA 8** contain carbon, hydrogen and oxygen only.

Half fill the 250 cm^3 beaker with water and heat it to about 80 °C. Turn off the Bunsen burner. This will be used as a water bath.

To a 2 cm depth of aqueous silver nitrate in a boiling tube add 2 drops of aqueous sodium hydroxide and then add ammonia dropwise until the brown solid just disappears. This solution is Tollens' reagent and is needed in a test in **(i)**.

Select page

HIGH

MIDDLE

LOW

Your Mark

3(a)(i) ☐

3(a)(ii) ☐

3(a)(iii) ☐

3(a)(iv) ☐

3(a)(v) ☐

3(a)(vi) ☐

Q3 Mark scheme

(a)(i)

FA 5	FA 6	FA 7	FA 8
Fizz / bubbles / effervescence	Fizz / bubbles / effervescence	no change	no change
Gas turns limewater milky / cloudy white / white ppt / chalky	Gas turns limewater milky / cloudy white / white ppt / chalky	No reaction/no change	No reaction/no change
Silver / black / dark grey and mirror / solid / ppt	No reaction / no change / no silver mirror	No reaction / no change / no silver mirror	Silver / black / dark grey **and** mirror / solid / ppt
Purple to colourless or solution / MnO_4^- / manganate (VII) decolourised/ disappeared	No reaction or remains / turns purple or pink	Purple to colourless or solution / MnO_4^-/ manganate(VII) decolourised / disappeared	Purple to colourless or solution / MnO_4^-/ manganate (VII) decolourised / disappeared

[4]

(a)(ii)	(–)CO_2H / carboxylic acid **[1]**
(a)(iii)	(–)CHO / aldehyde / alkanal **or** alkene / C=C **[1]**
(a)(iv)	Oxidation of organic compound / reduction of MnO_4^-/ redox **or** if alkene in (iii) then electrophilic addition **[1]**
(a)(v)	(–)OH / (1° / 2°) alcohol / alkanol / hydroxy **or** alkene / C=C **[1]**
(a)(vi)	transport / transporter / carrier, protein ; R pump protein Add Na to give effervescence / hydrogen / gas which pops with lighted splint, **or** Add PCl_5 / $SOCl_2$ to give misty fumes / steamy fumes / HC*l*, or Add carboxylic acid AND (conc) sulfuric acid to produce fruity / sweet smell **or** if alkene in (**v**) Br_2 decolourised / brown to colourless **[1]** **[Total: 9]**

EXAMINER COMMENTS

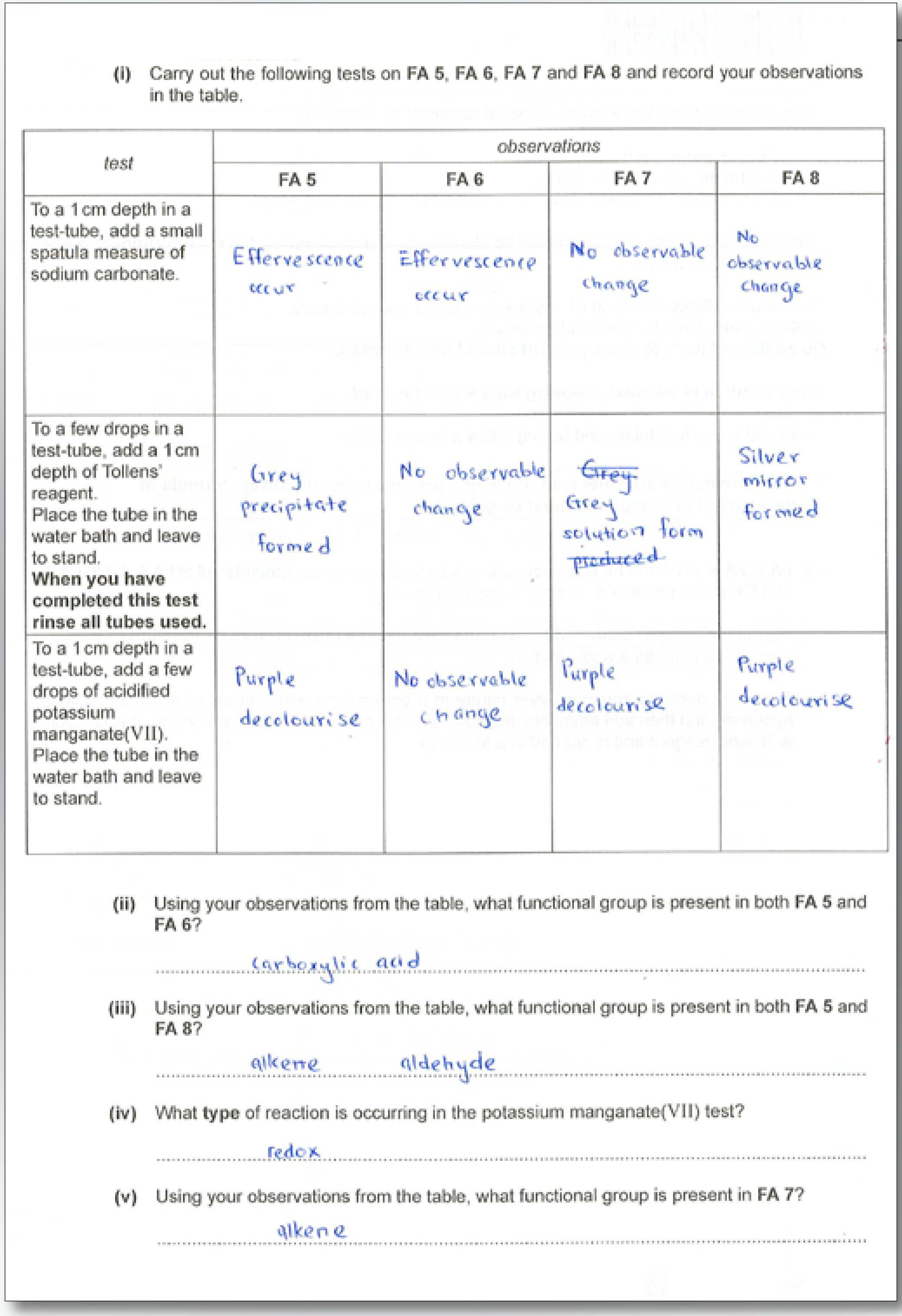
MARK SCHEME

Select page

HIGH

MIDDLE

LOW



(i) Carry out the following tests on **FA 5**, **FA 6**, **FA 7** and **FA 8** and record your observations in the table.

test	*observations*			
	FA 5	**FA 6**	**FA 7**	**FA 8**
To a 1 cm depth in a test-tube, add a small spatula measure of sodium carbonate.	Effervescence occur	Effervescence occur	No observable change	No observable change
To a few drops in a test-tube, add a 1 cm depth of Tollens' reagent. Place the tube in the water bath and leave to stand. **When you have completed this test rinse all tubes used.**	Grey precipitate formed	No observable change	~~Grey~~ Grey solution form ~~produced~~	Silver mirror formed
To a 1 cm depth in a test-tube, add a few drops of acidified potassium manganate(VII). Place the tube in the water bath and leave to stand.	Purple decolourise	No observable change	Purple decolourise	Purple decolourise

(ii) Using your observations from the table, what functional group is present in both **FA 5** and **FA 6**?

carboxylic acid

(iii) Using your observations from the table, what functional group is present in both **FA 5** and **FA 8**?

alkene aldehyde

(iv) What **type** of reaction is occurring in the potassium manganate(VII) test?

redox

(v) Using your observations from the table, what functional group is present in **FA 7**?

alkene

Your Mark

3(a)(i)

3(a)(ii)

3(a)(iii)

3(a)(iv)

3(a)(v)

3(a)(vi)

Q3 Mark scheme

(a)(i)

FA 5	**FA 6**	**FA 7**	**FA 8**
Fizz / bubbles / effervescence	Fizz / bubbles / effervescence	no change	no change
Gas turns limewater milky / cloudy white / white ppt / chalky	Gas turns limewater milky / cloudy white / white ppt / chalky	No reaction/no change	No reaction/no change
Silver / black / dark grey and mirror / solid / ppt	No reaction / no change / no silver mirror	No reaction / no change / no silver mirror	Silver / black / dark grey **and** mirror / solid / ppt
Purple to colourless or solution / MnO_4^- / manganate (VII) decolourised/ disappeared	No reaction or remains / turns purple or pink	Purple to colourless or solution / MnO_4^-/ manganate(VII) decolourised / disappeared	Purple to colourless or solution / MnO_4^-/ manganate (VII) decolourised / disappeared

[4]

(a)(ii)	(–)CO_2H / carboxylic acid	**[1]**
(a)(iii)	(–)CHO / aldehyde / alkanal **or** alkene / C=C	**[1]**
(a)(iv)	Oxidation of organic compound / reduction of MnO_4^-/ redox **or** if alkene in (iii) then electrophilic addition	**[1]**
(a)(v)	(–)OH / (1° / 2°) alcohol / alkanol / hydroxy **or** alkene / C=C	**[1]**
(a)(vi)	transport / transporter / carrier, protein ; R pump protein Add Na to give effervescence / hydrogen / gas which pops with lighted splint, **or** Add PCl_5 / $SOCl_2$ to give misty fumes / steamy fumes / HC*l*, or Add carboxylic acid AND (conc) sulfuric acid to produce fruity / sweet smell **or** if alkene in (**v**) Br_2 decolourised / brown to colourless	**[1]** **[Total: 9]**

EXAMINER COMMENTS

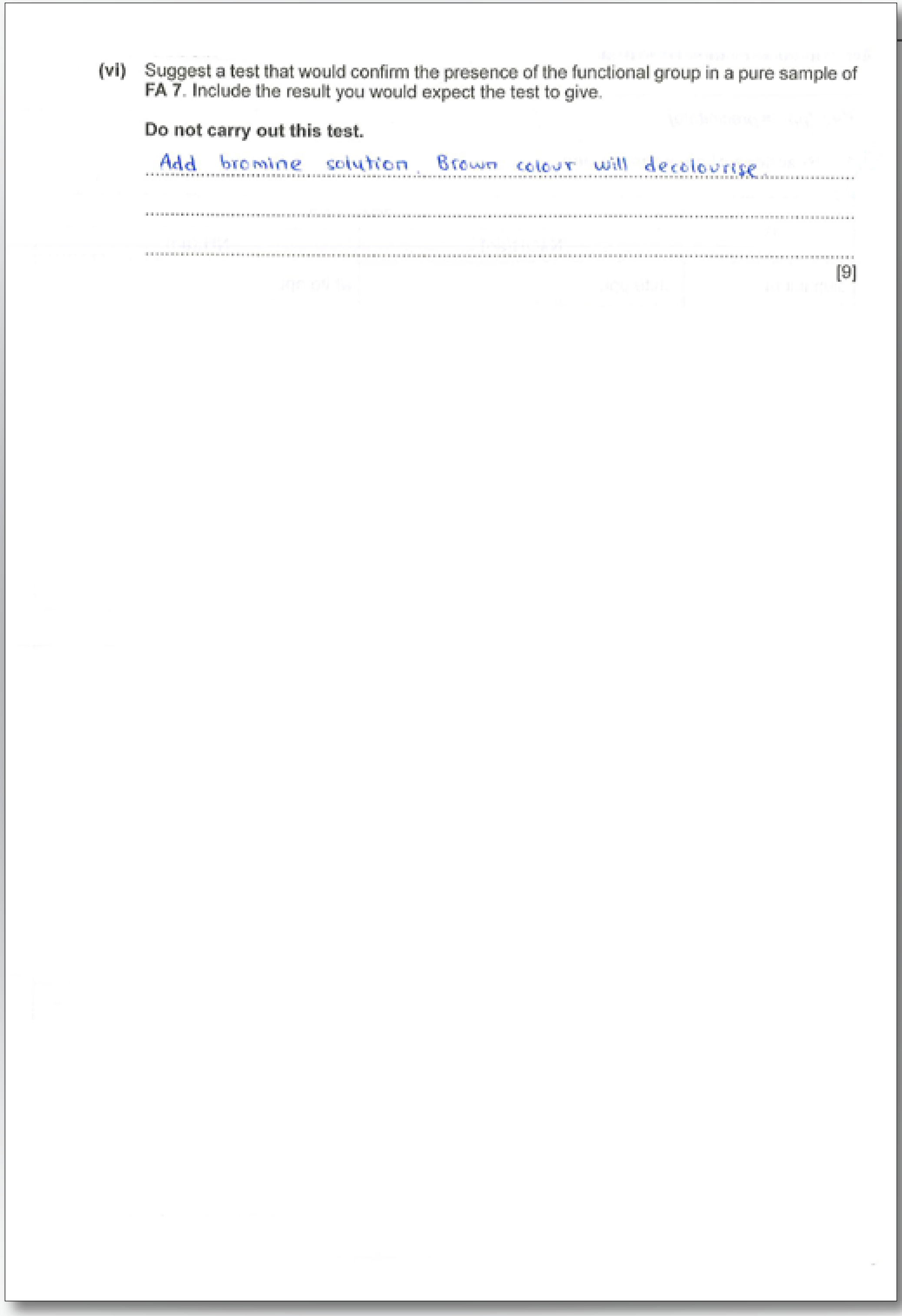
MARK SCHEME

Select page

HIGH

MIDDLE

LOW



(vi) Suggest a test that would confirm the presence of the functional group in a pure sample of FA 7. Include the result you would expect the test to give.

Do not carry out this test.

Add bromine solution. Brown colour will decolourise

[9]

Your Mark

3(a)(i) ☐

3(a)(ii) ☐

3(a)(iii) ☐

3(a)(iv) ☐

3(a)(v) ☐

3(a)(vi) ☐

Q3 Mark scheme

(a)(i)

FA 5	**FA 6**	**FA 7**	**FA 8**
Fizz / bubbles / effervescence	Fizz / bubbles / effervescence	no change	no change
Gas turns limewater milky / cloudy white / white ppt / chalky	Gas turns limewater milky / cloudy white / white ppt / chalky	No reaction/no change	No reaction/no change
Silver / black / dark grey and mirror / solid / ppt	No reaction / no change / no silver mirror	No reaction / no change / no silver mirror	Silver / black / dark grey **and** mirror / solid / ppt
Purple to colourless or solution / MnO_4^- / manganate (VII) decolourised/ disappeared	No reaction or remains / turns purple or pink	Purple to colourless or solution / MnO_4^-/ manganate(VII) decolourised / disappeared	Purple to colourless or solution / MnO_4^-/ manganate (VII) decolourised / disappeared

[4]

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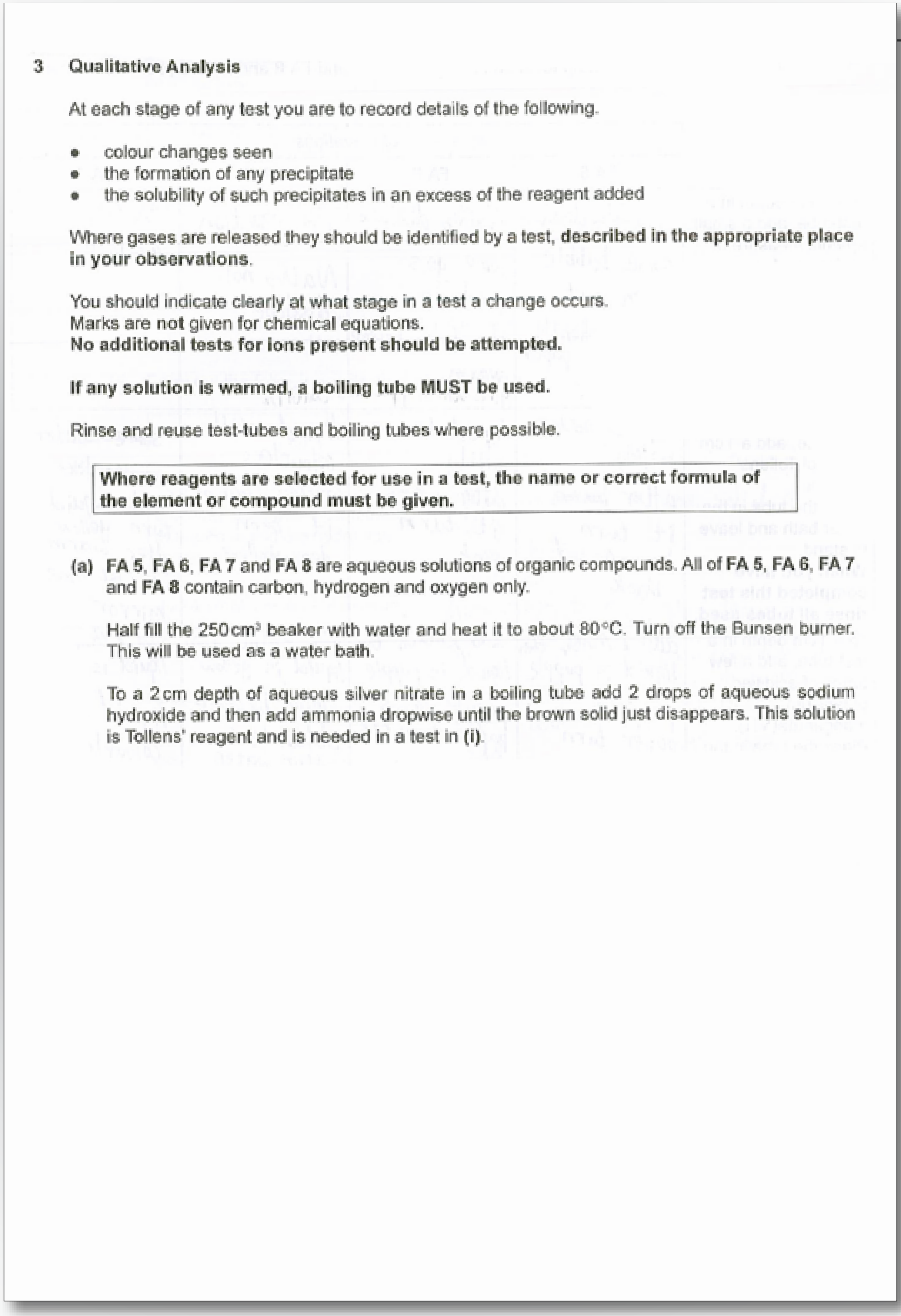
(a)(iv)	Oxidation of organic compound / reduction of MnO_4^-/ redox **or** if alkene in (iii) then electrophilic addition	**[1]**
(a)(v)	(–)OH / (1° / 2°) alcohol / alkanol / hydroxy **or** alkene / C=C	**[1]**
(a)(vi)	transport / transporter / carrier, protein ; R pump protein Add Na to give effervescence / hydrogen / gas which pops with lighted splint, **or** Add PCl_5 / $SOCl_2$ to give misty fumes / steamy fumes / HCl, or Add carboxylic acid AND (conc) sulfuric acid to produce fruity / sweet smell **or** if alkene in (**v**) Br_2 decolourised / brown to colourless	**[1]** **[Total: 9]**

EXAMINER COMMENTS

MARK SCHEME



3 **Qualitative Analysis**

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations.**

You should indicate clearly at what stage in a test a change occurs.
Marks are **not** given for chemical equations.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.

Rinse and reuse test-tubes and boiling tubes where possible.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

(a) **FA 5**, **FA 6**, **FA 7** and **FA 8** are aqueous solutions of organic compounds. All of **FA 5**, **FA 6**, **FA 7** and **FA 8** contain carbon, hydrogen and oxygen only.

Half fill the 250 cm^3 beaker with water and heat it to about 80 °C. Turn off the Bunsen burner. This will be used as a water bath.

To a 2 cm depth of aqueous silver nitrate in a boiling tube add 2 drops of aqueous sodium hydroxide and then add ammonia dropwise until the brown solid just disappears. This solution is Tollens' reagent and is needed in a test in **(i)**.

Select page

HIGH MIDDLE LOW

Your Mark

3(a)(i) ☐

3(a)(ii) ☐

3(a)(iii) ☐

3(a)(iv) ☐

3(a)(v) ☐

3(a)(vi) ☐

Q3 Mark scheme

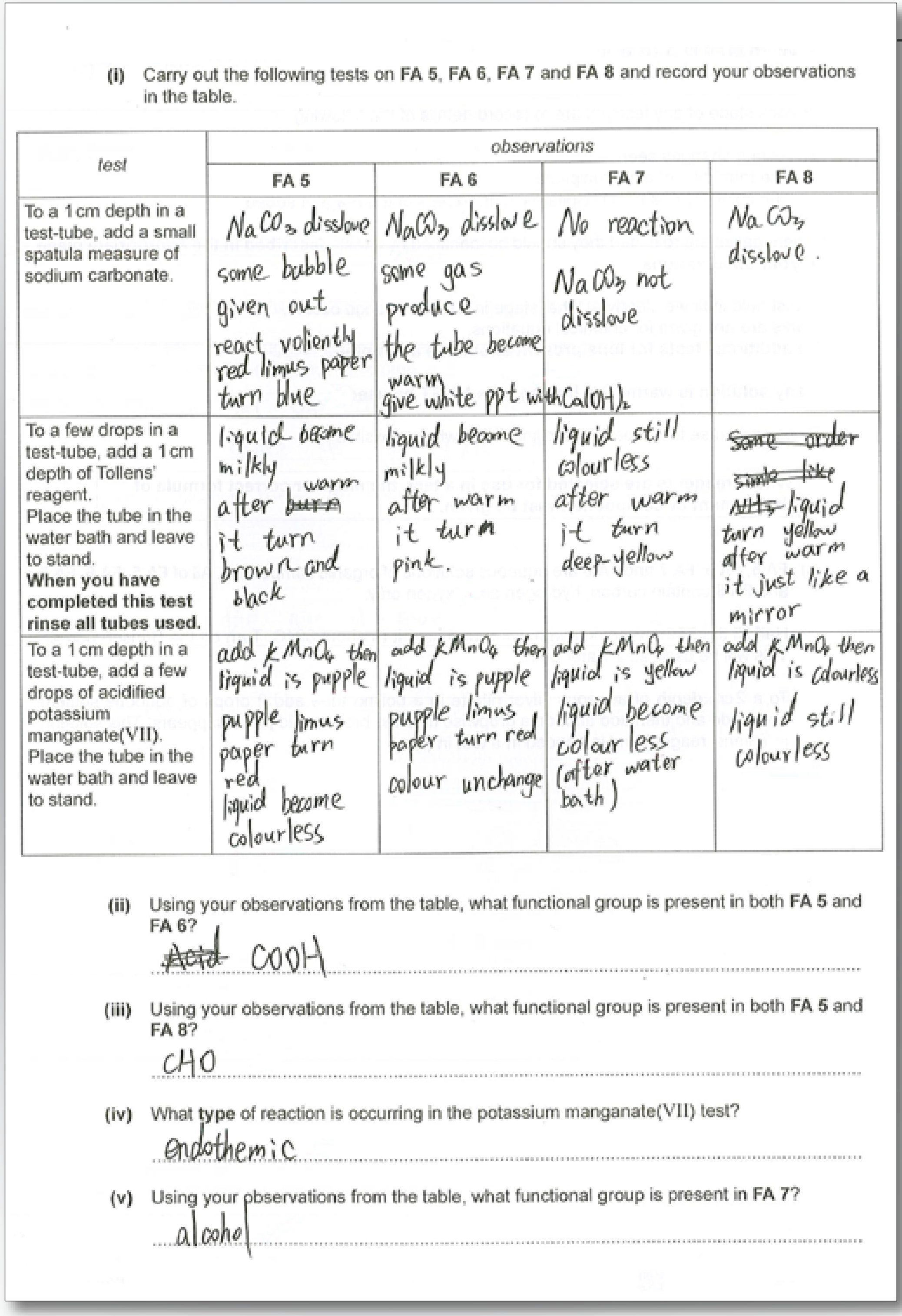
(a)(i)

FA 5	FA 6	FA 7	FA 8
Fizz / bubbles / effervescence	Fizz / bubbles / effervescence	no change	no change
Gas turns limewater milky / cloudy white / white ppt / chalky	Gas turns limewater milky / cloudy white / white ppt / chalky	No reaction/no change	No reaction/no change
Silver / black / dark grey and mirror / solid / ppt	No reaction / no change / no silver mirror	No reaction / no change / no silver mirror	Silver / black / dark grey **and** mirror / solid / ppt
Purple to colourless or solution / MnO$_4^-$ / manganate (VII) decolourised/ disappeared	No reaction or remains / turns purple or pink	Purple to colourless or solution / MnO$_4^-$/ manganate(VII) decolourised / disappeared	Purple to colourless or solution / MnO$_4^-$/ manganate (VII) decolourised / disappeared

[4]

(a)(ii)	(–)CO$_2$H / carboxylic acid	**[1]**
(a)(iii)	(–)CHO / aldehyde / alkanal **or** alkene / C=C	**[1]**
(a)(iv)	Oxidation of organic compound / reduction of MnO$_4^-$/ redox **or** if alkene in (iii) then electrophilic addition	**[1]**
(a)(v)	(–)OH / (1° / 2°) alcohol / alkanol / hydroxy **or** alkene / C=C	**[1]**
(a)(vi)	transport / transporter / carrier, protein ; R pump protein Add Na to give effervescence / hydrogen / gas which pops with lighted splint, **or** Add PCl_5 / SOCl_2 to give misty fumes / steamy fumes / HCl , or Add carboxylic acid AND (conc) sulfuric acid to produce fruity / sweet smell **or** if alkene in (**v**) Br$_2$ decolourised / brown to colourless	**[1]** **[Total: 9]**

EXAMINER COMMENTS MARK SCHEME



(i) Carry out the following tests on **FA 5**, **FA 6**, **FA 7** and **FA 8** and record your observations in the table.

test	*observations* **FA 5**	 **FA 6**	 **FA 7**	 **FA 8**
To a 1 cm depth in a test-tube, add a small spatula measure of sodium carbonate.	$NaCO_3$ dislove some bubble given out react volienthly red limus paper turn blue	$NaCO_3$ dislove some gas produce the tube become warm give white ppt with $Ca(OH)_2$	No reaction $NaCO_3$ not dislove	$NaCO_3$ dislove.
To a few drops in a test-tube, add a 1 cm depth of Tollens' reagent. Place the tube in the water bath and leave to stand. **When you have completed this test rinse all tubes used.**	liquid become milkly after ~~burn~~ warm it turn brown and black	liquid become milkly after warm it turn pink.	liquid still colourless after warm it turn deep-yellow	~~Same order~~ ~~Smile like~~ ~~NH3~~ liquid turn yellow after warm it just like a mirror
To a 1 cm depth in a test-tube, add a few drops of acidified potassium manganate(VII). Place the tube in the water bath and leave to stand.	add $KMnO_4$ then liquid is pupple pupple limus paper turn red liquid become colourless	add $KMnO_4$ then liquid is pupple pupple limus paper turn red colour unchange	add $KMnO_4$ then liquid is yellow liquid become colourless (after water bath)	add $KMnO_4$ then liquid is colourless liquid still colourless

(ii) Using your observations from the table, what functional group is present in both **FA 5** and **FA 6**?

~~Acid~~ COOH

(iii) Using your observations from the table, what functional group is present in both **FA 5** and **FA 8**?

CHO

(iv) What type of reaction is occurring in the potassium manganate(VII) test?

endothemic

(v) Using your observations from the table, what functional group is present in **FA 7**?

alcohol

Your Mark

3(a)(i) ☐
3(a)(ii) ☐
3(a)(iii) ☐
3(a)(iv) ☐
3(a)(v) ☐
3(a)(vi) ☐

Q3 Mark scheme

(a)(i)

FA 5	FA 6	FA 7	FA 8
Fizz / bubbles / effervescence	Fizz / bubbles / effervescence	no change	no change
Gas turns limewater milky / cloudy white / white ppt / chalky	Gas turns limewater milky / cloudy white / white ppt / chalky	No reaction/no change	No reaction/no change
Silver / black / dark grey and mirror / solid / ppt	No reaction / no change / no silver mirror	No reaction / no change / no silver mirror	Silver / black / dark grey **and** mirror / solid / ppt
Purple to colourless or solution / MnO_4^- / manganate (VII) decolourised/ disappeared	No reaction or remains / turns purple or pink	Purple to colourless or solution / MnO_4^-/ manganate(VII) decolourised / disappeared	Purple to colourless or solution / MnO_4^-/ manganate (VII) decolourised / disappeared

[4]

(a)(ii) (–)CO_2H / carboxylic acid **[1]**

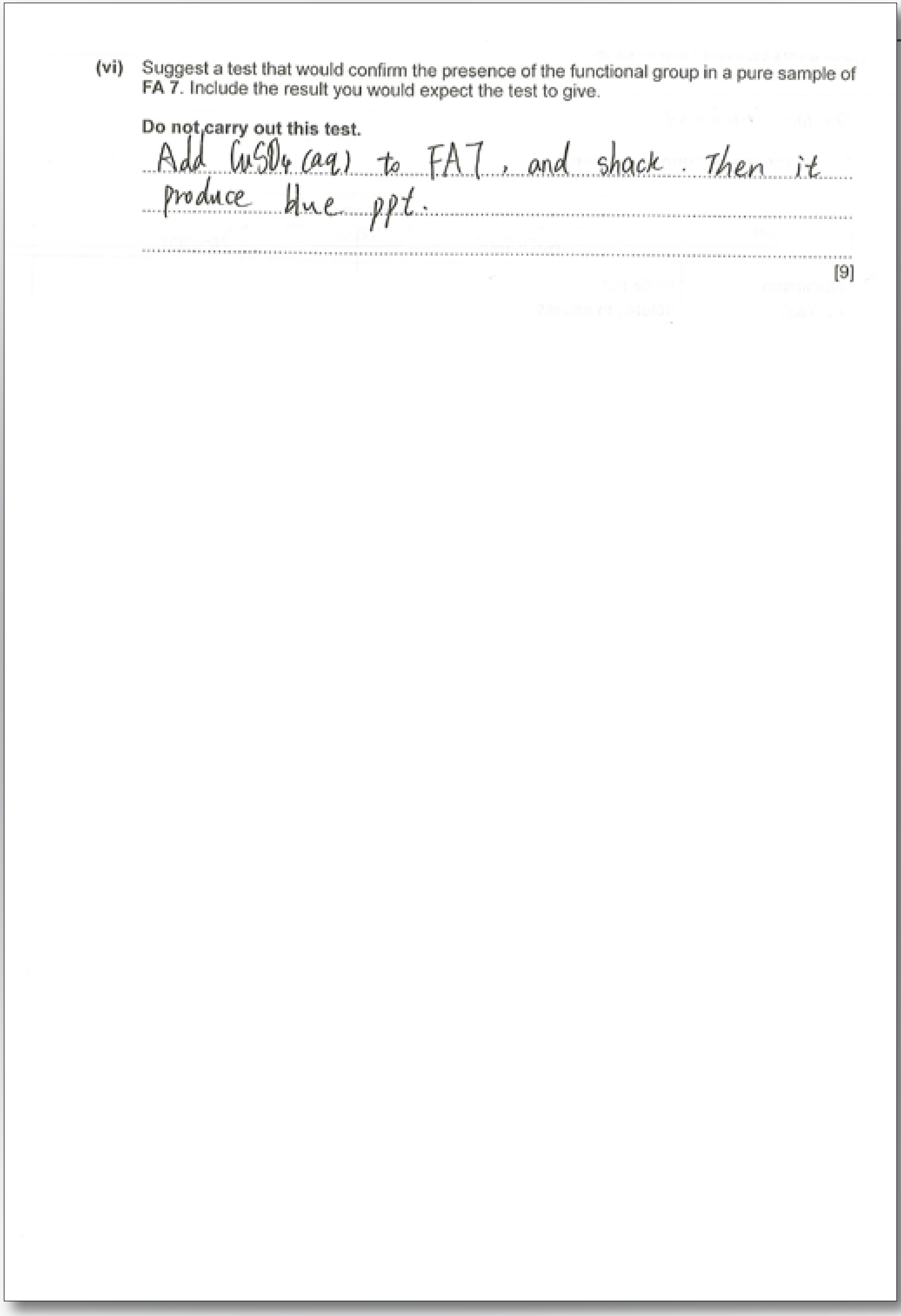
(a)(iii) (–)CHO / aldehyde / alkanal
or
alkene / C=C **[1]**

(a)(iv) Oxidation of organic compound / reduction of MnO_4^-/ redox
or
if alkene in (iii) then electrophilic addition **[1]**

(a)(v) (–)OH / (1° / 2°) alcohol / alkanol / hydroxy
or
alkene / C=C **[1]**

(a)(vi) transport / transporter / carrier, protein ; R pump protein
Add Na to give effervescence / hydrogen / gas which pops with lighted splint, **or**
Add PCl_5 / $SOCl_2$ to give misty fumes / steamy fumes / HCl , or Add carboxylic acid AND (conc) sulfuric acid to produce fruity / sweet smell
or
if alkene in (**v**) Br_2 decolourised / brown to colourless **[1]**

[Total: 9]



(vi) Suggest a test that would confirm the presence of the functional group in a pure sample of FA 7. Include the result you would expect the test to give.

Do not carry out this test.

Add $CuSO_4$ (aq) to FA7, and shack. Then it produce blue ppt.

[9]

Select page

HIGH MIDDLE LOW

Your Mark

3(a)(i) ☐

3(a)(ii) ☐

3(a)(iii) ☐

3(a)(iv) ☐

3(a)(v) ☐

3(a)(vi) ☐

Q3 Mark scheme

(a)(i)

FA 5	FA 6	FA 7	FA 8
Fizz / bubbles / effervescence	Fizz / bubbles / effervescence	no change	no change
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[4]

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(a)(iii)	(–)CHO / aldehyde / alkanal **or** alkene / C=C	**[1]**
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(a)(vi)	transport / transporter / carrier, protein ; R pump protein Add Na to give effervescence / hydrogen / gas which pops with lighted splint, **or** Add PCl_5 / $SOCl_2$ to give misty fumes / steamy fumes / HCl, or Add carboxylic acid AND (conc) sulfuric acid to produce fruity / sweet smell **or** if alkene in (**v**) Br_2 decolourised / brown to colourless	**[1]** **[Total: 9]**

EXAMINER COMMENTS

MARK SCHEME

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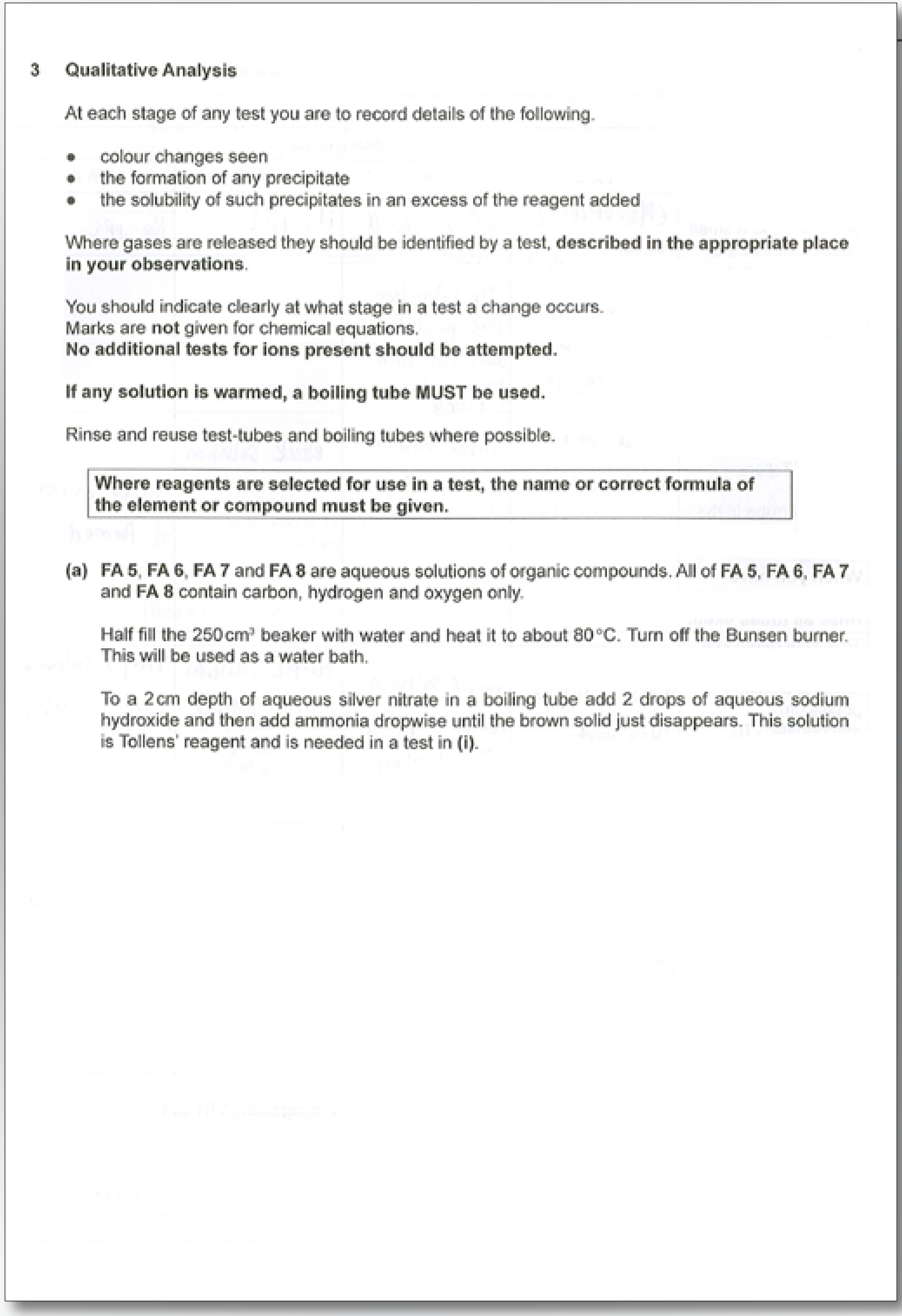

3 **Qualitative Analysis**

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.
Marks are **not** given for chemical equations.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.

Rinse and reuse test-tubes and boiling tubes where possible.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

(a) FA 5, FA 6, FA 7 and FA 8 are aqueous solutions of organic compounds. All of FA 5, FA 6, FA 7 and FA 8 contain carbon, hydrogen and oxygen only.

Half fill the 250 cm³ beaker with water and heat it to about 80 °C. Turn off the Bunsen burner. This will be used as a water bath.

To a 2 cm depth of aqueous silver nitrate in a boiling tube add 2 drops of aqueous sodium hydroxide and then add ammonia dropwise until the brown solid just disappears. This solution is Tollens' reagent and is needed in a test in (**i**).

Your Mark

3(a)(i)

3(a)(ii)

3(a)(iii)

3(a)(iv)

3(a)(v)

3(a)(vi)

Q3 **Mark scheme**

(a)(i)

FA 5	**FA 6**	**FA 7**	**FA 8**
Fizz / bubbles / effervescence	Fizz / bubbles / effervescence	no change	no change
Gas turns limewater milky / cloudy white / white ppt / chalky	Gas turns limewater milky / cloudy white / white ppt / chalky	No reaction/no change	No reaction/no change
Silver / black / dark grey and mirror / solid / ppt	No reaction / no change / no silver mirror	No reaction / no change / no silver mirror	Silver / black / dark grey **and** mirror / solid / ppt
Purple to colourless or solution / MnO_4^- / manganate (VII) decolourised/ disappeared	No reaction or remains / turns purple or pink	Purple to colourless or solution / MnO_4^-/ manganate(VII) decolourised / disappeared	Purple to colourless or solution / MnO_4^-/ manganate (VII) decolourised / disappeared

[4]

(a)(ii)	(–)CO_2H / carboxylic acid	**[1]**
(a)(iii)	(–)CHO / aldehyde / alkanal **or** alkene / C=C	**[1]**
(a)(iv)	Oxidation of organic compound / reduction of MnO_4^-/ redox **or** if alkene in (iii) then electrophilic addition	**[1]**
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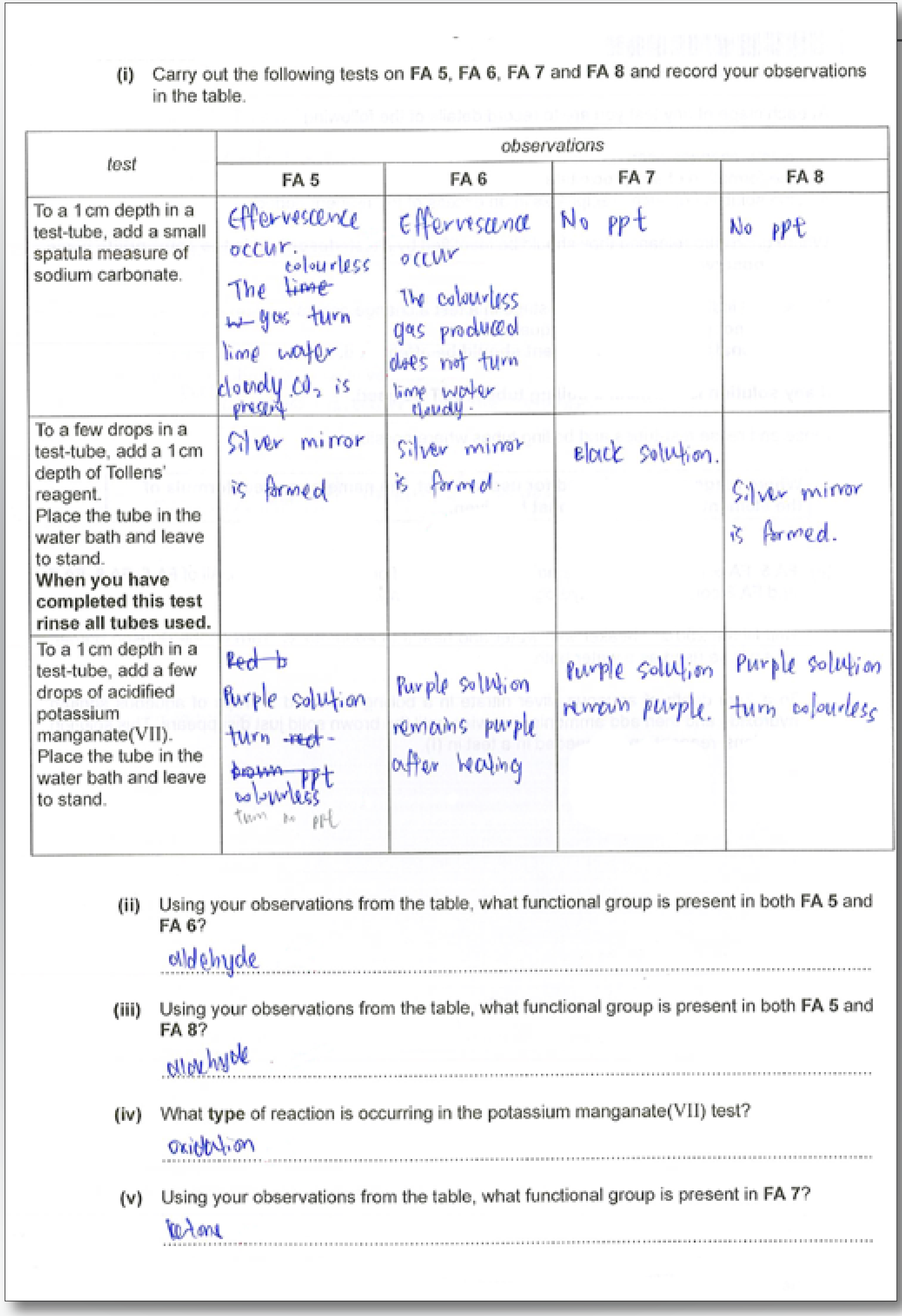
(a)(vi)	transport / transporter / carrier, protein ; R pump protein Add Na to give effervescence / hydrogen / gas which pops with lighted splint, **or** Add PCl_5 / $SOCl_2$ to give misty fumes / steamy fumes / HCl , or Add carboxylic acid AND (conc) sulfuric acid to produce fruity / sweet smell **or** if alkene in (**v**) Br_2 decolourised / brown to colourless	**[1]** **[Total: 9]**

EXAMINER COMMENTS

MARK SCHEME



(i) Carry out the following tests on **FA 5**, **FA 6**, **FA 7** and **FA 8** and record your observations in the table.

test	*observations*			
	FA 5	**FA 6**	**FA 7**	**FA 8**
To a 1 cm depth in a test-tube, add a small spatula measure of sodium carbonate.	Effervescence occur. The ~~lime~~ colourless ~~w~~ gas turn lime water cloudy. CO_2 is present	Effervescence occur The colourless gas produced does not turn lime water cloudy.	No ppt	No ppt
To a few drops in a test-tube, add a 1 cm depth of Tollens' reagent. Place the tube in the water bath and leave to stand. **When you have completed this test rinse all tubes used.**	Silver mirror is formed	Silver mirror is formed.	Black solution.	Silver mirror is formed.
To a 1 cm depth in a test-tube, add a few drops of acidified potassium manganate(VII). Place the tube in the water bath and leave to stand.	~~Red b~~ Purple solution turn ~~red~~ ~~brown~~ ppt colourless turn to ppt	Purple solution remains purple after heating	Purple solution remain purple.	Purple solution turn colourless

(ii) Using your observations from the table, what functional group is present in both **FA 5** and **FA 6**?

aldehyde

(iii) Using your observations from the table, what functional group is present in both **FA 5** and **FA 8**?

aldehyde

(iv) What type of reaction is occurring in the potassium manganate(VII) test?

oxidation

(v) Using your observations from the table, what functional group is present in **FA 7**?

ketone

Your Mark

3(a)(i) ☐

3(a)(ii) ☐

3(a)(iii) ☐

3(a)(iv) ☐

3(a)(v) ☐

3(a)(vi) ☐

Q3 Mark scheme

(a)(i)

FA 5	FA 6	FA 7	FA 8
Fizz / bubbles / effervescence	Fizz / bubbles / effervescence	no change	no change
Gas turns limewater milky / cloudy white / white ppt / chalky	Gas turns limewater milky / cloudy white / white ppt / chalky	No reaction/no change	No reaction/no change
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Purple to colourless or solution / MnO_4^- / manganate (VII) decolourised/ disappeared	No reaction **or** remains / turns purple or pink	Purple to colourless or solution / MnO_4^-/ manganate(VII) decolourised / disappeared	Purple to colourless or solution / MnO_4^-/ manganate (VII) decolourised / disappeared

[4]

(a)(ii)	(–)CO_2H / carboxylic acid	**[1]**
(a)(iii)	(–)CHO / aldehyde / alkanal **or** alkene / C=C	**[1]**
(a)(iv)	Oxidation of organic compound / reduction of MnO_4^-/ redox **or** if alkene in (iii) then electrophilic addition	**[1]**
(a)(v)	(–)OH / (1° / 2°) alcohol / alkanol / hydroxy **or** alkene / C=C	**[1]**
(a)(vi)	transport / transporter / carrier, protein ; R pump protein Add Na to give effervescence / hydrogen / gas which pops with lighted splint, **or** Add PCl_5 / $SOCl_2$ to give misty fumes / steamy fumes / HCl, or Add carboxylic acid AND (conc) sulfuric acid to produce fruity / sweet smell **or** if alkene in (**v**) Br_2 decolourised / brown to colourless	**[1]** **[Total: 9]**

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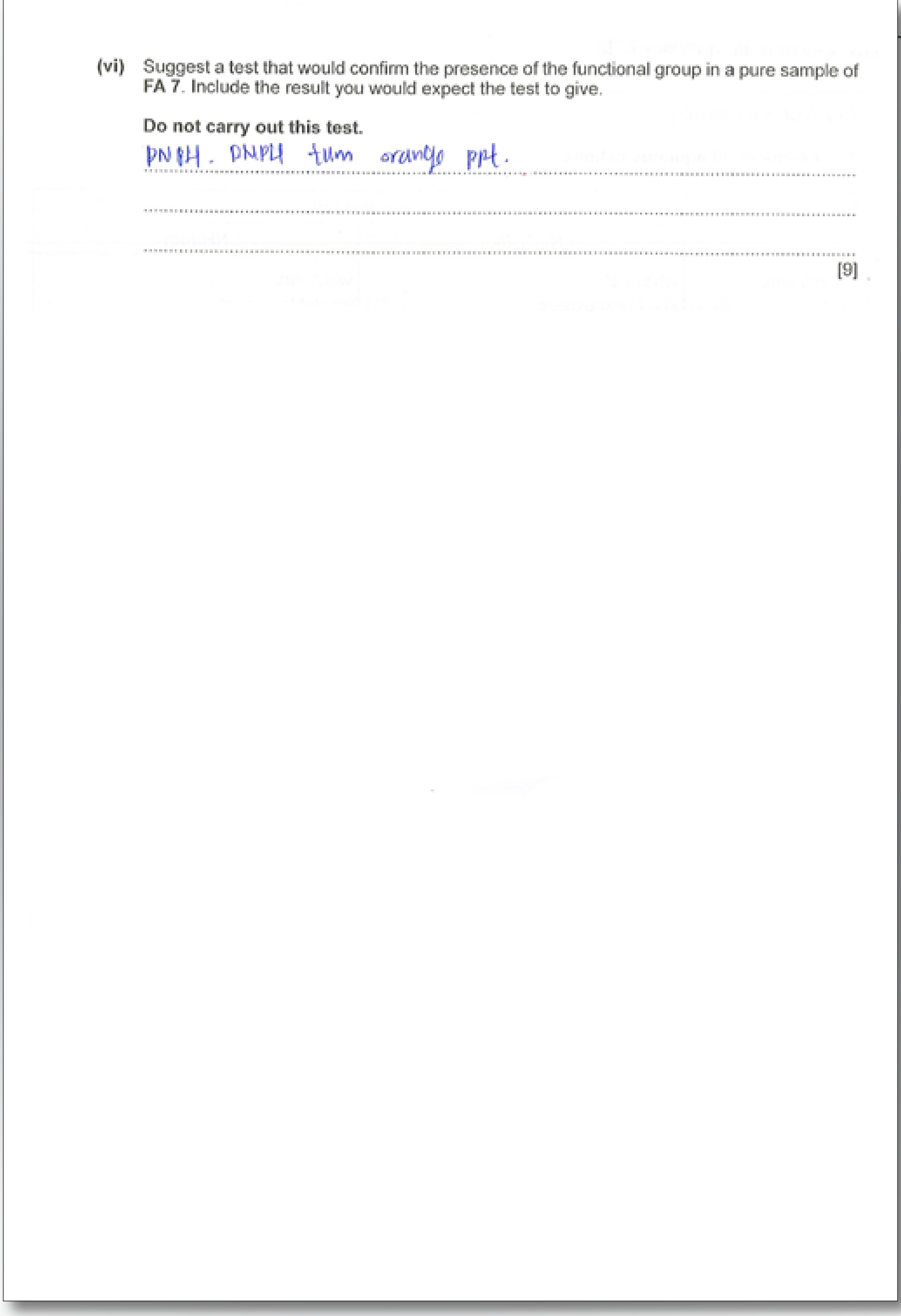

(vi) Suggest a test that would confirm the presence of the functional group in a pure sample of FA 7. Include the result you would expect the test to give.

Do not carry out this test.

DNPH. DNPH turn orange ppt.

[9]

Your Mark

3(a)(i) ☐

3(a)(ii) ☐

3(a)(iii) ☐

3(a)(iv) ☐

3(a)(v) ☐

3(a)(vi) ☐

Q3 **Mark scheme**

(a)(i)

FA 5	FA 6	FA 7	FA 8
Fizz / bubbles / effervescence	Fizz / bubbles / effervescence	no change	no change
Gas turns limewater milky / cloudy white / white ppt / chalky	Gas turns limewater milky / cloudy white / white ppt / chalky	No reaction/no change	No reaction/no change
Silver / black / dark grey and mirror / solid / ppt	No reaction / no change / no silver mirror	No reaction / no change / no silver mirror	Silver / black / dark grey **and** mirror / solid / ppt
Purple to colourless or solution / MnO_4^- / manganate (VII) decolourised/ disappeared	No reaction or remains / turns purple or pink	Purple to colourless or solution / MnO_4^-/ manganate(VII) decolourised / disappeared	Purple to colourless or solution / MnO_4^-/ manganate (VII) decolourised / disappeared

[4]

(a)(ii)	(–)CO_2H / carboxylic acid **[1]**
(a)(iii)	(–)CHO / aldehyde / alkanal **or** alkene / C=C **[1]**
(a)(iv)	Oxidation of organic compound / reduction of MnO_4^-/ redox **or** if alkene in (iii) then electrophilic addition **[1]**
(a)(v)	(–)OH / (1° / 2°) alcohol / alkanol / hydroxy **or** alkene / C=C **[1]**
(a)(vi)	transport / transporter / carrier, protein ; R pump protein Add Na to give effervescence / hydrogen / gas which pops with lighted splint, **or** Add PCl_5 / $SOCl_2$ to give misty fumes / steamy fumes / HCl , or Add carboxylic acid AND (conc) sulfuric acid to produce fruity / sweet smell **or** if alkene in (**v**) Br_2 decolourised / brown to colourless **[1]** **[Total: 9]**

EXAMINER COMMENTS

MARK SCHEME

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Interactive Example Candidate Responses
Paper 42 (May/June 2016), Question 1

Cambridge International AS & A Level
Chemistry 9701

Version 1.0

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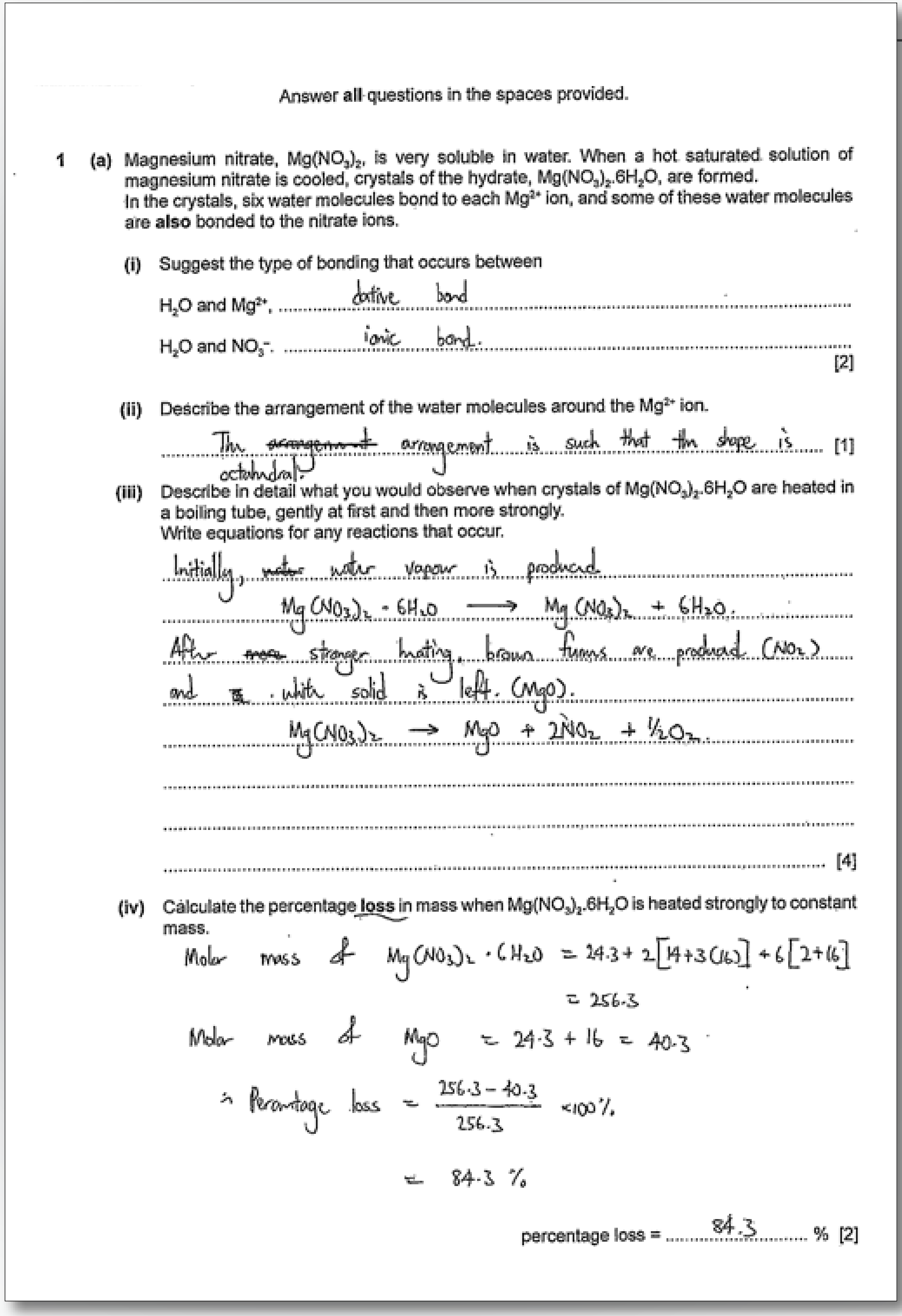

Answer **all** questions in the spaces provided.

1 (a) Magnesium nitrate, $Mg(NO_3)_2$, is very soluble in water. When a hot saturated solution of magnesium nitrate is cooled, crystals of the hydrate, $Mg(NO_3)_2.6H_2O$, are formed. In the crystals, six water molecules bond to each Mg^{2+} ion, and some of these water molecules are **also** bonded to the nitrate ions.

(i) Suggest the type of bonding that occurs between

H_2O and Mg^{2+}, dative bond

H_2O and NO_3^-. ionic bond. [2]

(ii) Describe the arrangement of the water molecules around the Mg^{2+} ion.

The ~~arrangement~~ arrangement is such that the shape is octahedral. [1]

(iii) Describe in detail what you would observe when crystals of $Mg(NO_3)_2.6H_2O$ are heated in a boiling tube, gently at first and then more strongly.
Write equations for any reactions that occur.

Initially, ~~water~~ water vapour is produced

$Mg(NO_3)_2 \cdot 6H_2O \longrightarrow Mg(NO_3)_2 + 6H_2O.$

After ~~more~~ stronger heating, brown fumes are produced (NO₂) and ~~a~~ white solid is left. (MgO).

$Mg(NO_3)_2 \longrightarrow MgO + 2NO_2 + \frac{1}{2}O_2.$

[4]

(iv) Calculate the percentage **loss** in mass when $Mg(NO_3)_2.6H_2O$ is heated strongly to constant mass.

Molar mass of $Mg(NO_3)_2 \cdot 6H_2O = 24.3 + 2[14+3(16)] + 6[2+16]$

$= 256.3$

Molar mass of $MgO = 24.3 + 16 = 40.3$

$\therefore$ Percentage loss $= \frac{256.3 - 40.3}{256.3} \times 100\%$

$= 84.3\ \%$

percentage loss = 84.3 % [2]

Select page

HIGH

MIDDLE

LOW

Your Mark

1(a)(i) ☐

1(a)(ii) ☐

1(a)(iii) ☐

1(a)(iv) ☐

1(b) ☐

1(c) ☐

Q1	Mark scheme	
(a)(I)	dative (covalent) or coordinate Hydrogen / H (boding)	[2]
(a)(ii)	octahedral	[1]
(a)(iii)	$Mg(NO_3)_2.6H_2O$ → Mg(NO3)2 + 6H2O $Mg(NO_3)_2$ → $MgO + 2NO_2 + ½\ O_2$ *any three of* (solid) dissolves / turns to liquid condensation on tube white solid (forms / remains) brown fumes (evolved) gas formed that relights a glowing splint	[4]
(a)(iv)	M_r values: $Mg(NO_3)_2.6H_2O$ = 256.3 MgO = 40.3 **or** (loss in molar mass = 256.3 – 40.3 =) 216 percentage loss = 100 × 216 / 256.3 = **84.3 / 84.4**%	[2]
(b)	cat)-ionic radius / ion size increases (down the group) less polarisation / distortion of nitrate ion / NO_3^-	[2]
(c)	$2AgNO_3 \rightarrow 2Ag + 2NO_2 + O_2$	[1] [Total: 12]

EXAMINER COMMENTS

MARK SCHEME

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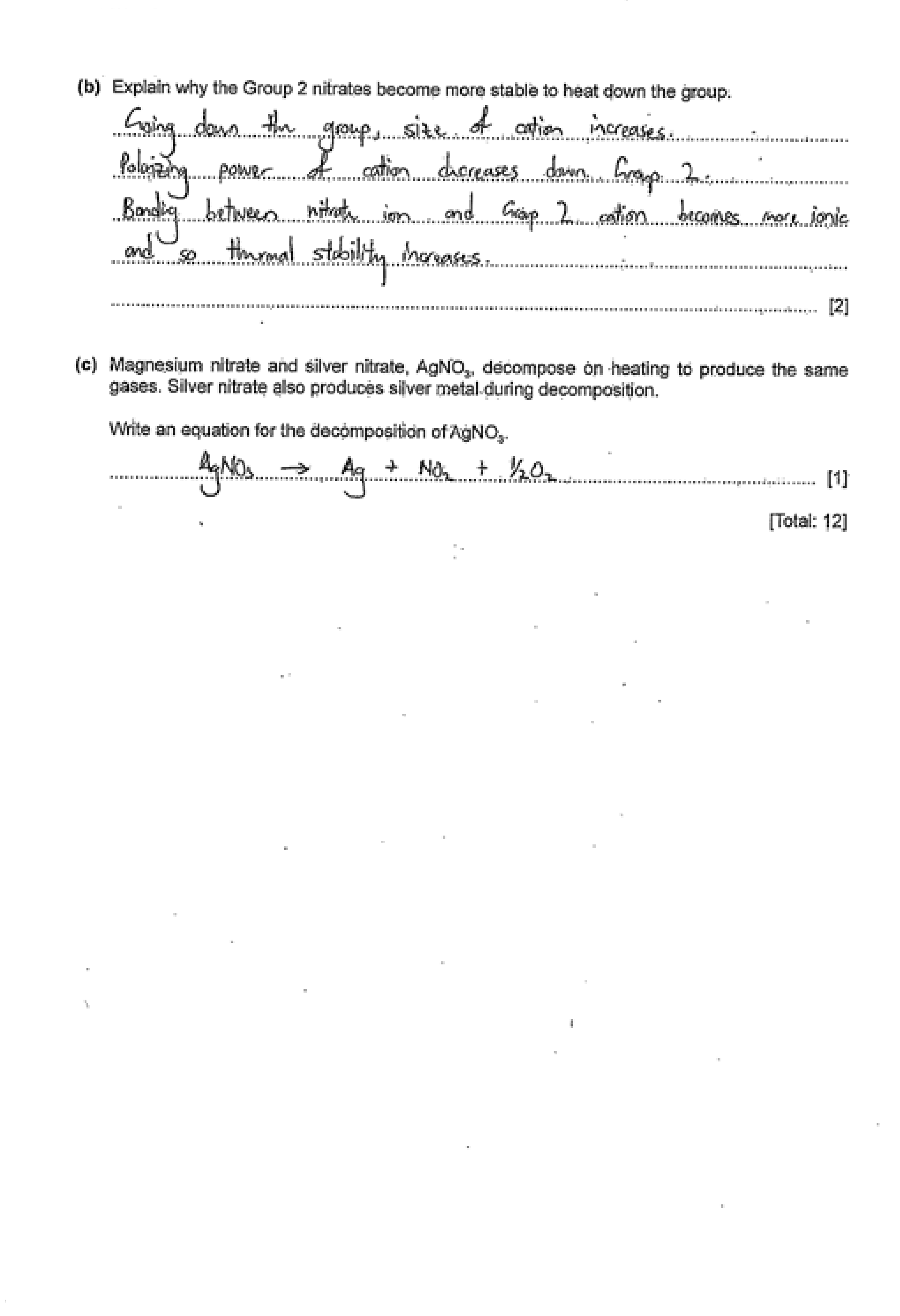
HIGH MIDDLE LOW



(b) Explain why the Group 2 nitrates become more stable to heat down the group.

Going down the group, size of cation increases.
Polarizing power of cation decreases down Group 2.
Bonding between nitrate ion and Group 2 cation becomes more ionic
and so thermal stability increases.
[2]

(c) Magnesium nitrate and silver nitrate, $AgNO_3$, decompose on heating to produce the same gases. Silver nitrate also produces silver metal during decomposition.

Write an equation for the decomposition of $AgNO_3$.

$AgNO_3 \rightarrow Ag + NO_2 + \frac{1}{2}O_2$ [1]

[Total: 12]

Your Mark

1(a)(i) ☐

1(a)(ii) ☐

1(a)(iii) ☐

1(a)(iv) ☐

1(b) ☐

1(c) ☐

Q1	Mark scheme
(a)(I)	dative (covalent) or coordinate Hydrogen / H (boding) **[2]**
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(a)(iii)	$\mathrm{Mg(NO_3)_2.6H_2O \rightarrow Mg(NO3)2 + 6H2O}$ $\mathrm{Mg(NO_3)_2 \rightarrow MgO + 2NO_2 + \frac{1}{2}\,O_2}$ *any three of* (solid) dissolves / turns to liquid condensation on tube white solid (forms / remains) brown fumes (evolved) gas formed that relights a glowing splint **[4]**
(a)(iv)	M_r values: $\mathrm{Mg(NO_3)_2.6H_2O}$ = 256.3 MgO = 40.3 **or** (loss in molar mass = 256.3 – 40.3 =) 216 percentage loss = 100 × 216 / 256.3 = **84.3 / 84.4**% **[2]**
(b)	cat)-ionic radius / ion size increases (down the group) less polarisation / distortion of nitrate ion / NO_3^- **[2]**
(c)	$\mathrm{2AgNO_3 \rightarrow 2Ag + 2NO_2 + O_2}$ **[1]** **[Total: 12]**

EXAMINER COMMENTS

MARK SCHEME

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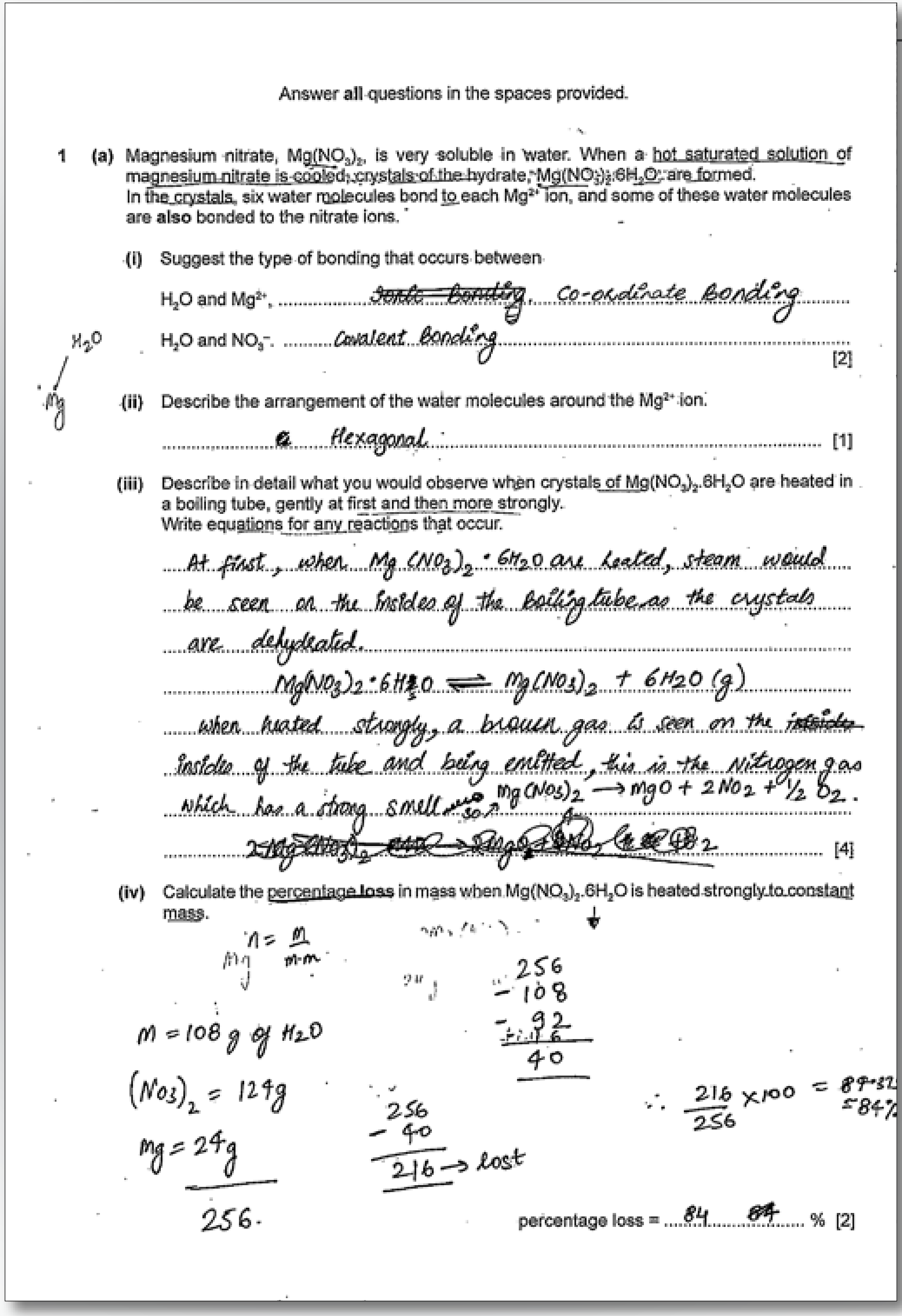

Answer all questions in the spaces provided.

1 (a) Magnesium nitrate, $Mg(NO_3)_2$, is very soluble in water. When a hot saturated solution of magnesium nitrate is cooled, crystals of the hydrate, $Mg(NO_3)_2.6H_2O$, are formed.
In the crystals, six water molecules bond to each Mg^{2+} ion, and some of these water molecules are also bonded to the nitrate ions.

(i) Suggest the type of bonding that occurs between

H_2O and Mg^{2+}, ~~Ionic Bonding~~, Co-ordinate Bonding

H_2O and NO_3^-. Covalent Bonding [2]

H_2O
/
Mg

(ii) Describe the arrangement of the water molecules around the Mg^{2+} ion.

~~a~~ Hexagonal [1]

(iii) Describe in detail what you would observe when crystals of $Mg(NO_3)_2.6H_2O$ are heated in a boiling tube, gently at first and then more strongly.
Write equations for any reactions that occur.

At first, when $Mg(NO_3)_2 \cdot 6H_2O$ are heated, steam would be seen on the insides of the boiling tube as the crystals are dehydrated.

$Mg(NO_3)_2 \cdot 6H_2O \rightleftharpoons Mg(NO_3)_2 + 6H_2O (g)$

when heated strongly, a brown gas is seen on the ~~insides~~ insides of the tube and being emitted, this is the Nitrogen gas which has a strong smell.

$Mg(NO_3)_2 \longrightarrow MgO + 2NO_2 + \frac{1}{2} O_2$.

~~[illegible]~~ [4]

(iv) Calculate the percentage loss in mass when $Mg(NO_3)_2.6H_2O$ is heated strongly to constant mass.

$n = \frac{m}{m.m}$

$M = 108g$ of H_2O

$(NO_3)_2 = 124g$

$Mg = 24g$

256.

$$\begin{array}{r} 256 \\ -108 \\ -92 \\ \hline 40 \\ \hline \end{array}$$

$$\begin{array}{r} 256 \\ -40 \\ \hline 216 \end{array} \rightarrow \text{lost}$$

$\therefore \frac{216}{256} \times 100 = 84.37$
$\approx 84\%$

percentage loss = 84 84 % [2]

Your Mark

1(a)(i) ☐

1(a)(ii) ☐

1(a)(iii) ☐

1(a)(iv) ☐

1(b) ☐

1(c) ☐

Q1	Mark scheme
(a)(I)	dative (covalent) or coordinate Hydrogen / H (boding) [2]
(a)(ii)	octahedral [1]
(a)(iii)	$Mg(NO_3)_2.6H_2O \rightarrow Mg(NO3)2 + 6H2O$ $Mg(NO_3)_2 \rightarrow MgO + 2NO_2 + ½ O_2$ *any three of* (solid) dissolves / turns to liquid condensation on tube white solid (forms / remains) brown fumes (evolved) gas formed that relights a glowing splint [4]
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(b)	cat)-ionic radius / ion size increases (down the group) less polarisation / distortion of nitrate ion / NO_3^- [2]
(c)	$2AgNO_3 \rightarrow 2Ag + 2NO_2 + O_2$ [1] **[Total: 12]**

EXAMINER COMMENTS

MARK SCHEME

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MIDDLE

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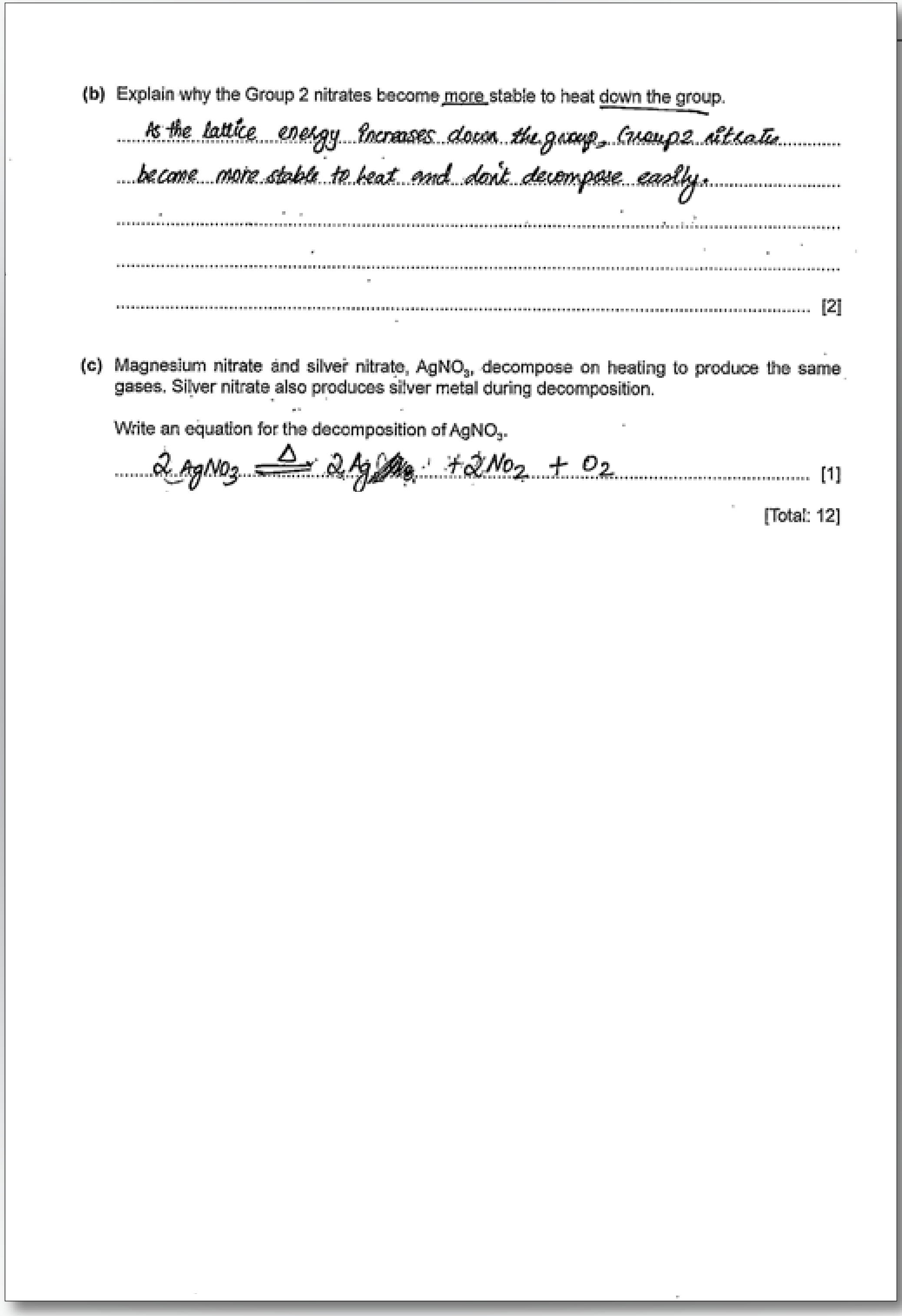

(b) Explain why the Group 2 nitrates become <u>more</u> stable to heat <u>down the group</u>.

As the lattice energy increases down the group, Group2 nitrate become more stable to heat and don't decompose easily.

[2]

(c) Magnesium nitrate and silver nitrate, $AgNO_3$, decompose on heating to produce the same gases. Silver nitrate also produces silver metal during decomposition.

Write an equation for the decomposition of $AgNO_3$.

$2AgNo_3 \xrightarrow{\Delta} 2Ag + 2No_2 + O_2$

[1]

[Total: 12]

Your Mark

1(a)(i) ☐

1(a)(ii) ☐

1(a)(iii) ☐

1(a)(iv) ☐

1(b) ☐

1(c) ☐

Q1	Mark scheme
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(c)	$2AgNO_3 \rightarrow 2Ag + 2NO_2 + O_2$ **[1]** **[Total: 12]**

EXAMINER COMMENTS

MARK SCHEME

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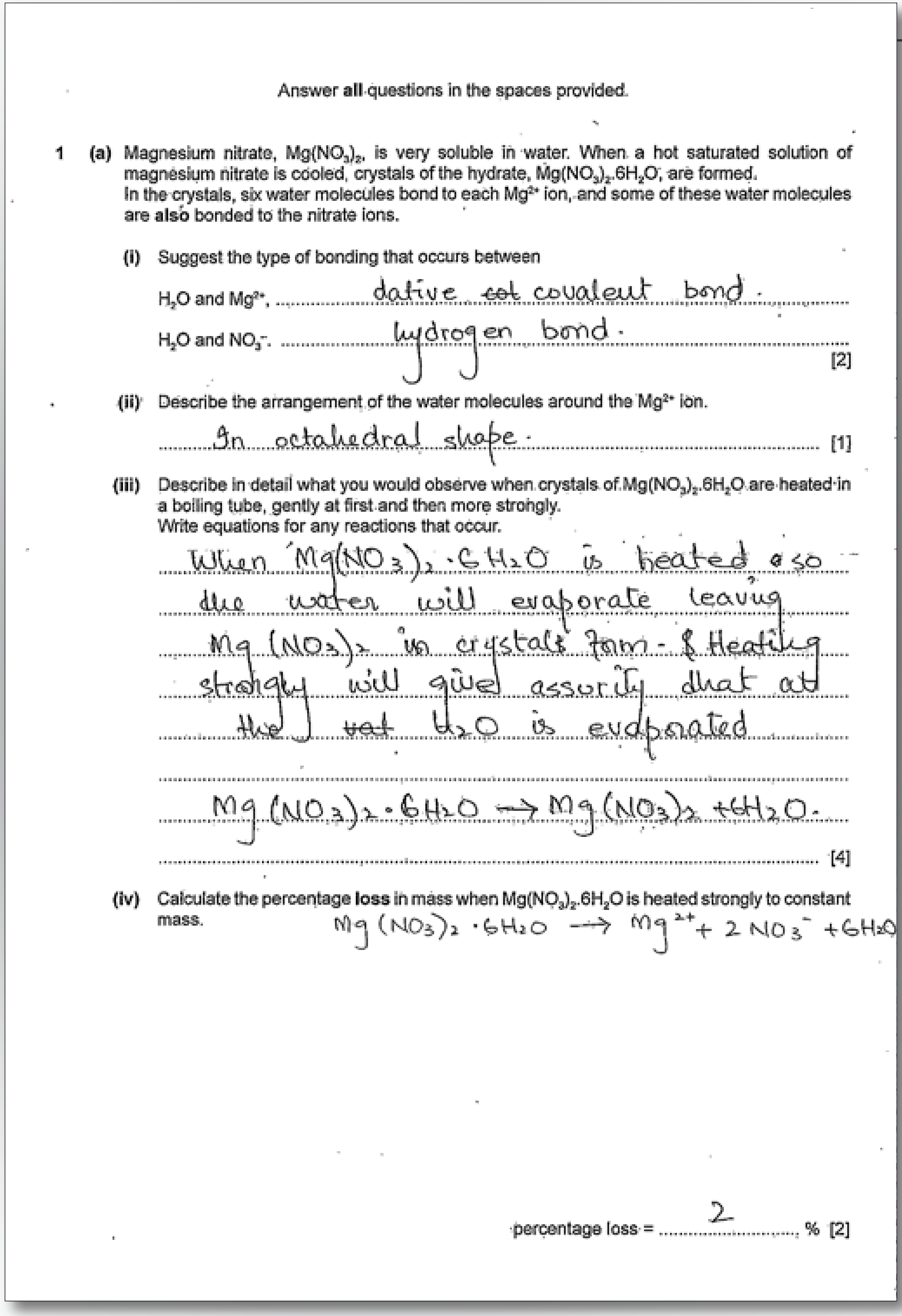

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(i) Suggest the type of bonding that occurs between

H_2O and Mg^{2+}, dative ~~cot~~ covalent bond.

H_2O and NO_3^-. hydrogen bond. [2]

(ii) Describe the arrangement of the water molecules around the Mg^{2+} ion.

In octahedral shape. [1]

(iii) Describe in detail what you would observe when crystals of $Mg(NO_3)_2.6H_2O$ are heated in a boiling tube, gently at first and then more strongly.
Write equations for any reactions that occur.

When $Mg(NO_3)_2 \cdot 6H_2O$ is heated, so the water will evaporate leaving $Mg(NO_3)_2$ in crystals form - & Heating strongly will give assurity that all the ~~wat~~ H_2O is evaporated

$Mg(NO_3)_2 \cdot 6H_2O \rightarrow Mg(NO_3)_2 + 6H_2O$.

[4]

(iv) Calculate the percentage loss in mass when $Mg(NO_3)_2.6H_2O$ is heated strongly to constant mass.

$Mg(NO_3)_2 \cdot 6H_2O \rightarrow Mg^{2+} + 2NO_3^- + 6H_2O$

percentage loss = 2 % [2]

Your Mark

1(a)(i) ☐

1(a)(ii) ☐

1(a)(iii) ☐

1(a)(iv) ☐

1(b) ☐

1(c) ☐

Q1	Mark scheme	
(a)(I)	dative (covalent) or coordinate Hydrogen / H (boding)	[2]
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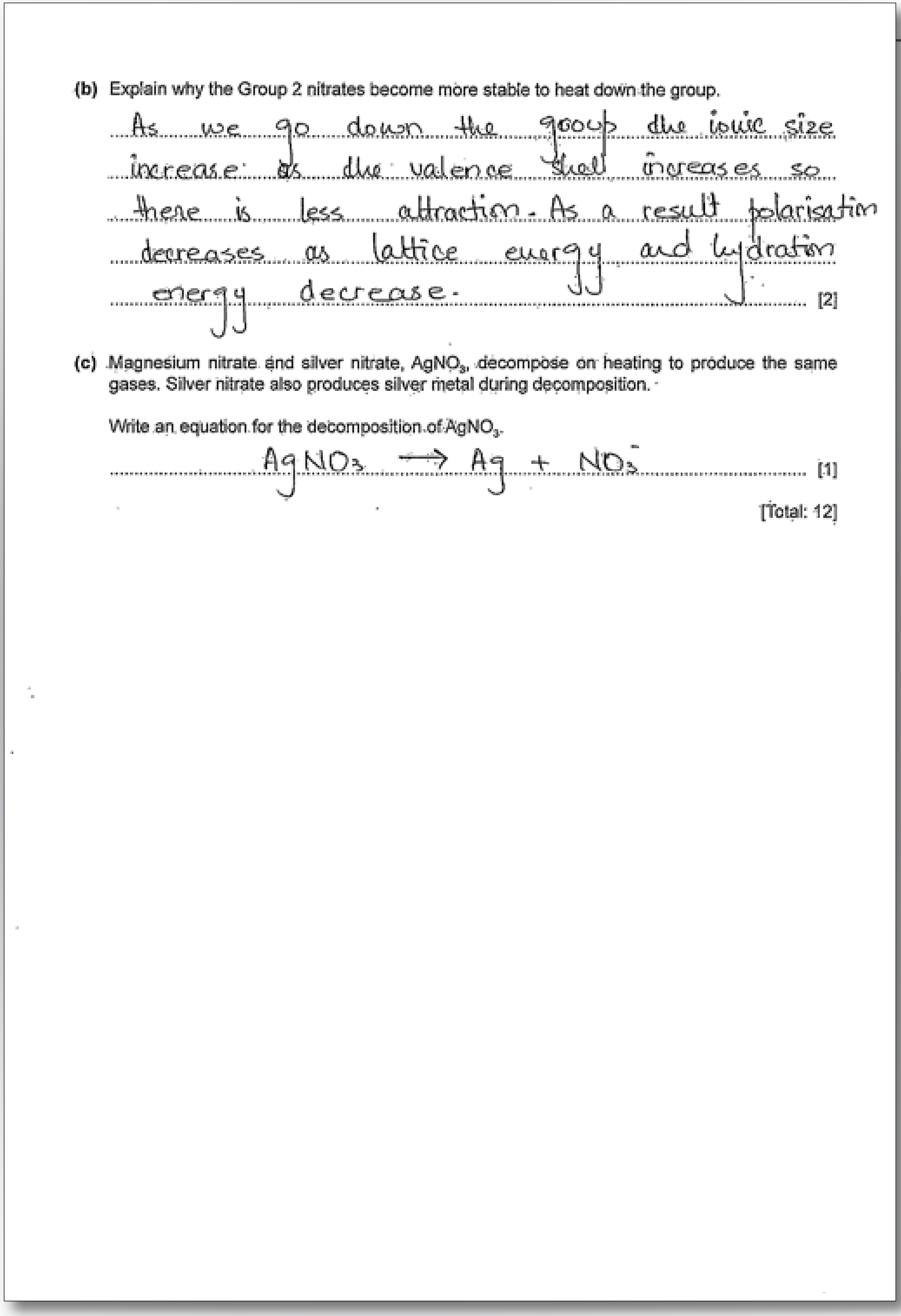
(b)	cat)-ionic radius / ion size increases (down the group) less polarisation / distortion of nitrate ion / NO_3^-	[2]
(c)	$2AgNO_3 \rightarrow 2Ag + 2NO_2 + O_2$	[1] [Total: 12]

EXAMINER COMMENTS

MARK SCHEME



(b) Explain why the Group 2 nitrates become more stable to heat down the group.

As we go down the group the ionic size increase: as the valence shell increases so there is less attraction. As a result polarisation decreases as lattice energy and hydration energy decrease. [2]

(c) Magnesium nitrate and silver nitrate, $AgNO_3$, decompose on heating to produce the same gases. Silver nitrate also produces silver metal during decomposition.

Write an equation for the decomposition of $AgNO_3$.

$AgNO_3 \rightarrow Ag + NO_3^-$ [1]

[Total: 12]

Your Mark

1(a)(i) ☐

1(a)(ii) ☐

1(a)(iii) ☐

1(a)(iv) ☐

1(b) ☐

1(c) ☐

Q1	Mark scheme
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(b)	cat)-ionic radius / ion size increases (down the group) less polarisation / distortion of nitrate ion / NO_3^- **[2]**
(c)	$2AgNO_3 \rightarrow 2Ag + 2NO_2 + O_2$ **[1]** **[Total: 12]**

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Interactive Example Candidate Responses
Paper 42 (May/June 2016), Question 2

Cambridge International AS & A Level
Chemistry 9701

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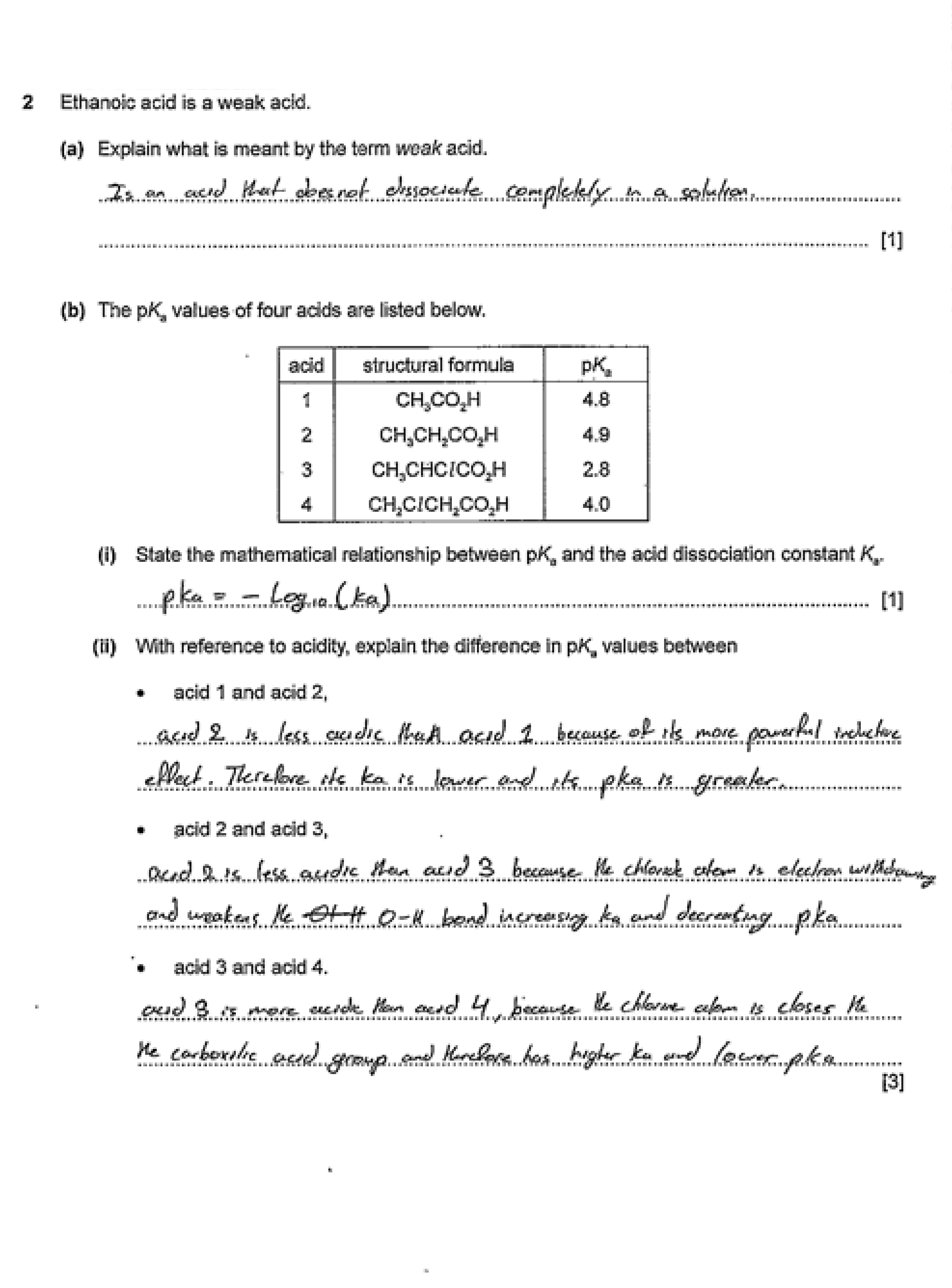


2 Ethanoic acid is a weak acid.

(a) Explain what is meant by the term *weak* acid.

Is an acid that does not dissociate completely in a solution. [1]

(b) The pK_a values of four acids are listed below.

acid	structural formula	pK_a
1	CH_3CO_2H	4.8
2	$CH_3CH_2CO_2H$	4.9
3	$CH_3CHClCO_2H$	2.8
4	$CH_2ClCH_2CO_2H$	4.0

(i) State the mathematical relationship between pK_a and the acid dissociation constant K_a.

pka = − Log₁₀ (ka) [1]

(ii) With reference to acidity, explain the difference in pK_a values between

- acid 1 and acid 2,

acid 2 is less acidic than acid 1 because of its more powerful inductive effect. Therefore its ka is lower and its pka is greater.

- acid 2 and acid 3,

acid 2 is less acidic than acid 3 because the chloride atom is electron withdrawing and weakens the ~~O-H~~ O-H bond increasing ka and decreasing pka

- acid 3 and acid 4.

acid 3 is more acidic than acid 4, because the chlorine atom is closes the the carboxilic acid group and therefore has higher ka and lower pka [3]

Your Mark

2(a) ☐

2(b)(i) ☐

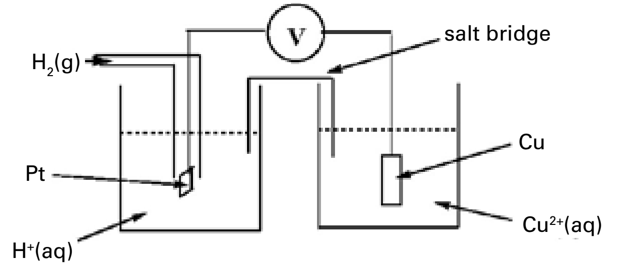
2(b)(ii) ☐

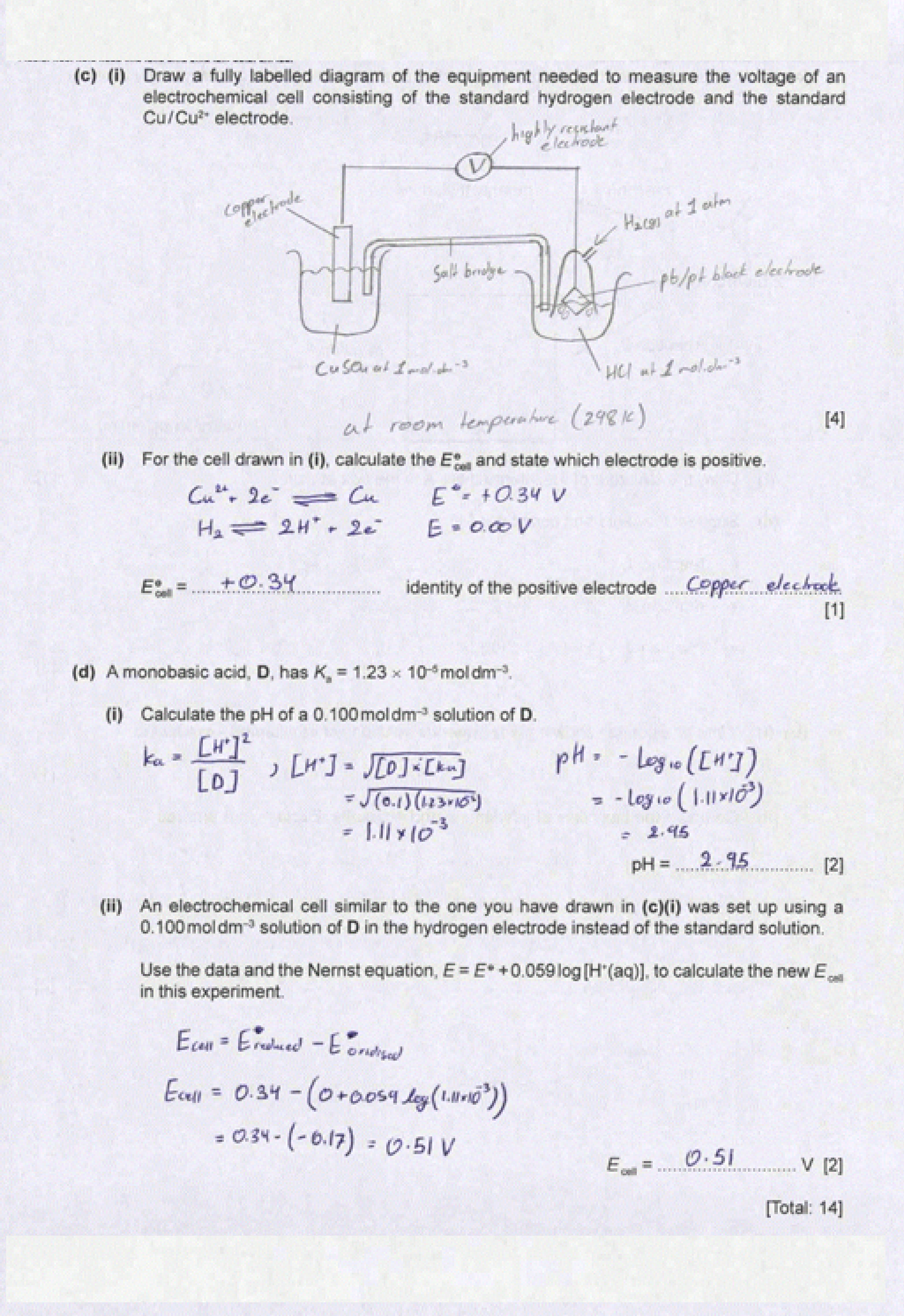
2(c)(i) ☐

2(c)(ii) ☐

2(d)(i) ☐

2(d)(ii) ☐

Q2	Mark scheme
(a)	(an acid that is) partially / incompletely ionised / dissociated **[1]**
(b)(i)	pK_a = −logK_a or $K_a = 10^{-pKa}$ **[1]**
(b)(ii)	ethanoic acid (1) is **more acidic** than propanoic acid (2) due to smaller electron-donating (R / alkyl) group / less electron-donating (R / alkyl) group(s) 2-chloropropanoic acid (3) is more acidic than propanoic acid (2) due to electron-withdrawing / electronegative (C*l* / chlorine) atom 2-chloropropanoic acid (3) is more acidic than 3¬-chloropropanoic acid (4) since the C*l* / chlorine / electronegative atom is closer to the CO_2^-/ acid **[3]**
(c)(i)	 M1: voltmeter / V **and** salt bridge labelled M2: Cu and Cu^{2+}/ $CuSO_4$ (any soluble Cu(II) salt) M3: H_2 (arrow in) **and** H^+/ HC*l* / H_2SO_4 / any mineral acid M4 Pt **and** one solution at 1 M / 1 mol dm^{-3} OR H_2 at 1 atm **[4]**
(c)(ii)	E°cell = 0.34 (V) **and** (Cu^{2+}) / Cu is the positive electrode **[3]**
(d)(i)	$K_a = 1.23 \times 10^{-5}$ $[H^+] = \sqrt{(K_a.c)} = \sqrt{(1.23 \times 10^{-5} \times 0.1)} = 1.11 \times 10^{-3}$ mol dm^{-3} pH = **3.0 (2.96)** ecf from [H⁺] **[1]**
(d)(ii)	$E = 0.0 + 0.059\log(1.11 \times 10^{-3})$ OR = −0.17(4)V so new E_{cell} = 0.34 + 0.17 = **0.51V** ecf from (d)(i) **[2]** **[Total: 14]**



(c) (i) Draw a fully labelled diagram of the equipment needed to measure the voltage of an electrochemical cell consisting of the standard hydrogen electrode and the standard Cu/Cu^{2+} electrode.

at room temperature (298 K) [4]

(ii) For the cell drawn in **(i)**, calculate the E°_{cell} and state which electrode is positive.

$Cu^{2+} + 2e^- \rightleftharpoons Cu \quad E^\circ = +0.34\ V$

$H_2 \rightleftharpoons 2H^+ + 2e^- \quad E = 0.00\ V$

E°_{cell} = +0.34 identity of the positive electrode Copper electrode

[1]

(d) A monobasic acid, **D**, has $K_a = 1.23 \times 10^{-5}\ mol\ dm^{-3}$.

(i) Calculate the pH of a 0.100 mol dm^{-3} solution of **D**.

$$k_a = \frac{[H^+]^2}{[D]}, \quad [H^+] = \sqrt{[D]\times[k_a]} = \sqrt{(0.1)(1.23\times10^{-5})} = 1.11\times10^{-3}$$

$$pH = -\log_{10}([H^+]) = -\log_{10}(1.11\times10^{-3}) = 2.95$$

pH = 2.95 [2]

(ii) An electrochemical cell similar to the one you have drawn in **(c)(i)** was set up using a 0.100 mol dm^{-3} solution of **D** in the hydrogen electrode instead of the standard solution.

Use the data and the Nernst equation, $E = E^\circ + 0.059\log[H^+(aq)]$, to calculate the new E_{cell} in this experiment.

$$E_{cell} = E^\circ_{reduced} - E^\circ_{oxidised}$$

$$E_{cell} = 0.34 - (0 + 0.059\log(1.11\times10^{-3}))$$

$$= 0.34 - (-0.17) = 0.51\ V$$

E_{cell} = 0.51 V [2]

[Total: 14]

Your Mark

2(a)

2(b)(i)

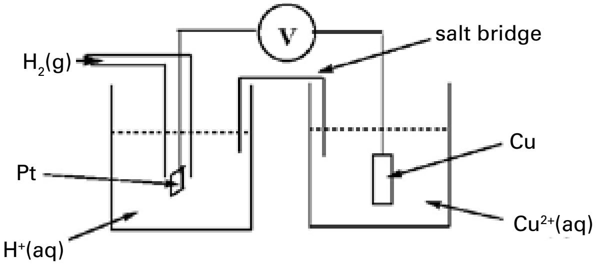
2(b)(ii)

2(c)(i)

2(c)(ii)

2(d)(i)

2(d)(ii)

Q2	Mark scheme
(a)	(an acid that is) partially / incompletely ionised / dissociated **[1]**
(b)(i)	pK_a = –logK_a or K_a = 10^{-pKa} **[1]**
(b)(ii)	ethanoic acid (1) is **more acidic** than propanoic acid (2) due to smaller electron-donating (R / alkyl) group / less electron-donating (R / alkyl) group(s) 2-chloropropanoic acid (3) is more acidic than propanoic acid (2) due to electron-withdrawing / electronegative (C*l* / chlorine) atom 2-chloropropanoic acid (3) is more acidic than 3¬-chloropropanoic acid (4) since the C*l* / chlorine / electronegative atom is closer to the CO_2^-/ acid **[3]**
(c)(i)	 M1: voltmeter / V **and** salt bridge labelled M2: Cu and Cu^{2+}/ $CuSO_4$ (any soluble Cu(II) salt) M3: H_2 (arrow in) **and** H^+/ HC*l* / H_2SO_4 / any mineral acid M4 Pt **and** one solution at 1 M / 1 mol dm^{-3} OR H_2 at 1 atm **[4]**
(c)(ii)	E°cell = 0.34 (V) **and** (Cu^{2+}) / Cu is the positive electrode **[3]**
(d)(i)	K_a = 1.23 × 10^{-5} [H^+] = √(K_a.c) = √(1.23 × 10^{-5} × 0.1) = 1.11 × 10^{-3} mol dm^{-3} pH = **3.0 (2.96)** ecf from [H^+] **[1]**
(d)(ii)	*E* = 0.0 + 0.059log(1.11 × 10^{-3}) OR = –0.17(4)V so new E_{cell} = 0.34 + 0.17 = **0.51V** ecf from (d)(i) **[2]** **[Total: 14]**

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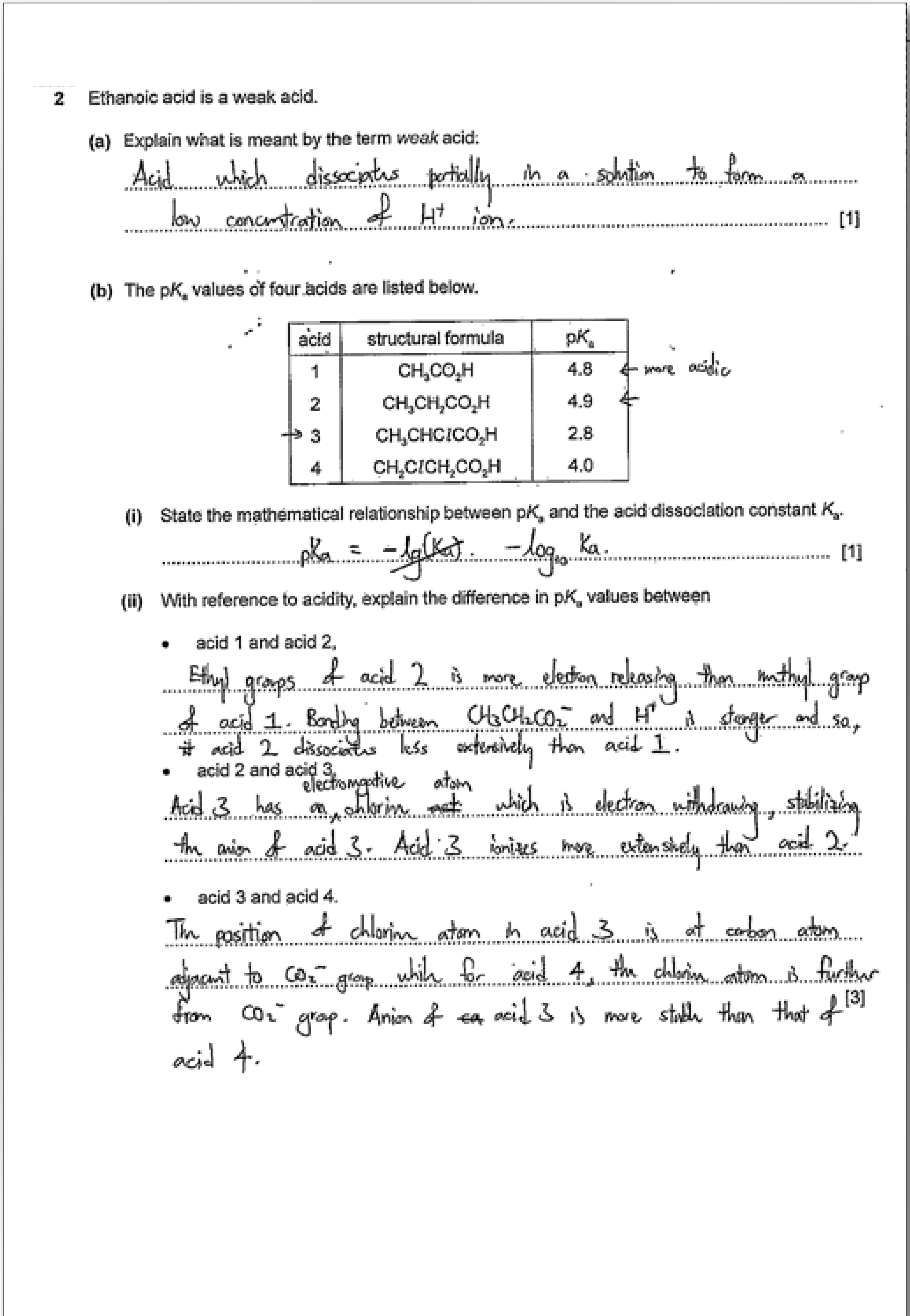


2 Ethanoic acid is a weak acid.

(a) Explain what is meant by the term *weak* acid:

Acid which dissociates partially in a solution to form a low concentration of H^+ ion. [1]

(b) The pK_a values of four acids are listed below.

acid	structural formula	pK_a
1	CH_3CO_2H	4.8 ← more acidic
2	$CH_3CH_2CO_2H$	4.9 ←
→ 3	$CH_3CHClCO_2H$	2.8
4	$CH_2ClCH_2CO_2H$	4.0

(i) State the mathematical relationship between pK_a and the acid dissociation constant K_a.

pKa = ~~−lg(Ka)~~. $-\log_{10}$ Ka. [1]

(ii) With reference to acidity, explain the difference in pK_a values between

- acid 1 and acid 2,

Ethyl groups of acid 2 is more electron releasing than methyl group of acid 1. Bonding between $CH_3CH_2CO_2^-$ and H^+ is stronger and so, ~~#~~ acid 2 dissociates less extensively than acid 1.

- acid 2 and acid 3,

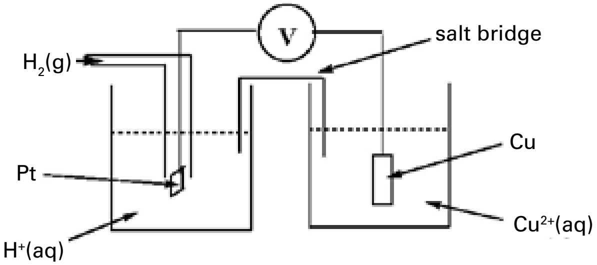
Acid 3 has an electronegative chlorine ~~not~~ atom which is electron withdrawing, stabilizing the anion of acid 3. Acid 3 ionizes more extensively than acid 2.

- acid 3 and acid 4.

The position of chlorine atom in acid 3 is at carbon atom adjacent to CO_2^- group while for acid 4, the chlorine atom is further from CO_2^- group. Anion of ~~an~~ acid 3 is more stable than that of acid 4. [3]

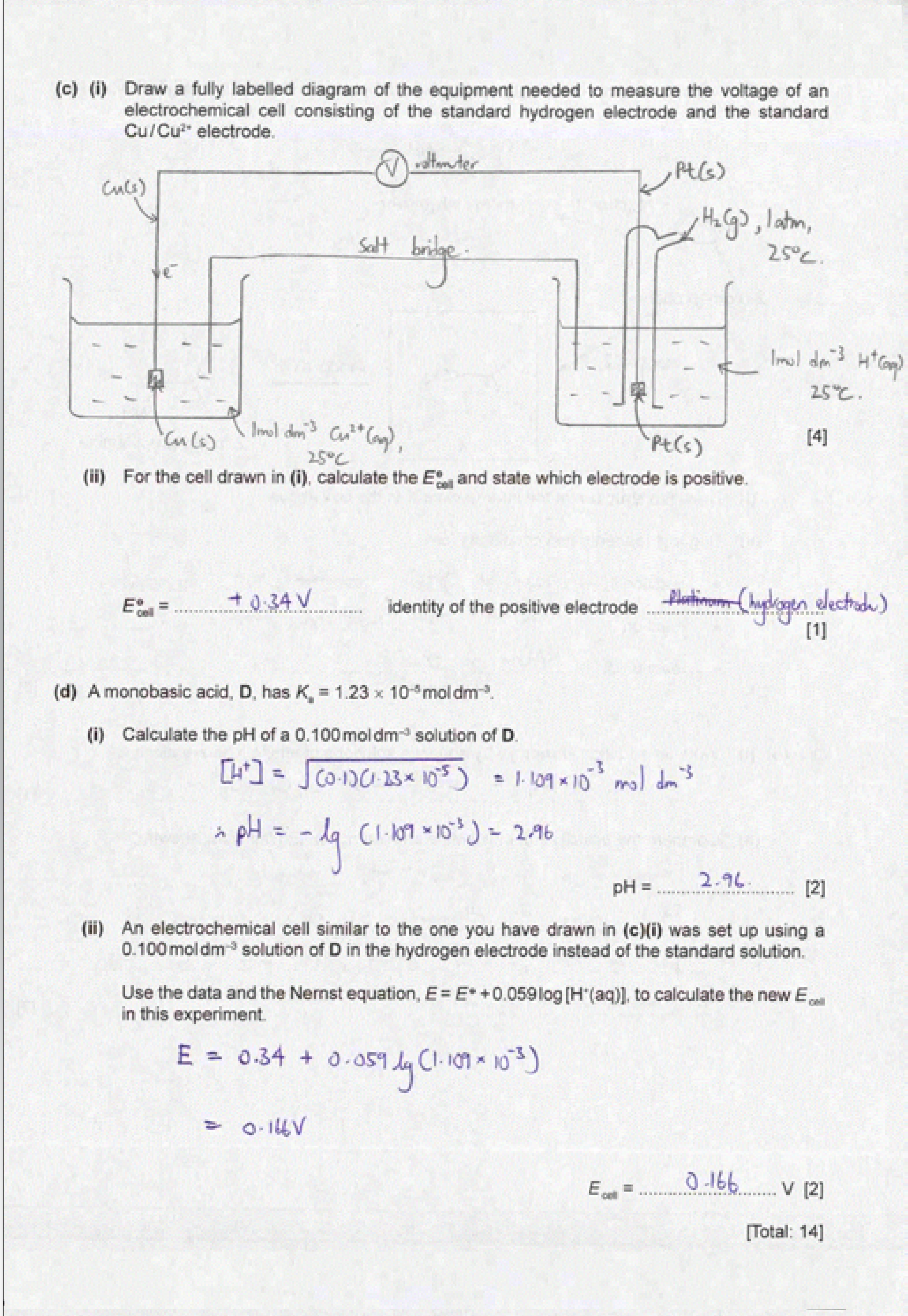
Your Mark

2(a)	
2(b)(i)	
2(b)(ii)	
2(c)(i)	
2(c)(ii)	
2(d)(i)	
2(d)(ii)	

Q2	Mark scheme
(a)	(an acid that is) partially / incompletely ionised / dissociated **[1]**
(b)(i)	pK_a = –logK_a or K_a = 10^{-pKa} **[1]**
(b)(ii)	ethanoic acid (1) is **more acidic** than propanoic acid (2) due to smaller electron-donating (R / alkyl) group / less electron-donating (R / alkyl) group(s) 2-chloropropanoic acid (3) is more acidic than propanoic acid (2) due to electron-withdrawing / electronegative (C*l* / chlorine) atom 2-chloropropanoic acid (3) is more acidic than 3¬-chloropropanoic acid (4) since the C*l* / chlorine / electronegative atom is closer to the CO_2^-/ acid **[3]**
(c)(i)	 M1: voltmeter / V **and** salt bridge labelled M2: Cu and Cu^{2+}/ $CuSO_4$ (any soluble Cu(II) salt) M3: H_2 (arrow in) **and** H^+/ HC*l* / H_2SO_4 / any mineral acid M4 Pt **and** one solution at 1 M / 1 mol dm^{-3} OR H_2 at 1 atm **[4]**
(c)(ii)	E°cell = 0.34 (V) **and** (Cu^{2+}) / Cu is the positive electrode **[3]**
(d)(i)	$K_a = 1.23 \times 10^{-5}$ $[H^+] = \sqrt{(K_a.c)} = \sqrt{(1.23 \times 10^{-5} \times 0.1)} = 1.11 \times 10^{-3}$ mol dm^{-3} pH = **3.0 (2.96)** ecf from $[H^+]$ **[1]**
(d)(ii)	$E = 0.0 + 0.059\log(1.11 \times 10^{-3})$ OR $= -0.17(4)$V so new $E_{cell} = 0.34 + 0.17 =$ **0.51V** ecf from (d)(i) **[2]** **[Total: 14]**

EXAMINER COMMENTS

MARK SCHEME



(c) (i) Draw a fully labelled diagram of the equipment needed to measure the voltage of an electrochemical cell consisting of the standard hydrogen electrode and the standard Cu/Cu²⁺ electrode.

[4]

(ii) For the cell drawn in (i), calculate the E°_{cell} and state which electrode is positive.

E°_{cell} = ...+ 0.34 V.... identity of the positive electrode ....~~Platinum~~ (hydrogen electrode)

[1]

(d) A monobasic acid, D, has $K_a = 1.23 \times 10^{-5}$ mol dm⁻³.

(i) Calculate the pH of a 0.100 mol dm⁻³ solution of D.

$$[H^+] = \sqrt{(0.1)(1.23\times10^{-5})} = 1.109\times10^{-3}\ \text{mol dm}^{-3}$$

$$\therefore pH = -\lg(1.109\times10^{-3}) = 2.96$$

pH = ...2.96.... [2]

(ii) An electrochemical cell similar to the one you have drawn in (c)(i) was set up using a 0.100 mol dm⁻³ solution of D in the hydrogen electrode instead of the standard solution.

Use the data and the Nernst equation, $E = E^\circ + 0.059\log[H^+(aq)]$, to calculate the new E_{cell} in this experiment.

$$E = 0.34 + 0.059\lg(1.109\times10^{-3})$$

$$= 0.166V$$

E_{cell} = ...0.166.... V [2]

[Total: 14]

Your Mark

2(a) ☐

2(b)(i) ☐

2(b)(ii) ☐

2(c)(i) ☐

2(c)(ii) ☐

2(d)(i) ☐

2(d)(ii) ☐

Q2	Mark scheme
(a)	(an acid that is) partially / incompletely ionised / dissociated **[1]**
(b)(i)	$pK_a = -\log K_a$ or $K_a = 10^{-pKa}$ **[1]**
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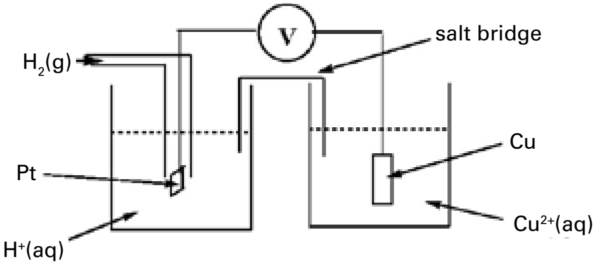
(c)(i)	 M1: voltmeter / V **and** salt bridge labelled M2: Cu and Cu²⁺/ $CuSO_4$ (any soluble Cu(II) salt) M3: H_2 (arrow in) **and** H⁺/ HCl / H_2SO_4 / any mineral acid M4 Pt **and** one solution at 1 M / 1 mol dm⁻³ OR H_2 at 1 atm **[4]**
(c)(ii)	E°cell = 0.34 (V) **and** (Cu²⁺) / Cu is the positive electrode **[3]**
(d)(i)	$K_a = 1.23 \times 10^{-5}$ $[H^+] = \sqrt{(K_a.c)} = \sqrt{(1.23 \times 10^{-5} \times 0.1)} = 1.11 \times 10^{-3}$ mol dm⁻³ pH = **3.0 (2.96)** ecf from [H⁺] **[1]**
(d)(ii)	$E = 0.0 + 0.059\log(1.11 \times 10^{-3})$ OR = –0.17(4)V so new E_{cell} = 0.34 + 0.17 = **0.51V** ecf from (d)(i) **[2]** **[Total: 14]**

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HIGH

MIDDLE

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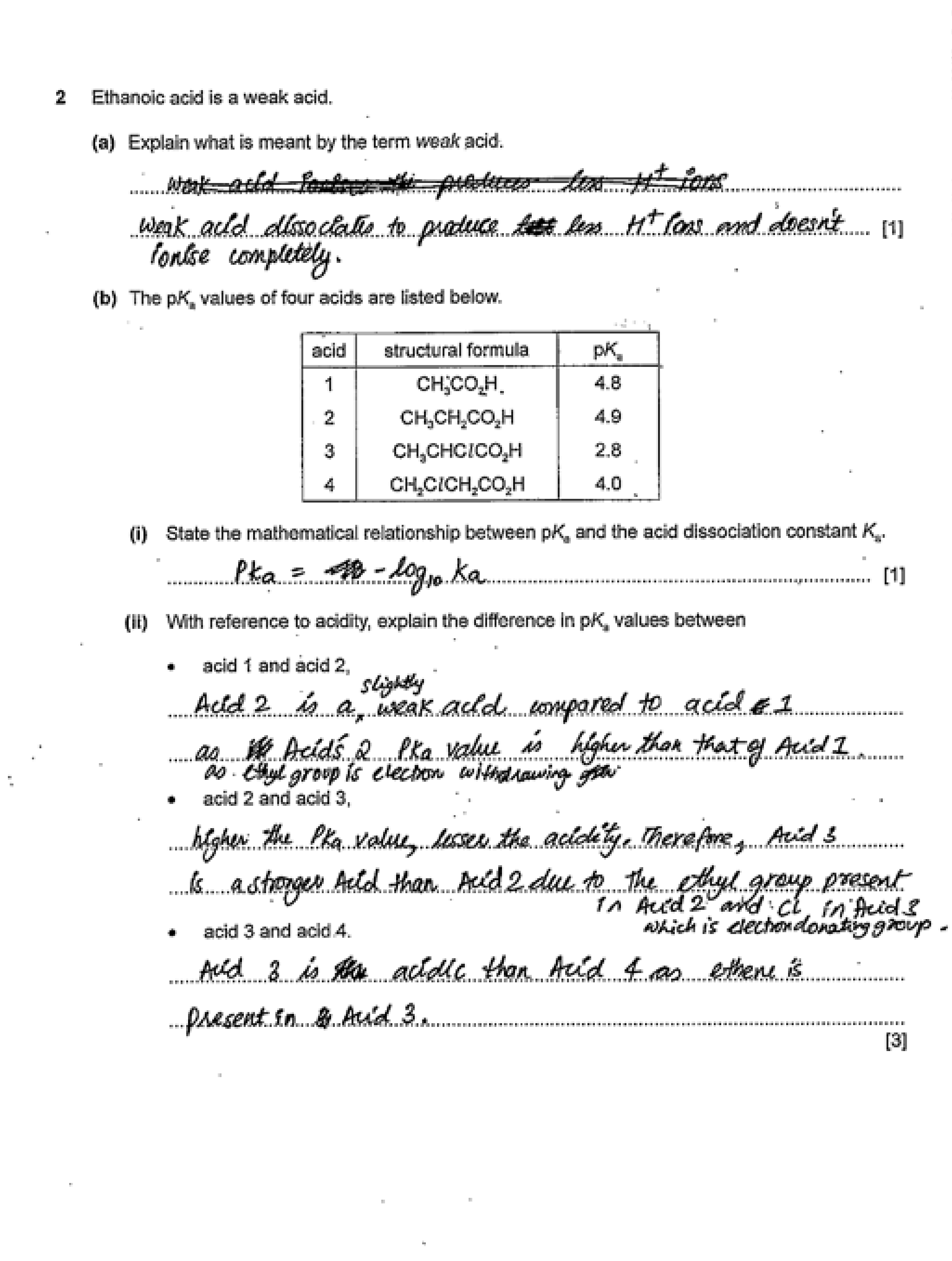

2 Ethanoic acid is a weak acid.

(a) Explain what is meant by the term *weak* acid.

~~Weak acid [illegible] produces less H^+ ions~~

Weak acid dissociate to produce ~~[illegible]~~ less H^+ ions and doesn't ionise completely. [1]

(b) The pK_a values of four acids are listed below.

acid	structural formula	pK_a
1	CH_3CO_2H	4.8
2	$CH_3CH_2CO_2H$	4.9
3	$CH_3CHClCO_2H$	2.8
4	$CH_2ClCH_2CO_2H$	4.0

(i) State the mathematical relationship between pK_a and the acid dissociation constant K_a.

Pka = ~~[illegible]~~ $-\log_{10}$ Ka [1]

(ii) With reference to acidity, explain the difference in pK_a values between

- acid 1 and acid 2,

Acid 2 is a slightly weak acid compared to acid ~~[illegible]~~ 1 as ~~[illegible]~~ Acid's 2 Pka value is higher than that of Acid 1.
as ethyl group is electron withdrawing grp

- acid 2 and acid 3,

higher the Pka value, lesser the acidity. Therefore, Acid 3 is a stronger Acid than Acid 2 due to the ethyl group present in Acid 2 and Cl in Acid 3 which is electrondonating group.

- acid 3 and acid 4.

Acid 3 is ~~the~~ acidic than Acid 4 as ethene is present in ~~[illegible]~~ Acid 3.

[3]

Your Mark

2(a) ☐

2(b)(i) ☐

2(b)(ii) ☐

2(c)(i) ☐

2(c)(ii) ☐

2(d)(i) ☐

2(d)(ii) ☐

Q2	Mark scheme
(a)	(an acid that is) partially / incompletely ionised / dissociated **[1]**
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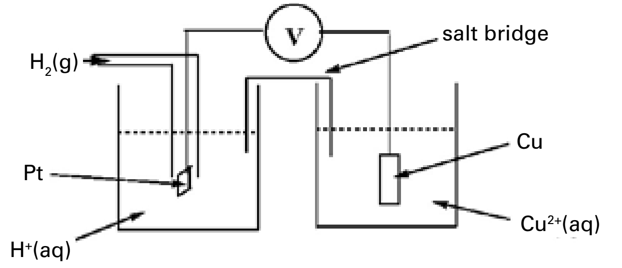
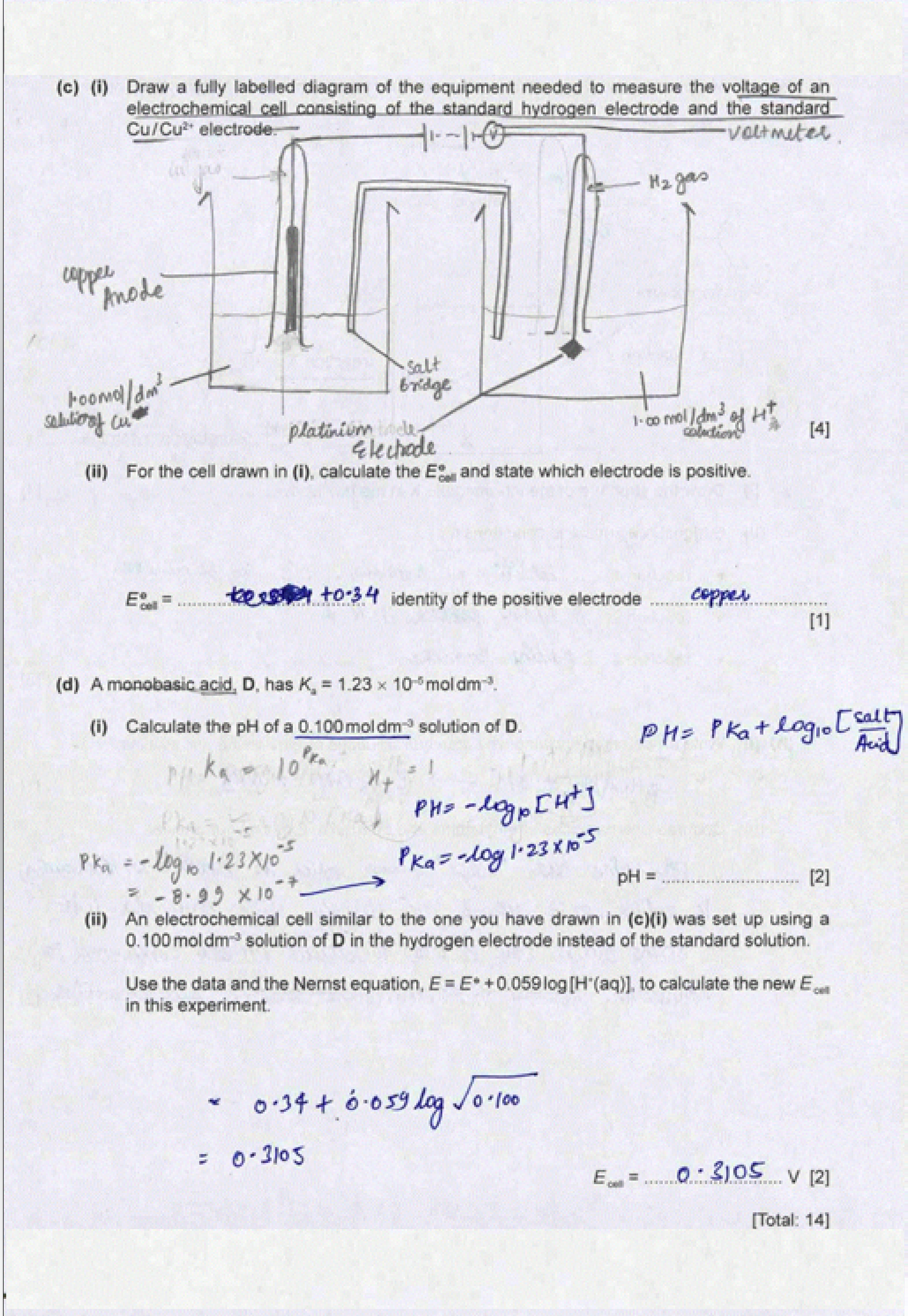
(b)(ii)	ethanoic acid (1) is **more acidic** than propanoic acid (2) due to smaller electron-donating (R / alkyl) group / less electron-donating (R / alkyl) group(s) 2-chloropropanoic acid (3) is more acidic than propanoic acid (2) due to electron-withdrawing / electronegative (C*l* / chlorine) atom 2-chloropropanoic acid (3) is more acidic than 3¬-chloropropanoic acid (4) since the C*l* / chlorine / electronegative atom is closer to the CO_2^-/ acid **[3]**
(c)(i)	 M1: voltmeter / V **and** salt bridge labelled M2: Cu and Cu^{2+}/ $CuSO_4$ (any soluble Cu(II) salt) M3: H_2 (arrow in) **and** H^+/ HC*l* / H_2SO_4 / any mineral acid M4 Pt **and** one solution at 1 M / 1 mol dm^{-3} OR H_2 at 1 atm **[4]**
(c)(ii)	E°cell = 0.34 (V) **and** (Cu^{2+}) / Cu is the positive electrode **[3]**
(d)(i)	$K_a = 1.23 \times 10^{-5}$ $[H^+] = \sqrt{(K_a.c)} = \sqrt{(1.23 \times 10^{-5} \times 0.1)} = 1.11 \times 10^{-3}$ mol dm^{-3} pH = **3.0 (2.96)** ecf from [H⁺] **[1]**
(d)(ii)	$E = 0.0 + 0.059\log(1.11 \times 10^{-3})$ OR = –0.17(4)V so new E_{cell} = 0.34 + 0.17 = **0.51V** ecf from (d)(i) **[2]** **[Total: 14]**

EXAMINER COMMENTS

MARK SCHEME



(c) (i) Draw a fully labelled diagram of the equipment needed to measure the voltage of an electrochemical cell consisting of the standard hydrogen electrode and the standard Cu/Cu²⁺ electrode.

[4]

(ii) For the cell drawn in (i), calculate the E°_{cell} and state which electrode is positive.

E°_{cell} = ~~[illegible]~~ +0·34 identity of the positive electrode copper

[1]

(d) A monobasic acid, D, has $K_a = 1.23 \times 10^{-5}$ mol dm⁻³.

(i) Calculate the pH of a 0.100 mol dm⁻³ solution of D.

$pH = pK_a + \log_{10}\left[\frac{salt}{Acid}\right]$

$pH = -\log_{10}[H^+]$

$pK_a = -\log 1{\cdot}23 \times 10^{-5}$

$pK_a = -\log_{10} 1{\cdot}23 \times 10^{-5}$

$= -8{\cdot}99 \times 10^{-7}$ →

pH = ... [2]

(ii) An electrochemical cell similar to the one you have drawn in (c)(i) was set up using a 0.100 mol dm⁻³ solution of D in the hydrogen electrode instead of the standard solution.

Use the data and the Nernst equation, $E = E^\circ + 0.059\log[H^+(aq)]$, to calculate the new E_{cell} in this experiment.

$= 0{\cdot}34 + 0{\cdot}059 \log \sqrt{0{\cdot}100}$

$= 0{\cdot}3105$

E_{cell} = 0·3105 V [2]

[Total: 14]

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HIGH MIDDLE LOW

Your Mark

2(a) ☐

2(b)(i) ☐

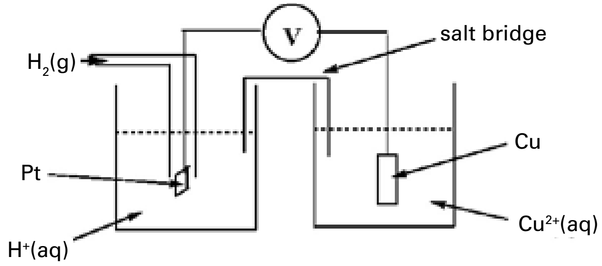
2(b)(ii) ☐

2(c)(i) ☐

2(c)(ii) ☐

2(d)(i) ☐

2(d)(ii) ☐

Q2	Mark scheme
(a)	(an acid that is) partially / incompletely ionised / dissociated **[1]**
(b)(i)	$pK_a = -\log K_a$ or $K_a = 10^{-pKa}$ **[1]**
(b)(ii)	ethanoic acid (1) is **more acidic** than propanoic acid (2) due to smaller electron-donating (R / alkyl) group / less electron-donating (R / alkyl) group(s) 2-chloropropanoic acid (3) is more acidic than propanoic acid (2) due to electron-withdrawing / electronegative (Cl / chlorine) atom 2-chloropropanoic acid (3) is more acidic than 3¬-chloropropanoic acid (4) since the Cl / chlorine / electronegative atom is closer to the CO_2^-/ acid **[3]**
(c)(i)	 M1: voltmeter / V **and** salt bridge labelled M2: Cu and Cu^{2+}/ $CuSO_4$ (any soluble Cu(II) salt) M3: H_2 (arrow in) **and** H^+/ HCl / H_2SO_4 / any mineral acid M4 Pt **and** one solution at 1 M / 1 mol dm⁻³ OR H_2 at 1 atm **[4]**
(c)(ii)	E°cell = 0.34 (V) **and** (Cu^{2+}) / Cu is the positive electrode **[3]**
(d)(i)	$K_a = 1.23 \times 10^{-5}$ $[H^+] = \sqrt{(K_a.c)} = \sqrt{(1.23 \times 10^{-5} \times 0.1)} = 1.11 \times 10^{-3}$ mol dm⁻³ pH = **3.0 (2.96)** ecf from [H⁺] **[1]**
(d)(ii)	$E = 0.0 + 0.059\log(1.11 \times 10^{-3})$ OR $= -0.17(4)$V so new $E_{cell} = 0.34 + 0.17 =$ **0.51V** ecf from (d)(i) **[2]** **[Total: 14]**

EXAMINER COMMENTS

MARK SCHEME

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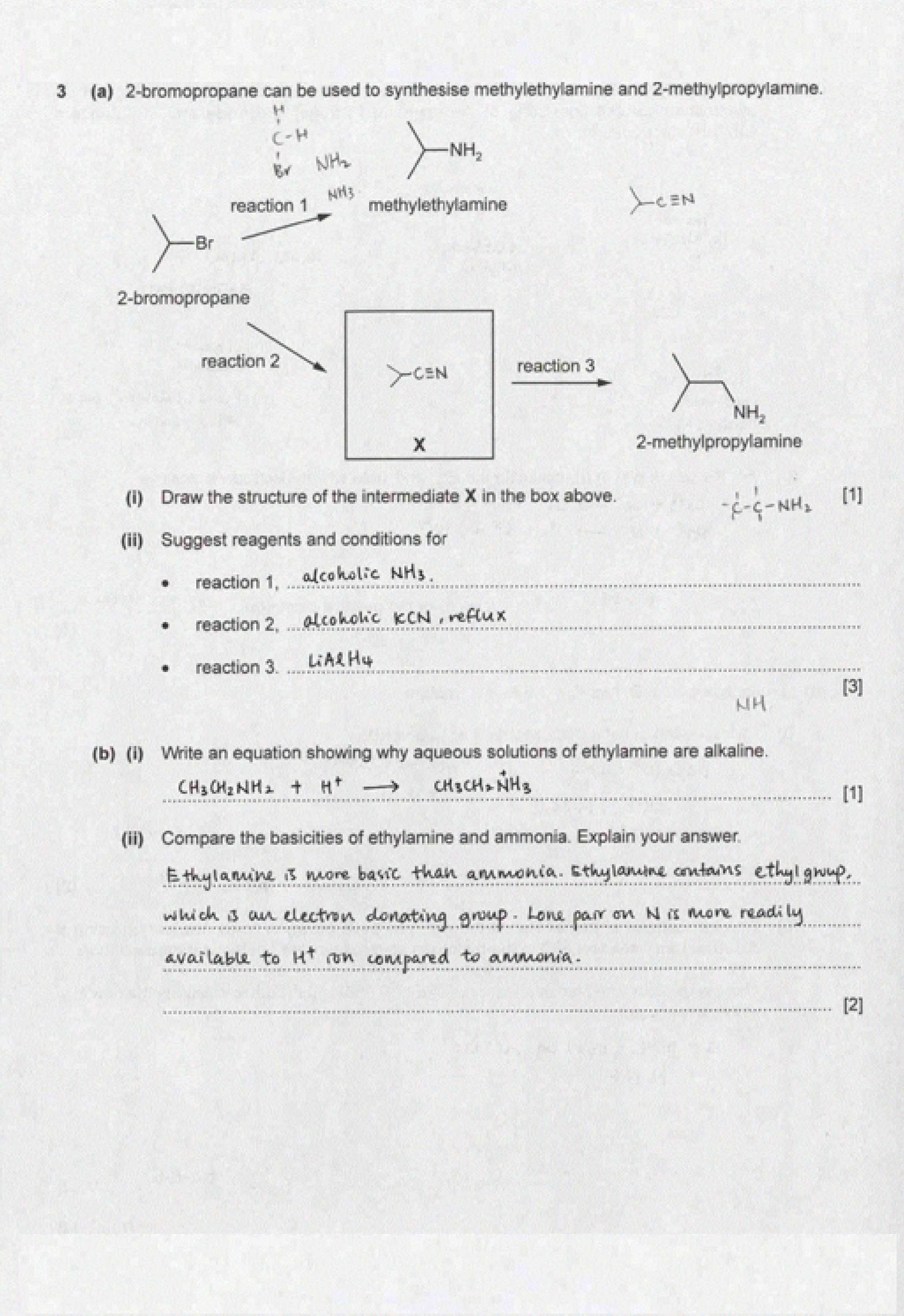
Interactive Example Candidate Responses
Paper 42 (May/June 2016), Question 3

Cambridge International AS & A Level
Chemistry 9701

Version 1.0



3 (a) 2-bromopropane can be used to synthesise methylethylamine and 2-methylpropylamine.

(i) Draw the structure of the intermediate **X** in the box above. -C-C-NH₂ [1]

(ii) Suggest reagents and conditions for

- reaction 1, alcoholic NH_3.
- reaction 2, alcoholic KCN, reflux
- reaction 3. LiAlH4

[3]

NH

(b) (i) Write an equation showing why aqueous solutions of ethylamine are alkaline.

$CH_3CH_2NH_2 + H^+ \longrightarrow CH_3CH_2\overset{+}{N}H_3$ [1]

(ii) Compare the basicities of ethylamine and ammonia. Explain your answer.

Ethylamine is more basic than ammonia. Ethylamine contains ethyl group, which is an electron donating group. Lone pair on N is more readily available to H^+ ion compared to ammonia.

[2]

Your Mark

3(a)(i) ☐

3(a)(ii) ☐

3(b)(i) ☐

3(b)(ii) ☐

3(c)(i) ☐

3(c)(ii) ☐

Q3	Mark scheme
(a)(i)	$(CH_3)_2CHCN$ **[1]**
(a)(ii)	reaction 1: NH_3 (in ethanol) under pressure (+ heat) or heat NH_3 in a sealed tube reaction 2: KCN / NaCN and heat / reflux (in ethanol) reaction 3: H_2 + Ni or LiA*l* H_4 **[3]**
(b)(i)	$CH_3CH_2NH_2 + H_2O \rightarrow CH_3CH_2NH_3^+$ (+) OH^- **[1]**
(b)(ii)	ethylamine is more basic than ammonia… because of electron-donating (alkyl / ethyl / R) group (in ethylamine) which makes the <u>lone pair</u> (on N) more available for donation or the <u>lone pair</u> (on N) more available for a proton / H^+ **[2]**
(c)(i)	A solution which resists / minimises / roughly maintains changes in <u>pH</u> when (small amounts of) H^+ or OH^- are added **[1]**
(c)(ii)	$CH_3NH_2 + H^+ \rightarrow CH_3NH_3^+$ $CH_3NH_3Cl + OH \rightarrow CH_3NH_2 + H_2O + Cl$ **[2]** **[Total: 10]**

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MIDDLE

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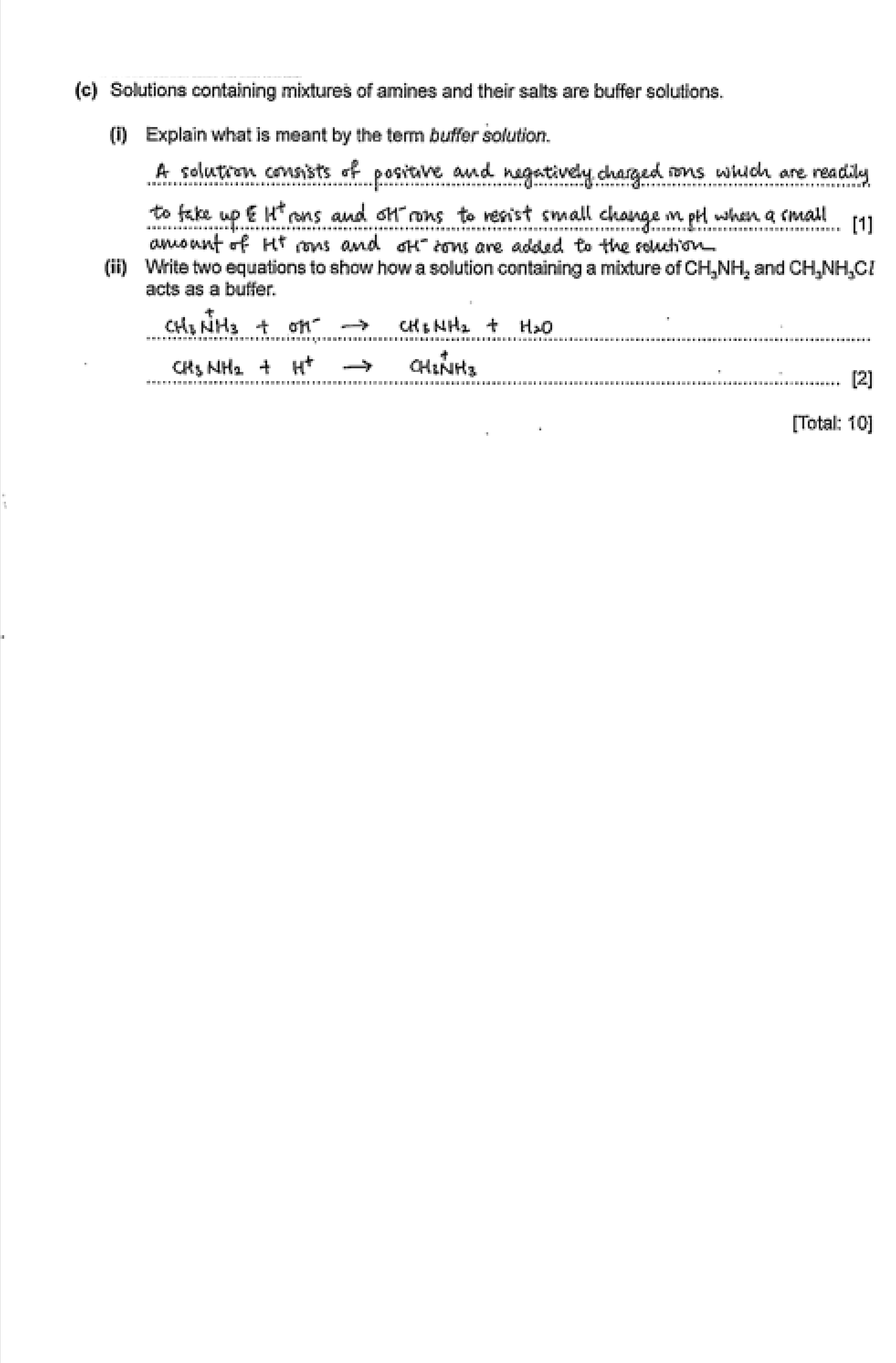

(c) Solutions containing mixtures of amines and their salts are buffer solutions.

(i) Explain what is meant by the term *buffer solution*.

A solution consists of positive and negatively charged ions which are readily to take up ~~E~~ H^+ ions and OH^- ions to resist small change in pH when a small amount of H^+ ions and OH^- ions are added to the solution. [1]

(ii) Write two equations to show how a solution containing a mixture of CH_3NH_2 and CH_3NH_3Cl acts as a buffer.

$CH_3\overset{+}{N}H_3 + OH^- \longrightarrow CH_3NH_2 + H_2O$

$CH_3NH_2 + H^+ \longrightarrow CH_3\overset{+}{N}H_3$ [2]

[Total: 10]

Your Mark

3(a)(i) ☐

3(a)(ii) ☐

3(b)(i) ☐

3(b)(ii) ☐

3(c)(i) ☐

3(c)(ii) ☐

Q3	Mark scheme
(a)(i)	$(CH_3)_2CHCN$ **[1]**
(a)(ii)	reaction 1: NH_3 (in ethanol) under pressure (+ heat) or heat NH_3 in a sealed tube reaction 2: KCN / NaCN and heat / reflux (in ethanol) reaction 3: H_2 + Ni or $LiAlH_4$ **[3]**
(b)(i)	$CH_3CH_2NH_2 + H_2O \rightarrow CH_3CH_2NH_3^+ (+) OH^-$ **[1]**
(b)(ii)	ethylamine is more basic than ammonia… because of electron-donating (alkyl / ethyl / R) group (in ethylamine) which makes the lone pair (on N) more available for donation or the lone pair (on N) more available for a proton / H^+ **[2]**
(c)(i)	A solution which resists / minimises / roughly maintains changes in pH when (small amounts of) H^+ or OH^- are added **[1]**
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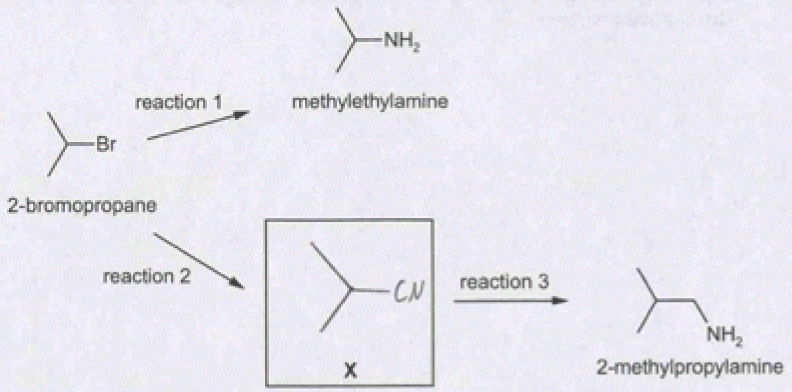
EXAMINER COMMENTS

MARK SCHEME

Select page

HIGH MIDDLE LOW

3 (a) 2-bromopropane can be used to synthesise methylethylamine and 2-methylpropylamine.



(i) Draw the structure of the intermediate **X** in the box above. [1]

(ii) Suggest reagents and conditions for

- reaction 1, heat with ethanolic ammonia (NH_3 (ethanol))
- reaction 2, heat with ethanolic KCN
- reaction 3. pass over nickel catalyst with hydrogen gas.

[3]

(b) (i) Write an equation showing why aqueous solutions of ethylamine are alkaline.

$C_2H_5NH_{2(aq)} + H^+_{(aq)} \rightleftharpoons C_2H_5NH_3^+{}_{(aq)}$ [1]

(ii) Compare the basicities of ethylamine and ammonia. Explain your answer.

ethylamine is more basic than ammonia, because ethyl is an electron donating group and increases the ability of nitrogen to form dative bond with proton, while hydrogen is not as strong of an electron donating group as ethyl [2]

Your Mark

3(a)(i) ☐

3(a)(ii) ☐

3(b)(i) ☐

3(b)(ii) ☐

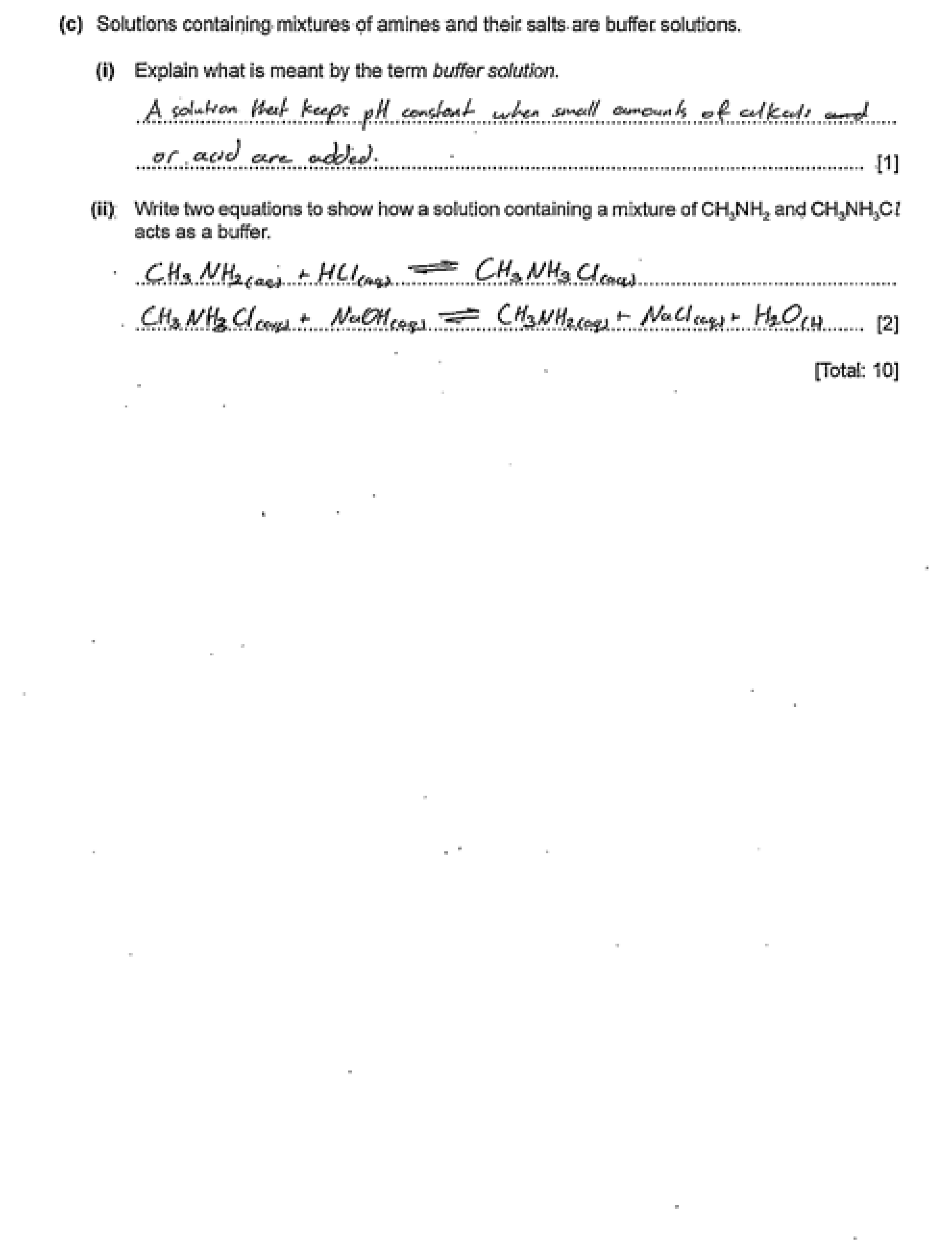
3(c)(i) ☐

3(c)(ii) ☐

Q3	Mark scheme
(a)(i)	$(CH_3)_2CHCN$ **[1]**
(a)(ii)	reaction 1: NH_3 (in ethanol) under pressure (+ heat) or heat NH_3 in a sealed tube reaction 2: KCN / NaCN and heat / reflux (in ethanol) reaction 3: H_2 + Ni or $LiAlH_4$ **[3]**
(b)(i)	$CH_3CH_2NH_2 + H_2O \rightarrow CH_3CH_2NH_3^+ (+) OH^-$ **[1]**
(b)(ii)	ethylamine is more basic than ammonia… because of electron-donating (alkyl / ethyl / R) group (in ethylamine) which makes the <u>lone pair</u> (on N) more available for donation or the <u>lone pair</u> (on N) more available for a proton / H^+ **[2]**
(c)(i)	A solution which resists / minimises / roughly maintains changes in <u>pH</u> when (small amounts of) H^+ or OH^- are added **[1]**
(c)(ii)	$CH_3NH_2 + H^+ \rightarrow CH_3NH_3^+$ $CH_3NH_3Cl + OH \rightarrow CH_3NH_2 + H_2O + Cl$ **[2]** **[Total: 10]**

EXAMINER COMMENTS

MARK SCHEME



(c) Solutions containing mixtures of amines and their salts are buffer solutions.

(i) Explain what is meant by the term *buffer solution*.

A solution that keeps pH constant when small amounts of alkali ~~and~~ or acid are added. [1]

(ii) Write two equations to show how a solution containing a mixture of CH_3NH_2 and CH_3NH_3Cl acts as a buffer.

$CH_3NH_{2(aq)} + HCl_{(aq)} \rightleftharpoons CH_3NH_3Cl_{(aq)}$

$CH_3NH_3Cl_{(aq)} + NaOH_{(aq)} \rightleftharpoons CH_3NH_{2(aq)} + NaCl_{(aq)} + H_2O_{(l}$ [2]

[Total: 10]

Your Mark

3(a)(i) ☐

3(a)(ii) ☐

3(b)(i) ☐

3(b)(ii) ☐

3(c)(i) ☐

3(c)(ii) ☐

Q3	Mark scheme
(a)(i)	$(CH_3)_2CHCN$ **[1]**
(a)(ii)	reaction 1: NH_3 (in ethanol) under pressure (+ heat) or heat NH_3 in a sealed tube reaction 2: KCN / NaCN and heat / reflux (in ethanol) reaction 3: H_2 + Ni or $LiAlH_4$ **[3]**
(b)(i)	$CH_3CH_2NH_2 + H_2O \rightarrow CH_3CH_2NH_3^+ (+) OH^-$ **[1]**
(b)(ii)	ethylamine is more basic than ammonia… because of electron-donating (alkyl / ethyl / R) group (in ethylamine) which makes the <u>lone pair</u> (on N) more available for donation or the <u>lone pair</u> (on N) more available for a proton / H^+ **[2]**
(c)(i)	A solution which resists / minimises / roughly maintains changes in <u>pH</u> when (small amounts of) H^+ or OH^- are added **[1]**
(c)(ii)	$CH_3NH_2 + H^+ \rightarrow CH_3NH_3^+$ $CH_3NH_3Cl + OH \rightarrow CH_3NH_2 + H_2O + Cl$ **[2]** **[Total: 10]**

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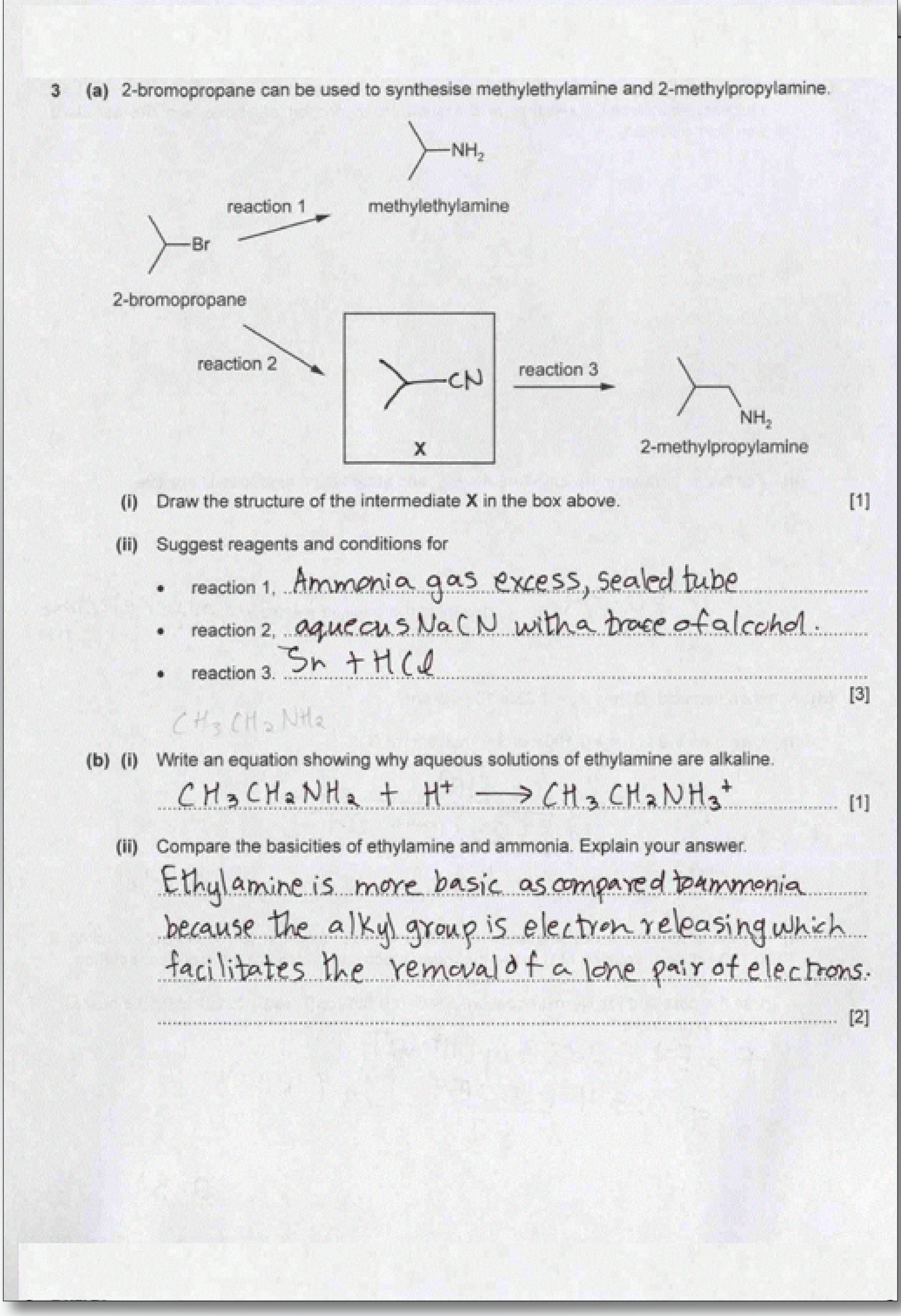


3 (a) 2-bromopropane can be used to synthesise methylethylamine and 2-methylpropylamine.

(i) Draw the structure of the intermediate **X** in the box above. [1]

(ii) Suggest reagents and conditions for

- reaction 1, Ammonia gas excess, sealed tube
- reaction 2, aquecus NaCN with a trace of alcohol.
- reaction 3. Sn + HCl

[3]

CH3CH2NH2

(b) (i) Write an equation showing why aqueous solutions of ethylamine are alkaline.

$CH_3CH_2NH_2 + H^+ \longrightarrow CH_3CH_2NH_3^+$ [1]

(ii) Compare the basicities of ethylamine and ammonia. Explain your answer.

Ethylamine is more basic as compared to ammonia because the alkyl group is electron releasing which facilitates the removal of a lone pair of electrons.

[2]

Your Mark

3(a)(i) ☐

3(a)(ii) ☐

3(b)(i) ☐

3(b)(ii) ☐

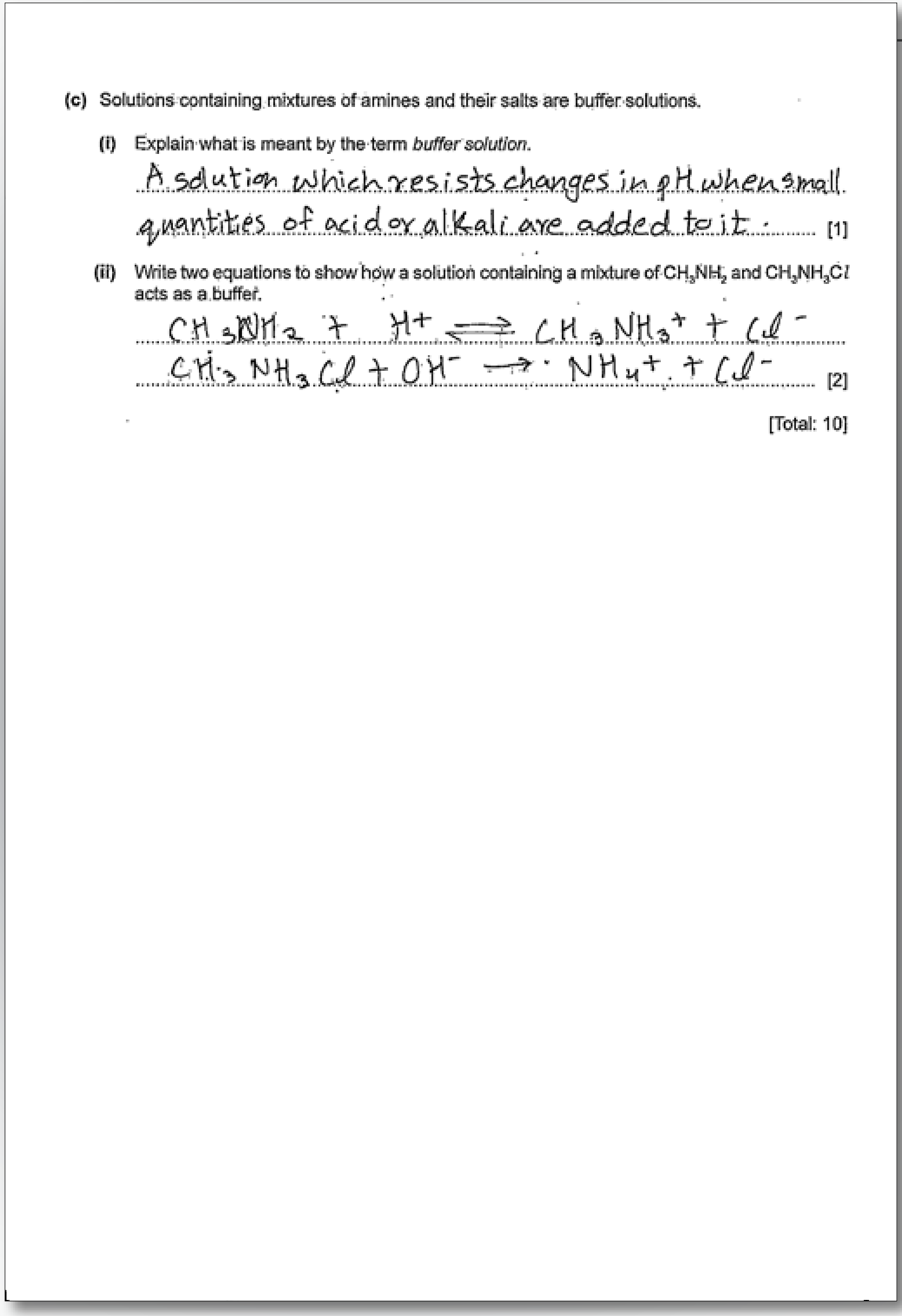
3(c)(i) ☐

3(c)(ii) ☐

Q3	Mark scheme	
(a)(i)	$(CH_3)_2CHCN$	**[1]**
(a)(ii)	reaction 1: NH_3 (in ethanol) under pressure (+ heat) or heat NH_3 in a sealed tube reaction 2: KCN / NaCN and heat / reflux (in ethanol) reaction 3: H_2 + Ni or $LiAlH_4$	**[3]**
(b)(i)	$CH_3CH_2NH_2 + H_2O \rightarrow CH_3CH_2NH_3^+ (+) OH^-$	**[1]**
(b)(ii)	ethylamine is more basic than ammonia… because of electron-donating (alkyl / ethyl / R) group (in ethylamine) which makes the <u>lone pair</u> (on N) more available for donation or the <u>lone pair</u> (on N) more available for a proton / H^+	**[2]**
(c)(i)	A solution which resists / minimises / roughly maintains changes in <u>pH</u> when (small amounts of) H^+ or OH^- are added	**[1]**
(c)(ii)	$CH_3NH_2 + H^+ \rightarrow CH_3NH_3^+$ $CH_3NH_3Cl + OH \rightarrow CH_3NH_2 + H_2O + Cl$	**[2]** **[Total: 10]**

EXAMINER COMMENTS

MARK SCHEME



(c) Solutions containing mixtures of amines and their salts are buffer solutions.

(i) Explain what is meant by the term *buffer solution*.

A solution which resists changes in pH when small quantities of acid or alkali are added to it. [1]

(ii) Write two equations to show how a solution containing a mixture of CH_3NH_2 and CH_3NH_3Cl acts as a buffer.

$CH_3NH_2 + H^+ \rightleftharpoons CH_3NH_3^+ + Cl^-$

$CH_3NH_3Cl + OH^- \rightarrow NH_4^+ + Cl^-$ [2]

[Total: 10]

Select page

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LOW

Your Mark

3(a)(i) ☐

3(a)(ii) ☐

3(b)(i) ☐

3(b)(ii) ☐

3(c)(i) ☐

3(c)(ii) ☐

Q3	Mark scheme	
(a)(i)	$(CH_3)_2CHCN$	**[1]**
(a)(ii)	reaction 1: NH_3 (in ethanol) under pressure (+ heat) or heat NH_3 in a sealed tube reaction 2: KCN / NaCN and heat / reflux (in ethanol) reaction 3: H_2 + Ni or $LiAlH_4$	**[3]**
(b)(i)	$CH_3CH_2NH_2 + H_2O \rightarrow CH_3CH_2NH_3^+ (+) OH^-$	**[1]**
(b)(ii)	ethylamine is more basic than ammonia… because of electron-donating (alkyl / ethyl / R) group (in ethylamine) which makes the <u>lone pair</u> (on N) more available for donation or the <u>lone pair</u> (on N) more available for a proton / H^+	**[2]**
(c)(i)	A solution which resists / minimises / roughly maintains changes in <u>pH</u> when (small amounts of) H^+ or OH^- are added	**[1]**
(c)(ii)	$CH_3NH_2 + H^+ \rightarrow CH_3NH_3^+$ $CH_3NH_3Cl + OH \rightarrow CH_3NH_2 + H_2O + Cl$	**[2]** **[Total: 10]**

EXAMINER COMMENTS

MARK SCHEME

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Interactive Example Candidate Responses
Paper 42 (May/June 2016), Question 4

Cambridge International AS & A Level
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Version 1.0

Cambridge Pathway

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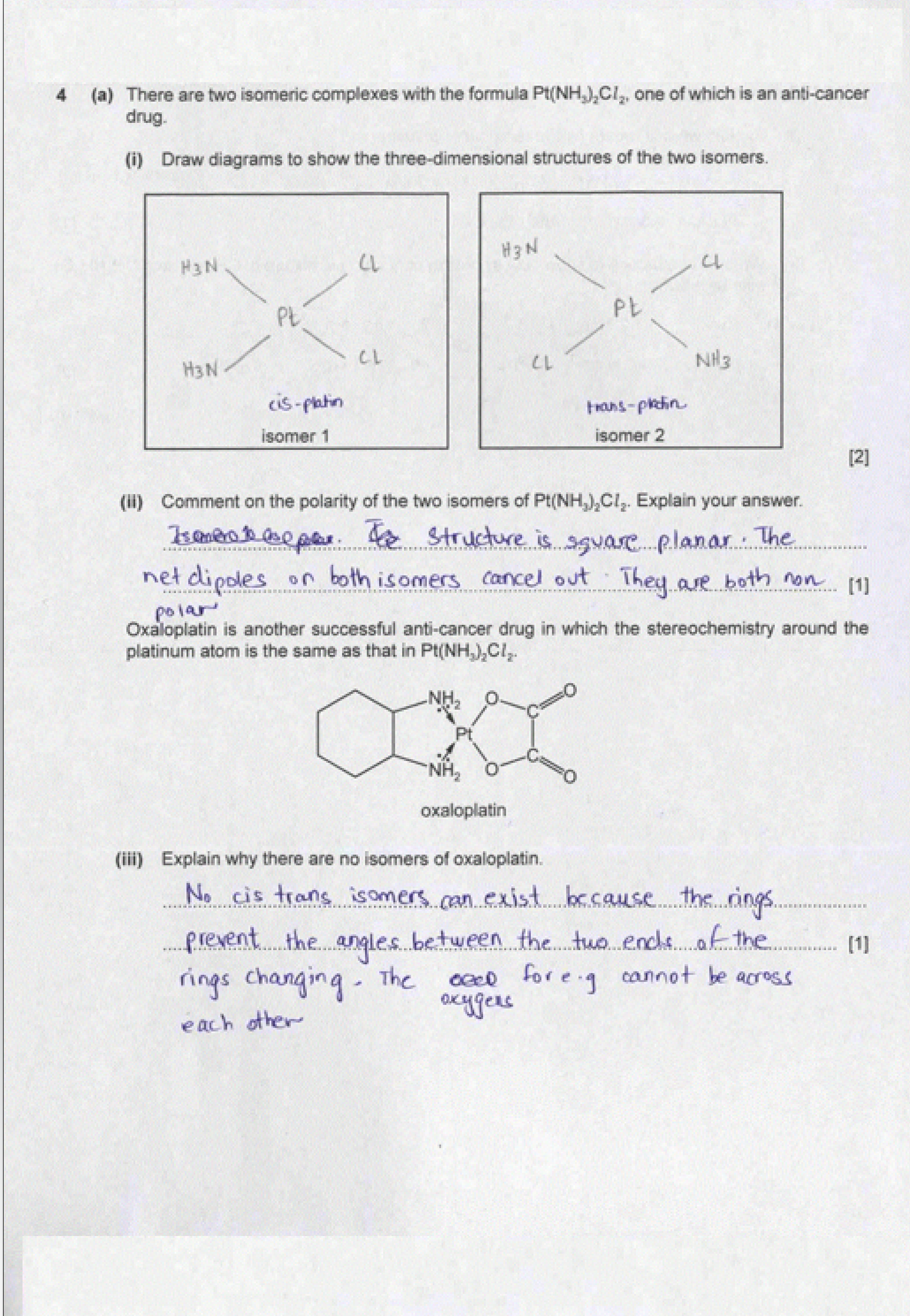


4 (a) There are two isomeric complexes with the formula $Pt(NH_3)_2Cl_2$, one of which is an anti-cancer drug.

(i) Draw diagrams to show the three-dimensional structures of the two isomers.

[2]

(ii) Comment on the polarity of the two isomers of $Pt(NH_3)_2Cl_2$. Explain your answer.

~~Isomers are polar~~. ~~The~~ Structure is square planar. The net dipoles on both isomers cancel out. They are both non polar [1]

Oxaloplatin is another successful anti-cancer drug in which the stereochemistry around the platinum atom is the same as that in $Pt(NH_3)_2Cl_2$.

(iii) Explain why there are no isomers of oxaloplatin.

No cis trans isomers can exist because the rings prevent the angles between the two ends of the rings changing. The ~~oxo~~ oxygens for e.g cannot be across each other [1]

Your Mark

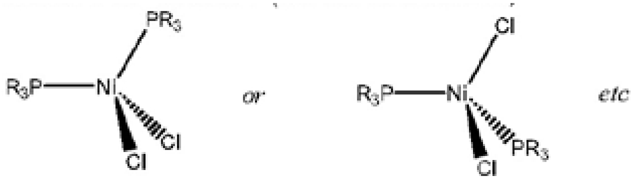
4(a)(i) ☐

4(a)(ii) ☐

4(a)(iii) ☐

4(b)(i) ☐

4(b)(ii) ☐

Q4	Mark scheme
(a)(i)	 **[2]**
(a)(ii)	***cis*** is (more) **polar** due to both $Cl^{(\delta-)}$ on same side **or** ***cis*** is (more) **polar** as dipoles do not cancel / unsymmetrical **or** **trans** is **non-polar** as it is bond dipoles cancel **[1]**
(a)(iii)	(This can only be *cis*) its mirror image is the same / superimposable **or** the distance between two coordinating nitrogens / oxygens is too small to bond trans **or** difficult for the NH_2 and O to change places (since 5-memebered rings can only bridge adjacent positions) **[1]**
(b)(i)	It's not square planar or it's tetrahedral **[1]**
(b)(ii)	must be 3D structure (i.e. tetrahedral-like)  **[1]** **[Total: 6]**

EXAMINER COMMENTS

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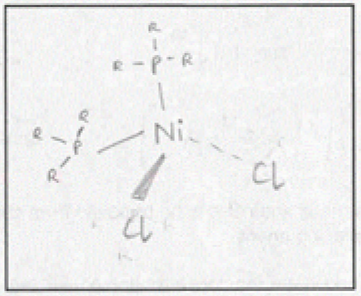
(b) Only one structure of the complex $[Ni(R_3P)_2Cl_2]$ is known. ($R = CH_3$, R_3P is a monodentate ligand)

(i) What does this indicate about the stereochemistry around the nickel atom?

It is tetrahedral (because if square planar there could be isomers) [1]

(ii) Draw a three-dimensional diagram showing the structure of this complex.



[1]

[Total: 6]

Your Mark

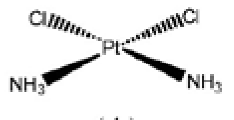
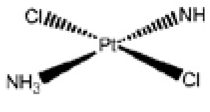
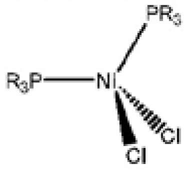
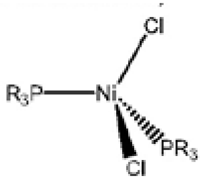
4(a)(i)

4(a)(ii)

4(a)(iii)

4(b)(i)

4(b)(ii)

Q4	Mark scheme
(a)(i)	 (cis)  (trans) **[2]**
(a)(ii)	***cis*** is (more) **polar** due to both Cl($^{\delta-}$) on same side **or** ***cis*** is (more) **polar** as dipoles do not cancel / unsymmetrical **or** **trans** is **non-polar** as it is bond dipoles cancel **[1]**
(a)(iii)	(This can only be *cis*) its mirror image is the same / superimposable **or** the distance between two coordinating nitrogens / oxygens is too small to bond trans **or** difficult for the NH_2 and O to change places (since 5-memebered rings can only bridge adjacent positions) **[1]**
(b)(i)	It's not square planar or it's tetrahedral **[1]**
(b)(ii)	must be 3D structure (i.e. tetrahedral-like)  *or*  *etc* **[1]** **[Total: 6]**

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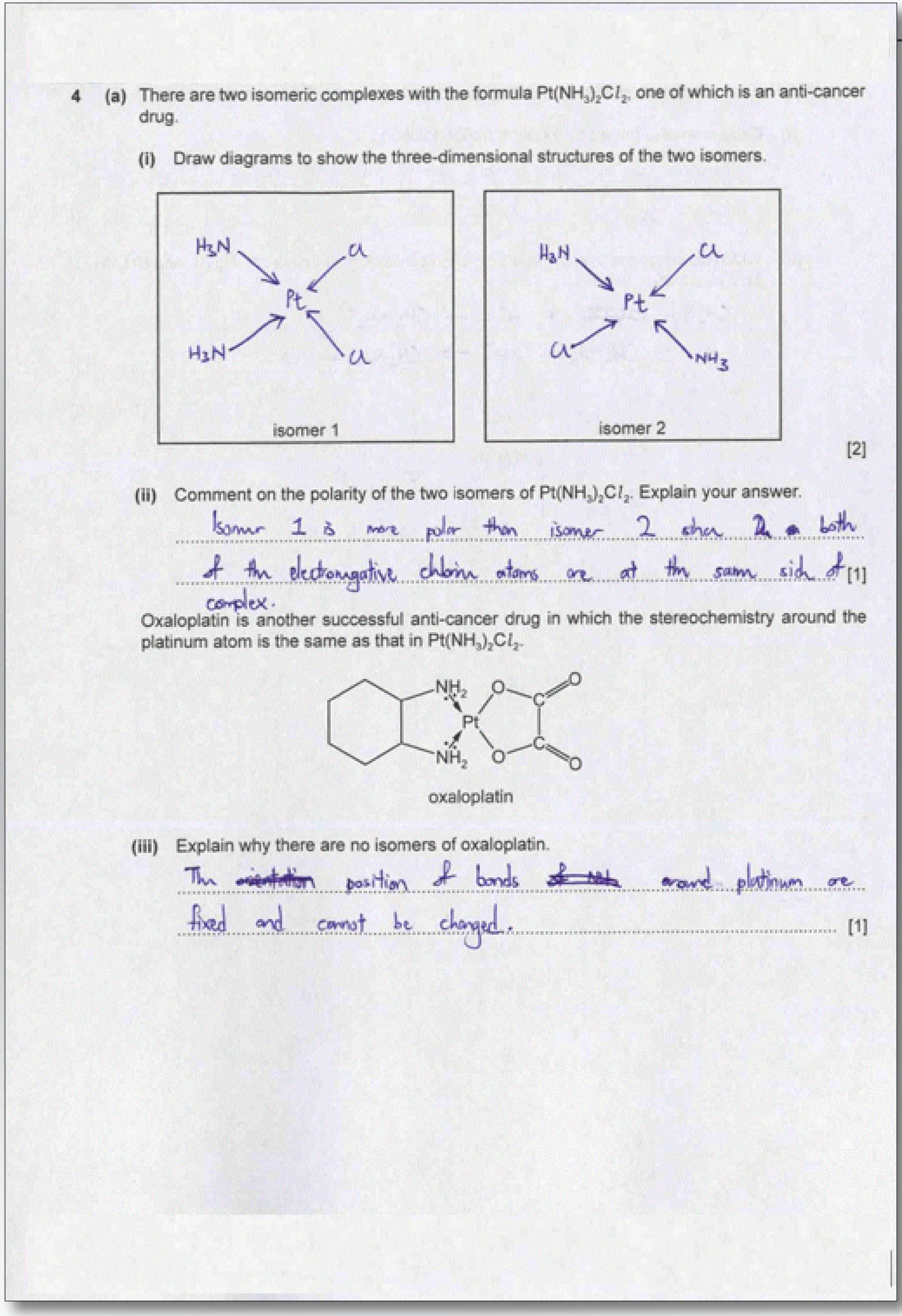


4 (a) There are two isomeric complexes with the formula $Pt(NH_3)_2Cl_2$, one of which is an anti-cancer drug.

(i) Draw diagrams to show the three-dimensional structures of the two isomers.

[2]

(ii) Comment on the polarity of the two isomers of $Pt(NH_3)_2Cl_2$. Explain your answer.

Isomer 1 is more polar than isomer 2 since ~~2~~ both of the electronegative chlorine atoms are at the same side of complex. [1]

Oxaloplatin is another successful anti-cancer drug in which the stereochemistry around the platinum atom is the same as that in $Pt(NH_3)_2Cl_2$.

oxaloplatin

(iii) Explain why there are no isomers of oxaloplatin.

The ~~orientation~~ position of bonds ~~of the~~ around platinum are fixed and cannot be changed. [1]

Your Mark

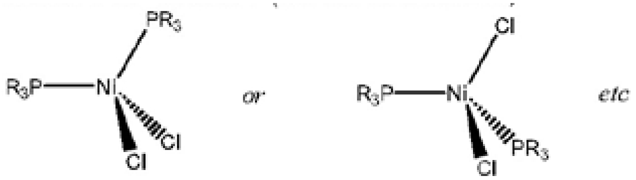
4(a)(i) ☐

4(a)(ii) ☐

4(a)(iii) ☐

4(b)(i) ☐

4(b)(ii) ☐

Q4	**Mark scheme**
(a)(i)	 **[2]**
(a)(ii)	***cis*** is (more) **polar** due to both $Cl^{(\delta-)}$ on same side **or** ***cis*** is (more) **polar** as dipoles do not cancel / unsymmetrical **or** **trans** is **non-polar** as it is bond dipoles cancel **[1]**
(a)(iii)	(This can only be *cis*) its mirror image is the same / superimposable **or** the distance between two coordinating nitrogens / oxygens is too small to bond trans **or** difficult for the NH_2 and O to change places (since 5-memebered rings can only bridge adjacent positions) **[1]**
(b)(i)	It's not square planar or it's tetrahedral **[1]**
(b)(ii)	must be 3D structure (i.e. tetrahedral-like)  **[1]** **[Total: 6]**

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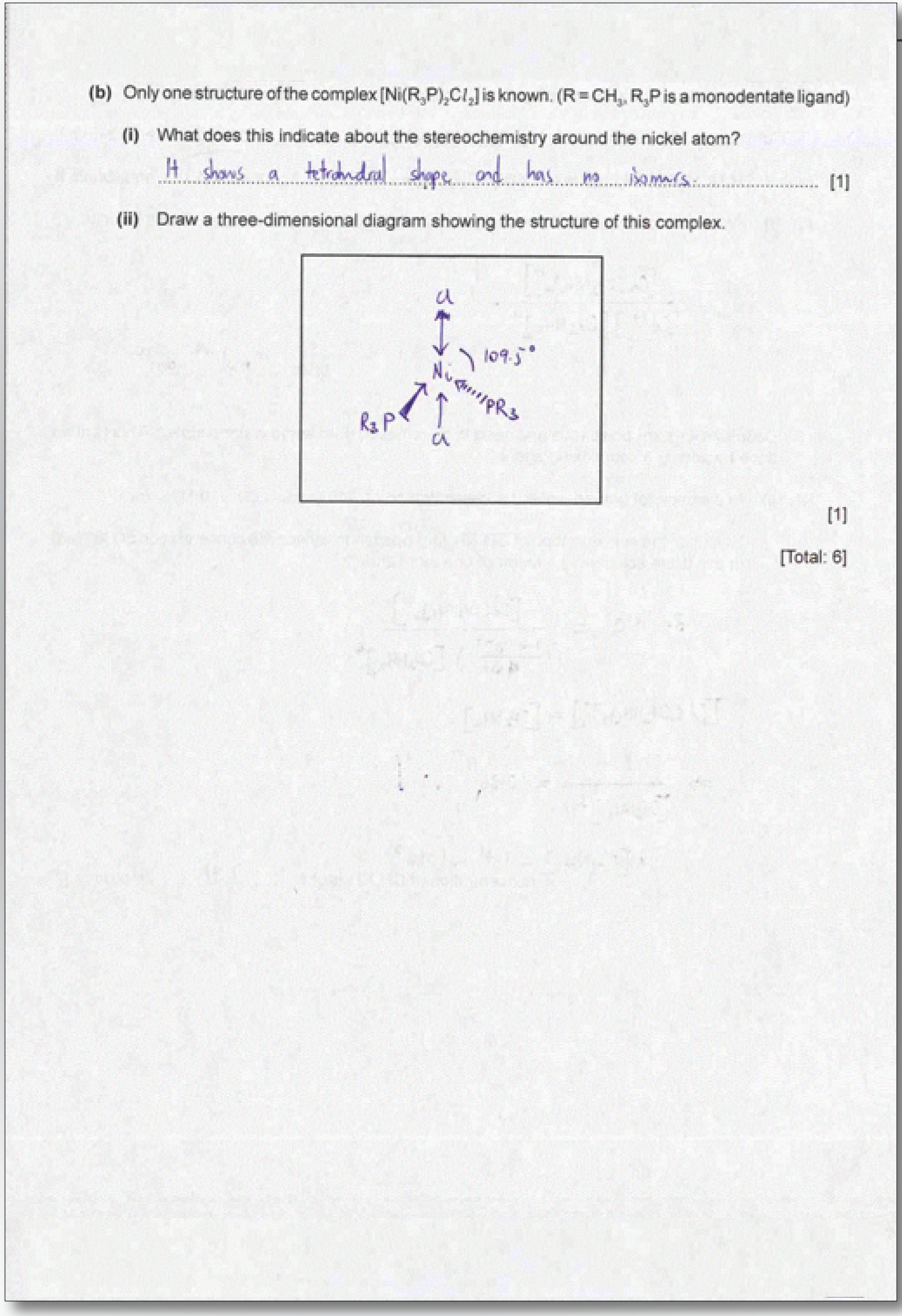


(b) Only one structure of the complex $[Ni(R_3P)_2Cl_2]$ is known. ($R = CH_3$, R_3P is a monodentate ligand)

(i) What does this indicate about the stereochemistry around the nickel atom?

It shows a tetrahedral shape and has no isomers. [1]

(ii) Draw a three-dimensional diagram showing the structure of this complex.

[1]

[Total: 6]

Your Mark

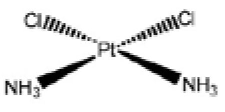
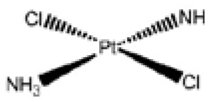
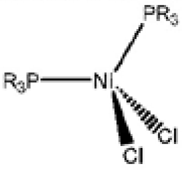
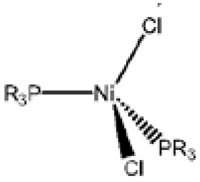
4(a)(i) ☐

4(a)(ii) ☐

4(a)(iii) ☐

4(b)(i) ☐

4(b)(ii) ☐

Q4	Mark scheme
(a)(i)	 (cis)  (trans) [2]
(a)(ii)	***cis*** is (more) **polar** due to both Cl(δ−) on same side **or** ***cis*** is (more) **polar** as dipoles do not cancel / unsymmetrical **or** **trans** is **non-polar** as it is bond dipoles cancel [1]
(a)(iii)	(This can only be *cis*) its mirror image is the same / superimposable **or** the distance between two coordinating nitrogens / oxygens is too small to bond trans **or** difficult for the NH_2 and O to change places (since 5-memebered rings can only bridge adjacent positions) [1]
(b)(i)	It's not square planar or it's tetrahedral [1]
(b)(ii)	must be 3D structure (i.e. tetrahedral-like)  *or*  *etc* [1] [Total: 6]

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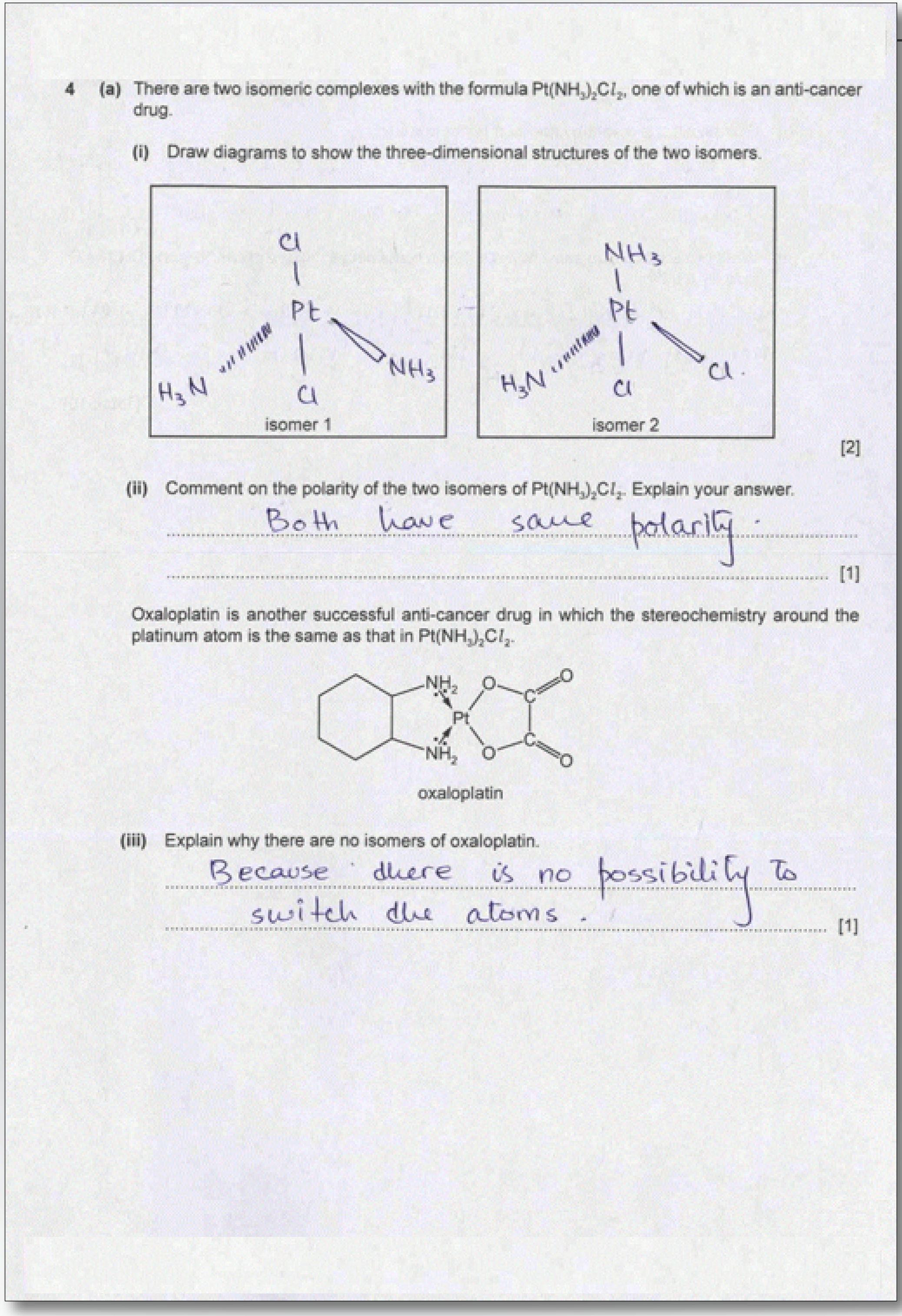


4 (a) There are two isomeric complexes with the formula $Pt(NH_3)_2Cl_2$, one of which is an anti-cancer drug.

(i) Draw diagrams to show the three-dimensional structures of the two isomers.

[2]

(ii) Comment on the polarity of the two isomers of $Pt(NH_3)_2Cl_2$. Explain your answer.

Both have same polarity.

[1]

Oxaloplatin is another successful anti-cancer drug in which the stereochemistry around the platinum atom is the same as that in $Pt(NH_3)_2Cl_2$.

oxaloplatin

(iii) Explain why there are no isomers of oxaloplatin.

Because there is no possibility to switch the atoms.

[1]

Your Mark

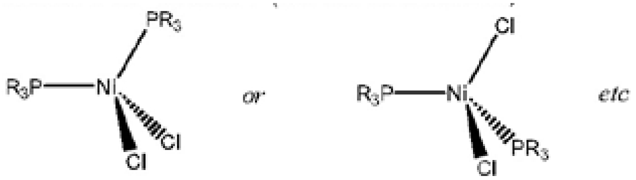
4(a)(i) ☐

4(a)(ii) ☐

4(a)(iii) ☐

4(b)(i) ☐

4(b)(ii) ☐

Q4	Mark scheme
(a)(i)	 **[2]**
(a)(ii)	***cis*** is (more) **polar** due to both Cl($^{\delta-}$) on same side **or** ***cis*** is (more) **polar** as dipoles do not cancel / unsymmetrical **or** **trans** is **non-polar** as it is bond dipoles cancel **[1]**
(a)(iii)	(This can only be *cis*) its mirror image is the same / superimposable **or** the distance between two coordinating nitrogens / oxygens is too small to bond trans **or** difficult for the NH_2 and O to change places (since 5-memebered rings can only bridge adjacent positions) **[1]**
(b)(i)	It's not square planar or it's tetrahedral **[1]**
(b)(ii)	must be 3D structure (i.e. tetrahedral-like)  **[1]** **[Total: 6]**

EXAMINER COMMENTS

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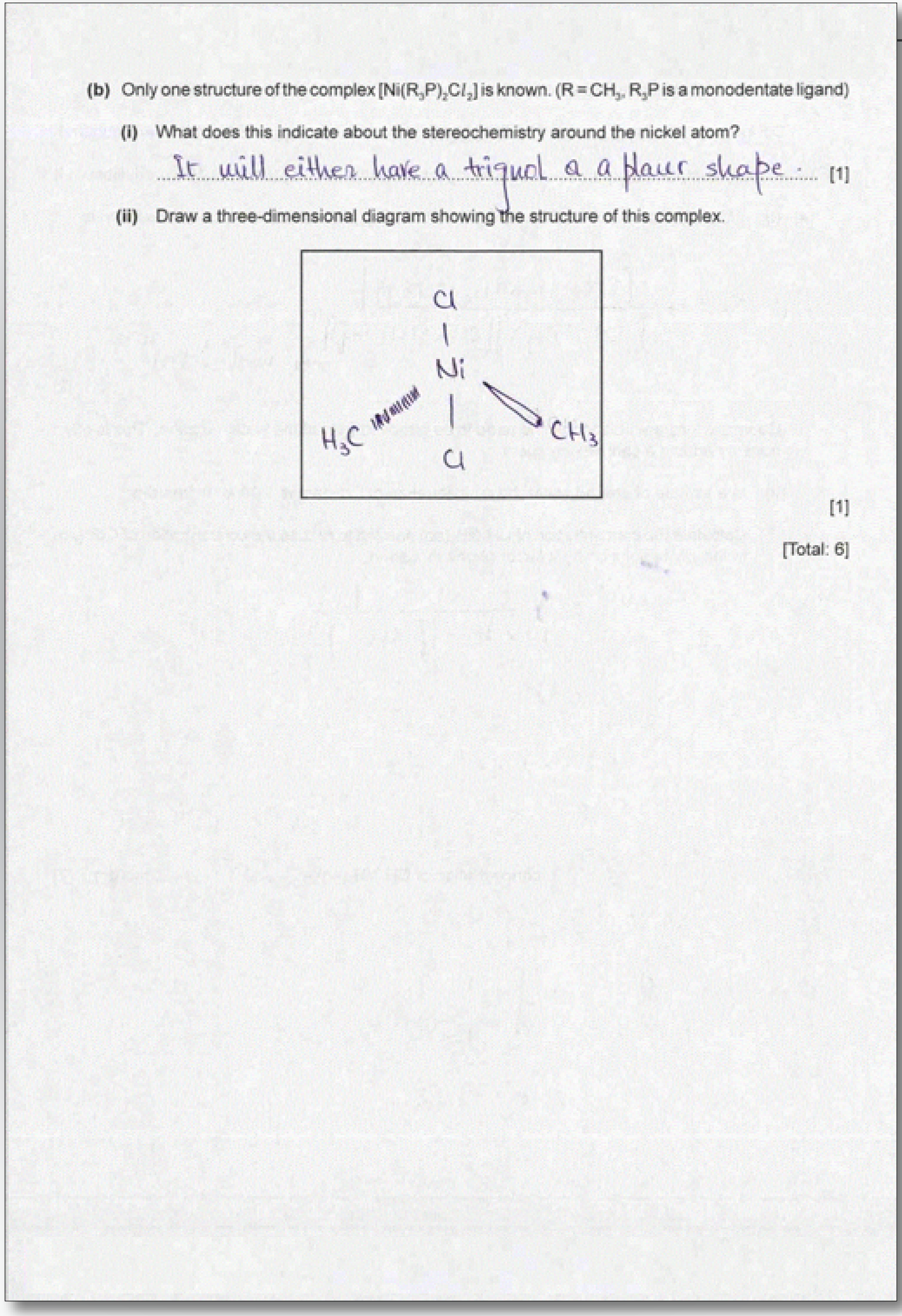


(b) Only one structure of the complex $[Ni(R_3P)_2Cl_2]$ is known. ($R = CH_3$, R_3P is a monodentate ligand)

(i) What does this indicate about the stereochemistry around the nickel atom?

It will either have a triqual a a plaur shape. [1]

(ii) Draw a three-dimensional diagram showing the structure of this complex.

[1]

[Total: 6]

Your Mark

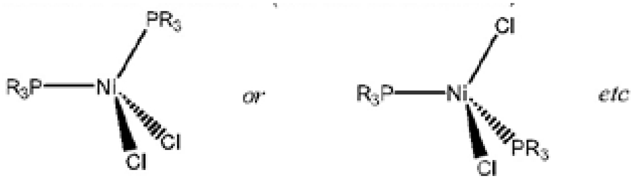
4(a)(i) ☐

4(a)(ii) ☐

4(a)(iii) ☐

4(b)(i) ☐

4(b)(ii) ☐

Q4	**Mark scheme**
(a)(i)	 (cis) (trans) **[2]**
(a)(ii)	***cis*** is (more) **polar** due to both Cl($^{\delta-}$) on same side **or** ***cis*** is (more) **polar** as dipoles do not cancel / unsymmetrical **or** **trans** is **non-polar** as it is bond dipoles cancel **[1]**
(a)(iii)	(This can only be *cis*) its mirror image is the same / superimposable **or** the distance between two coordinating nitrogens / oxygens is too small to bond trans **or** difficult for the NH_2 and O to change places (since 5-memebered rings can only bridge adjacent positions) **[1]**
(b)(i)	It's not square planar or it's tetrahedral **[1]**
(b)(ii)	must be 3D structure (i.e. tetrahedral-like)  **[1]** **[Total: 6]**

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MARK SCHEME

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Interactive Example Candidate Responses
Paper 42 (May/June 2016), Question 5

Cambridge International AS & A Level
Chemistry 9701

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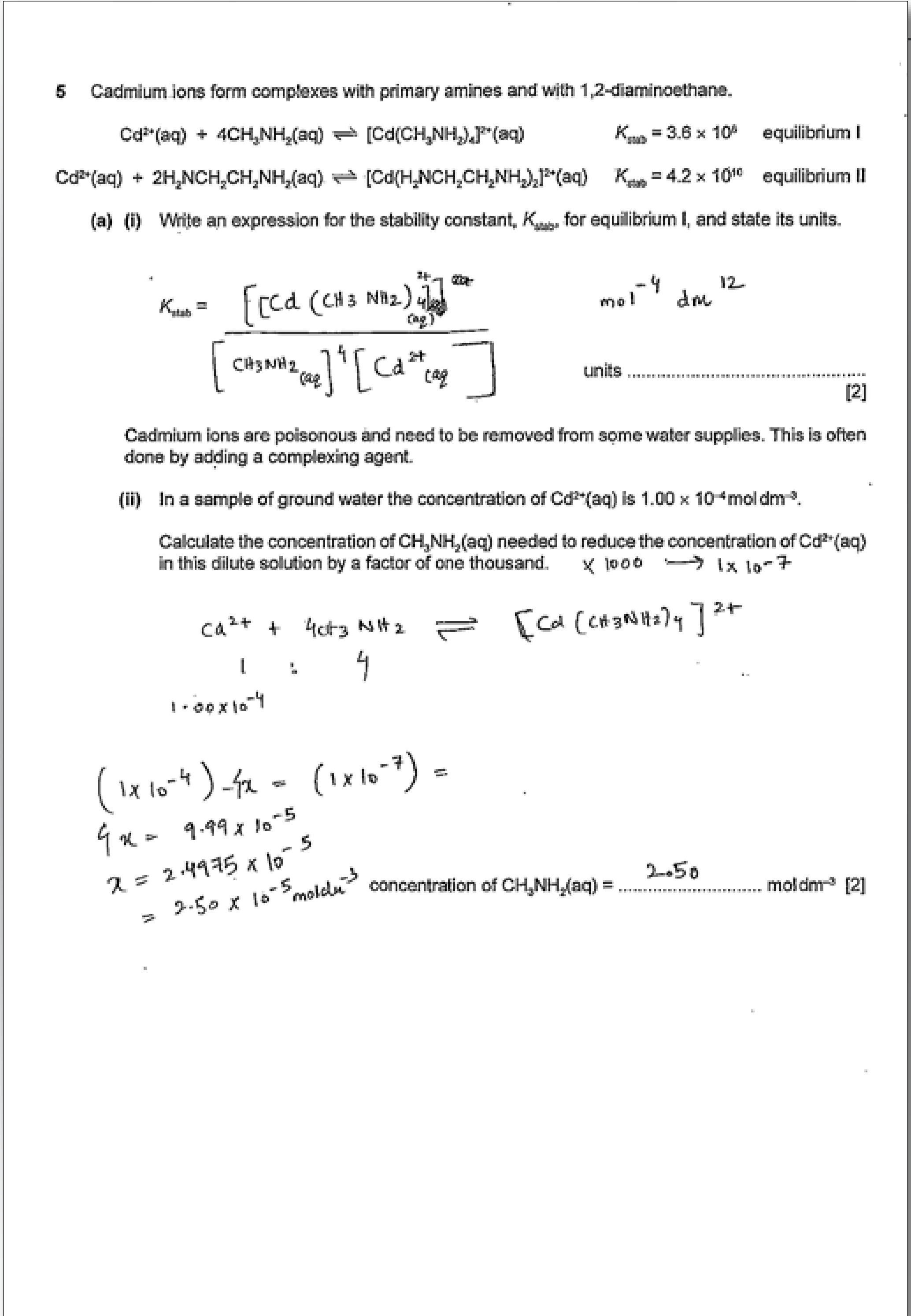

5 Cadmium ions form complexes with primary amines and with 1,2-diaminoethane.

$Cd^{2+}(aq) + 4CH_3NH_2(aq) \rightleftharpoons [Cd(CH_3NH_2)_4]^{2+}(aq)$ $K_{stab} = 3.6 \times 10^6$ equilibrium I

$Cd^{2+}(aq) + 2H_2NCH_2CH_2NH_2(aq) \rightleftharpoons [Cd(H_2NCH_2CH_2NH_2)_2]^{2+}(aq)$ $K_{stab} = 4.2 \times 10^{10}$ equilibrium II

(a) (i) Write an expression for the stability constant, K_{stab}, for equilibrium I, and state its units.

$$K_{stab} = \frac{[[Cd(CH_3NH_2)_4]^{2+}_{(aq)}]}{[CH_3NH_{2(aq)}]^4[Cd^{2+}_{(aq)}]}$$

$mol^{-4}\ dm^{12}$

units .... [2]

Cadmium ions are poisonous and need to be removed from some water supplies. This is often done by adding a complexing agent.

(ii) In a sample of ground water the concentration of $Cd^{2+}(aq)$ is $1.00 \times 10^{-4}\ mol\ dm^{-3}$.

Calculate the concentration of $CH_3NH_2(aq)$ needed to reduce the concentration of $Cd^{2+}(aq)$ in this dilute solution by a factor of one thousand. $\times 1000 \longrightarrow 1 \times 10^{-7}$

$Cd^{2+} + 4CH_3NH_2 \rightleftharpoons [Cd(CH_3NH_2)_4]^{2+}$

$1 : 4$

1.00×10^{-4}

$(1 \times 10^{-4}) - 4x = (1 \times 10^{-7}) =$

$4x = 9.99 \times 10^{-5}$

$x = 2.4975 \times 10^{-5}$

$= 2.50 \times 10^{-5}\ mol\,dm^{-3}$

concentration of $CH_3NH_2(aq)$ = ...2.50......... $mol\ dm^{-3}$ [2]

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Your Mark

5(a)(i) ☐

5(a)(ii) ☐

5(b)(i) ☐

5(b)(ii) ☐

5(b)(iii) ☐

5(b)(iv) ☐

Q5	Mark scheme
(a)(i)	$K_{stab} = \dfrac{[Cd(CH_3NH_2)_4{}^{2+}]}{[Cd^{2+}]\,[CH_3NH_2]^4}$ units: $mol^{-4}\ dm^{12}$ **[2]**
(a)(ii)	$Cd^{2+} + 4CH_3NH_2 \rightleftharpoons [Cd(CH_3NH_2)4]^{2+}$ at start: 1×1^{-4} **0** at eqm: 1×10^{-7} **y** **$1 \times 10^{-4} - 1 \times 10^{-7}$** **or 9.99×10^{-5} or 1.0×10^{-4}** $9.99 \times 10^{-5} / (\boldsymbol{y}^4 \times 10^{-7}) = 3.6 \times 10^6$ and $y = 4\sqrt{}(9.99 \times 10^{-5}) / (1 \times 10^{-7} \times 3.6 \times 10^6)$ = **0.129 / 0.13** **[2]**
(b)(i)	(each complex is formed by) making (4 ×)N-Cd bonds and breaking (6 ×) O-Cd bonds **or** same types of / similar bonds forming / breaking **or** same number of bonds forming / breaking **[1]**
(b)(ii)	$\Delta S = (\Delta H - \Delta G) / T = (60.7 - 56.5) \times 1000 / 298$ = (+)**14** / (+)**14.1** **[1]**
(b)(iii)	fewer moles (of solutes) are forming (one mole of) the complex (so less loss of disorder) **or** one en displaces two H_2O whereas one CH_3NH_2 only displaces one H_2O **[1]**
(b)(iv)	The $[Cd(H_2NCH_2CH_2NH_2)_2]^{2+}$ / equilibrium 2 complex (is more stable) because: *either* K_{stab} is greater or ΔG° is more negative. **[1]** **[Total: 8]**

EXAMINER COMMENTS

MARK SCHEME

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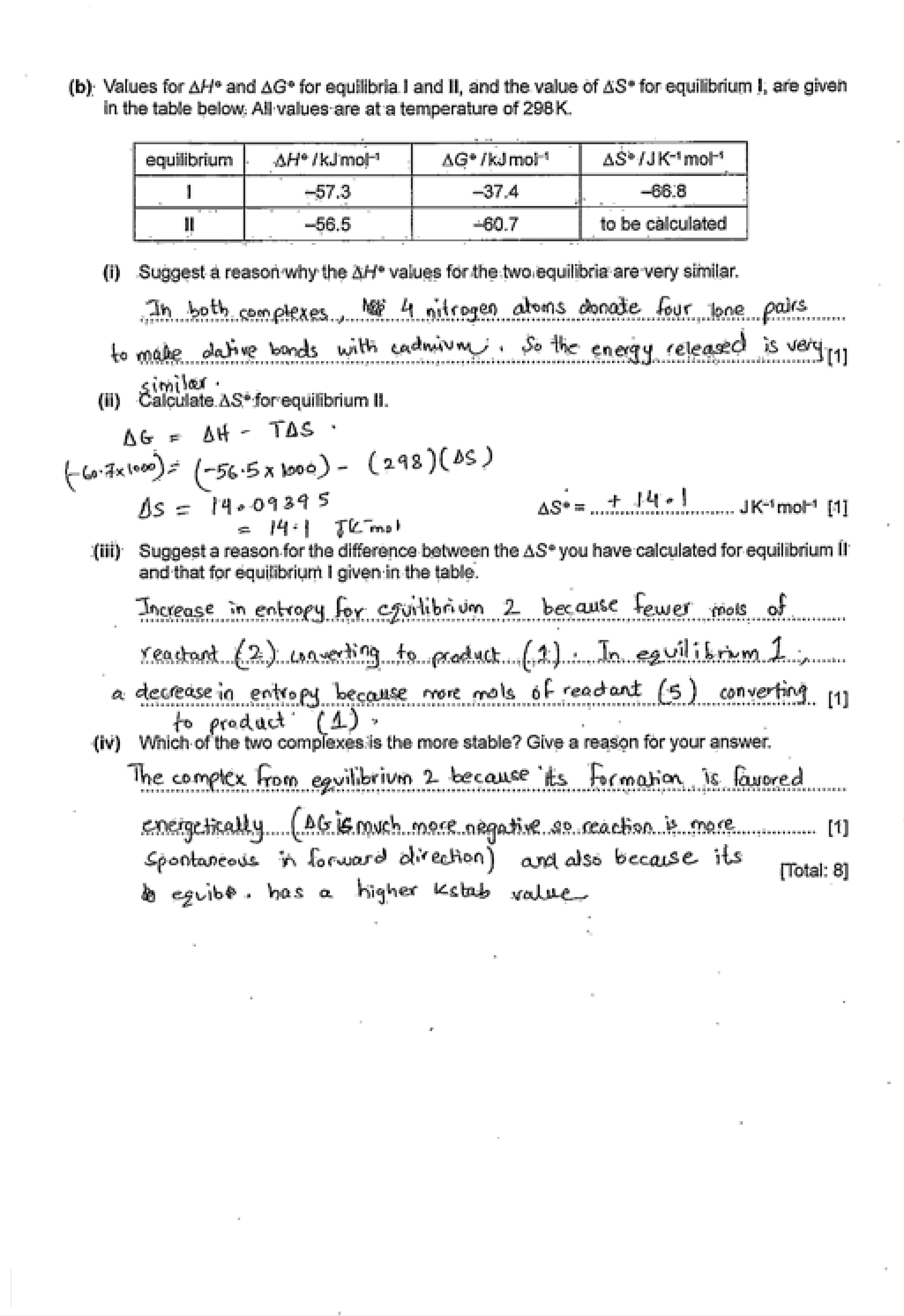

(b) Values for ΔH° and ΔG° for equilibria I and II, and the value of ΔS° for equilibrium I, are given in the table below. All values are at a temperature of 298 K.

equilibrium	ΔH° / kJ mol^{-1}	ΔG° / kJ mol^{-1}	ΔS° / J K^{-1} mol^{-1}
I	–57.3	–37.4	–66.8
II	–56.5	–60.7	to be calculated

(i) Suggest a reason why the ΔH° values for the two equilibria are very similar.

In both complexes, ~~N~~ 4 nitrogen atoms donate four lone pairs to make dative bonds with cadmium. So the energy released is very similar. [1]

(ii) Calculate ΔS° for equilibrium II.

$\Delta G = \Delta H - T\Delta S$

$(-60.7 \times 1000) = (-56.5 \times 1000) - (298)(\Delta S)$

$\Delta S = 14.09395$

$= 14.1 \ \mathrm{JK^{-}mol}$

$\Delta S^\circ =$ + 14.1 JK^{-1}mol^{-1} [1]

(iii) Suggest a reason for the difference between the ΔS° you have calculated for equilibrium II and that for equilibrium I given in the table.

Increase in entropy for equilibrium 2 because fewer mols of reactant (2) converting to product (1). In equilibrium 1, a decrease in entropy because more mols of reactant (5) converting to product (1). [1]

(iv) Which of the two complexes is the more stable? Give a reason for your answer.

The complex from equilibrium 2 because its formation is favored energetically (ΔG is much more negative so reaction is more spontaneous in forward direction) and also because its ~~e~~ equib. has a higher Kstab value [1]

[Total: 8]

Your Mark

- **5(a)(i)** ☐
- **5(a)(ii)** ☐
- **5(b)(i)** ☐
- **5(b)(ii)** ☐
- **5(b)(iii)** ☐
- **5(b)(iv)** ☐

Q5	Mark scheme
(a)(i)	$K_{stab} = \dfrac{[\mathrm{Cd(CH_3NH_2)_4}^{2+}]}{[\mathrm{Cd^{2+}}]\,[\mathrm{CH_3NH_2}]^4}$ units: $\mathrm{mol^{-4}\ dm^{12}}$ **[2]**
(a)(ii)	$\mathrm{Cd^{2+} + 4CH_3NH_2 \rightleftharpoons [Cd(CH_3NH_2)4]^{2+}}$ at start: 1×1^{-4} **0** at eqm: 1×10^{-7} **y** **$1 \times 10^{-4} - 1 \times 10^{-7}$** **or 9.99×10^{-5} or 1.0×10^{-4}** $9.99 \times 10^{-5} / (y^4 \times 10^{-7}) = 3.6 \times 10^6$ and $y = 4\sqrt{}(9.99 \times 10^{-5}) / (1 \times 10^{-7} \times 3.6 \times 10^6) =$ **0.129 / 0.13** **[2]**
(b)(i)	(each complex is formed by) making (4 ×)N-Cd bonds and breaking (6 ×) O-Cd bonds **or** same types of / similar bonds forming / breaking **or** same number of bonds forming / breaking **[1]**
(b)(ii)	$\Delta S = (\Delta H - \Delta G) / T = (60.7 - 56.5) \times 1000 / 298 = (+)$**14** / (+)**14.1** **[1]**
(b)(iii)	fewer moles (of solutes) are forming (one mole of) the complex (so less loss of disorder) **or** one en displaces two $\mathrm{H_2O}$ whereas one $\mathrm{CH_3NH_2}$ only displaces one $\mathrm{H_2O}$ **[1]**
(b)(iv)	The $\mathrm{[Cd(H_2NCH_2CH_2NH_2)_2]^{2+}}$ / equilibrium 2 complex (is more stable) because: *either* K_{stab} is greater or ΔG^{o} is more negative. **[1]** **[Total: 8]**

EXAMINER COMMENTS

MARK SCHEME

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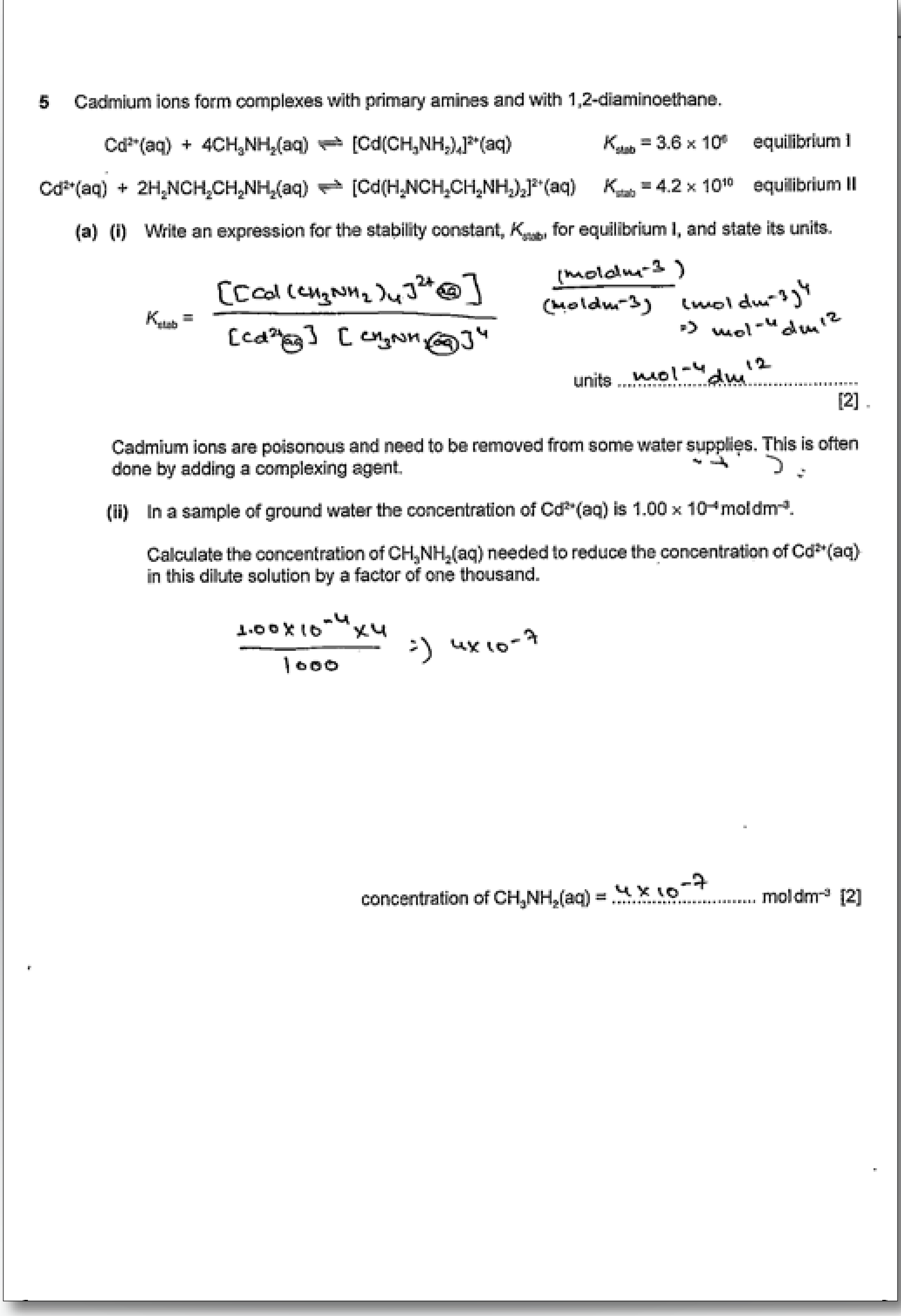

5 Cadmium ions form complexes with primary amines and with 1,2-diaminoethane.

$Cd^{2+}(aq) + 4CH_3NH_2(aq) \rightleftharpoons [Cd(CH_3NH_2)_4]^{2+}(aq)$ $K_{stab} = 3.6 \times 10^6$ equilibrium I

$Cd^{2+}(aq) + 2H_2NCH_2CH_2NH_2(aq) \rightleftharpoons [Cd(H_2NCH_2CH_2NH_2)_2]^{2+}(aq)$ $K_{stab} = 4.2 \times 10^{10}$ equilibrium II

(a) (i) Write an expression for the stability constant, K_{stab}, for equilibrium I, and state its units.

$$K_{stab} = \frac{[[Cd(CH_3NH_2)_4]^{2+}(aq)]}{[Cd^{2+}(aq)]\ [CH_3NH_2(aq)]^4}$$

$$\frac{(mol dm^{-3})}{(mol dm^{-3})\ (mol dm^{-3})^4} \Rightarrow mol^{-4} dm^{12}$$

units $mol^{-4} dm^{12}$ [2]

Cadmium ions are poisonous and need to be removed from some water supplies. This is often done by adding a complexing agent.

(ii) In a sample of ground water the concentration of $Cd^{2+}(aq)$ is 1.00×10^{-4} mol dm^{-3}.

Calculate the concentration of $CH_3NH_2(aq)$ needed to reduce the concentration of $Cd^{2+}(aq)$ in this dilute solution by a factor of one thousand.

$$\frac{1.00 \times 10^{-4} \times 4}{1000} \Rightarrow 4 \times 10^{-7}$$

concentration of $CH_3NH_2(aq)$ = 4×10^{-7} mol dm^{-3} [2]

Your Mark

5(a)(i) ☐

5(a)(ii) ☐

5(b)(i) ☐

5(b)(ii) ☐

5(b)(iii) ☐

5(b)(iv) ☐

Q5	Mark scheme
(a)(i)	$K_{stab} = \frac{[Cd(CH_3NH_2)_4{}^{2+}]}{[Cd^{2+}]\ [CH_3NH_2]^4}$ units: $mol^{-4}\ dm^{12}$ **[2]**
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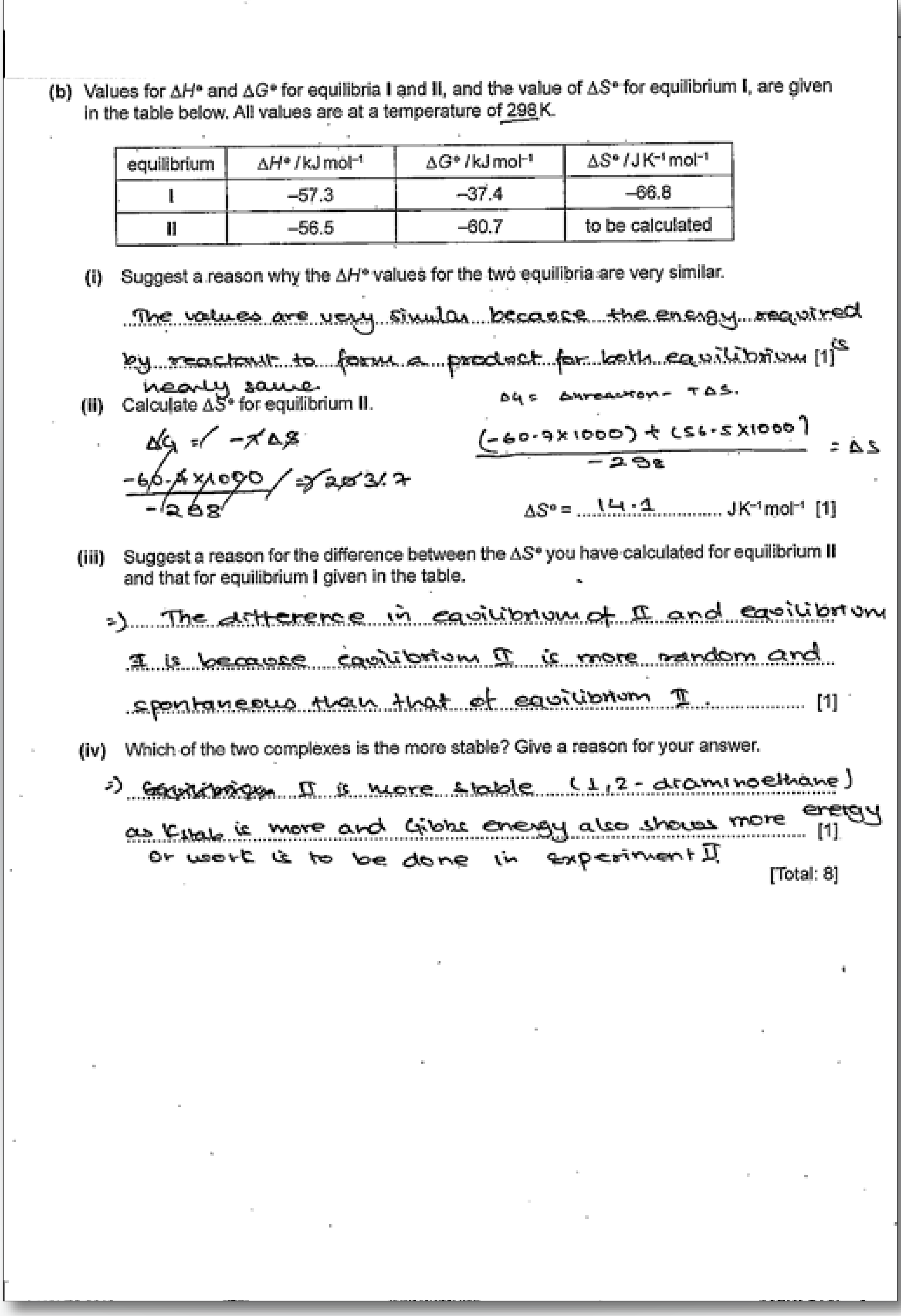
(b)(i)	(each complex is formed by) making (4 ×)N-Cd bonds and breaking (6 ×) O-Cd bonds **or** same types of / similar bonds forming / breaking **or** same number of bonds forming / breaking **[1]**
(b)(ii)	ΔS = (ΔH – ΔG) /T = (60.7 – 56.5) × 1000 / 298 = (+)**14** / (+)**14.1** **[1]**
(b)(iii)	fewer moles (of solutes) are forming (one mole of) the complex (so less loss of disorder) **or** one en displaces two H_2O whereas one CH_3NH_2 only displaces one H_2O **[1]**
(b)(iv)	The $[Cd(H_2NCH_2CH_2NH_2)_2]^{2+}$ / equilibrium 2 complex (is more stable) because: *either* K_{stab} is greater or $\Delta G^{\ominus}$ is more negative. **[1]** **[Total: 8]**

EXAMINER COMMENTS

MARK SCHEME



(b) Values for ΔH° and ΔG° for equilibria I and II, and the value of ΔS° for equilibrium I, are given in the table below. All values are at a temperature of 298 K.

equilibrium	ΔH° / kJ mol^{-1}	ΔG° / kJ mol^{-1}	ΔS° / J K^{-1} mol^{-1}
I	–57.3	–37.4	–66.8
II	–56.5	–60.7	to be calculated

(i) Suggest a reason why the ΔH° values for the two equilibria are very similar.

The values are very similar because the energy required by reactant to form a product for both equilibrium is nearly same. [1]

(ii) Calculate ΔS° for equilibrium II.

~~ΔG = H − TΔS~~

~~−60.7 × 1000 / −298 ⇒ 203.7~~

ΔG = ΔHreaction − TΔS.

$\frac{(-60.7 \times 1000) + (56.5 \times 1000)}{-298} = \Delta S$

ΔS° = 14.1 JK^{-1}mol^{-1} [1]

(iii) Suggest a reason for the difference between the ΔS° you have calculated for equilibrium II and that for equilibrium I given in the table.

⇒ The difference in equilibrium of II and equilibrium I is because equilibrium II is more random and spontaneous than that of equilibrium I. [1]

(iv) Which of the two complexes is the more stable? Give a reason for your answer.

⇒ ~~Equilibrium~~ II is more stable (1,2-diaminoethane) as Kstab is more and Gibbs energy also shows more energy or work is to be done in experiment II [1]

[Total: 8]

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Your Mark

5(a)(i) ☐

5(a)(ii) ☐

5(b)(i) ☐

5(b)(ii) ☐

5(b)(iii) ☐

5(b)(iv) ☐

Q5	Mark scheme
(a)(i)	$K_{stab} = \frac{[Cd(CH_3NH_2)_4{}^{2+}]}{[Cd^{2+}]\,[CH_3NH_2]^4}$ units: mol^{-4} dm^{12} **[2]**
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(b)(i)	(each complex is formed by) making (4 ×)N-Cd bonds and breaking (6 ×) O-Cd bonds **or** same types of / similar bonds forming / breaking **or** same number of bonds forming / breaking **[1]**
(b)(ii)	ΔS = (ΔH – ΔG) /T = (60.7 – 56.5) × 1000 / 298 = (+)**14** / (+)**14.1** **[1]**
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(b)(iv)	The $[Cd(H_2NCH_2CH_2NH_2)_2]^{2+}$ / equilibrium 2 complex (is more stable) because: *either* K_{stab} is greater or ΔG° is more negative. **[1]** **[Total: 8]**

EXAMINER COMMENTS

MARK SCHEME

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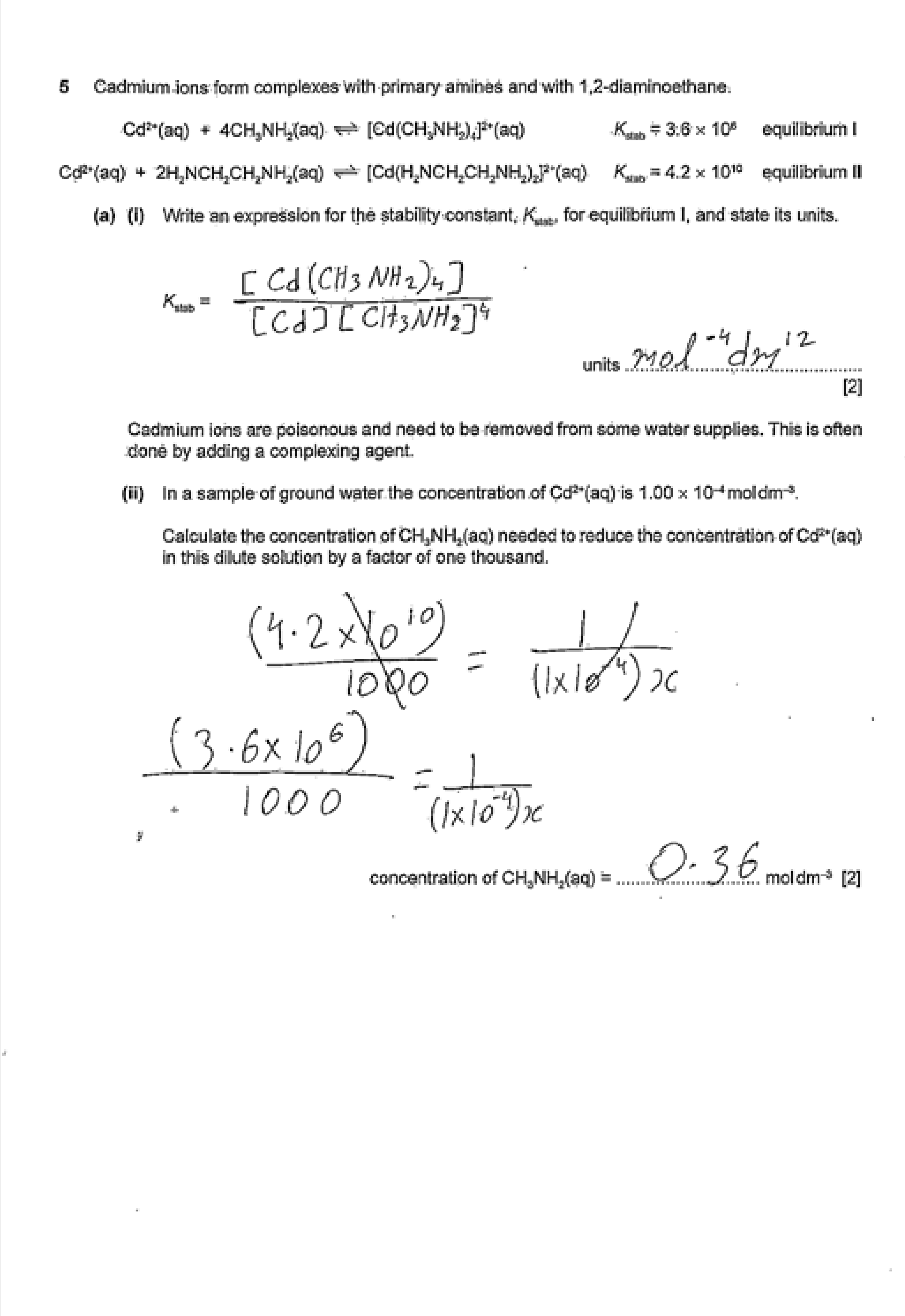


5 Cadmium ions form complexes with primary amines and with 1,2-diaminoethane.

$Cd^{2+}(aq) + 4CH_3NH_2(aq) \rightleftharpoons [Cd(CH_3NH_2)_4]^{2+}(aq)$ $K_{stab} = 3.6 \times 10^6$ equilibrium I

$Cd^{2+}(aq) + 2H_2NCH_2CH_2NH_2(aq) \rightleftharpoons [Cd(H_2NCH_2CH_2NH_2)_2]^{2+}(aq)$ $K_{stab} = 4.2 \times 10^{10}$ equilibrium II

(a) (i) Write an expression for the stability constant, K_{stab}, for equilibrium I, and state its units.

$$K_{stab} = \frac{[Cd(CH_3NH_2)_4]}{[Cd][CH_3NH_2]^4}$$

units $mol^{-4} dm^{12}$

[2]

Cadmium ions are poisonous and need to be removed from some water supplies. This is often done by adding a complexing agent.

(ii) In a sample of ground water the concentration of $Cd^{2+}(aq)$ is 1.00×10^{-4} mol dm^{-3}.

Calculate the concentration of $CH_3NH_2(aq)$ needed to reduce the concentration of $Cd^{2+}(aq)$ in this dilute solution by a factor of one thousand.

$$\cancel{\frac{(4.2 \times 10^{10})}{1000} = \frac{1}{(1 \times 10^{-4})x}}$$

$$\frac{(3.6 \times 10^6)}{1000} = \frac{1}{(1 \times 10^{-4})x}$$

concentration of $CH_3NH_2(aq)$ = 0.36 mol dm^{-3} [2]

Your Mark

5(a)(i) ☐

5(a)(ii) ☐

5(b)(i) ☐

5(b)(ii) ☐

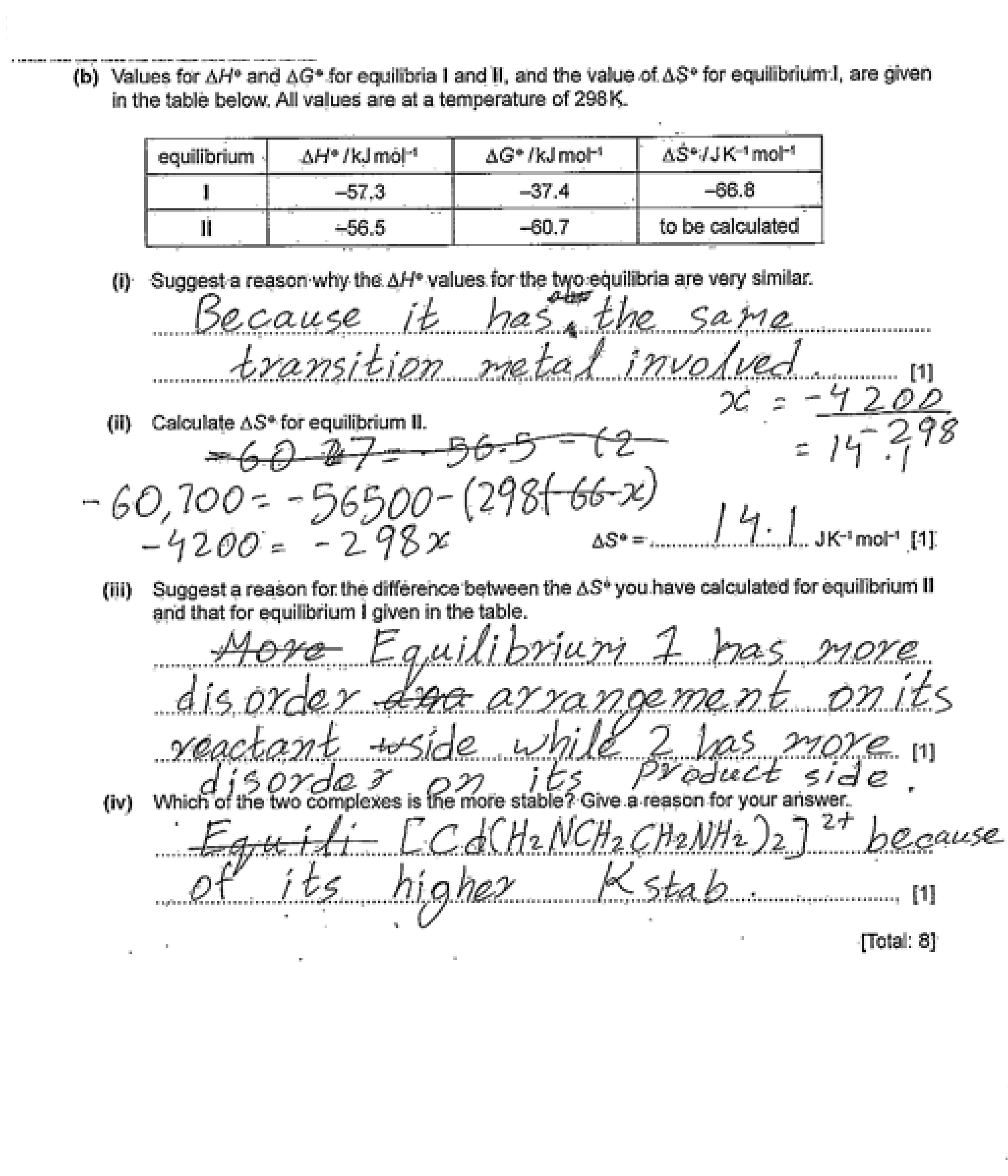
5(b)(iii) ☐

5(b)(iv) ☐

Q5	Mark scheme
(a)(i)	$K_{stab} = \frac{[Cd(CH_3NH_2)_4{}^{2+}]}{[Cd^{2+}][CH_3NH_2]^4}$ units: $mol^{-4} dm^{12}$ **[2]**
(a)(ii)	$Cd^{2+} + 4CH_3NH_2 \rightleftharpoons [Cd(CH_3NH_2)4]^{2+}$ at start: 1×1^{-4} **0** at eqm: 1×10^{-7} ***y*** **$1 \times 10^{-4} - 1 \times 10^{-7}$** **or 9.99×10^{-5} or 1.0×10^{-4}** $9.99 \times 10^{-5} / (y^4 \times 10^{-7}) = 3.6 \times 10^6$ and $y = 4\sqrt{(9.99 \times 10^{-5}) / (1 \times 10^{-7} \times 3.6 \times 10^6)}$ = **0.129 / 0.13** **[2]**
(b)(i)	(each complex is formed by) making (4 ×)N-Cd bonds and breaking (6 ×) O-Cd bonds **or** same types of / similar bonds forming / breaking **or** same number of bonds forming / breaking **[1]**
(b)(ii)	$\Delta S = (\Delta H - \Delta G) / T = (60.7 - 56.5) \times 1000 / 298 = (+)$**14** / (+)**14.1** **[1]**
(b)(iii)	fewer moles (of solutes) are forming (one mole of) the complex (so less loss of disorder) **or** one en displaces two H_2O whereas one CH_3NH_2 only displaces one H_2O **[1]**
(b)(iv)	The $[Cd(H_2NCH_2CH_2NH_2)_2]^{2+}$ / equilibrium 2 complex (is more stable) because: *either* K_{stab} is greater or ΔG° is more negative. **[1]** **[Total: 8]**

EXAMINER COMMENTS

MARK SCHEME



(b) Values for ΔH° and ΔG° for equilibria I and II, and the value of ΔS° for equilibrium I, are given in the table below. All values are at a temperature of 298 K.

equilibrium	ΔH° / kJ mol^{-1}	ΔG° / kJ mol^{-1}	ΔS° / J K^{-1} mol^{-1}
I	−57.3	−37.4	−66.8
II	−56.5	−60.7	to be calculated

(i) Suggest a reason why the ΔH° values for the two equilibria are very similar.

Because it has ~~one~~ the same transition metal involved. [1]

(ii) Calculate ΔS° for equilibrium II.

~~−60.7 = −56.5 − (2~~

−60,700 = −56500 − (298(~~−66~~ −x)

−4200 = −298x

$x = \frac{-4200}{-298}$

= 14.1

ΔS° = 14.1 JK^{-1} mol^{-1} [1]

(iii) Suggest a reason for the difference between the ΔS° you have calculated for equilibrium II and that for equilibrium I given in the table.

~~More~~ Equilibrium 1 has more disorder ~~dua~~ arrangement on its reactant ~~w~~side while 2 has more disorder on its Product side. [1]

(iv) Which of the two complexes is the more stable? Give a reason for your answer.

~~Equili~~ $[Cd(H_2NCH_2CH_2NH_2)_2]^{2+}$ because of its higher Kstab. [1]

[Total: 8]

Your Mark

5(a)(i) ☐

5(a)(ii) ☐

5(b)(i) ☐

5(b)(ii) ☐

5(b)(iii) ☐

5(b)(iv) ☐

Q5	**Mark scheme**
(a)(i)	$K_{stab} = \frac{[Cd(CH_3NH_2)_4^{2+}]}{[Cd^{2+}][CH_3NH_2]^4}$ units: mol^{-4} dm^{12} **[2]**
(a)(ii)	$Cd^{2+} + 4CH_3NH_2 \rightleftharpoons [Cd(CH_3NH_2)4]^{2+}$ at start: 1×1^{-4} **0** at eqm: 1×10^{-7} **y** **$1 \times 10^{-4} - 1 \times 10^{-7}$** **or 9.99×10^{-5} or 1.0×10^{-4}** $9.99 \times 10^{-5} / (y^4 \times 10^{-7}) = 3.6 \times 10^6$ and y = $4\sqrt{(9.99 \times 10^{-5}) / (1 \times 10^{-7} \times 3.6 \times 10^6)}$ = **0.129 / 0.13** **[2]**
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(b)(iv)	The $[Cd(H_2NCH_2CH_2NH_2)_2]^{2+}$ / equilibrium 2 complex (is more stable) because: *either* K_{stab} is greater or ΔG° is more negative. **[1]** **[Total: 8]**

EXAMINER COMMENTS
MARK SCHEME

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Paper 42 (May/June 2016), Question 6

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Cambridge Pathway

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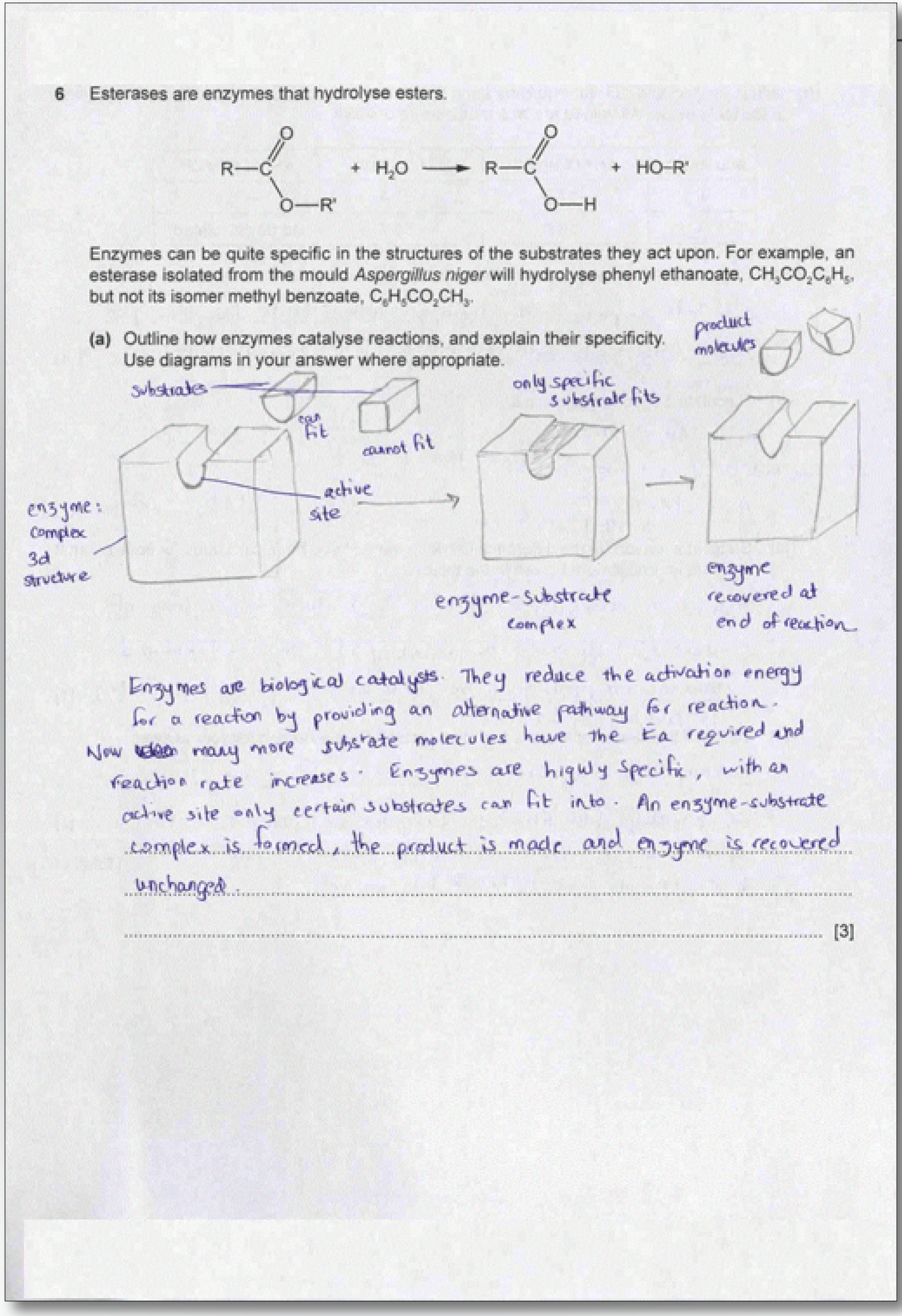

6 Esterases are enzymes that hydrolyse esters.

$$R{-}C(=O){-}O{-}R' + H_2O \longrightarrow R{-}C(=O){-}O{-}H + HO{-}R'$$

Enzymes can be quite specific in the structures of the substrates they act upon. For example, an esterase isolated from the mould *Aspergillus niger* will hydrolyse phenyl ethanoate, $CH_3CO_2C_6H_5$, but not its isomer methyl benzoate, $C_6H_5CO_2CH_3$.

(a) Outline how enzymes catalyse reactions, and explain their specificity. Use diagrams in your answer where appropriate.

Enzymes are biological catalysts. They reduce the activation energy for a reaction by providing an alternative pathway for reaction. Now ~~[illegible]~~ many more substrate molecules have the Ea required and reaction rate increases. Enzymes are highly specific, with an active site only certain substrates can fit into. An enzyme-substrate complex is formed, the product is made and enzyme is recovered unchanged.

[3]

Select page

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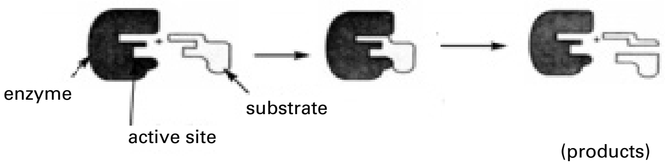
Your Mark

6(a)

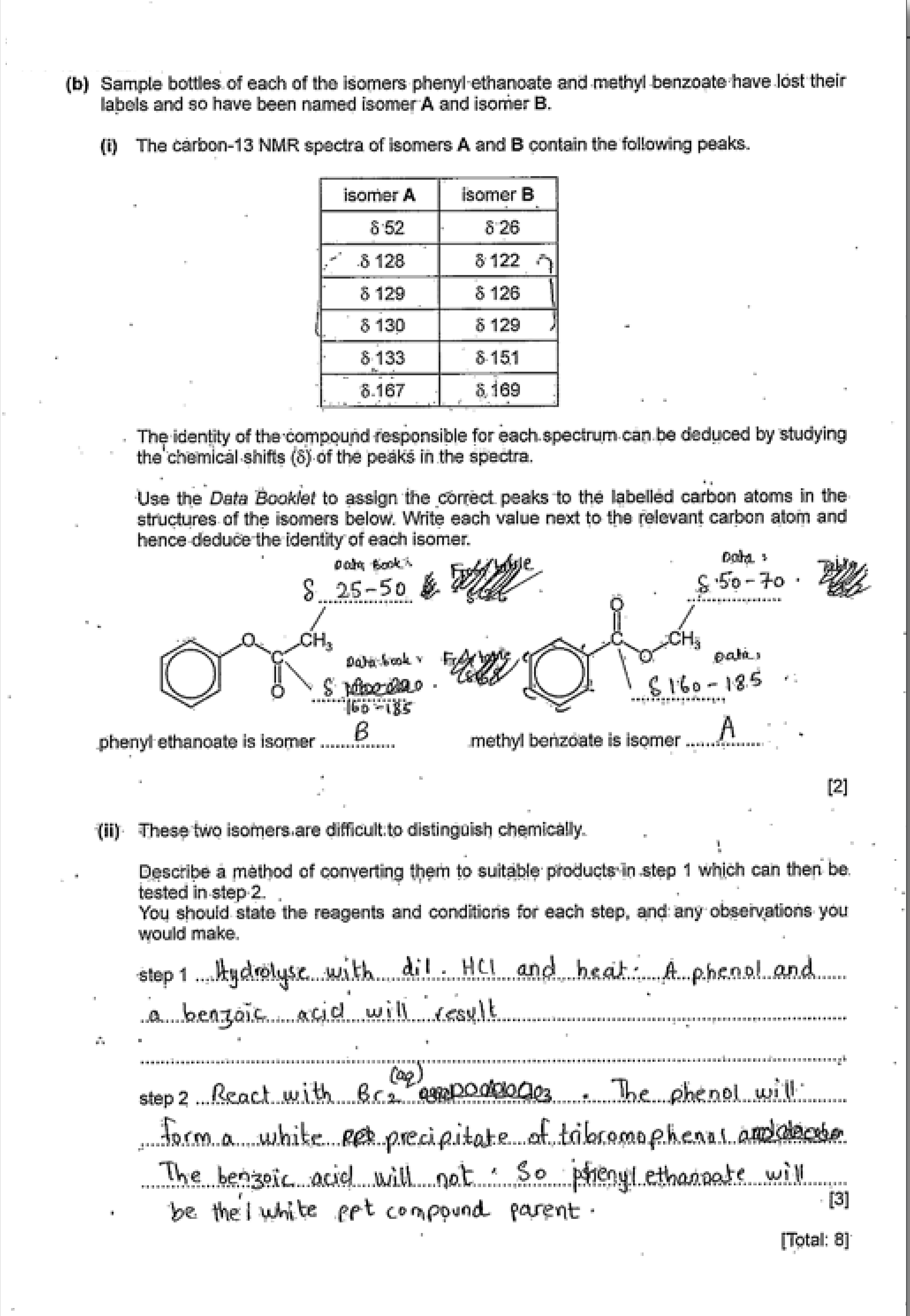
6(b)(i)

6(b)(ii)

Q6	Mark scheme
(a)	*essential mark* M1 the reactants / substrate has a **shape** complementary / **specific** to **<u>active site</u>** – can be awarded from a labelled diagram as below or diagrams showing this specificity clearly *any two of* M2: reactants / substrate binds to / fits into the <u>active site</u> of the enzyme M3: (Interaction with site) causes a specific bond to be weakened, (which breaks) **or** lowers activation energy M4: forms an E-S complex M5: products released from enzyme / active site **labelled diagrams**  **[3]**
(b)(i)	δ 26 is **C**H3-CO δ 52 is **C**H3-O δ 169 is CH3**CO** δ 167 is phenyl-**C**O <u>Phenyl ethanoate</u> is **B** <u>methyl benzoate</u> is **A** M1 = any two correct δ linked to phenylethanoate / methyl benzoate M2 = the rest correct **[2]**
(b)(iI)	heat with H_3O^+ (to hydrolyse the ester) then add Br_2(aq) / bromine water decolourises/gives white ppt. (with phenol from **B**) **[3]** **[Total: 8]**

EXAMINER COMMENTS

MARK SCHEME



(b) Sample bottles of each of the isomers phenyl ethanoate and methyl benzoate have lost their labels and so have been named isomer **A** and isomer **B**.

(i) The carbon-13 NMR spectra of isomers **A** and **B** contain the following peaks.

isomer A	isomer B
δ 52	δ 26
δ 128	δ 122
δ 129	δ 126
δ 130	δ 129
δ 133	δ 151
δ 167	δ 169

The identity of the compound responsible for each spectrum can be deduced by studying the chemical shifts (δ) of the peaks in the spectra.

Use the *Data Booklet* to assign the correct peaks to the labelled carbon atoms in the structures of the isomers below. Write each value next to the relevant carbon atom and hence deduce the identity of each isomer.

Data Book :
δ 25-50

Data book :
δ ~~160-220~~
160-185

Data :
δ 50-70

Data :
δ 160-185

phenyl ethanoate is isomer B

methyl benzoate is isomer A

[2]

(ii) These two isomers are difficult to distinguish chemically.

Describe a method of converting them to suitable products in step 1 which can then be tested in step 2.
You should state the reagents and conditions for each step, and any observations you would make.

step 1 Hydrolyse with dil. HCl and heat. A phenol and a benzoic acid will result

step 2 React with Br_2 (aq) ~~[illegible]~~. The phenol will form a white ~~ppt~~ precipitate of tribromophenol ~~and decolo~~ The benzoic acid will not. So phenyl ethanoate will be the white ppt compound parent.

[3]

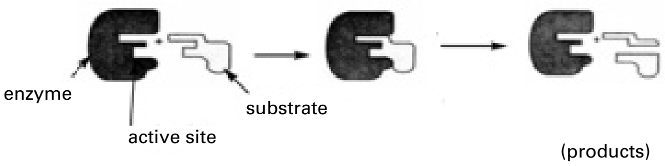
[Total: 8]

Your Mark

6(a) ☐

6(b)(i) ☐

6(b)(ii) ☐

Q6	Mark scheme
(a)	*essential mark* M1 the reactants / substrate has a **shape** complementary / **specific** to **<u>active site</u>** – can be awarded from a labelled diagram as below or diagrams showing this specificity clearly *any two of* M2: reactants / substrate binds to / fits into the <u>active site</u> of the enzyme M3: (Interaction with site) causes a specific bond to be weakened, (which breaks) **or** lowers activation energy M4: forms an E-S complex M5: products released from enzyme / active site **labelled diagrams**  **[3]**
(b)(i)	δ 26 is **C**H3-CO δ 52 is **C**H3-O δ 169 is CH3**CO** δ 167 is phenyl-**C**O <u>Phenyl ethanoate</u> is **B** <u>methyl benzoate</u> is **A** M1 = any two correct δ linked to phenylethanoate / methyl benzoate M2 = the rest correct **[2]**
(b)(ii)	heat with H_3O^+ (to hydrolyse the ester) then add Br_2(aq) / bromine water decolourises/gives white ppt. (with phenol from **B**) **[3]** **[Total: 8]**

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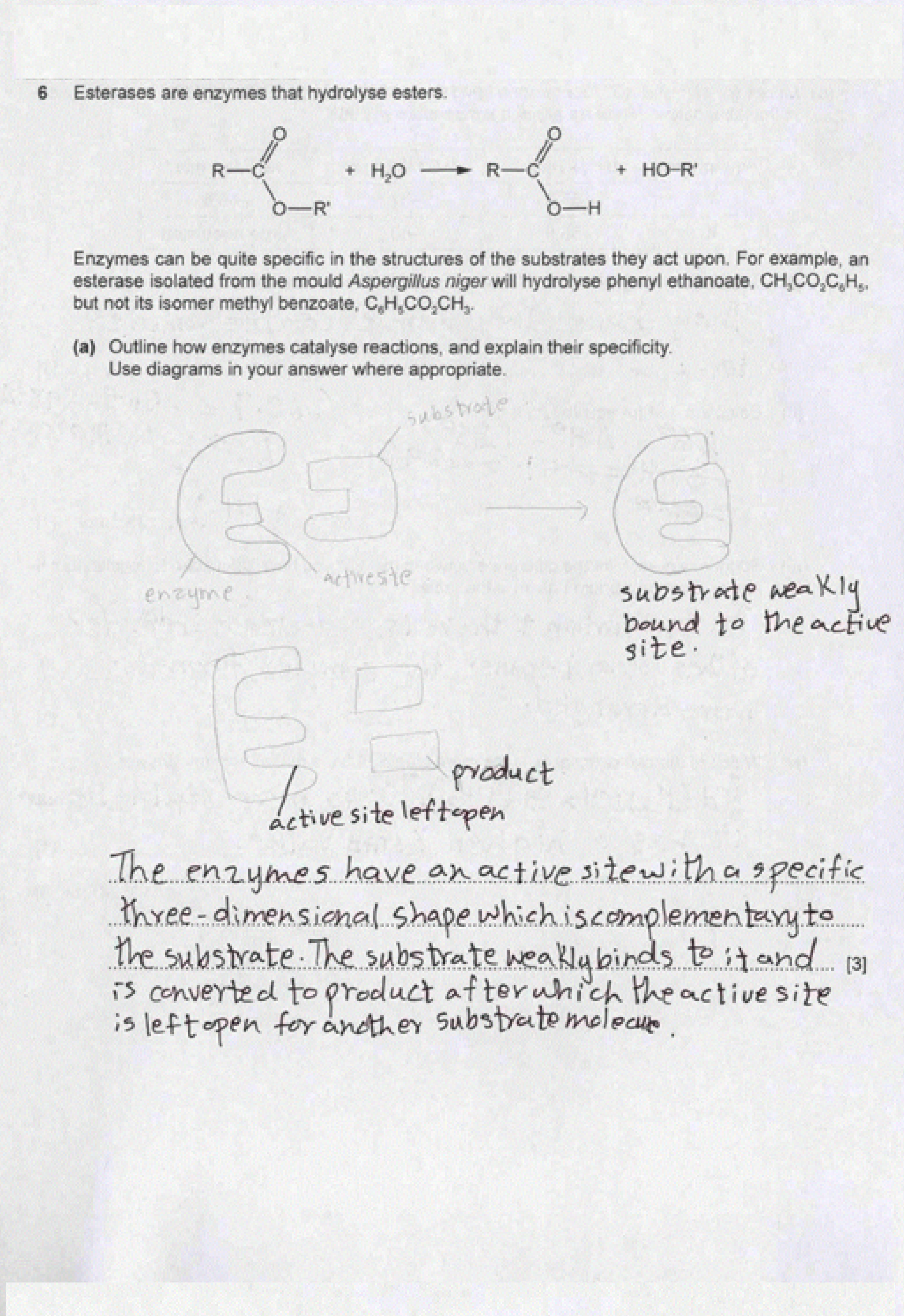


6 Esterases are enzymes that hydrolyse esters.

$$R{-}C({=}O){-}O{-}R' + H_2O \longrightarrow R{-}C({=}O){-}O{-}H + HO{-}R'$$

Enzymes can be quite specific in the structures of the substrates they act upon. For example, an esterase isolated from the mould *Aspergillus niger* will hydrolyse phenyl ethanoate, $CH_3CO_2C_6H_5$, but not its isomer methyl benzoate, $C_6H_5CO_2CH_3$.

(a) Outline how enzymes catalyse reactions, and explain their specificity. Use diagrams in your answer where appropriate.

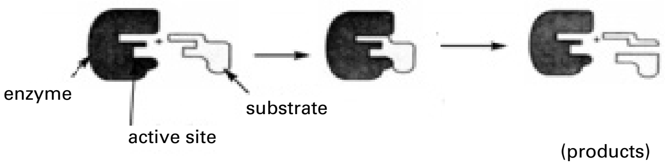
The enzymes have an active site with a specific three-dimensional shape which is complementary to the substrate. The substrate weakly binds to it and is converted to product after which the active site is left open for another substrate molecule. [3]

Your Mark

6(a) ☐

6(b)(i) ☐

6(b)(ii) ☐

Q6	Mark scheme
(a)	*essential mark* M1 the reactants / substrate has a **shape** complementary / **specific** to **<u>active site</u>** – can be awarded from a labelled diagram as below or diagrams showing this specificity clearly *any two of* M2: reactants / substrate binds to / fits into the <u>active site</u> of the enzyme M3: (Interaction with site) causes a specific bond to be weakened, (which breaks) **or** lowers activation energy M4: forms an E-S complex M5: products released from enzyme / active site **labelled diagrams**  **[3]**
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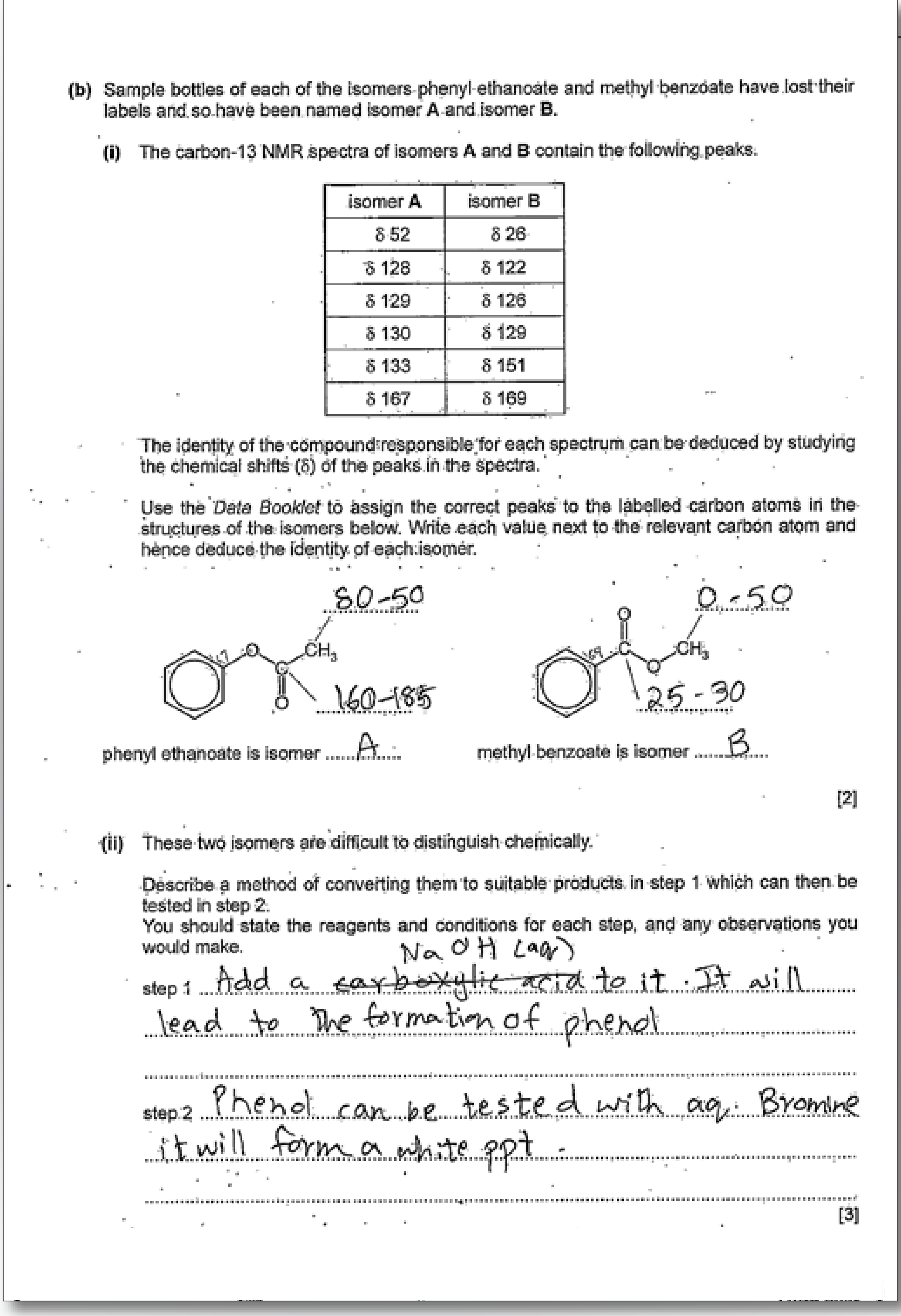
(b)(iI)	heat with H_3O^+ (to hydrolyse the ester) then add $Br_2(aq)$ / bromine water decolourises/gives white ppt. (with phenol from **B**) **[3]** **[Total: 8]**

EXAMINER COMMENTS

MARK SCHEME



(b) Sample bottles of each of the isomers phenyl ethanoate and methyl benzoate have lost their labels and so have been named isomer **A** and isomer **B**.

(i) The carbon-13 NMR spectra of isomers **A** and **B** contain the following peaks.

isomer A	isomer B
δ 52	δ 26
δ 128	δ 122
δ 129	δ 126
δ 130	δ 129
δ 133	δ 151
δ 167	δ 169

The identity of the compound responsible for each spectrum can be deduced by studying the chemical shifts (δ) of the peaks in the spectra.

Use the *Data Booklet* to assign the correct peaks to the labelled carbon atoms in the structures of the isomers below. Write each value next to the relevant carbon atom and hence deduce the identity of each isomer.

phenyl ethanoate is isomer ......A...... methyl benzoate is isomer ......B......

[2]

(ii) These two isomers are difficult to distinguish chemically.

Describe a method of converting them to suitable products in step 1 which can then be tested in step 2.
You should state the reagents and conditions for each step, and any observations you would make.

step 1 Add a ~~carboxylic acid~~ NaOH (aq) to it. It will lead to the formation of phenol

step 2 Phenol can be tested with aq. Bromine it will form a white ppt.

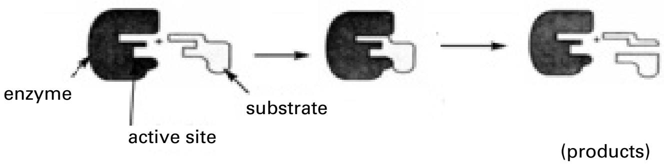
[3]

Your Mark

6(a) ☐

6(b)(i) ☐

6(b)(ii) ☐

Q6	Mark scheme
(a)	*essential mark* M1 the reactants / substrate has a **shape** complementary / **specific** to **<u>active site</u>** – can be awarded from a labelled diagram as below or diagrams showing this specificity clearly *any two of* M2: reactants / substrate binds to / fits into the <u>active site</u> of the enzyme M3: (Interaction with site) causes a specific bond to be weakened, (which breaks) **or** lowers activation energy M4: forms an E-S complex M5: products released from enzyme / active site **labelled diagrams**  **[3]**
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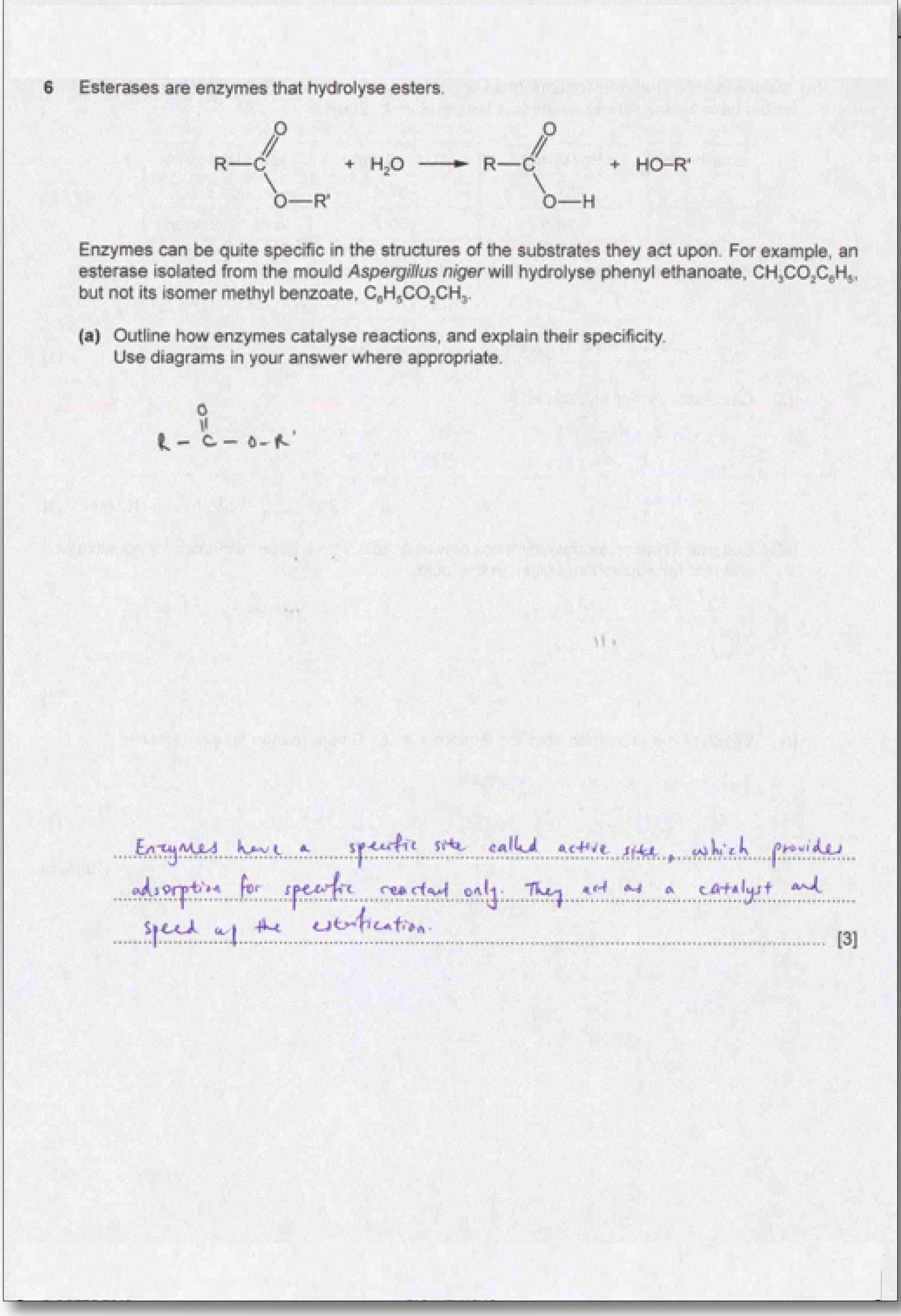

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(a) Outline how enzymes catalyse reactions, and explain their specificity. Use diagrams in your answer where appropriate.

$R - \overset{O}{\overset{\|}{C}} - O - R'$

Enzymes have a specific site called active site, which provides adsorption for specific reactant only. They act as a catalyst and speed up the esterification.

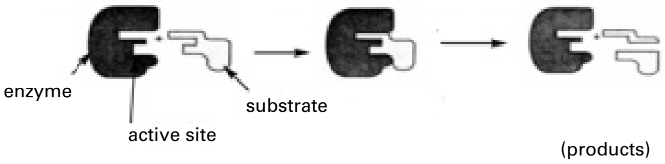
[3]

Your Mark

6(a) ☐

6(b)(i) ☐

6(b)(ii) ☐

Q6	**Mark scheme**
(a)	*essential mark* M1 the reactants / substrate has a **shape** complementary / **specific** to **<u>active site</u>** – can be awarded from a labelled diagram as below or diagrams showing this specificity clearly *any two of* M2: reactants / substrate binds to / fits into the <u>active site</u> of the enzyme M3: (Interaction with site) causes a specific bond to be weakened, (which breaks) **or** lowers activation energy M4: forms an E-S complex M5: products released from enzyme / active site **labelled diagrams**  **[3]**
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EXAMINER COMMENTS MARK SCHEME

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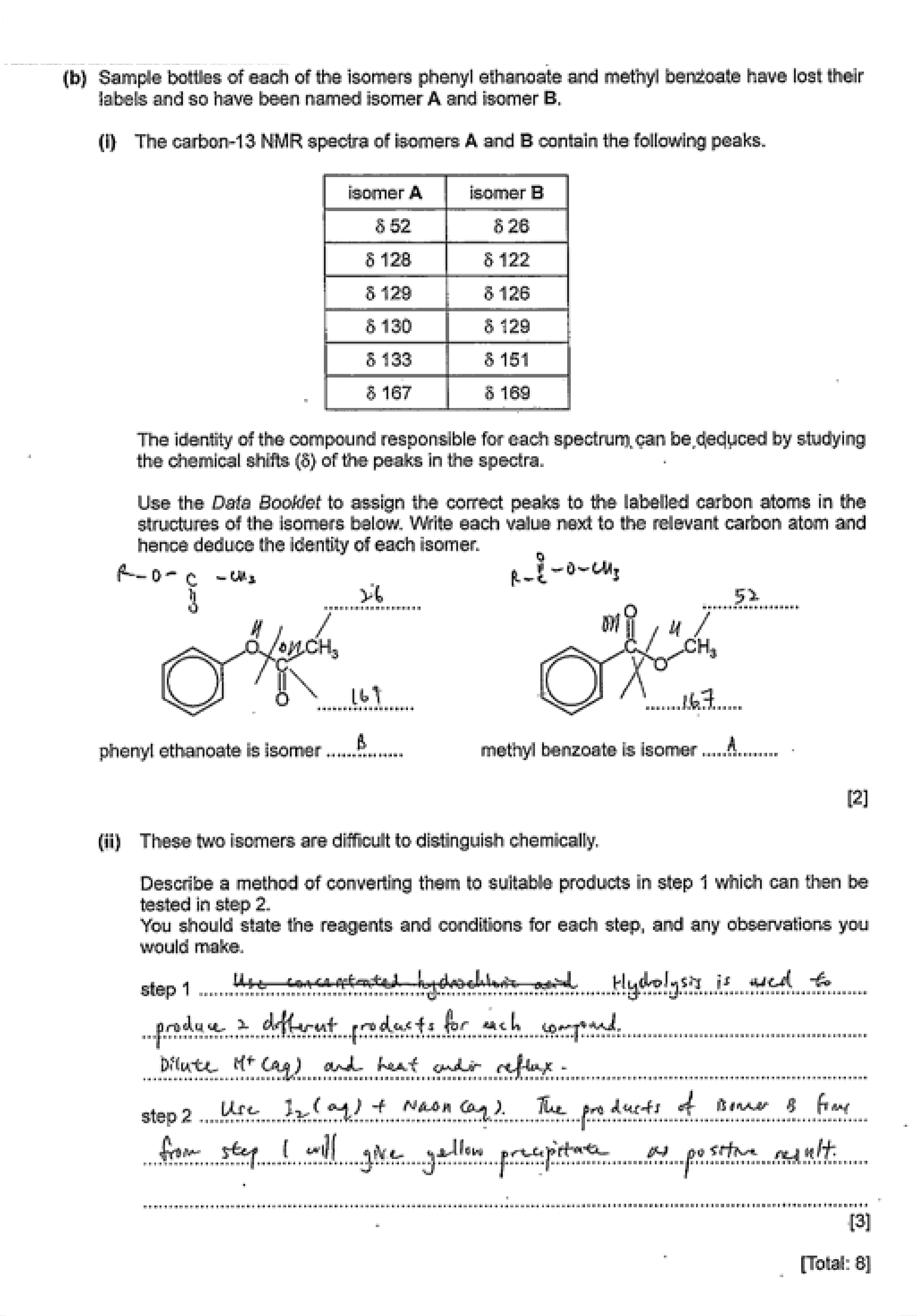

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The identity of the compound responsible for each spectrum can be deduced by studying the chemical shifts (δ) of the peaks in the spectra.

Use the *Data Booklet* to assign the correct peaks to the labelled carbon atoms in the structures of the isomers below. Write each value next to the relevant carbon atom and hence deduce the identity of each isomer.

R–O–C(=O)–CH₃

26

167

R–C(=O)–O–CH₃

52

167

phenyl ethanoate is isomer ....B....

methyl benzoate is isomer ....A....

[2]

(ii) These two isomers are difficult to distinguish chemically.

Describe a method of converting them to suitable products in step 1 which can then be tested in step 2.
You should state the reagents and conditions for each step, and any observations you would make.

step 1 ~~Use concentrated hydrochloric acid~~ Hydolysis is used to produce 2 different products for each compound. Dilute H^+(aq) and heat under reflux.

step 2 Use I_2(aq) + NaOH(aq). The products of Isomer B from from step 1 will give yellow precipitate as positive result.

[3]

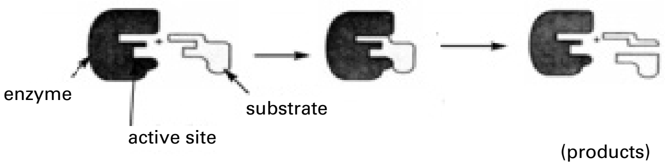
[Total: 8]

Your Mark

6(a) ☐

6(b)(i) ☐

6(b)(ii) ☐

Q6	Mark scheme
(a)	*essential mark* M1 the reactants / substrate has a **shape** complementary / **specific** to **active site** – can be awarded from a labelled diagram as below or diagrams showing this specificity clearly *any two of* M2: reactants / substrate binds to / fits into the active site of the enzyme M3: (Interaction with site) causes a specific bond to be weakened, (which breaks) **or** lowers activation energy M4: forms an E-S complex M5: products released from enzyme / active site **labelled diagrams**  **[3]**
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EXAMINER COMMENTS

MARK SCHEME

Cambridge Assessment International Education
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Cambridge Assessment
International Education

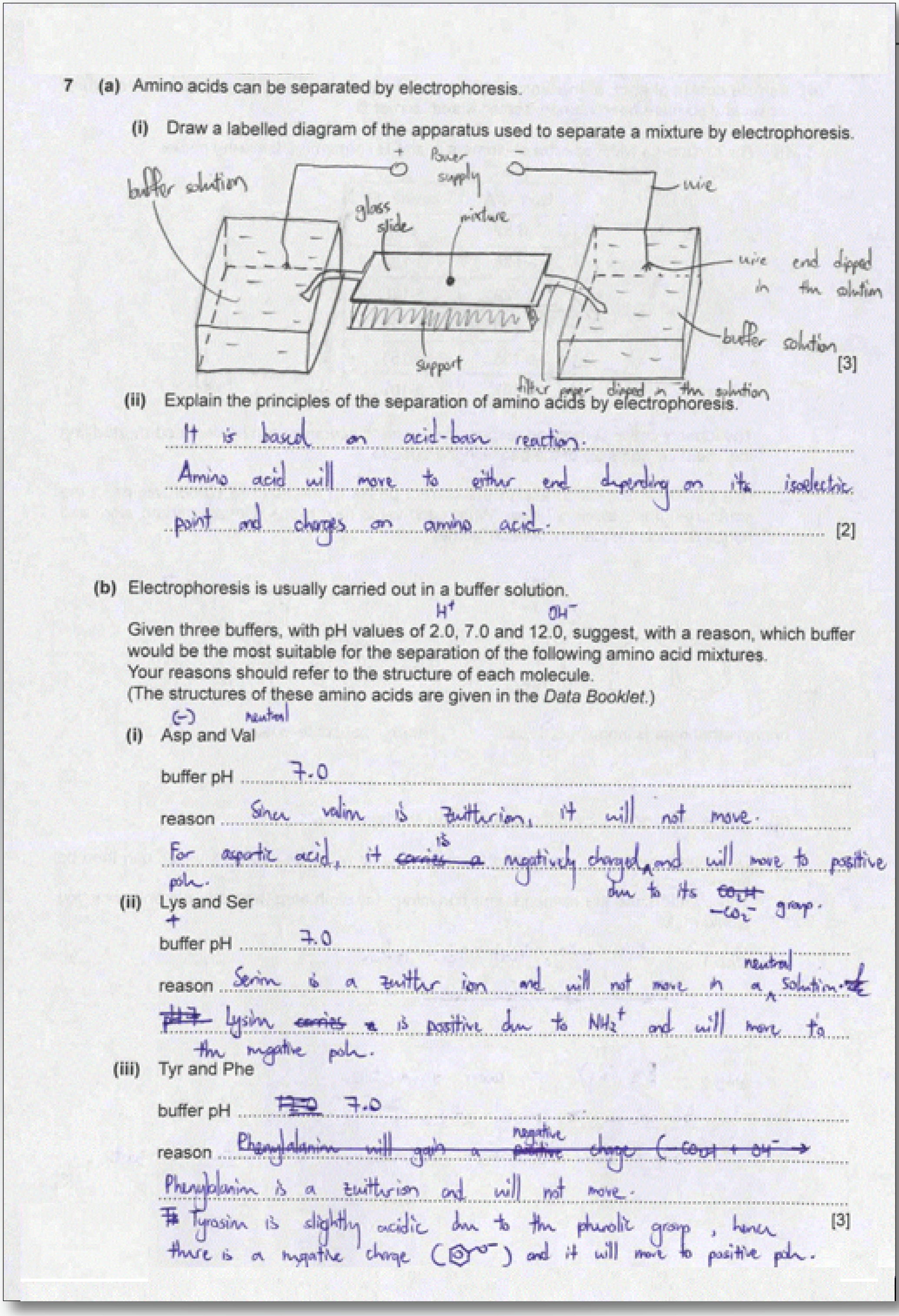
Interactive

Interactive Example Candidate Responses
Paper 42 (May/June 2016), Question 7

Cambridge International AS & A Level
Chemistry 9701

Version 1.0

Cambridge Pathway



7 (a) Amino acids can be separated by electrophoresis.

(i) Draw a labelled diagram of the apparatus used to separate a mixture by electrophoresis.

buffer solution

\+ Power supply −

wire

glass slide

mixture

wire end dipped in the solution

buffer solution

support

filter paper dipped in the solution

[3]

(ii) Explain the principles of the separation of amino acids by electrophoresis.

It is based on acid-base reaction.

Amino acid will move to either end depending on its isoelectric point and charges on amino acid. [2]

(b) Electrophoresis is usually carried out in a buffer solution.

Given three buffers, with pH values of 2.0, 7.0 and 12.0, suggest, with a reason, which buffer would be the most suitable for the separation of the following amino acid mixtures.

H^+ OH^-

Your reasons should refer to the structure of each molecule.

(The structures of these amino acids are given in the *Data Booklet*.)

(i) Asp and Val

(−) neutral

buffer pH 7.0

reason Since valin is zwitterion, it will not move.

For aspartic acid, it ~~carries a~~ is negatively charged and will move to positive pole. due to its ~~CO_2H~~ $-CO_2^-$ group.

(ii) Lys and Ser

\+

buffer pH 7.0

reason Serin is a zwitter ion and will not move in a neutral solution. ~~of~~

~~pH7~~ lysin ~~carries~~ ~~a~~ is positive due to NH_3^+ and will move to the negative pole.

(iii) Tyr and Phe

buffer pH ~~12.0~~ 7.0

reason ~~Phenylalanin will gain a~~ ~~positive~~ negative ~~charge (−CO_2H + OH^- →~~

Phenylalanin is a zwitterion and will not move.

~~Ph~~ Tyrosin is slightly acidic due to the phenolic group, hence there is a negative charge ( ) and it will move to positive pole. [3]

Your Mark

7(a)(i) ☐

7(a)(ii) ☐

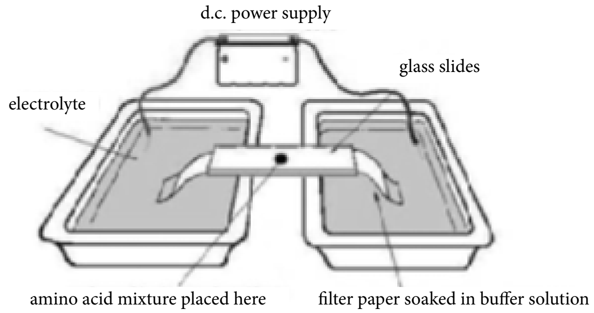
7(b)(i) ☐

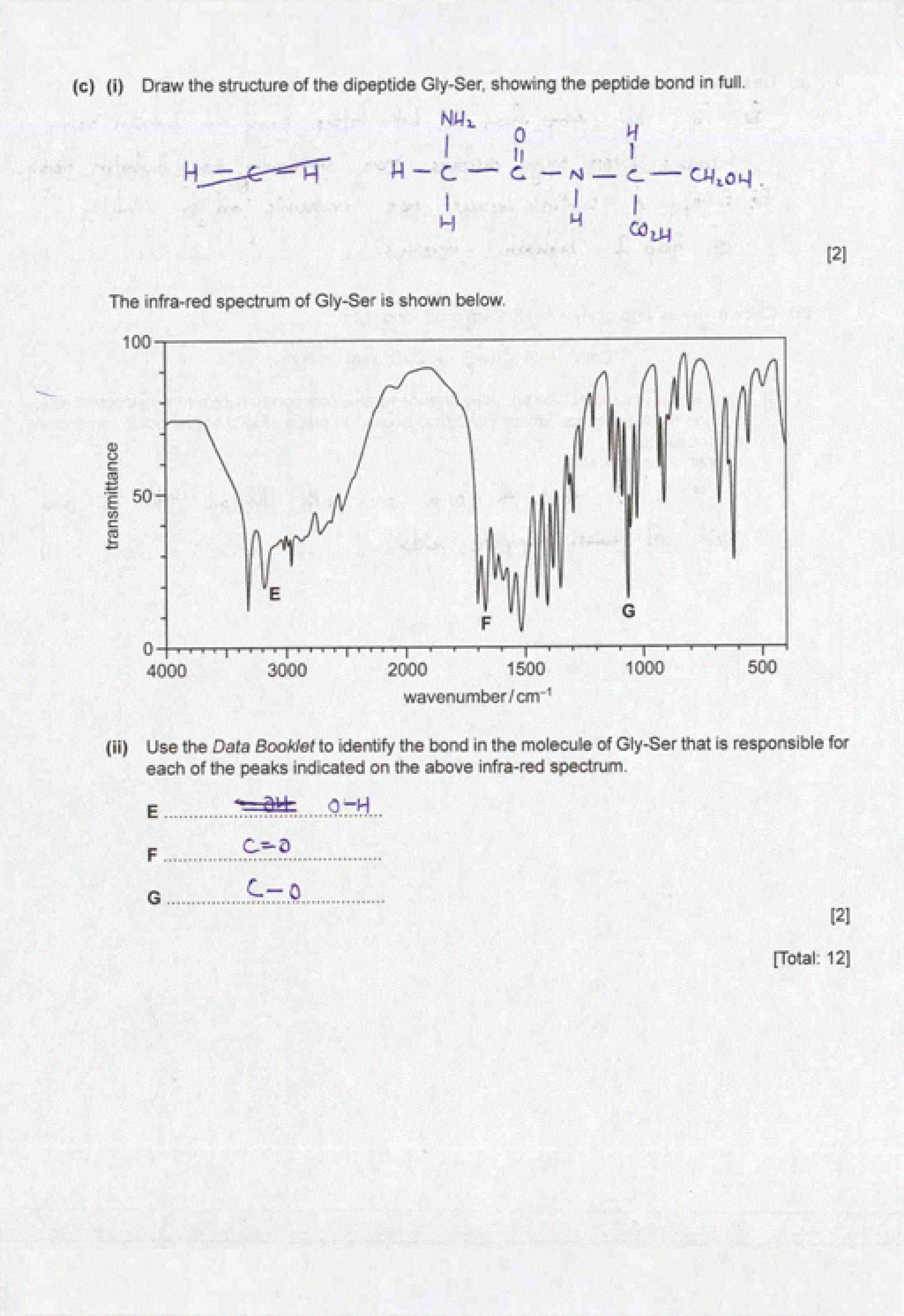
7(b)(ii) ☐

7(b)(iii) ☐

7(c)(i) ☐

7(c)(i) ☐

Q7	Mark scheme
(a)(i)	*labelled with* M1: DC power supply + and – / battery / cell / + and – sign (on cell / electrodes) with a complete circuit M2: buffer solution / electrolyte labelled M3: (amino acid) mixture / **x** on (filter) paper / gel / agarose **[3]** 
(a)(ii)	direction of movement related to charge (of amino acids) distance travelled depends on charge / Mr (of amino acids) **[2]**
(b)(i)	Asp + Val: **pH 12** because Asp will be –CH_2COO^- (R-group) moves further (to positive electrode than Val) **or pH 12** Asp more negative so moves further (to positive electrode) **or pH 12** because Asp has a charge of 2– but Val has a charge of 1– **or** best at **pH 7** because Asp will be negatively charged (anionic) but Val neutral **[1]**
(b)(ii)	Lys + Ser: **pH 2** because Lys will be $(CH_2)_4NH_3^+$ (R-group) moves further (to negative electrode than Ser) **or pH 2** Lys more positive so moves further (to negative electrode) **or pH 2** because Lys has a charge of 2+ and Ser has a charge of 1+ **or pH 7** because Lys is positively charged (cationic) but Ser neutral / zwitterionic **[1]**
(b)(iii)	Tyr + Phe: **pH 12** because Tyr will be $C_6H_5CH_2O^-$ (R-group) moves further / more / faster (to positive electrode than Phe) **or pH12** because Tyr has a charge of 2– but Phe has a charge of 1– **[1]**



(c) (i) Draw the structure of the dipeptide Gly-Ser, showing the peptide bond in full.

~~H – C – H~~

[2]

The infra-red spectrum of Gly-Ser is shown below.

(ii) Use the *Data Booklet* to identify the bond in the molecule of Gly-Ser that is responsible for each of the peaks indicated on the above infra-red spectrum.

E ~~-OH~~ O–H

F C=O

G C–O

[2]

[Total: 12]

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Your Mark

7(a)(i) ☐

7(a)(ii) ☐

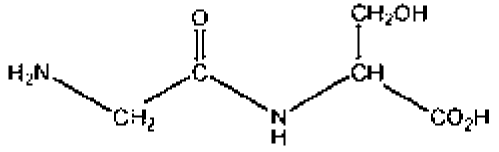
7(b)(i) ☐

7(b)(ii) ☐

7(b)(iii) ☐

7(c)(i) ☐

7(c)(i) ☐

Q7	Mark scheme
(c)(i)	 M1: for –CONH– as shown above M2: for rest of molecule and correct connectivity of the bonds **[3]**
(c)(ii)	from the IR spectrum • **E** is O-H or N-H (allow NH2) • **F** is C=O • **G** is C-O **[2]** **[Total: 9]**

EXAMINER COMMENTS

MARK SCHEME

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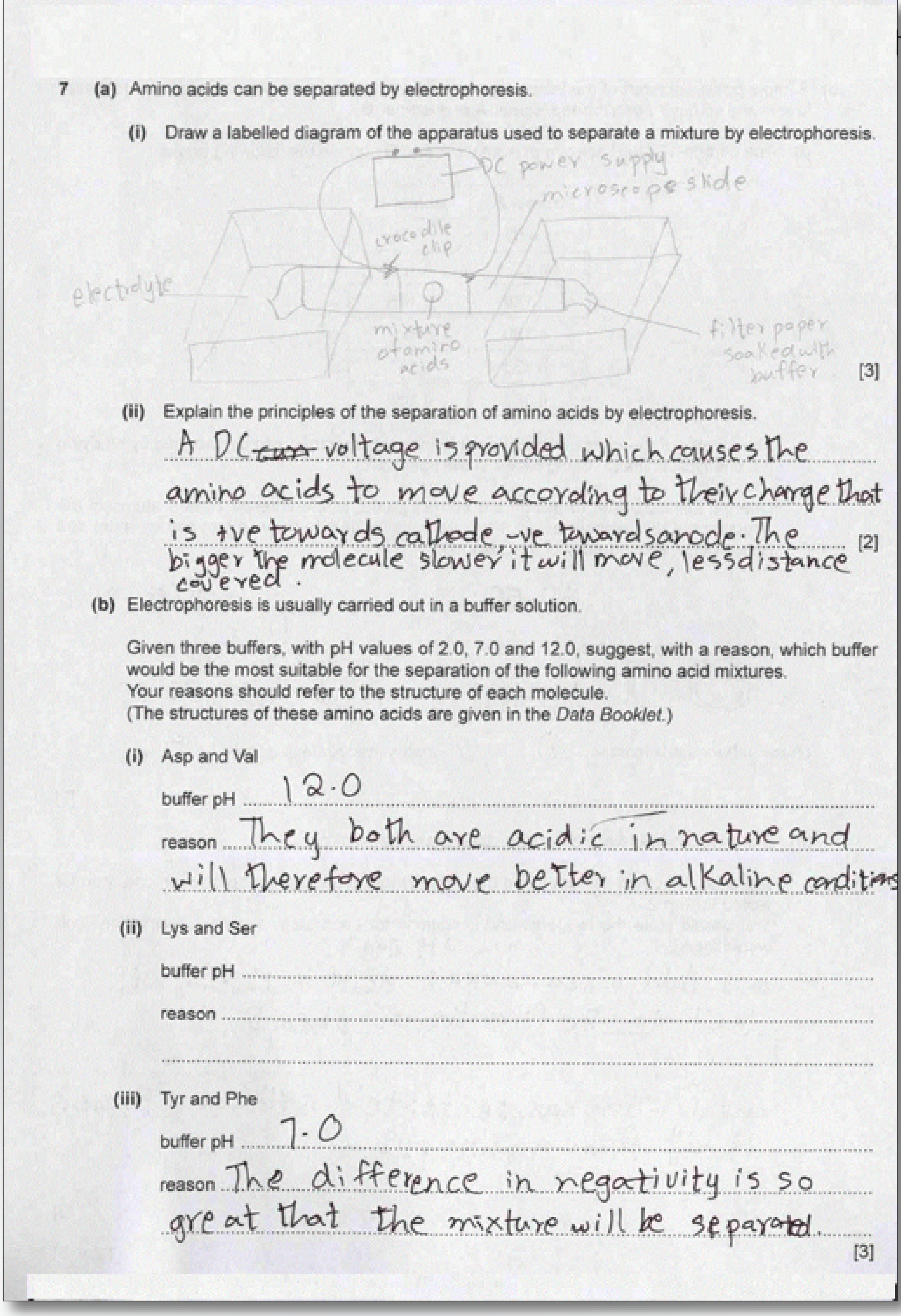


7 (a) Amino acids can be separated by electrophoresis.

(i) Draw a labelled diagram of the apparatus used to separate a mixture by electrophoresis.

[3]

(ii) Explain the principles of the separation of amino acids by electrophoresis.

A DC ~~curr~~ voltage is provided which causes the amino acids to move according to their charge that is +ve towards cathode, -ve towards anode. The bigger the molecule slower it will move, less distance covered. [2]

(b) Electrophoresis is usually carried out in a buffer solution.

Given three buffers, with pH values of 2.0, 7.0 and 12.0, suggest, with a reason, which buffer would be the most suitable for the separation of the following amino acid mixtures.
Your reasons should refer to the structure of each molecule.
(The structures of these amino acids are given in the *Data Booklet*.)

(i) Asp and Val

buffer pH 12.0

reason They both are acidic in nature and will therefore move better in alkaline conditions

(ii) Lys and Ser

buffer pH

reason

(iii) Tyr and Phe

buffer pH 7.0

reason The difference in negativity is so great that the mixture will be separated.

[3]

Your Mark

7(a)(i) ☐

7(a)(ii) ☐

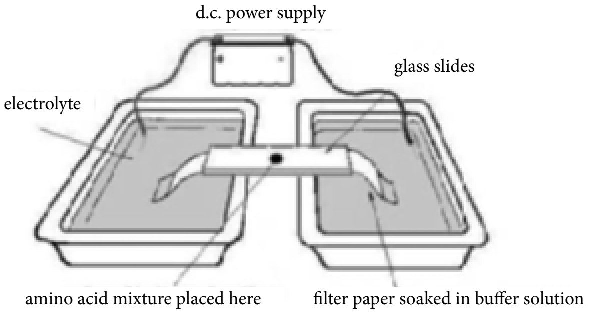
7(b)(i) ☐

7(b)(ii) ☐

7(b)(iii) ☐

7(c)(i) ☐

7(c)(i) ☐

Q7	Mark scheme
(a)(i)	*labelled with* M1: DC power supply + and – / battery / cell / + and – sign (on cell / electrodes) with a complete circuit M2: buffer solution / electrolyte labelled M3: (amino acid) mixture / **x** on (filter) paper / gel / agarose **[3]** 
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(b)(iii)	Tyr + Phe: **pH 12** because Tyr will be C$_6$H$_5$CH$_2$O$^-$ (R-group) moves further / more / faster (to positive electrode than Phe) **or pH12** because Tyr has a charge of 2– but Phe has a charge of 1– **[1]**

EXAMINER COMMENTS

MARK SCHEME

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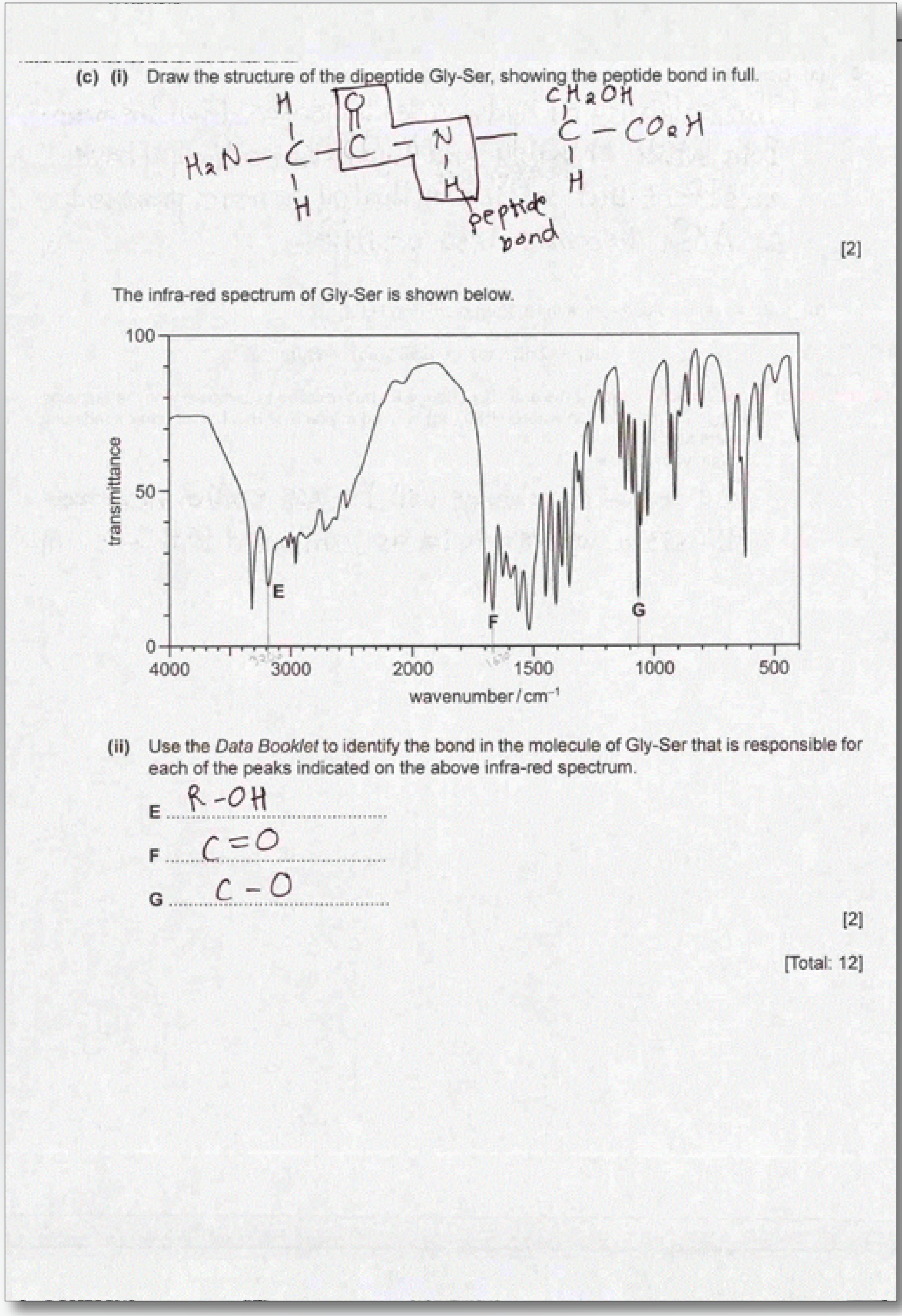


(c) (i) Draw the structure of the dipeptide Gly-Ser, showing the peptide bond in full.

[2]

The infra-red spectrum of Gly-Ser is shown below.

(ii) Use the *Data Booklet* to identify the bond in the molecule of Gly-Ser that is responsible for each of the peaks indicated on the above infra-red spectrum.

E R-OH

F C=O

G C-O

[2]

[Total: 12]

Your Mark

7(a)(i) ☐

7(a)(ii) ☐

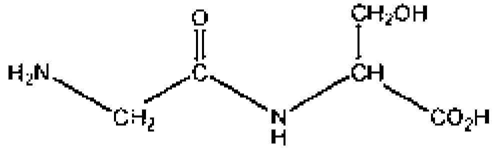
7(b)(i) ☐

7(b)(ii) ☐

7(b)(iii) ☐

7(c)(i) ☐

7(c)(i) ☐

Q7	Mark scheme
(c)(i)	 M1: for –CONH– as shown above M2: for rest of molecule and correct connectivity of the bonds **[3]**
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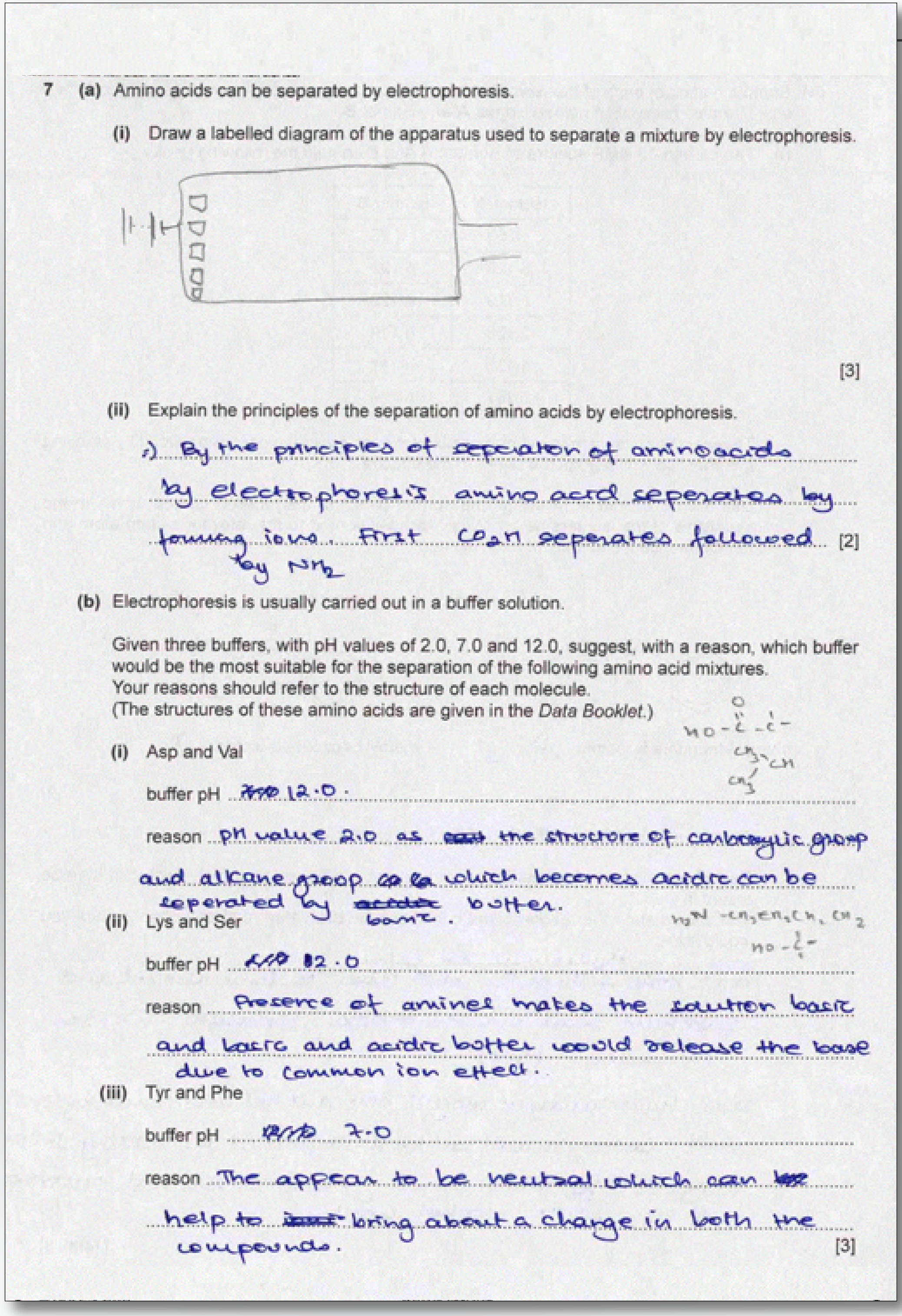


7 **(a)** Amino acids can be separated by electrophoresis.

(i) Draw a labelled diagram of the apparatus used to separate a mixture by electrophoresis.

[3]

(ii) Explain the principles of the separation of amino acids by electrophoresis.

i) By the principles of sepration of aminoacids by electrophoresis amino acid seperates by forming ions. First CO_2H seperates followed by NH_2 [2]

(b) Electrophoresis is usually carried out in a buffer solution.

Given three buffers, with pH values of 2.0, 7.0 and 12.0, suggest, with a reason, which buffer would be the most suitable for the separation of the following amino acid mixtures.
Your reasons should refer to the structure of each molecule.
(The structures of these amino acids are given in the *Data Booklet*.)

HO − C(O) − C −
CH_3 − CH
CH_3

(i) Asp and Val

buffer pH ~~[illegible]~~ 12.0.

reason pH value 2.0 as ~~[illegible]~~ the structure of carboxylic group and alkane group ~~[illegible]~~ which becomes acidic can be seperated by ~~acidic~~ basic butter.

H_2N − $CH_2CH_2CH_2CH_2$
HO − C −

(ii) Lys and Ser

buffer pH ~~[illegible]~~ 12.0

reason Presence of amines makes the solution basic and basic and acidic buffer would release the base due to common ion effect.

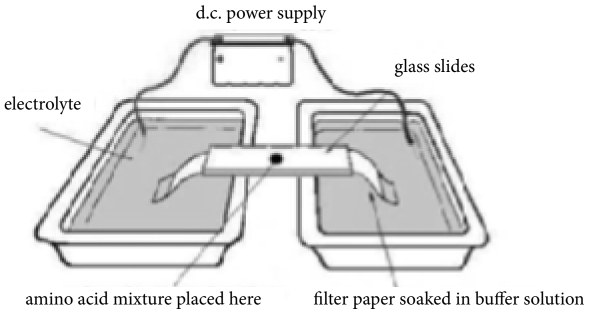
(iii) Tyr and Phe

buffer pH ~~[illegible]~~ 7.0

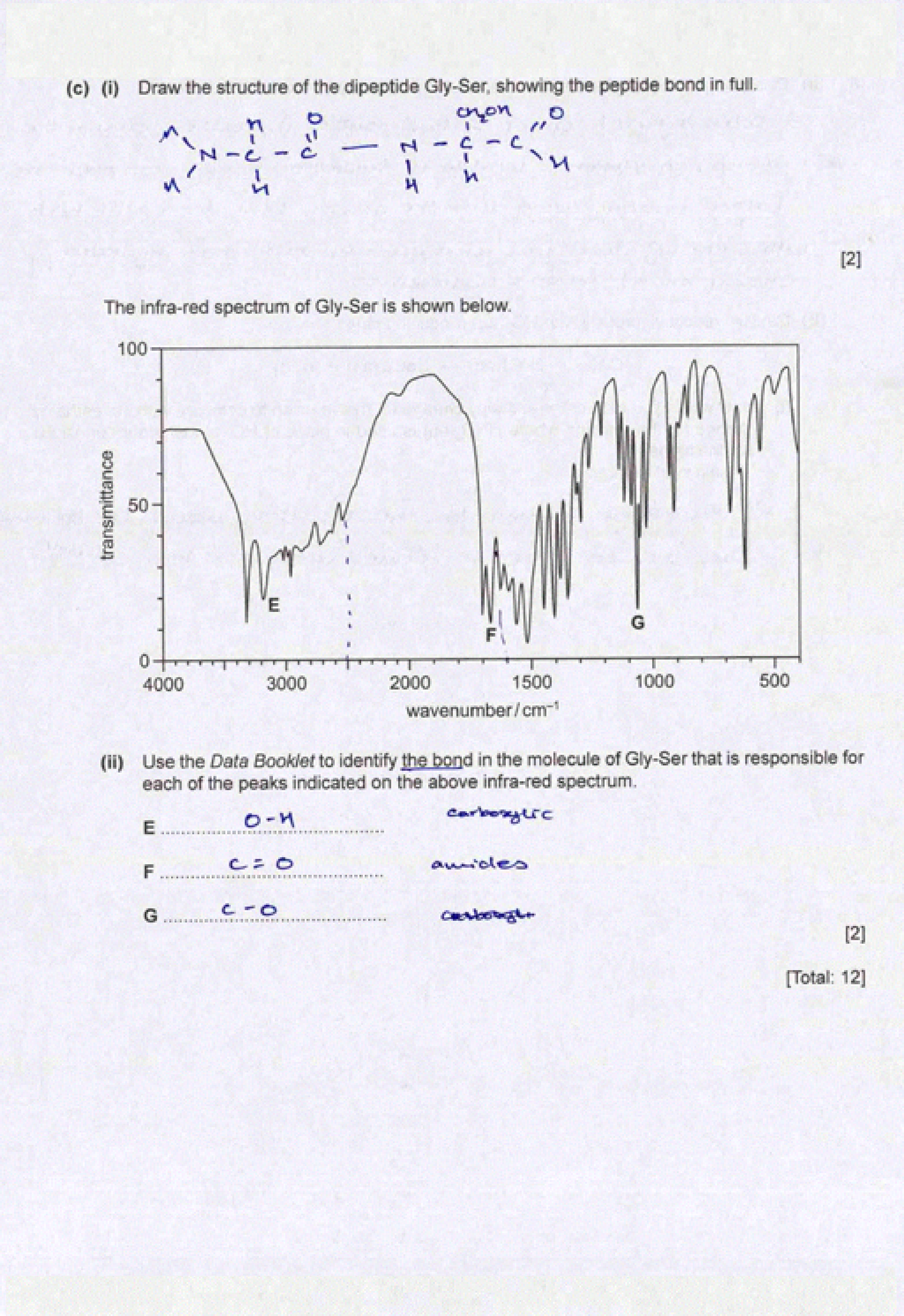
reason The appear to be neutral which can ~~[illegible]~~ help to ~~[illegible]~~ bring about a charge in both the compounds. [3]

Your Mark

7(a)(i) ☐
7(a)(ii) ☐
7(b)(i) ☐
7(b)(ii) ☐
7(b)(iii) ☐
7(c)(i) ☐
7(c)(i) ☐

Q7	Mark scheme
(a)(i)	*labelled with* M1: DC power supply + and – / battery / cell / + and – sign (on cell / electrodes) with a complete circuit M2: buffer solution / electrolyte labelled M3: (amino acid) mixture / **x** on (filter) paper / gel / agarose **[3]** 
(a)(ii)	direction of movement related to charge (of amino acids) distance travelled depends on charge / Mr (of amino acids) **[2]**
(b)(i)	Asp + Val: **pH 12** because Asp will be $–CH_2COO^–$ (R-group) moves further (to positive electrode than Val) **or pH 12** Asp more negative so moves further (to positive electrode) **or pH 12** because Asp has a charge of 2– but Val has a charge of 1– **or** best at **pH 7** because Asp will be negatively charged (anionic) but Val neutral **[1]**
(b)(ii)	Lys + Ser: **pH 2** because Lys will be $(CH_2)_4NH_3^+$ (R-group) moves further (to negative electrode than Ser) **or pH 2** Lys more positive so moves further (to negative electrode) **or pH 2** because Lys has a charge of 2+ and Ser has a charge of 1+ **or pH 7** because Lys is positively charged (cationic) but Ser neutral / zwitterionic **[1]**
(b)(iii)	Tyr + Phe: **pH 12** because Tyr will be $C_6H_5CH_2O^–$ (R-group) moves further / more / faster (to positive electrode than Phe) **or pH12** because Tyr has a charge of 2– but Phe has a charge of 1– **[1]**

EXAMINER COMMENTS
MARK SCHEME



(c) (i) Draw the structure of the dipeptide Gly-Ser, showing the peptide bond in full.

[2]

The infra-red spectrum of Gly-Ser is shown below.

(ii) Use the *Data Booklet* to identify the bond in the molecule of Gly-Ser that is responsible for each of the peaks indicated on the above infra-red spectrum.

E ....O-H.... carboxylic

F ....C=O.... amides

G ....C-O.... carboxylic

[2]

[Total: 12]

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Your Mark

7(a)(i) ☐

7(a)(ii) ☐

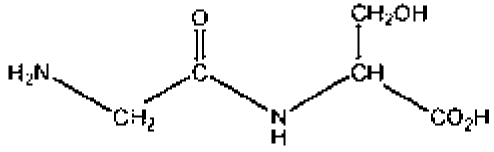
7(b)(i) ☐

7(b)(ii) ☐

7(b)(iii) ☐

7(c)(i) ☐

7(c)(i) ☐

Q7	Mark scheme
(c)(i)	 M1: for –CONH– as shown above M2: for rest of molecule and correct connectivity of the bonds **[3]**
(c)(ii)	from the IR spectrum • **E** is O-H or N-H (allow NH2) • **F** is C=O • **G** is C-O **[2]** **[Total: 9]**

EXAMINER COMMENTS

MARK SCHEME

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Interactive Example Candidate Responses
Paper 42 (May/June 2016), Question 9

Cambridge International AS & A Level
Chemistry 9701

Version 1.0

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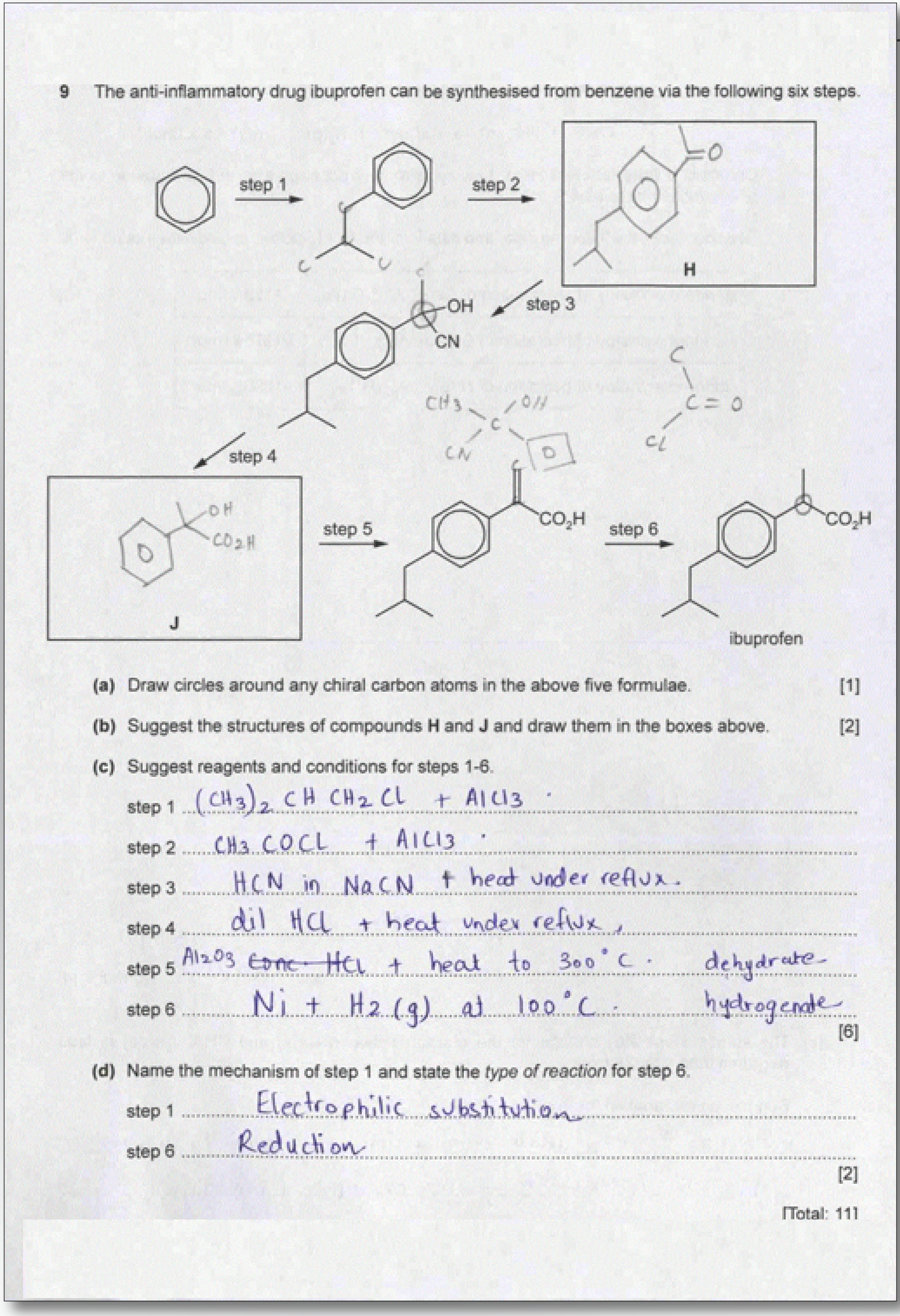


9 The anti-inflammatory drug ibuprofen can be synthesised from benzene via the following six steps.

(a) Draw circles around any chiral carbon atoms in the above five formulae. [1]

(b) Suggest the structures of compounds H and J and draw them in the boxes above. [2]

(c) Suggest reagents and conditions for steps 1-6.

step 1 $(CH_3)_2CH CH_2Cl$ + $AlCl_3$.

step 2 CH_3COCL + $AlCl_3$.

step 3 HCN in NaCN + heat under reflux.

step 4 dil HCl + heat under reflux,

step 5 Al_2O_3 ~~conc HCl~~ + heat to 300 °C. dehydrate

step 6 Ni + $H_2(g)$ at 100 °C. hydrogenate

[6]

(d) Name the mechanism of step 1 and state the *type of reaction* for step 6.

step 1 Electrophilic substitution

step 6 Reduction

[2]

[Total: 11]

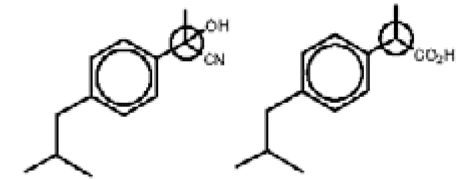
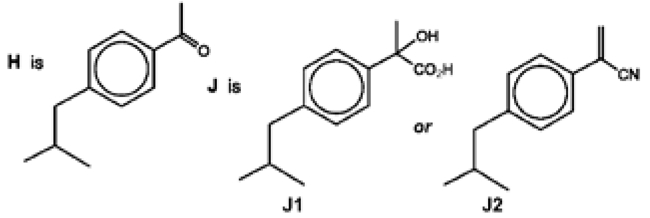
Your Mark

9(a)

9(b)

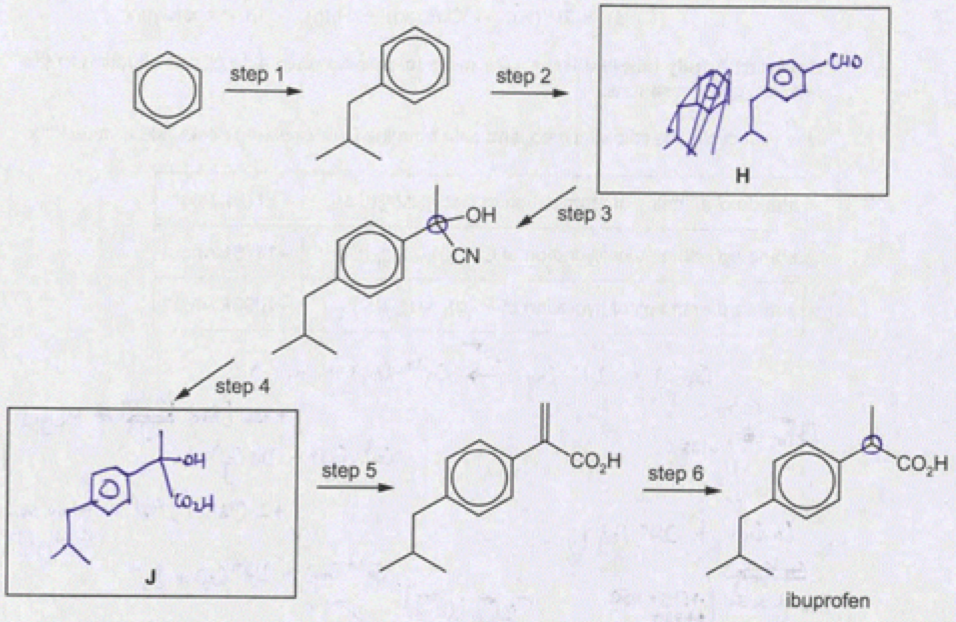
9(c)

9(d)

Q9	**Mark scheme**
(a)	 **[2]**
(b)	 **[2]**
(c)	step 1: $(CH_3)_2CHCH_2Cl + AlCl_3$ (+ heat) step 2: $CH_3COCl + AlCl_3$ (+ heat) step 3: HCN + NaCN **or** HCN + base or HCN + CN^- *(steps 4 and 5 could be reversed on J)* ***If J1** step 4 then step 5 **J2** step 5 then step 4* step 4: H_3O^+ + heat / aqueous HCl + heat step 5: conc H_2SO_4 + heat / conc H_3PO_4 + heat **or** Al_2O_3 + heat step 6: H_2 + Ni (+ heat) **[6]**
(d)	step 1: electrophilic substitution or alkylation step 6: reduction / hydrogenation / addition **[2]** **[Total: 11]**

EXAMINER COMMENTS

MARK SCHEME



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(b) Suggest the structures of compounds **H** and **J** and draw them in the boxes above. [2]

(c) Suggest reagents and conditions for steps 1-6.

step 1 $(CH_3)_2CHCH_2CH_2Cl$ in $AlCl_3$ heat under reflux.

step 2 $Cl-CHO$ with $AlCl_3$ heat under reflux.

step 3 HCN with a little NaCN heat under reflux.

step 4 HCl (aq) heat under reflux.

step 5 concentrated H_2SO_4 ~~heat~~ ~~he~~ heat at 180 °C.

step 6 H_2 (g) + Pt (s)

[6]

(d) Name the mechanism of step 1 and state the *type of reaction* for step 6.

step 1 Electrophilic substitution

step 6 Electrophilic addition.

[2]

[Total: 11]

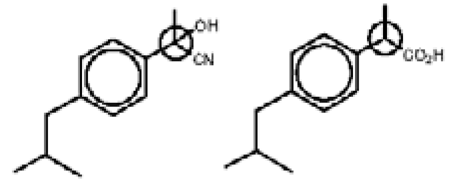
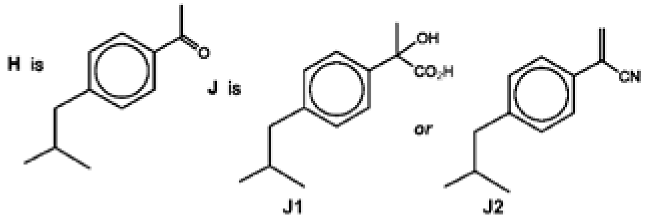
Your Mark

9(a)

9(b)

9(c)

9(d)

Q9	Mark scheme
(a)	 **[2]**
(b)	 **[2]**
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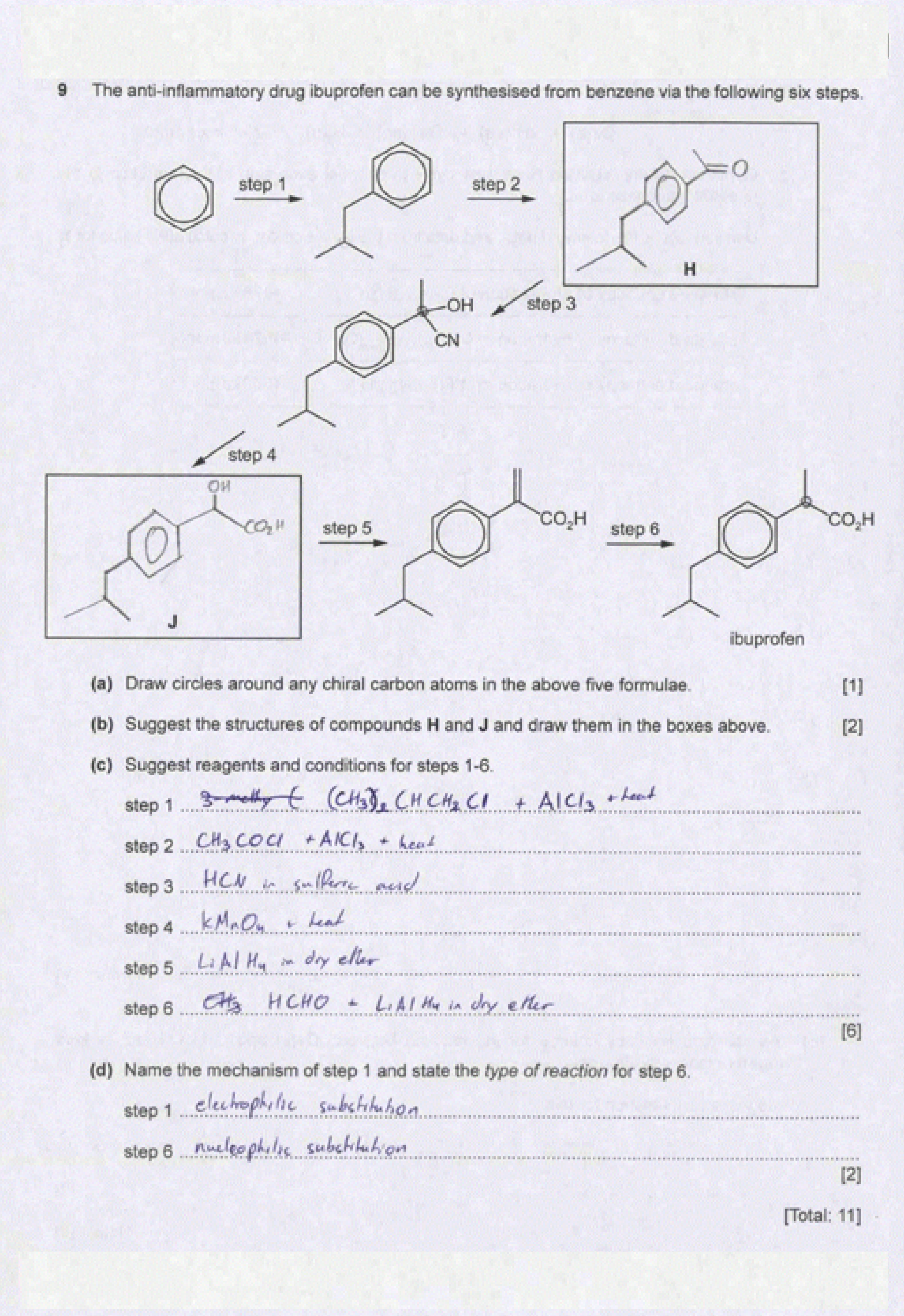


9 The anti-inflammatory drug ibuprofen can be synthesised from benzene via the following six steps.

(a) Draw circles around any chiral carbon atoms in the above five formulae. [1]

(b) Suggest the structures of compounds **H** and **J** and draw them in the boxes above. [2]

(c) Suggest reagents and conditions for steps 1-6.

step 1 ~~3-methyl~~ ($(CH_3)_2CHCH_2Cl$ + $AlCl_3$ + heat

step 2 CH_3COCl + $AlCl_3$ + heat

step 3 HCN in sulfuric acid

step 4 $KMnO_4$ + heat

step 5 $LiAlH_4$ in dry ether

step 6 ~~CH_3~~ HCHO + $LiAlH_4$ in dry ether

[6]

(d) Name the mechanism of step 1 and state the *type of reaction* for step 6.

step 1 electrophilic substitution

step 6 nucleophilic substitution

[2]

[Total: 11]

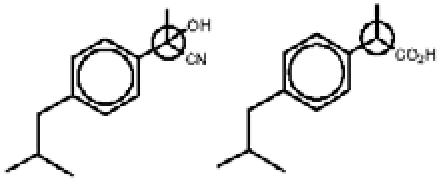
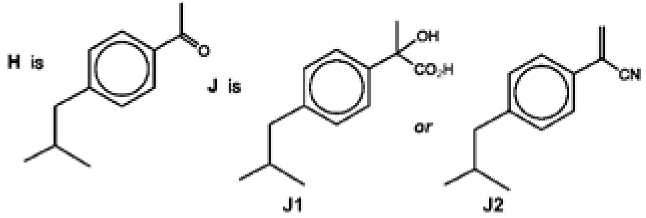
Your Mark

9(a) ☐

9(b) ☐

9(c) ☐

9(d) ☐

Q9	Mark scheme
(a)	 **[2]**
(b)	 **[2]**
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(d)	step 1: electrophilic substitution or alkylation step 6: reduction / hydrogenation / addition **[2]** **[Total: 11]**

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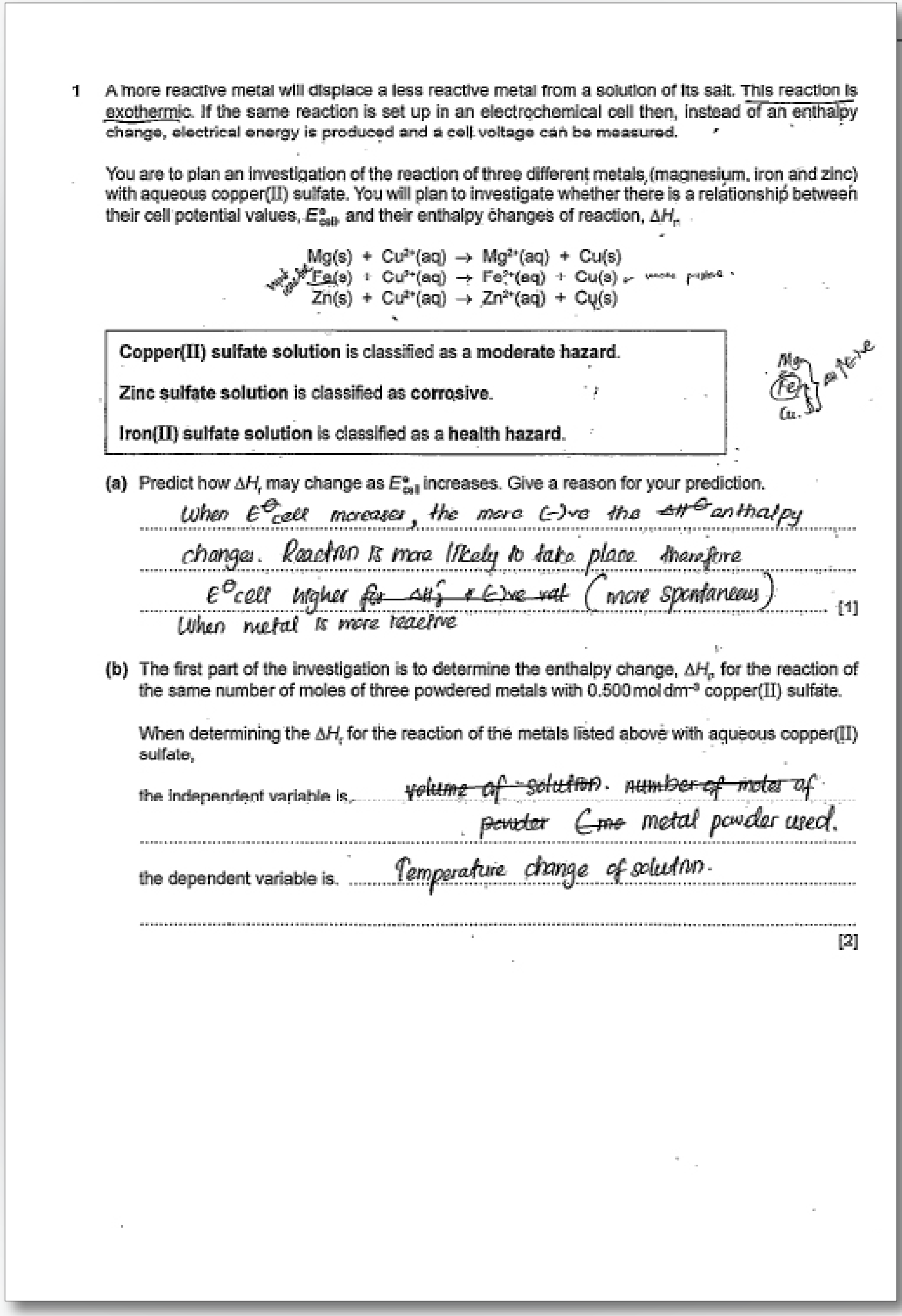


1 A more reactive metal will displace a less reactive metal from a solution of its salt. This reaction is exothermic. If the same reaction is set up in an electrochemical cell then, instead of an enthalpy change, electrical energy is produced and a cell voltage can be measured.

You are to plan an investigation of the reaction of three different metals (magnesium, iron and zinc) with aqueous copper(II) sulfate. You will plan to investigate whether there is a relationship between their cell potential values, E°_{cell}, and their enthalpy changes of reaction, ΔH_r.

$Mg(s) + Cu^{2+}(aq) \rightarrow Mg^{2+}(aq) + Cu(s)$

[illegible] $Fe(s) + Cu^{2+}(aq) \rightarrow Fe^{2+}(aq) + Cu(s)$ ← [illegible]

$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$

Copper(II) sulfate solution is classified as a **moderate hazard**.

Zinc sulfate solution is classified as **corrosive**.

Iron(II) sulfate solution is classified as a **health hazard**.

Mg
Fe
Cu. } more +ve

(a) Predict how ΔH_r may change as E°_{cell} increases. Give a reason for your prediction.

When $E^\ominus_{cell}$ increases, the more (–)ve the ~~ΔH~~$^\ominus$ enthalpy changes. Reaction is more likely to take place therefore $E^\ominus_{cell}$ higher ~~for ΔH ∝ (–)ve val~~ (more spontaneous) when metal is more reactive [1]

(b) The first part of the investigation is to determine the enthalpy change, ΔH_r, for the reaction of the same number of moles of three powdered metals with 0.500 mol dm^{-3} copper(II) sulfate.

When determining the ΔH_r for the reaction of the metals listed above with aqueous copper(II) sulfate,

the independent variable is ~~volume of solution~~. ~~number of moles of powder~~ ~~(mo~~ metal powder used.

the dependent variable is Temperature change of solution.

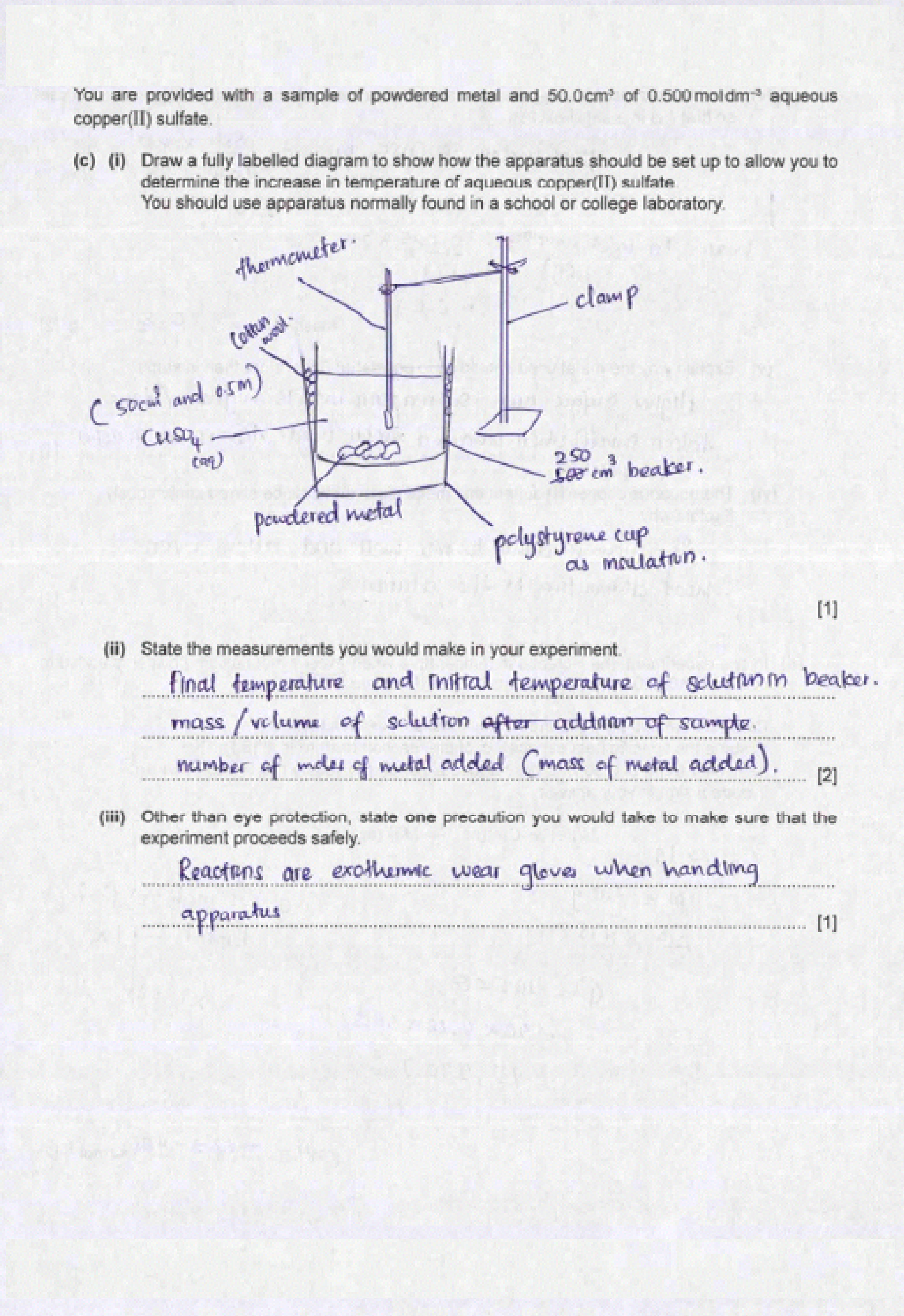
[2]

Your Mark	
1(a)	
1(b)	
1(c)(i)	
1(c)(ii)	
1(c)(iii)	
1(c)(iv)	
1(c)(v)	
1(c)(vi)	
1(d)	
1(e)	
1(f)	
1(g)	

Q1	Mark scheme
	Expected answer
(a)	(As the E° cell value increases) ΔH_r decreases or ΔH_r becomes more negative or ΔHr becomes more exothermic. AND The more reactive the metal then the greater the energy release will be. OR Energy output of both reactions is dependent upon the difference in reactivity (of metals). **[1]**
(b)	Independent variable: The (type of) metal Dependent variable: temperature change or rise or increase OR enthalpy change **[1]**
(c)(i)	Diagram should indicate a labelled insulated container AND a labelled thermometer in the liquid. **[1]**
(c)(ii)	Mass of metal before and after Initial temperature (before metal added) AND Highest temperature (after metal added) **[1]**
(c)(iii)	Wear gloves **[1]**
(c)(iv)	Moles CuSO4 = 0.025 mol, therefore moles of magnesium = 0.025 mol (minimum) mass Mg > (0.025 × 24.3 =) 0.6075 g AND mass required value is greater than 0.6075 g **[1]**
(c)(v)	Larger surface area AND causes increased rate of reaction **[1]**
(c)(vi)	Ensure uniformity of heating (of solution) **[1]**
(d)	50.0 × 4.18 × 58.5 = 12 226.5 (J) ΔHr = 12 226.5 / 0.025 = 489 000 = – 489 1000 **[1]**
(e)	Complete circuit involving labelled voltmeter; labelled salt bridge; two separate solutions; (Solutions are) magnesium sulfate or MgSO4 with magnesium or Mg rod and copper(II) sulfate CuSO4 with copper or Cu rod Concentration of solution(s) is 1 mol dm–3 or 1 M **[1]**
(f)	So that values can be compared **[1]**
(g)	Both ΔHr (Zn) and ΔHr (Fe) values which are consistent with the prediction in (a). **[1]**

EXAMINER COMMENTS

MARK SCHEME



You are provided with a sample of powdered metal and 50.0 cm³ of 0.500 mol dm⁻³ aqueous copper(II) sulfate.

(c) (i) Draw a fully labelled diagram to show how the apparatus should be set up to allow you to determine the increase in temperature of aqueous copper(II) sulfate.
You should use apparatus normally found in a school or college laboratory.

[1]

(ii) State the measurements you would make in your experiment.

final temperature and initial temperature of solution in beaker.

mass / volume of solution ~~after addition of sample~~.

number of moles of metal added (mass of metal added). [2]

(iii) Other than eye protection, state **one** precaution you would take to make sure that the experiment proceeds safely.

Reactions are exothermic wear gloves when handling apparatus [1]

Your Mark

1(a) ☐
1(b) ☐
1(c)(i) ☐
1(c)(ii) ☐
1(c)(iii) ☐
1(c)(iv) ☐
1(c)(v) ☐
1(c)(vi) ☐
1(d) ☐
1(e) ☐
1(f) ☐
1(g) ☐

Q1	Mark scheme
	Expected answer
(a)	(As the E° cell value increases) ΔH_r decreases or ΔH_r becomes more negative or ΔHr becomes more exothermic. AND The more reactive the metal then the greater the energy release will be. OR Energy output of both reactions is dependent upon the difference in reactivity (of metals). **[1]**
(b)	Independent variable: The (type of) metal Dependent variable: temperature change or rise or increase OR enthalpy change **[1]**
(c)(i)	Diagram should indicate a labelled insulated container AND a labelled thermometer in the liquid. **[1]**
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(f)	So that values can be compared **[1]**
(g)	Both ΔHr (Zn) and ΔHr (Fe) values which are consistent with the prediction in (a). **[1]**

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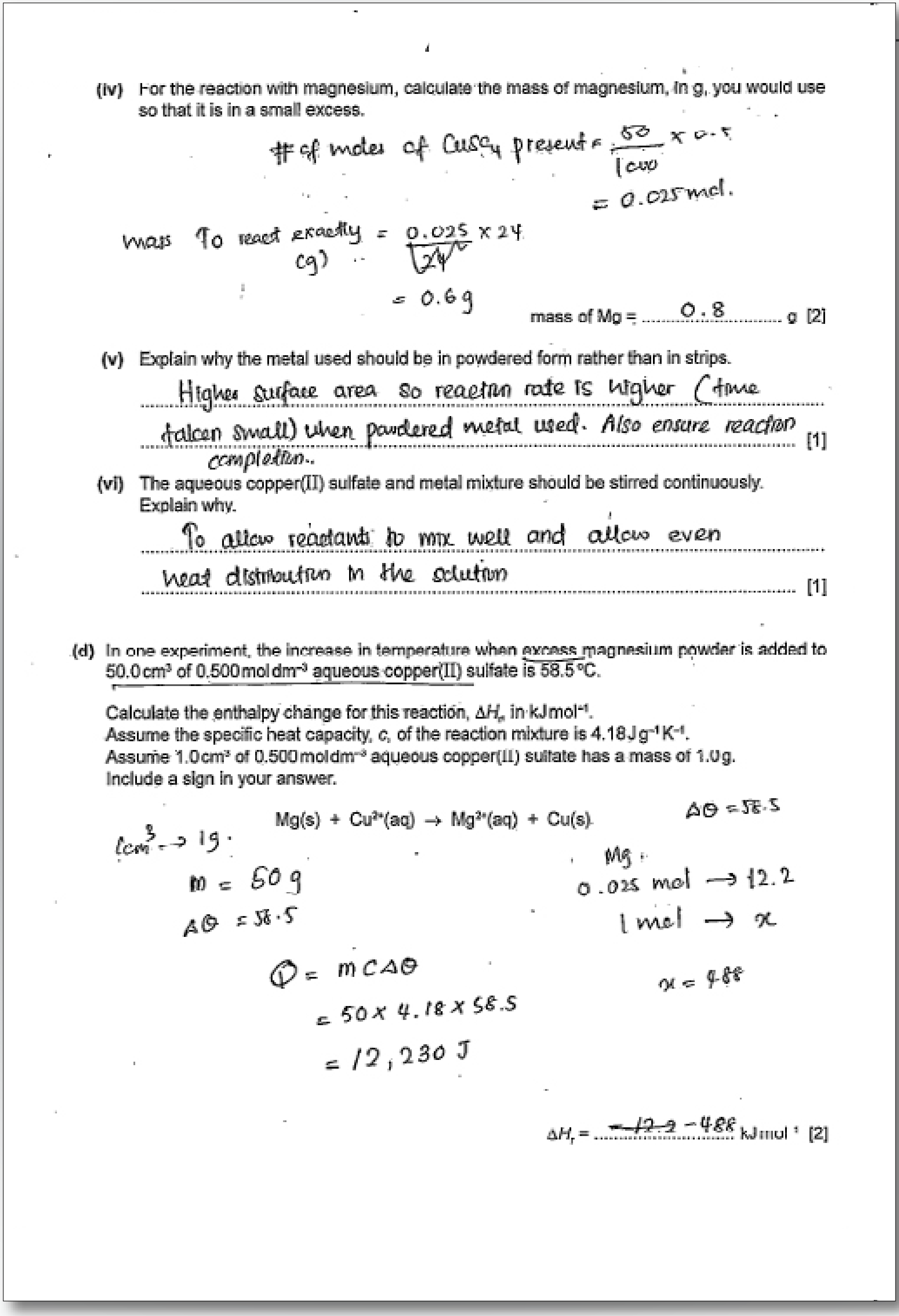
(iv) For the reaction with magnesium, calculate the mass of magnesium, in g, you would use so that it is in a small excess.

# of moles of $CuSO_4$ present = $\frac{50}{1000} \times 0.5$

= 0.025 mol.

mass To react exactly (g) = $\frac{0.025}{\cancel{24}} \times 24$

= 0.6 g

mass of Mg = 0.8 g [2]

(v) Explain why the metal used should be in powdered form rather than in strips.

Higher surface area so reaction rate is higher (time taken small) when powdered metal used. Also ensure reaction completion.. [1]

(vi) The aqueous copper(II) sulfate and metal mixture should be stirred continuously. Explain why.

To allow reactants to mix well and allow even heat distribution in the solution [1]

(d) In one experiment, the increase in temperature when excess magnesium powder is added to 50.0 cm³ of 0.500 mol dm⁻³ aqueous copper(II) sulfate is 58.5 °C.

Calculate the enthalpy change for this reaction, ΔH_r, in kJ mol⁻¹.
Assume the specific heat capacity, c, of the reaction mixture is 4.18 J g⁻¹ K⁻¹.
Assume 1.0 cm³ of 0.500 mol dm⁻³ aqueous copper(II) sulfate has a mass of 1.0 g.
Include a sign in your answer.

$$Mg(s) + Cu^{2+}(aq) \rightarrow Mg^{2+}(aq) + Cu(s)$$

$\Delta\theta = 58.5$

$1 cm^3 \rightarrow 1 g$.

$m = 50 g$

$\Delta\theta = 58.5$

$Q = mc\Delta\theta$

$= 50 \times 4.18 \times 58.5$

$= 12,230 J$

Mg:

0.025 mol → 12.2

1 mol → x

x = 488

ΔH_r = ~~-12.2~~ -488 kJ mol⁻¹ [2]

Your Mark

1(a) ☐

1(b) ☐

1(c)(i) ☐

1(c)(ii) ☐

1(c)(iii) ☐

1(c)(iv) ☐

1(c)(v) ☐

1(c)(vi) ☐

1(d) ☐

1(e) ☐

1(f) ☐

1(g) ☐

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(f)	So that values can be compared **[1]**
(g)	Both ΔHr (Zn) and ΔHr (Fe) values which are consistent with the prediction in (a). **[1]**

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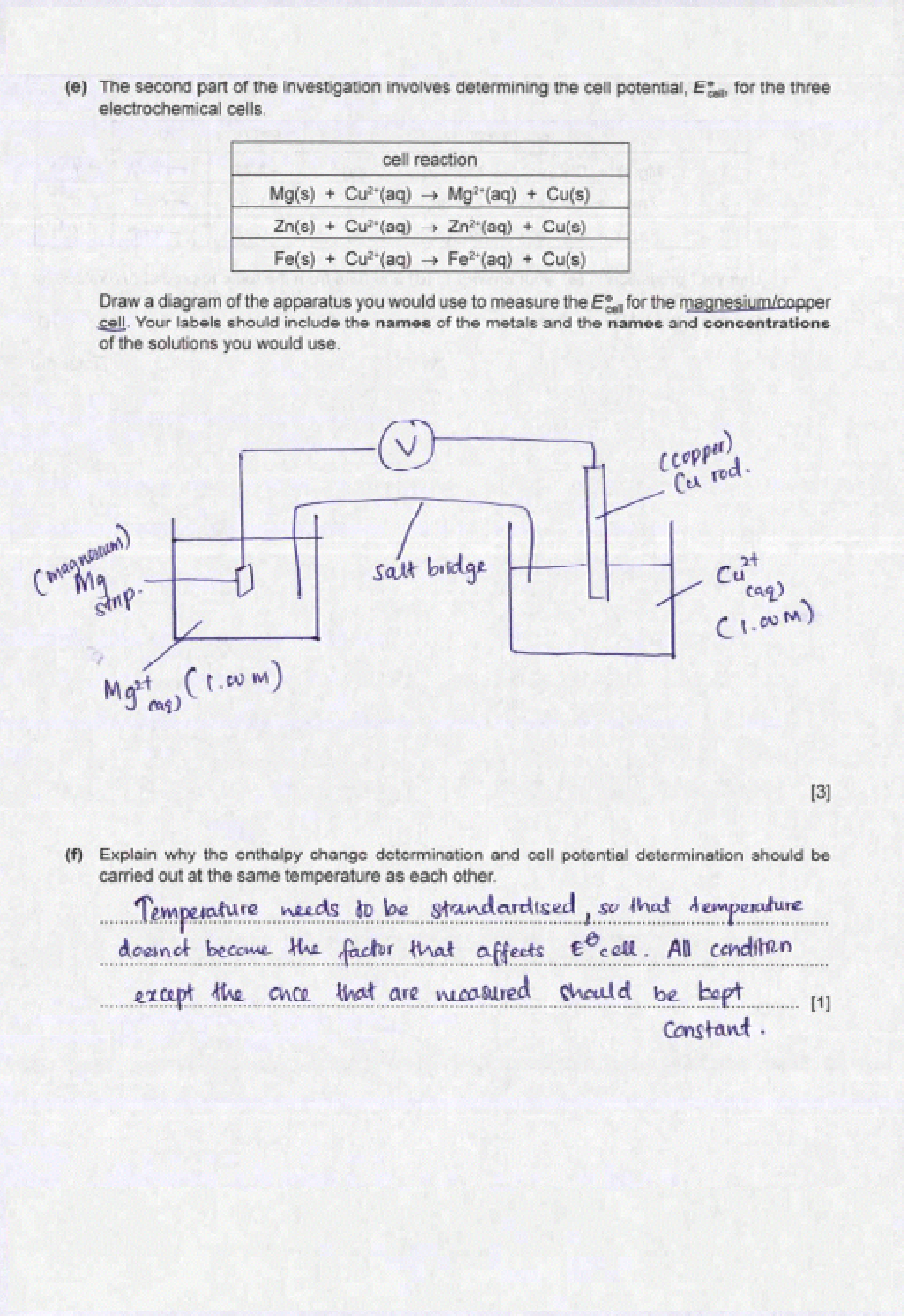

(e) The second part of the investigation involves determining the cell potential, $E^{\ominus}_{cell}$, for the three electrochemical cells.

cell reaction
$Mg(s) + Cu^{2+}(aq) \rightarrow Mg^{2+}(aq) + Cu(s)$
$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$
$Fe(s) + Cu^{2+}(aq) \rightarrow Fe^{2+}(aq) + Cu(s)$

Draw a diagram of the apparatus you would use to measure the $E^{\ominus}_{cell}$ for the magnesium/copper cell. Your labels should include the **names** of the metals and the **names** and **concentrations** of the solutions you would use.

[3]

(f) Explain why the enthalpy change determination and cell potential determination should be carried out at the same temperature as each other.

Temperature needs to be standardised, so that temperature doesnt become the factor that affects $E^{\ominus}$cell. All condition except the once that are measured should be kept constant. [1]

Your Mark

1(a) ☐
1(b) ☐
1(c)(i) ☐
1(c)(ii) ☐
1(c)(iii) ☐
1(c)(iv) ☐
1(c)(v) ☐
1(c)(vi) ☐
1(d) ☐
1(e) ☐
1(f) ☐
1(g) ☐

Q1	Mark scheme
	Expected answer
(a)	(As the E° cell value increases) ΔH_r decreases or ΔH_r becomes more negative or ΔHr becomes more exothermic. AND The more reactive the metal then the greater the energy release will be. OR Energy output of both reactions is dependent upon the difference in reactivity (of metals). **[1]**
(b)	Independent variable: The (type of) metal Dependent variable: temperature change or rise or increase OR enthalpy change **[1]**
(c)(i)	Diagram should indicate a labelled insulated container AND a labelled thermometer in the liquid. **[1]**
(c)(ii)	Mass of metal before and after Initial temperature (before metal added) AND Highest temperature (after metal added) **[1]**
(c)(iii)	Wear gloves **[1]**
(c)(iv)	Moles CuSO4 = 0.025 mol, therefore moles of magnesium = 0.025 mol (minimum) mass Mg > (0.025 × 24.3 =) 0.6075 g AND mass required value is greater than 0.6075 g **[1]**
(c)(v)	Larger surface area AND causes increased rate of reaction **[1]**
(c)(vi)	Ensure uniformity of heating (of solution) **[1]**
(d)	50.0 × 4.18 × 58.5 = 12 226.5 (J) ΔHr = 12 226.5 / 0.025 = 489 000 = – 489 1000 **[1]**
(e)	Complete circuit involving labelled voltmeter; labelled salt bridge; two separate solutions; (Solutions are) magnesium sulfate or MgSO4 with magnesium or Mg rod and copper(II) sulfate CuSO4 with copper or Cu rod Concentration of solution(s) is 1 mol dm–3 or 1 M **[1]**
(f)	So that values can be compared **[1]**
(g)	Both ΔHr (Zn) and ΔHr (Fe) values which are consistent with the prediction in (a). **[1]**

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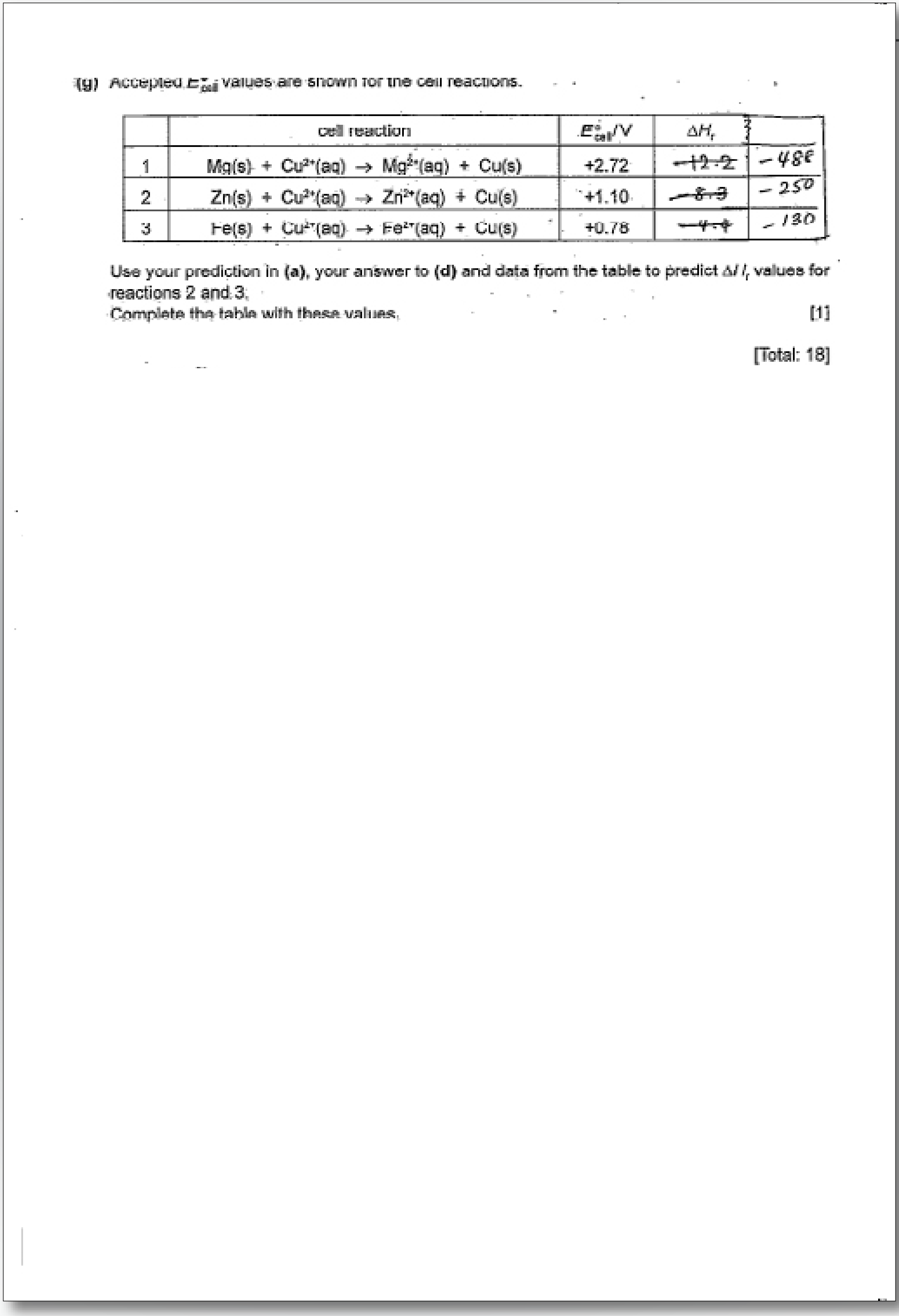

(g) Accepted E°_{cell} values are shown for the cell reactions.

	cell reaction	E°_{cell}/V	ΔH_r	
1	$Mg(s) + Cu^{2+}(aq) \rightarrow Mg^{2+}(aq) + Cu(s)$	+2.72	~~-12.2~~	-488
2	$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$	+1.10	~~-8.3~~	-250
3	$Fe(s) + Cu^{2+}(aq) \rightarrow Fe^{2+}(aq) + Cu(s)$	+0.78	~~-4.4~~	-130

Use your prediction in **(a)**, your answer to **(d)** and data from the table to predict ΔH_r values for reactions 2 and 3.

Complete the table with these values. [1]

[Total: 18]

Your Mark

1(a) ☐

1(b) ☐

1(c)(i) ☐

1(c)(ii) ☐

1(c)(iii) ☐

1(c)(iv) ☐

1(c)(v) ☐

1(c)(vi) ☐

1(d) ☐

1(e) ☐

1(f) ☐

1(g) ☐

Q1	**Mark scheme**
	Expected answer
(a)	(As the E° cell value increases) ΔH_r decreases or ΔH_r becomes more negative or ΔHr becomes more exothermic. AND The more reactive the metal then the greater the energy release will be. OR Energy output of both reactions is dependent upon the difference in reactivity (of metals). **[1]**
(b)	Independent variable: The (type of) metal Dependent variable: temperature change or rise or increase OR enthalpy change **[1]**
(c)(i)	Diagram should indicate a labelled insulated container AND a labelled thermometer in the liquid. **[1]**
(c)(ii)	Mass of metal before and after Initial temperature (before metal added) AND Highest temperature (after metal added) **[1]**
(c)(iii)	Wear gloves **[1]**
(c)(iv)	Moles CuSO4 = 0.025 mol, therefore moles of magnesium = 0.025 mol (minimum) mass Mg > (0.025 × 24.3 =) 0.6075 g AND mass required value is greater than 0.6075 g **[1]**
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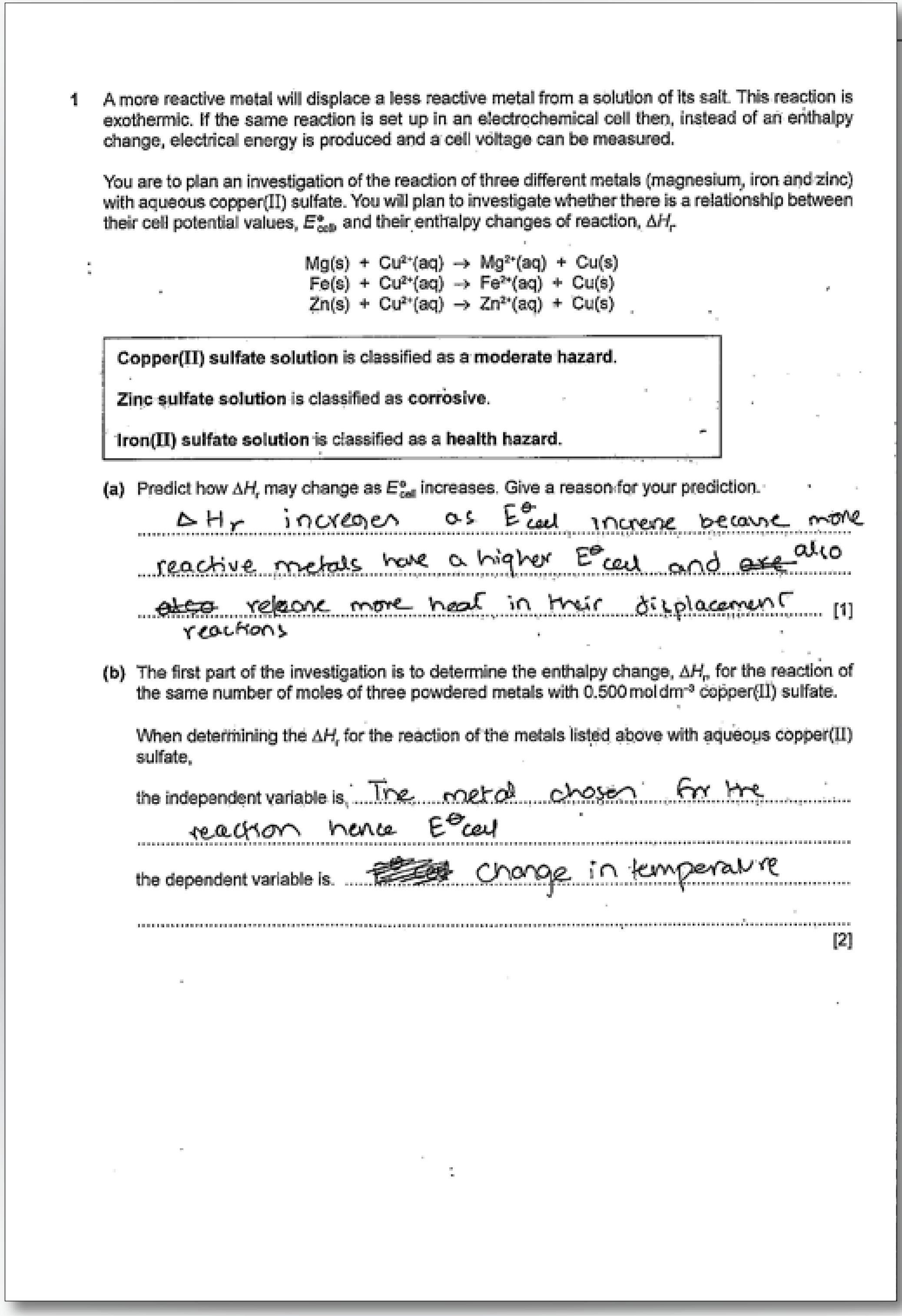
(e)	Complete circuit involving labelled voltmeter; labelled salt bridge; two separate solutions; (Solutions are) magnesium sulfate or MgSO4 with magnesium or Mg rod and copper(II) sulfate CuSO4 with copper or Cu rod Concentration of solution(s) is 1 mol dm–3 or 1 M **[1]**
(f)	So that values can be compared **[1]**
(g)	Both ΔHr (Zn) and ΔHr (Fe) values which are consistent with the prediction in (a). **[1]**

EXAMINER COMMENTS

MARK SCHEME



1 A more reactive metal will displace a less reactive metal from a solution of its salt. This reaction is exothermic. If the same reaction is set up in an electrochemical cell then, instead of an enthalpy change, electrical energy is produced and a cell voltage can be measured.

You are to plan an investigation of the reaction of three different metals (magnesium, iron and zinc) with aqueous copper(II) sulfate. You will plan to investigate whether there is a relationship between their cell potential values, E°_{cell}, and their enthalpy changes of reaction, ΔH_r.

$$Mg(s) + Cu^{2+}(aq) \rightarrow Mg^{2+}(aq) + Cu(s)$$
$$Fe(s) + Cu^{2+}(aq) \rightarrow Fe^{2+}(aq) + Cu(s)$$
$$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$$

Copper(II) sulfate solution is classified as a **moderate hazard.**

Zinc sulfate solution is classified as **corrosive.**

Iron(II) sulfate solution is classified as a **health hazard.**

(a) Predict how ΔH_r may change as E°_{cell} increases. Give a reason for your prediction.

ΔH_r increases as $E^\ominus_{cell}$ increase because more reactive metals have a higher $E^\ominus_{cell}$ and ~~are~~ also ~~also~~ release more heat in their displacement reactions [1]

(b) The first part of the investigation is to determine the enthalpy change, ΔH_r, for the reaction of the same number of moles of three powdered metals with 0.500 mol dm^{-3} copper(II) sulfate.

When determining the ΔH_r for the reaction of the metals listed above with aqueous copper(II) sulfate,

the independent variable is, The metal chosen for the reaction hence $E^\ominus_{cell}$

the dependent variable is. ~~[illegible]~~ change in temperature

[2]

Your Mark

1(a)
1(b)
1(c)(i)
1(c)(ii)
1(c)(iii)
1(c)(iv)
1(c)(v)
1(c)(vi)
1(d)
1(e)
1(f)
1(g)

Q1	Mark scheme
	Expected answer
(a)	(As the E° cell value increases) ΔH_r decreases or ΔH_r becomes more negative or ΔHr becomes more exothermic. AND The more reactive the metal then the greater the energy release will be. OR Energy output of both reactions is dependent upon the difference in reactivity (of metals). **[1]**
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(c)(i)	Diagram should indicate a labelled insulated container AND a labelled thermometer in the liquid. **[1]**
(c)(ii)	Mass of metal before and after Initial temperature (before metal added) AND Highest temperature (after metal added) **[1]**
(c)(iii)	Wear gloves **[1]**
(c)(iv)	Moles CuSO4 = 0.025 mol, therefore moles of magnesium = 0.025 mol (minimum) mass Mg > (0.025 × 24.3 =) 0.6075 g AND mass required value is greater than 0.6075 g **[1]**
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(c)(vi)	Ensure uniformity of heating (of solution) **[1]**
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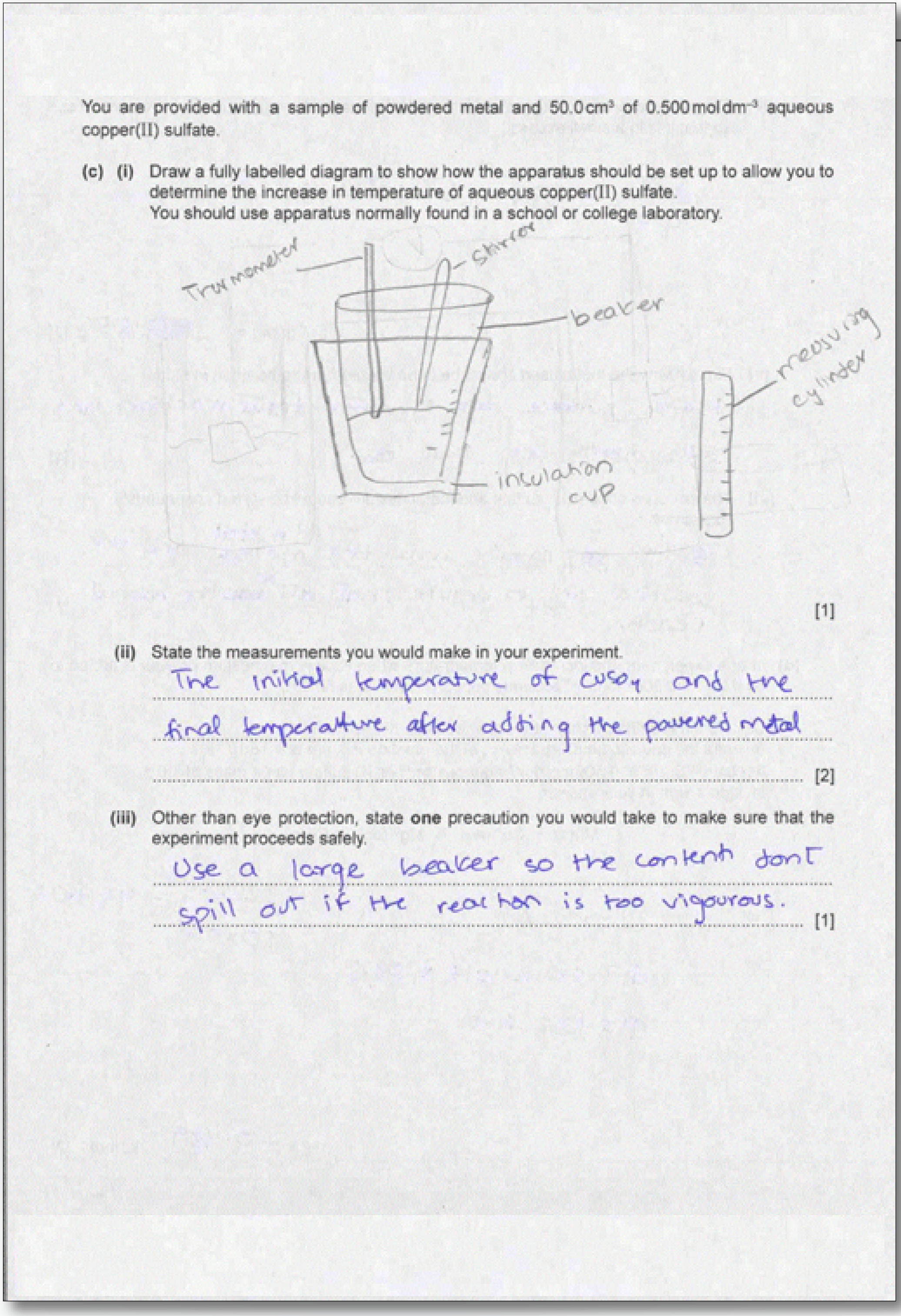
(e)	Complete circuit involving labelled voltmeter; labelled salt bridge; two separate solutions; (Solutions are) magnesium sulfate or MgSO4 with magnesium or Mg rod and copper(II) sulfate CuSO4 with copper or Cu rod Concentration of solution(s) is 1 mol dm–3 or 1 M **[1]**
(f)	So that values can be compared **[1]**
(g)	Both ΔHr (Zn) and ΔHr (Fe) values which are consistent with the prediction in (a). **[1]**



You are provided with a sample of powdered metal and 50.0 cm³ of 0.500 mol dm⁻³ aqueous copper(II) sulfate.

(c) (i) Draw a fully labelled diagram to show how the apparatus should be set up to allow you to determine the increase in temperature of aqueous copper(II) sulfate.
You should use apparatus normally found in a school or college laboratory.

[1]

(ii) State the measurements you would make in your experiment.

The initial temperature of $CuSO_4$ and the final temperature after adding the powered metal

[2]

(iii) Other than eye protection, state **one** precaution you would take to make sure that the experiment proceeds safely.

Use a large beaker so the content dont spill out if the reaction is too vigourous.

[1]

Your Mark

1(a)
1(b)
1(c)(i)
1(c)(ii)
1(c)(iii)
1(c)(iv)
1(c)(v)
1(c)(vi)
1(d)
1(e)
1(f)
1(g)

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	Expected answer
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(b)	Independent variable: The (type of) metal Dependent variable: temperature change or rise or increase OR enthalpy change **[1]**
(c)(i)	Diagram should indicate a labelled insulated container AND a labelled thermometer in the liquid. **[1]**
(c)(ii)	Mass of metal before and after Initial temperature (before metal added) AND Highest temperature (after metal added) **[1]**
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(c)(vi)	Ensure uniformity of heating (of solution) **[1]**
(d)	50.0 × 4.18 × 58.5 = 12 226.5 (J) ΔHr = 12 226.5 / 0.025 = 489 000 = – 489 1000 **[1]**
(e)	Complete circuit involving labelled voltmeter; labelled salt bridge; two separate solutions; (Solutions are) magnesium sulfate or MgSO4 with magnesium or Mg rod and copper(II) sulfate CuSO4 with copper or Cu rod Concentration of solution(s) is 1 mol dm–3 or 1 M **[1]**
(f)	So that values can be compared **[1]**
(g)	Both ΔHr (Zn) and ΔHr (Fe) values which are consistent with the prediction in (a). **[1]**

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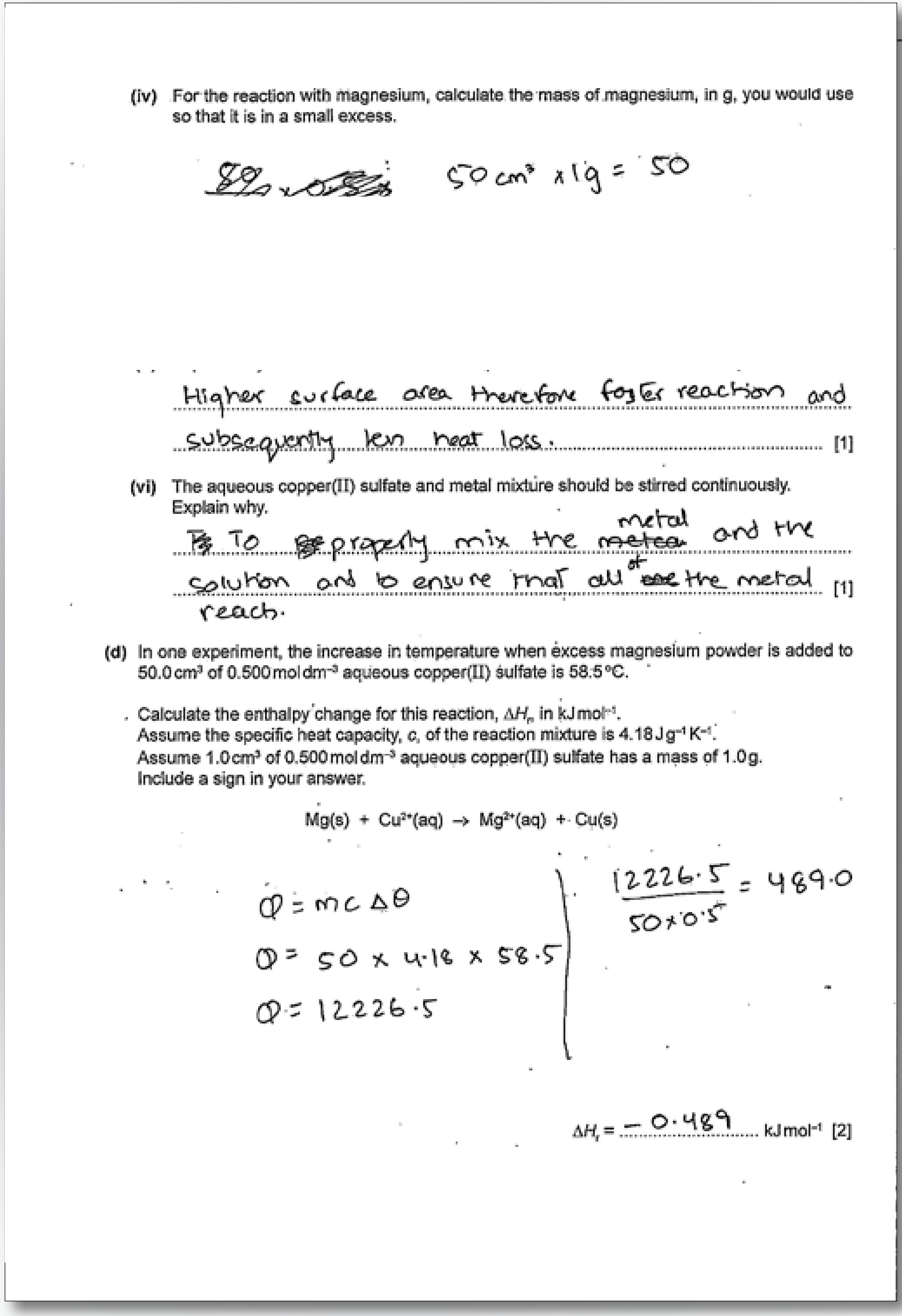

(iv) For the reaction with magnesium, calculate the mass of magnesium, in g, you would use so that it is in a small excess.

~~[illegible]~~ 50 cm³ x 1g = 50

Higher surface area therefore fas Er reaction and subsequently len heat loss. [1]

(vi) The aqueous copper(II) sulfate and metal mixture should be stirred continuously. Explain why.

To properly mix the metal ~~metea~~ and the solution and to ensure that all of ~~one~~ the metal reach. [1]

(d) In one experiment, the increase in temperature when excess magnesium powder is added to 50.0 cm³ of 0.500 mol dm⁻³ aqueous copper(II) sulfate is 58.5 °C.

Calculate the enthalpy change for this reaction, ΔH_r, in kJ mol⁻¹.
Assume the specific heat capacity, c, of the reaction mixture is 4.18 J g⁻¹ K⁻¹.
Assume 1.0 cm³ of 0.500 mol dm⁻³ aqueous copper(II) sulfate has a mass of 1.0 g.
Include a sign in your answer.

$$Mg(s) + Cu^{2+}(aq) \rightarrow Mg^{2+}(aq) + Cu(s)$$

$Q = mc\Delta\theta$

$Q = 50 \times 4.18 \times 58.5$

$Q = 12226.5$

$\frac{12226.5}{50 \times 0.5} = 489.0$

ΔH_r = – 0.489 kJ mol⁻¹ [2]

Your Mark

1(a) ☐
1(b) ☐
1(c)(i) ☐
1(c)(ii) ☐
1(c)(iii) ☐
1(c)(iv) ☐
1(c)(v) ☐
1(c)(vi) ☐
1(d) ☐
1(e) ☐
1(f) ☐
1(g) ☐

Q1	Mark scheme	
	Expected answer	
(a)	(As the E° cell value increases) ΔH_r decreases or ΔH_r becomes more negative or ΔHr becomes more exothermic. AND The more reactive the metal then the greater the energy release will be. OR Energy output of both reactions is dependent upon the difference in reactivity (of metals).	[1]
(b)	Independent variable: The (type of) metal Dependent variable: temperature change or rise or increase OR enthalpy change	[1]
(c)(i)	Diagram should indicate a labelled insulated container AND a labelled thermometer in the liquid.	[1]
(c)(ii)	Mass of metal before and after Initial temperature (before metal added) AND Highest temperature (after metal added)	[1]
(c)(iii)	Wear gloves	[1]
(c)(iv)	Moles CuSO4 = 0.025 mol, therefore moles of magnesium = 0.025 mol (minimum) mass Mg > (0.025 × 24.3 =) 0.6075 g AND mass required value is greater than 0.6075 g	[1]
(c)(v)	Larger surface area AND causes increased rate of reaction	[1]
(c)(vi)	Ensure uniformity of heating (of solution)	[1]
(d)	50.0 × 4.18 × 58.5 = 12 226.5 (J) ΔHr = 12 226.5 / 0.025 = 489 000 = – 489 1000	[1]
(e)	Complete circuit involving labelled voltmeter; labelled salt bridge; two separate solutions; (Solutions are) magnesium sulfate or MgSO4 with magnesium or Mg rod and copper(II) sulfate CuSO4 with copper or Cu rod Concentration of solution(s) is 1 mol dm–3 or 1 M	[1]
(f)	So that values can be compared	[1]
(g)	Both ΔHr (Zn) and ΔHr (Fe) values which are consistent with the prediction in (a).	[1]

EXAMINER COMMENTS

MARK SCHEME

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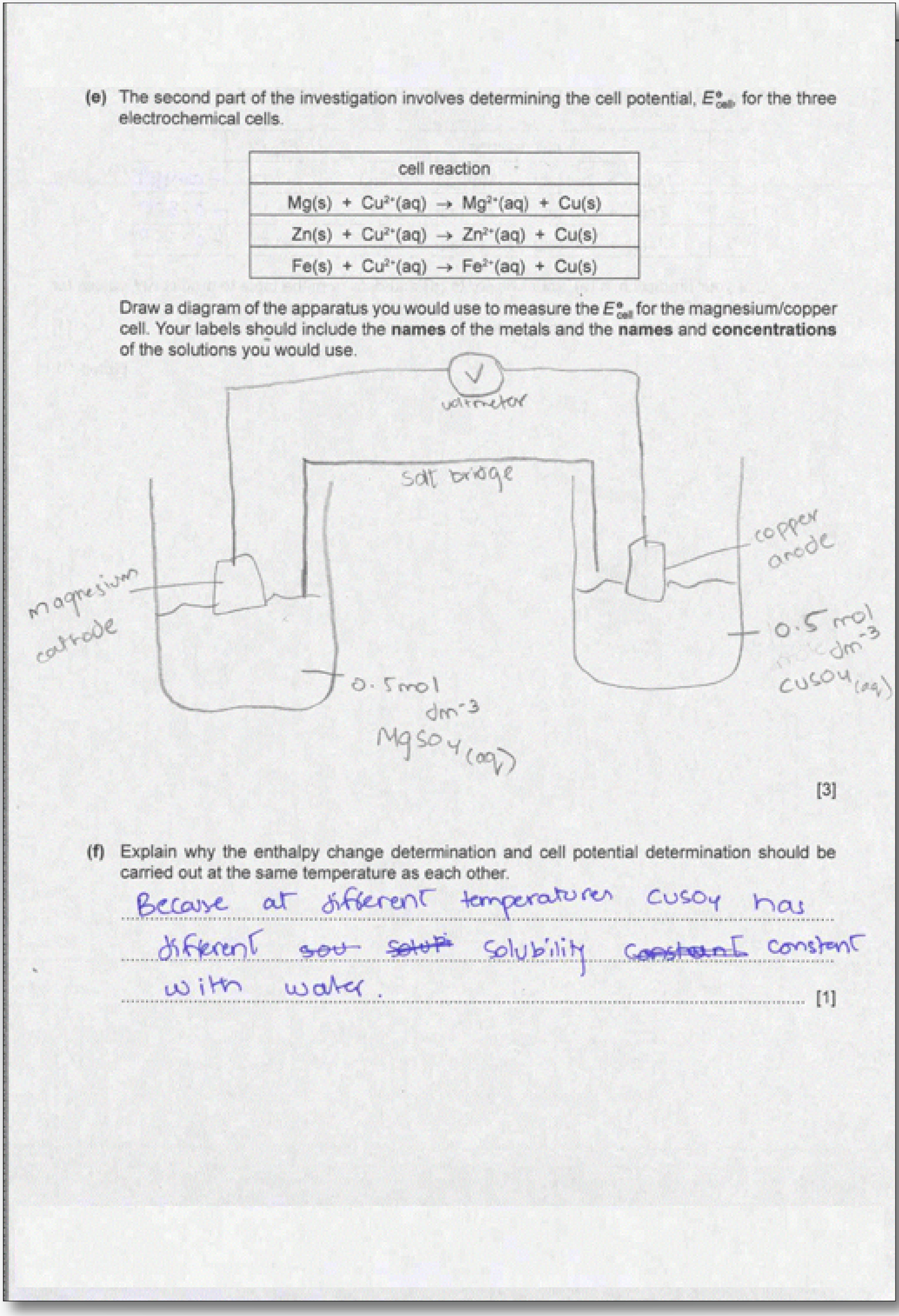
HIGH MIDDLE LOW



(e) The second part of the investigation involves determining the cell potential, E°_{cell}, for the three electrochemical cells.

cell reaction
$Mg(s) + Cu^{2+}(aq) \rightarrow Mg^{2+}(aq) + Cu(s)$
$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$
$Fe(s) + Cu^{2+}(aq) \rightarrow Fe^{2+}(aq) + Cu(s)$

Draw a diagram of the apparatus you would use to measure the E°_{cell} for the magnesium/copper cell. Your labels should include the **names** of the metals and the **names** and **concentrations** of the solutions you would use.

[3]

(f) Explain why the enthalpy change determination and cell potential determination should be carried out at the same temperature as each other.

Because at different temperatures CuSO4 has different ~~sou~~ ~~solut~~ solubility ~~constant~~ constant with water.

[1]

Your Mark

1(a)

1(b)

1(c)(i)

1(c)(ii)

1(c)(iii)

1(c)(iv)

1(c)(v)

1(c)(vi)

1(d)

1(e)

1(f)

1(g)

Q1	Mark scheme
	Expected answer
(a)	(As the E° cell value increases) ΔH_r decreases or ΔH_r becomes more negative or ΔHr becomes more exothermic. AND The more reactive the metal then the greater the energy release will be. OR Energy output of both reactions is dependent upon the difference in reactivity (of metals). **[1]**
(b)	Independent variable: The (type of) metal Dependent variable: temperature change or rise or increase OR enthalpy change **[1]**
(c)(i)	Diagram should indicate a labelled insulated container AND a labelled thermometer in the liquid. **[1]**
(c)(ii)	Mass of metal before and after Initial temperature (before metal added) AND Highest temperature (after metal added) **[1]**
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(c)(v)	Larger surface area AND causes increased rate of reaction **[1]**
(c)(vi)	Ensure uniformity of heating (of solution) **[1]**
(d)	$50.0 \times 4.18 \times 58.5 = 12\,226.5$ (J) $\Delta Hr = 12\,226.5 / 0.025 = 489\,000 = -489$ 1000 **[1]**
(e)	Complete circuit involving labelled voltmeter; labelled salt bridge; two separate solutions; (Solutions are) magnesium sulfate or $MgSO_4$ with magnesium or Mg rod and copper(II) sulfate $CuSO_4$ with copper or Cu rod Concentration of solution(s) is 1 mol dm^{-3} or 1 M **[1]**
(f)	So that values can be compared **[1]**
(g)	Both ΔHr (Zn) and ΔHr (Fe) values which are consistent with the prediction in (a). **[1]**

EXAMINER COMMENTS

MARK SCHEME

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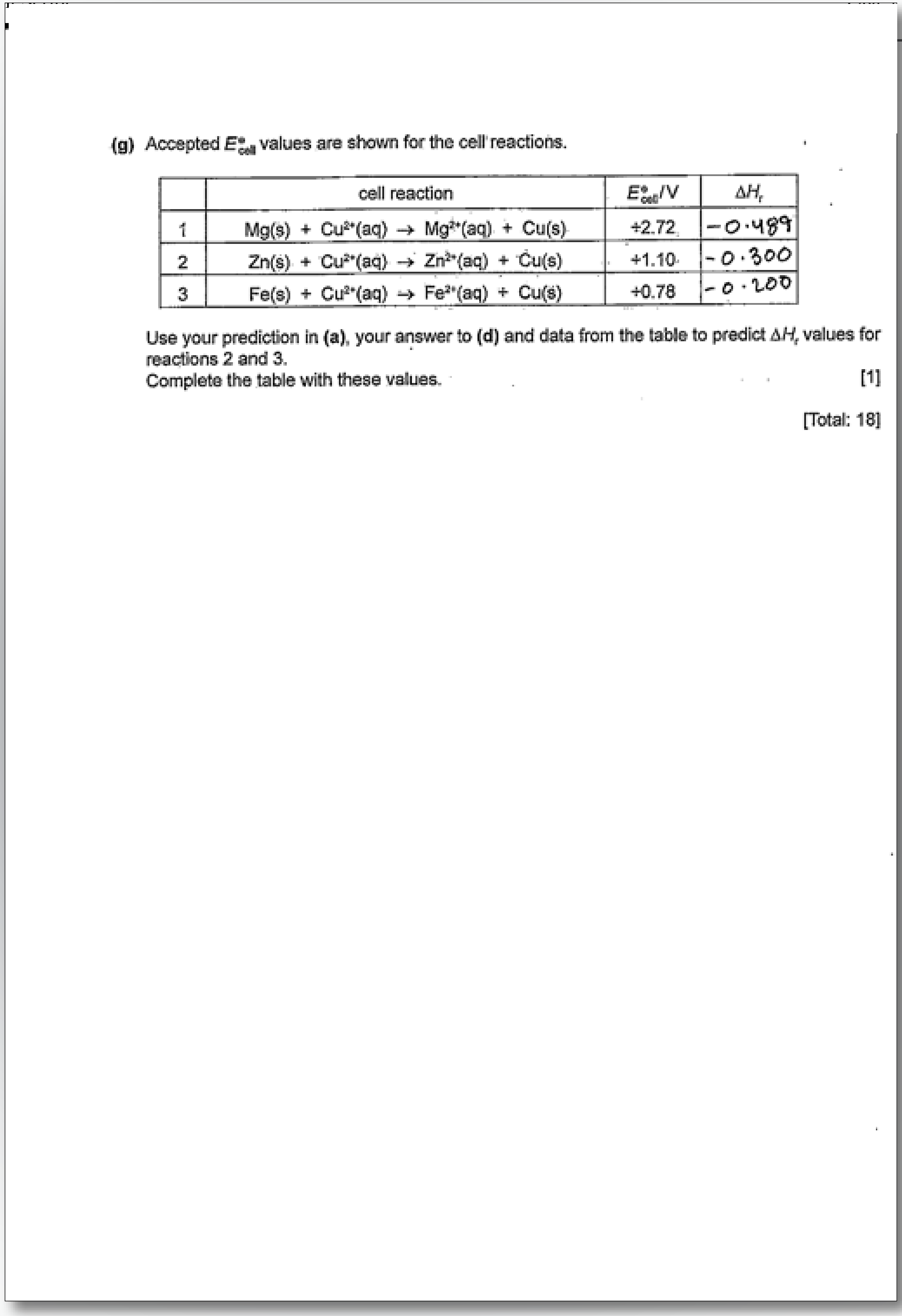
HIGH

MIDDLE

LOW



(g) Accepted E°_{cell} values are shown for the cell reactions.

	cell reaction	E°_{cell}/V	ΔH_r
1	$Mg(s) + Cu^{2+}(aq) \rightarrow Mg^{2+}(aq) + Cu(s)$	+2.72	−0·489
2	$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$	+1.10	−0·300
3	$Fe(s) + Cu^{2+}(aq) \rightarrow Fe^{2+}(aq) + Cu(s)$	+0.78	−0·200

Use your prediction in **(a)**, your answer to **(d)** and data from the table to predict ΔH_r values for reactions 2 and 3.
Complete the table with these values. [1]

[Total: 18]

Your Mark

1(a) ☐
1(b) ☐
1(c)(i) ☐
1(c)(ii) ☐
1(c)(iii) ☐
1(c)(iv) ☐
1(c)(v) ☐
1(c)(vi) ☐
1(d) ☐
1(e) ☐
1(f) ☐
1(g) ☐

Q1	Mark scheme
	Expected answer
(a)	(As the E° cell value increases) ΔH_r decreases or ΔH_r becomes more negative or ΔHr becomes more exothermic. AND The more reactive the metal then the greater the energy release will be. OR Energy output of both reactions is dependent upon the difference in reactivity (of metals). **[1]**
(b)	Independent variable: The (type of) metal Dependent variable: temperature change or rise or increase OR enthalpy change **[1]**
(c)(i)	Diagram should indicate a labelled insulated container AND a labelled thermometer in the liquid. **[1]**
(c)(ii)	Mass of metal before and after Initial temperature (before metal added) AND Highest temperature (after metal added) **[1]**
(c)(iii)	Wear gloves **[1]**
(c)(iv)	Moles CuSO4 = 0.025 mol, therefore moles of magnesium = 0.025 mol (minimum) mass Mg > (0.025 × 24.3 =) 0.6075 g AND mass required value is greater than 0.6075 g **[1]**
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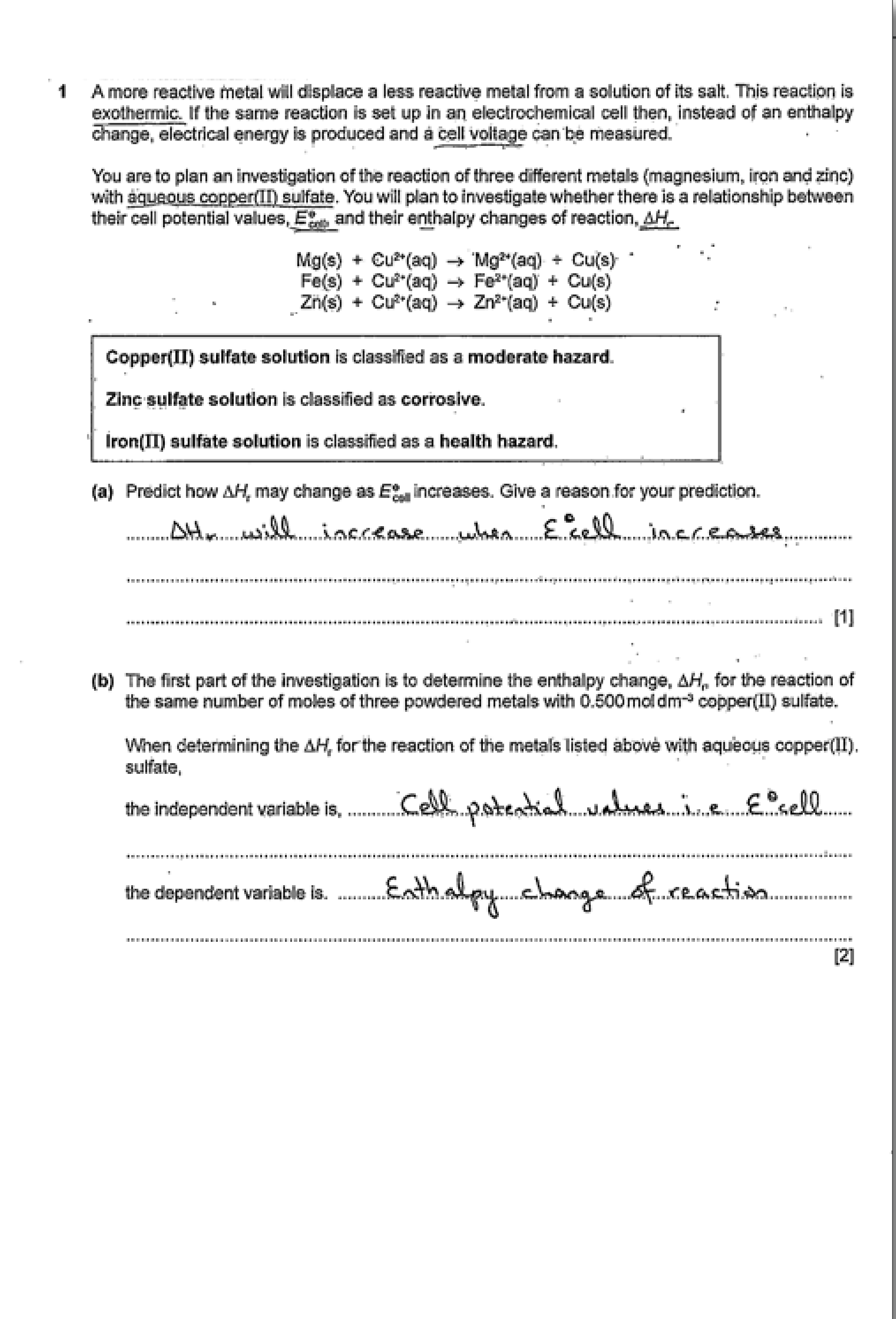
(f)	So that values can be compared **[1]**
(g)	Both ΔHr (Zn) and ΔHr (Fe) values which are consistent with the prediction in (a). **[1]**

EXAMINER COMMENTS

MARK SCHEME



1 A more reactive metal will displace a less reactive metal from a solution of its salt. This reaction is exothermic. If the same reaction is set up in an electrochemical cell then, instead of an enthalpy change, electrical energy is produced and a cell voltage can be measured.

You are to plan an investigation of the reaction of three different metals (magnesium, iron and zinc) with aqueous copper(II) sulfate. You will plan to investigate whether there is a relationship between their cell potential values, E°_{cell} and their enthalpy changes of reaction, ΔH_r.

$$Mg(s) + Cu^{2+}(aq) \rightarrow Mg^{2+}(aq) + Cu(s)$$
$$Fe(s) + Cu^{2+}(aq) \rightarrow Fe^{2+}(aq) + Cu(s)$$
$$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$$

Copper(II) sulfate solution is classified as a moderate hazard.

Zinc sulfate solution is classified as corrosive.

Iron(II) sulfate solution is classified as a health hazard.

(a) Predict how ΔH_r may change as E°_{cell} increases. Give a reason for your prediction.

ΔH_r will increase when E°cell increases

[1]

(b) The first part of the investigation is to determine the enthalpy change, ΔH_r, for the reaction of the same number of moles of three powdered metals with 0.500 mol dm^{-3} copper(II) sulfate.

When determining the ΔH_r for the reaction of the metals listed above with aqueous copper(II) sulfate,

the independent variable is, Cell potential values i.e E°cell

the dependent variable is. Enthalpy change of reaction

[2]

Your Mark

1(a) ☐
1(b) ☐
1(c)(i) ☐
1(c)(ii) ☐
1(c)(iii) ☐
1(c)(iv) ☐
1(c)(v) ☐
1(c)(vi) ☐
1(d) ☐
1(e) ☐
1(f) ☐
1(g) ☐

Q1	Mark scheme
	Expected answer
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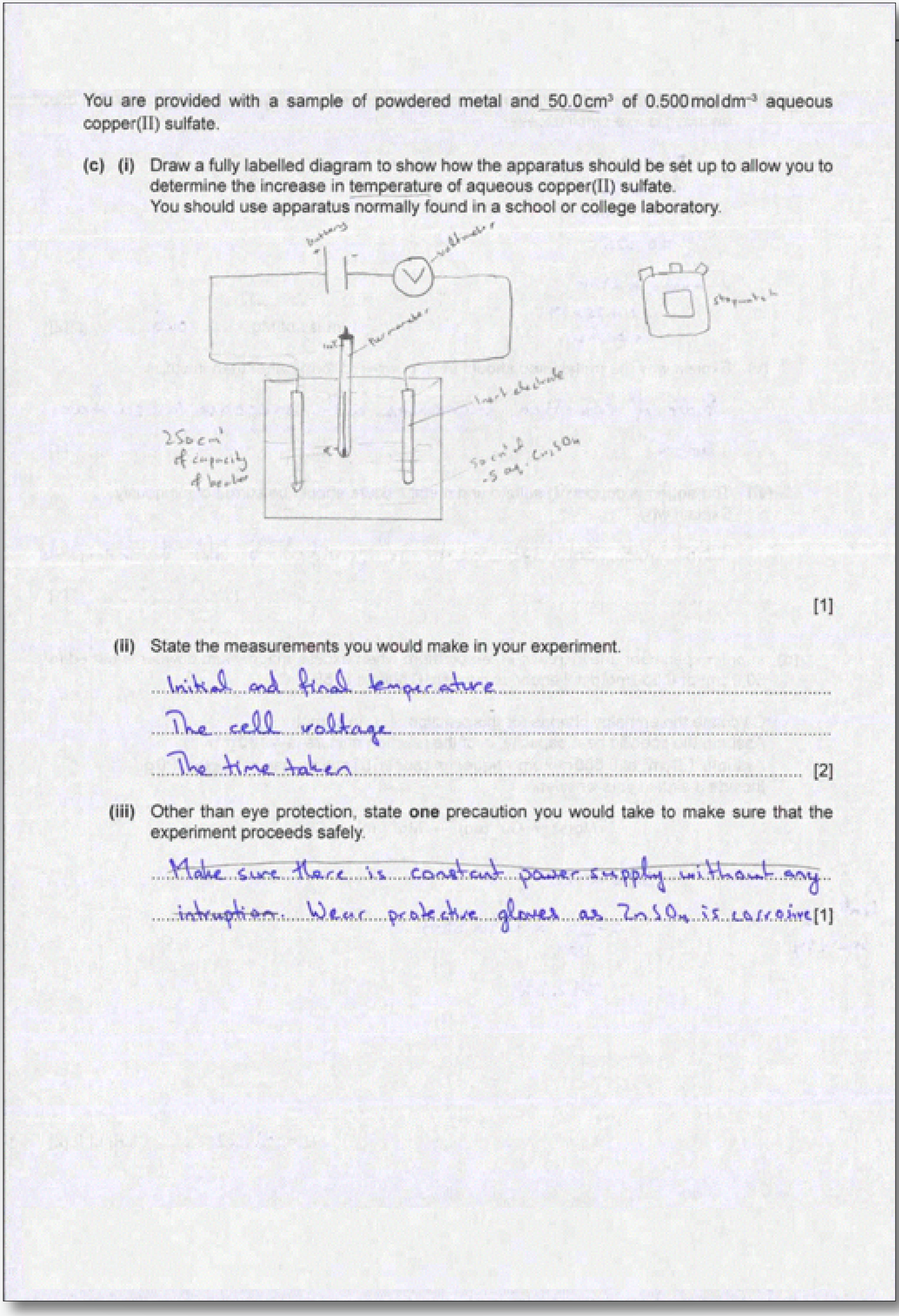
(g)	Both ΔHr (Zn) and ΔHr (Fe) values which are consistent with the prediction in (a). **[1]**



You are provided with a sample of powdered metal and 50.0 cm³ of 0.500 mol dm⁻³ aqueous copper(II) sulfate.

(c) (i) Draw a fully labelled diagram to show how the apparatus should be set up to allow you to determine the increase in temperature of aqueous copper(II) sulfate. You should use apparatus normally found in a school or college laboratory.

[1]

(ii) State the measurements you would make in your experiment.

Initial and final temperature

The cell voltage

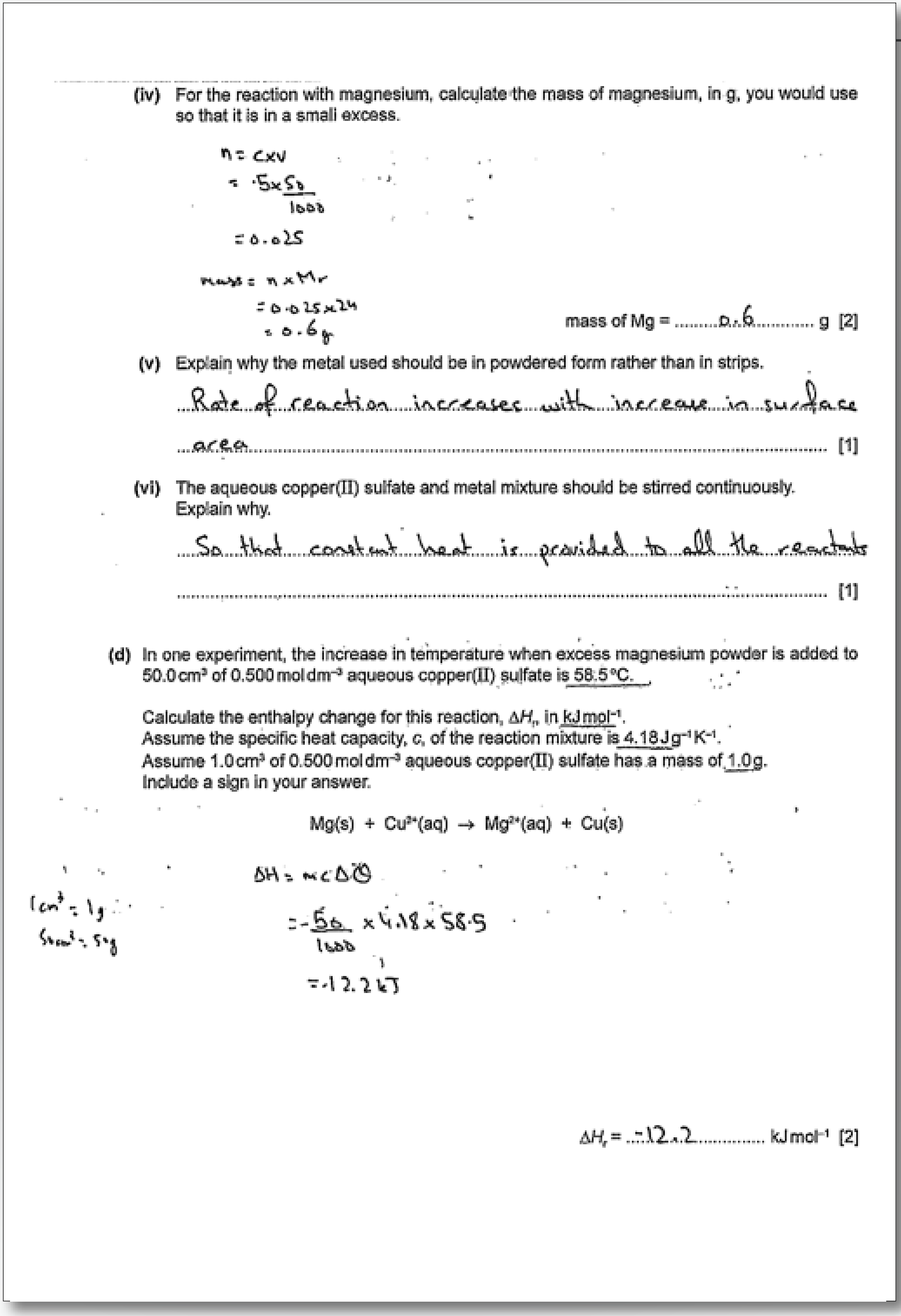
The time taken [2]

(iii) Other than eye protection, state **one** precaution you would take to make sure that the experiment proceeds safely.

~~Make sure there is constant power supply without any intruption.~~ Wear protective gloves as ZnSO4 is corroive [1]

Your Mark	
1(a)	
1(b)	
1(c)(i)	
1(c)(ii)	
1(c)(iii)	
1(c)(iv)	
1(c)(v)	
1(c)(vi)	
1(d)	
1(e)	
1(f)	
1(g)	

Q1	Mark scheme
	Expected answer
(a)	(As the E° cell value increases) ΔH_r decreases or ΔH_r becomes more negative or ΔHr becomes more exothermic. AND The more reactive the metal then the greater the energy release will be. OR Energy output of both reactions is dependent upon the difference in reactivity (of metals). **[1]**
(b)	Independent variable: The (type of) metal Dependent variable: temperature change or rise or increase OR enthalpy change **[1]**
(c)(i)	Diagram should indicate a labelled insulated container AND a labelled thermometer in the liquid. **[1]**
(c)(ii)	Mass of metal before and after Initial temperature (before metal added) AND Highest temperature (after metal added) **[1]**
(c)(iii)	Wear gloves **[1]**
(c)(iv)	Moles CuSO4 = 0.025 mol, therefore moles of magnesium = 0.025 mol (minimum) mass Mg > (0.025 × 24.3 =) 0.6075 g AND mass required value is greater than 0.6075 g **[1]**
(c)(v)	Larger surface area AND causes increased rate of reaction **[1]**
(c)(vi)	Ensure uniformity of heating (of solution) **[1]**
(d)	50.0 × 4.18 × 58.5 = 12 226.5 (J) ΔHr = 12 226.5 / 0.025 = 489 000 = – 489 1000 **[1]**
(e)	Complete circuit involving labelled voltmeter; labelled salt bridge; two separate solutions; (Solutions are) magnesium sulfate or MgSO4 with magnesium or Mg rod and copper(II) sulfate CuSO4 with copper or Cu rod Concentration of solution(s) is 1 mol dm–3 or 1 M **[1]**
(f)	So that values can be compared **[1]**
(g)	Both ΔHr (Zn) and ΔHr (Fe) values which are consistent with the prediction in (a). **[1]**



(iv) For the reaction with magnesium, calculate the mass of magnesium, in g, you would use so that it is in a small excess.

n = cxv

= ·5x$\frac{50}{1000}$

= 0.025

mass = n x Mr

= 0.025x24

= 0.6g

mass of Mg = ...0.6.......... g [2]

(v) Explain why the metal used should be in powdered form rather than in strips.

...Rate of reaction increases with increase in surface

...area... [1]

(vi) The aqueous copper(II) sulfate and metal mixture should be stirred continuously. Explain why.

...So that constant heat is provided to all the reactants

.... [1]

(d) In one experiment, the increase in temperature when excess magnesium powder is added to 50.0 cm³ of 0.500 mol dm⁻³ aqueous copper(II) sulfate is 58.5 °C.

Calculate the enthalpy change for this reaction, ΔH$_r$, in kJ mol⁻¹.
Assume the specific heat capacity, c, of the reaction mixture is 4.18 J g⁻¹ K⁻¹.
Assume 1.0 cm³ of 0.500 mol dm⁻³ aqueous copper(II) sulfate has a mass of 1.0 g.
Include a sign in your answer.

$$Mg(s) + Cu^{2+}(aq) \rightarrow Mg^{2+}(aq) + Cu(s)$$

1cm³ = 1g
50cm³ = 50g

ΔH = mcΔθ

= -$\frac{50}{1000}$ x 4.18 x 58.5

= -12.2 kJ

ΔH$_r$ = ..-12.2.......... kJ mol⁻¹ [2]

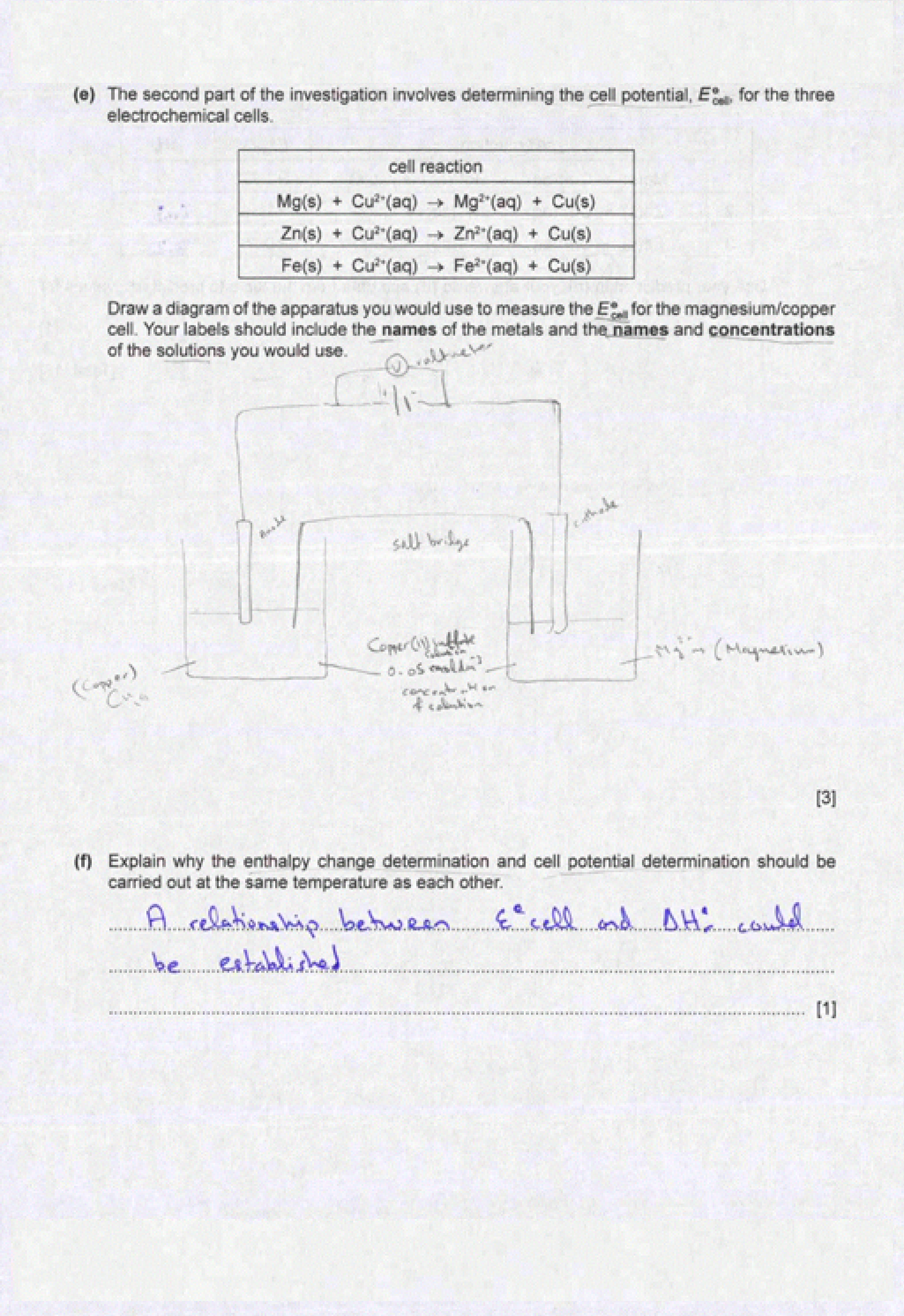
Your Mark

1(a)
1(b)
1(c)(i)
1(c)(ii)
1(c)(iii)
1(c)(iv)
1(c)(v)
1(c)(vi)
1(d)
1(e)
1(f)
1(g)

Q1	Mark scheme
	Expected answer
(a)	(As the E° cell value increases) ΔH$_r$ decreases or ΔH$_r$ becomes more negative or ΔHr becomes more exothermic. AND The more reactive the metal then the greater the energy release will be. OR Energy output of both reactions is dependent upon the difference in reactivity (of metals). **[1]**
(b)	Independent variable: The (type of) metal Dependent variable: temperature change or rise or increase OR enthalpy change **[1]**
(c)(i)	Diagram should indicate a labelled insulated container AND a labelled thermometer in the liquid. **[1]**
(c)(ii)	Mass of metal before and after Initial temperature (before metal added) AND Highest temperature (after metal added) **[1]**
(c)(iii)	Wear gloves **[1]**
(c)(iv)	Moles CuSO4 = 0.025 mol, therefore moles of magnesium = 0.025 mol (minimum) mass Mg > (0.025 × 24.3 =) 0.6075 g AND mass required value is greater than 0.6075 g **[1]**
(c)(v)	Larger surface area AND causes increased rate of reaction **[1]**
(c)(vi)	Ensure uniformity of heating (of solution) **[1]**
(d)	50.0 × 4.18 × 58.5 = 12 226.5 (J) ΔHr = 12 226.5 / 0.025 = 489 000 = – 489 1000 **[1]**
(e)	Complete circuit involving labelled voltmeter; labelled salt bridge; two separate solutions; (Solutions are) magnesium sulfate or MgSO4 with magnesium or Mg rod and copper(II) sulfate CuSO4 with copper or Cu rod Concentration of solution(s) is 1 mol dm–3 or 1 M **[1]**
(f)	So that values can be compared **[1]**
(g)	Both ΔHr (Zn) and ΔHr (Fe) values which are consistent with the prediction in (a). **[1]**

Select page

HIGH MIDDLE LOW



(e) The second part of the investigation involves determining the cell potential, E°_{cell}, for the three electrochemical cells.

cell reaction
$Mg(s) + Cu^{2+}(aq) \rightarrow Mg^{2+}(aq) + Cu(s)$
$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$
$Fe(s) + Cu^{2+}(aq) \rightarrow Fe^{2+}(aq) + Cu(s)$

Draw a diagram of the apparatus you would use to measure the E°_{cell} for the magnesium/copper cell. Your labels should include the **names** of the metals and the **names** and **concentrations** of the solutions you would use.

[3]

(f) Explain why the enthalpy change determination and cell potential determination should be carried out at the same temperature as each other.

A relationship between E°cell and ΔH$_r$ could be established

[1]

Your Mark

1(a)	
1(b)	
1(c)(i)	
1(c)(ii)	
1(c)(iii)	
1(c)(iv)	
1(c)(v)	
1(c)(vi)	
1(d)	
1(e)	
1(f)	
1(g)	

Q1	Mark scheme	
	Expected answer	
(a)	(As the E° cell value increases) ΔH$_r$ decreases or ΔH$_r$ becomes more negative or ΔHr becomes more exothermic. AND The more reactive the metal then the greater the energy release will be. OR Energy output of both reactions is dependent upon the difference in reactivity (of metals).	**[1]**
(b)	Independent variable: The (type of) metal Dependent variable: temperature change or rise or increase OR enthalpy change	**[1]**
(c)(i)	Diagram should indicate a labelled insulated container AND a labelled thermometer in the liquid.	**[1]**
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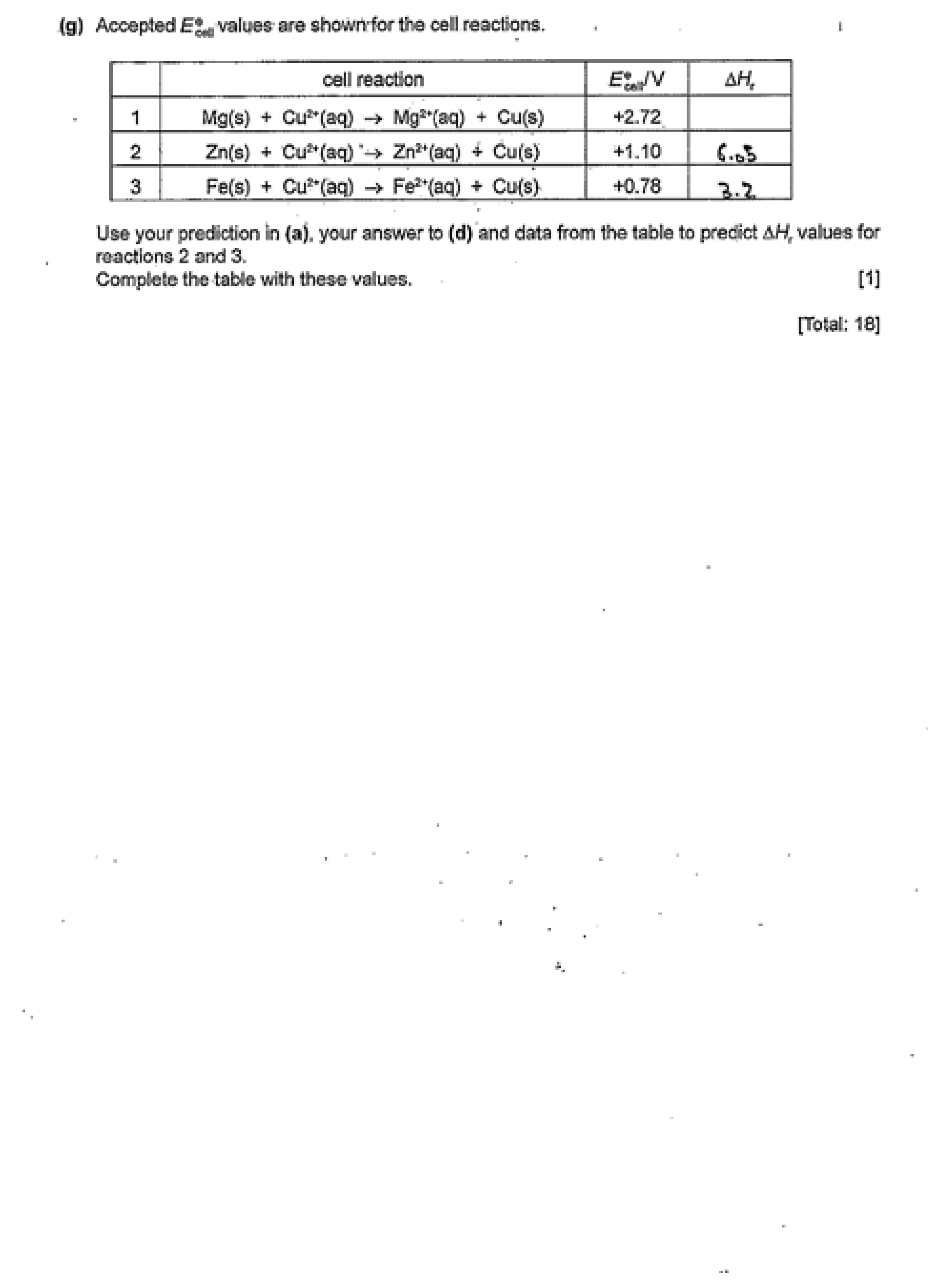
(f)	So that values can be compared	**[1]**
(g)	Both ΔHr (Zn) and ΔHr (Fe) values which are consistent with the prediction in (a).	**[1]**

EXAMINER COMMENTS

MARK SCHEME



(g) Accepted E°_{cell} values are shown for the cell reactions.

	cell reaction	E°_{cell}/V	ΔH_r
1	$Mg(s) + Cu^{2+}(aq) \rightarrow Mg^{2+}(aq) + Cu(s)$	+2.72	
2	$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$	+1.10	6.05
3	$Fe(s) + Cu^{2+}(aq) \rightarrow Fe^{2+}(aq) + Cu(s)$	+0.78	3.2

Use your prediction in **(a)**, your answer to **(d)** and data from the table to predict ΔH_r values for reactions 2 and 3.
Complete the table with these values. [1]

[Total: 18]

Select page

HIGH MIDDLE LOW

Your Mark

1(a)
1(b)
1(c)(i)
1(c)(ii)
1(c)(iii)
1(c)(iv)
1(c)(v)
1(c)(vi)
1(d)
1(e)
1(f)
1(g)

Q1	Mark scheme
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(g)	Both ΔHr (Zn) and ΔHr (Fe) values which are consistent with the prediction in (a). **[1]**

EXAMINER COMMENTS

MARK SCHEME

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Cambridge Assessment
International Education

Interactive

Interactive Example Candidate Responses
Paper 52 (May/June 2016), Question 2

Cambridge International AS & A Level
Chemistry 9701

Version 1.0

Cambridge
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Select page

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MIDDLE

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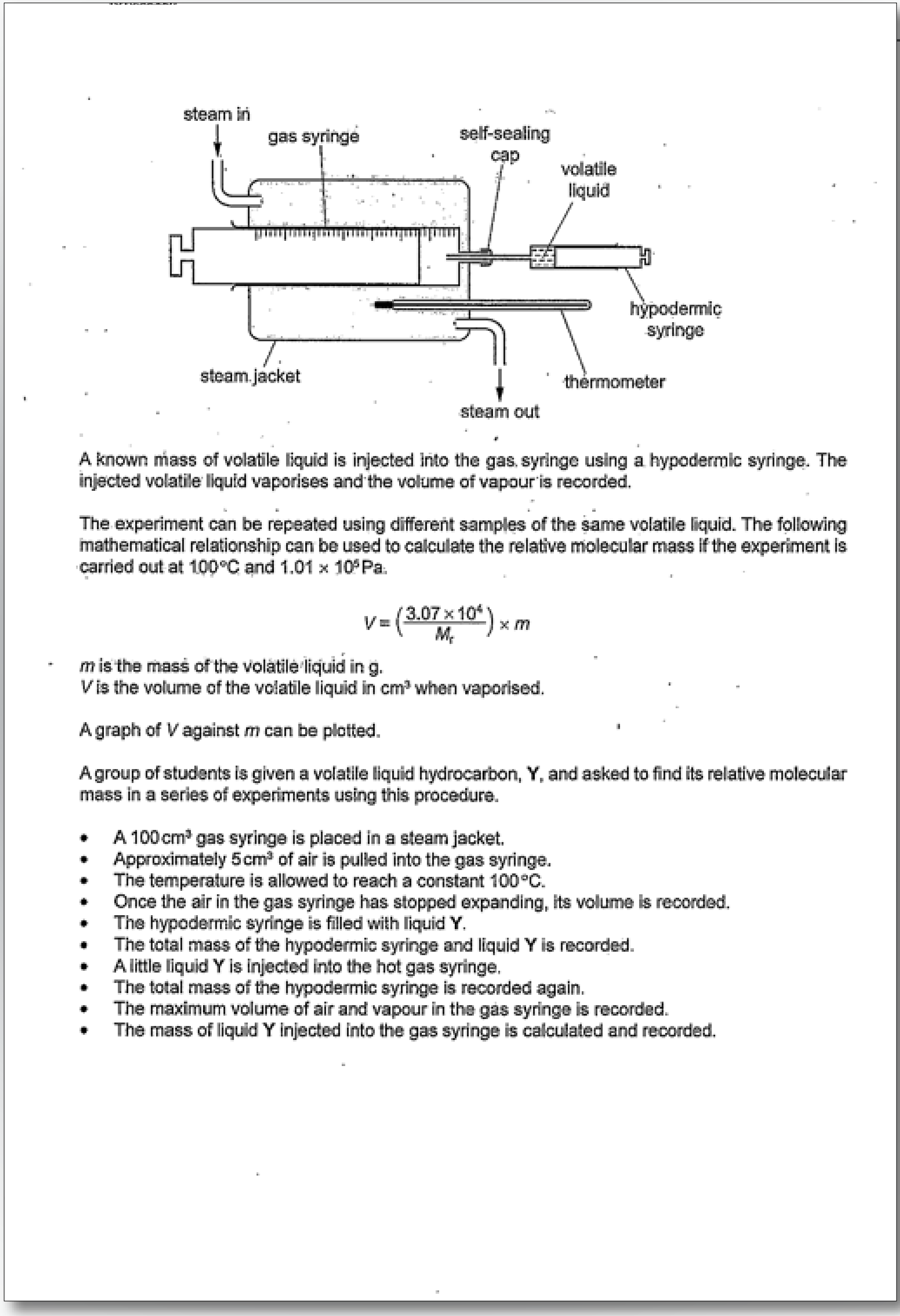

A known mass of volatile liquid is injected into the gas syringe using a hypodermic syringe. The injected volatile liquid vaporises and the volume of vapour is recorded.

The experiment can be repeated using different samples of the same volatile liquid. The following mathematical relationship can be used to calculate the relative molecular mass if the experiment is carried out at 100 °C and 1.01×10^5 Pa.

$$V = \left(\frac{3.07 \times 10^4}{M_r}\right) \times m$$

m is the mass of the volatile liquid in g.
V is the volume of the volatile liquid in cm³ when vaporised.

A graph of V against m can be plotted.

A group of students is given a volatile liquid hydrocarbon, **Y**, and asked to find its relative molecular mass in a series of experiments using this procedure.

- A 100 cm³ gas syringe is placed in a steam jacket.
- Approximately 5 cm³ of air is pulled into the gas syringe.
- The temperature is allowed to reach a constant 100 °C.
- Once the air in the gas syringe has stopped expanding, its volume is recorded.
- The hypodermic syringe is filled with liquid **Y**.
- The total mass of the hypodermic syringe and liquid **Y** is recorded.
- A little liquid **Y** is injected into the hot gas syringe.
- The total mass of the hypodermic syringe is recorded again.
- The maximum volume of air and vapour in the gas syringe is recorded.
- The mass of liquid **Y** injected into the gas syringe is calculated and recorded.

Your Mark

2(a) ☐

2(b) ☐

2(c)(i) ☐

2(c)(ii) ☐

2(d)(i) ☐

2(d)(ii) ☐

2(e) ☐

<table>
<tr><th>Q2</th><th colspan="2">Mark scheme</th></tr>
<tr><td></td><td colspan="2">Expected answer</td></tr>
<tr><td>(a)</td><td>
<table>
<tr><th>Mass of liquid Y used / g</th><th>Volume of vapour Y / cm³</th></tr>
<tr><td>0.15</td><td>48</td></tr>
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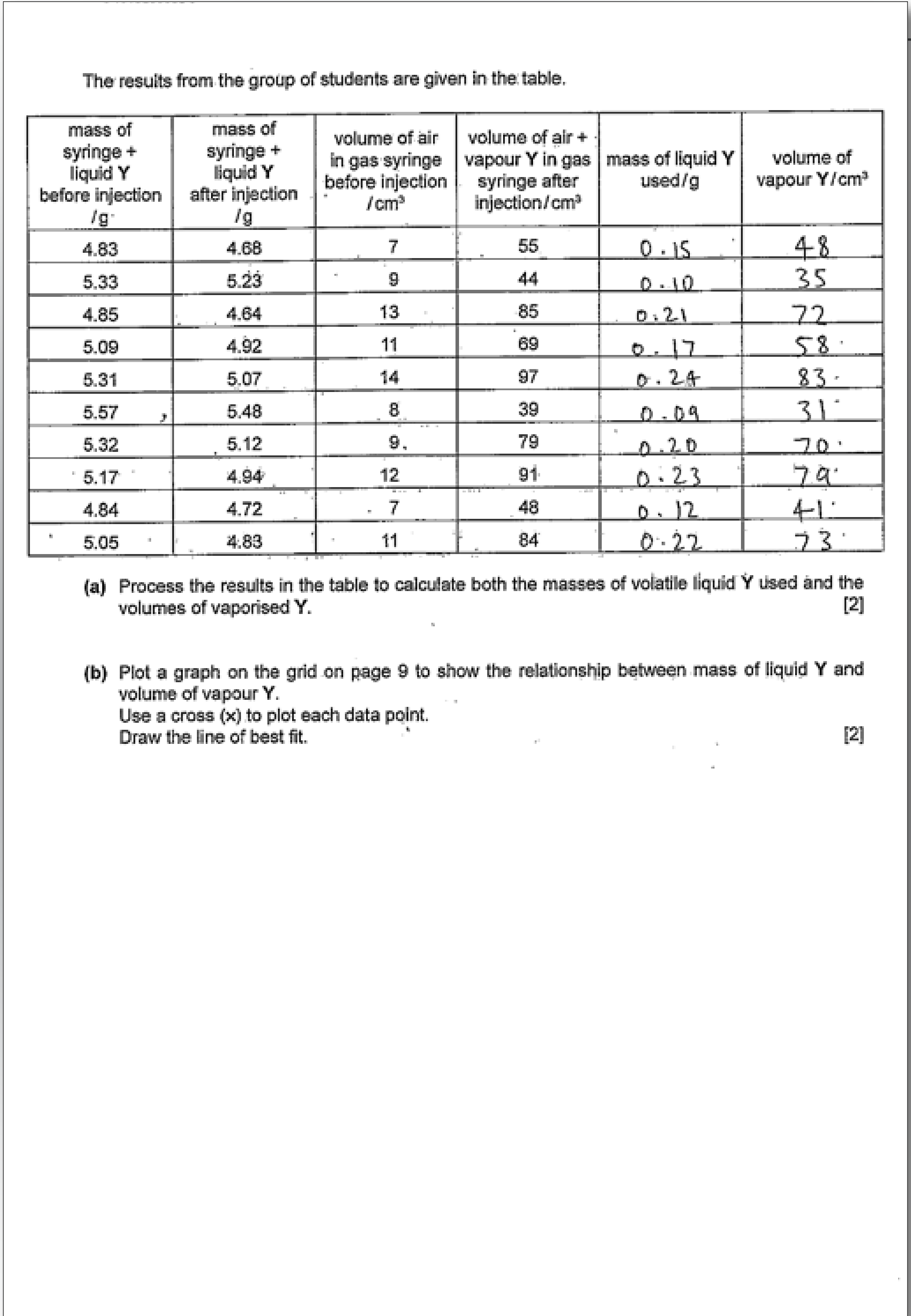
<tr><td>0.21</td><td>72</td></tr>
<tr><td>0.17</td><td>58</td></tr>
<tr><td>0.24</td><td>83</td></tr>
<tr><td>0.09</td><td>31</td></tr>
<tr><td>0.20</td><td>70</td></tr>
<tr><td>0.23</td><td>79</td></tr>
<tr><td>0.12</td><td>41</td></tr>
<tr><td>0.22</td><td>73</td></tr>
</table>
All mass values.
All volume values.</td><td>[1]
[1]</td></tr>
<tr><td>(b)</td><td>Candidate's points plotted correctly from table in 2(a).
Line of best fit drawn.</td><td>[1]
[1]</td></tr>
<tr><td>(c)(i)</td><td>Y evaporates from the (hypodermic) syringe
OR
Y evaporates before injection
OR
Y evaporates before weighing / after injection</td><td>[1]</td></tr>
<tr><td>(c)(ii)</td><td>(Stop evaporation by)
Keeping the syringe as cool as possible
OR
Closing off the needle end to stop evaporation
OR
Minimising length of time between each weighing</td><td>[1]</td></tr>
<tr><td>(d)(i)</td><td>correct co-ordinates.
correct calculation of the gradient
must be three significant figures</td><td>[1
[1]</td></tr>
<tr><td>(d)(ii)</td><td>Calculation of Mr = 3.07×10^4 / gradient in 2(d)(i)
Answer</td><td>[1]</td></tr>
<tr><td>(e)</td><td>Mr (from mass spectrum) = 84
OR
empirical formula = CH_2
OR
ratio of C and H seen as 1:2
Y is C_6H_{12}</td><td>[1]
Total: [12]</td></tr>
</table>

EXAMINER COMMENTS

MARK SCHEME



The results from the group of students are given in the table.

mass of syringe + liquid Y before injection /g	mass of syringe + liquid Y after injection /g	volume of air in gas syringe before injection /cm³	volume of air + vapour Y in gas syringe after injection/cm³	mass of liquid Y used/g	volume of vapour Y/cm³
4.83	4.68	7	55	0.15	48
5.33	5.23	9	44	0.10	35
4.85	4.64	13	85	0.21	72
5.09	4.92	11	69	0.17	58
5.31	5.07	14	97	0.24	83
5.57	5.48	8	39	0.09	31
5.32	5.12	9	79	0.20	70
5.17	4.94	12	91	0.23	79
4.84	4.72	7	48	0.12	41
5.05	4.83	11	84	0.22	73

(a) Process the results in the table to calculate both the masses of volatile liquid Y used and the volumes of vaporised Y. [2]

(b) Plot a graph on the grid on page 9 to show the relationship between mass of liquid Y and volume of vapour Y.
Use a cross (x) to plot each data point.
Draw the line of best fit. [2]

HIGH

MIDDLE

LOW

Your Mark

2(a) ☐

2(b) ☐

2(c)(i) ☐

2(c)(ii) ☐

2(d)(i) ☐

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Q2	Mark scheme	
	Expected answer	
(a)	(table above) All mass values. All volume values.	 [1] [1]
(b)	Candidate's points plotted correctly from table in 2(a). Line of best fit drawn.	[1] [1]
(c)(i)	Y evaporates from the (hypodermic) syringe OR Y evaporates before injection OR Y evaporates before weighing / after injection	[1]
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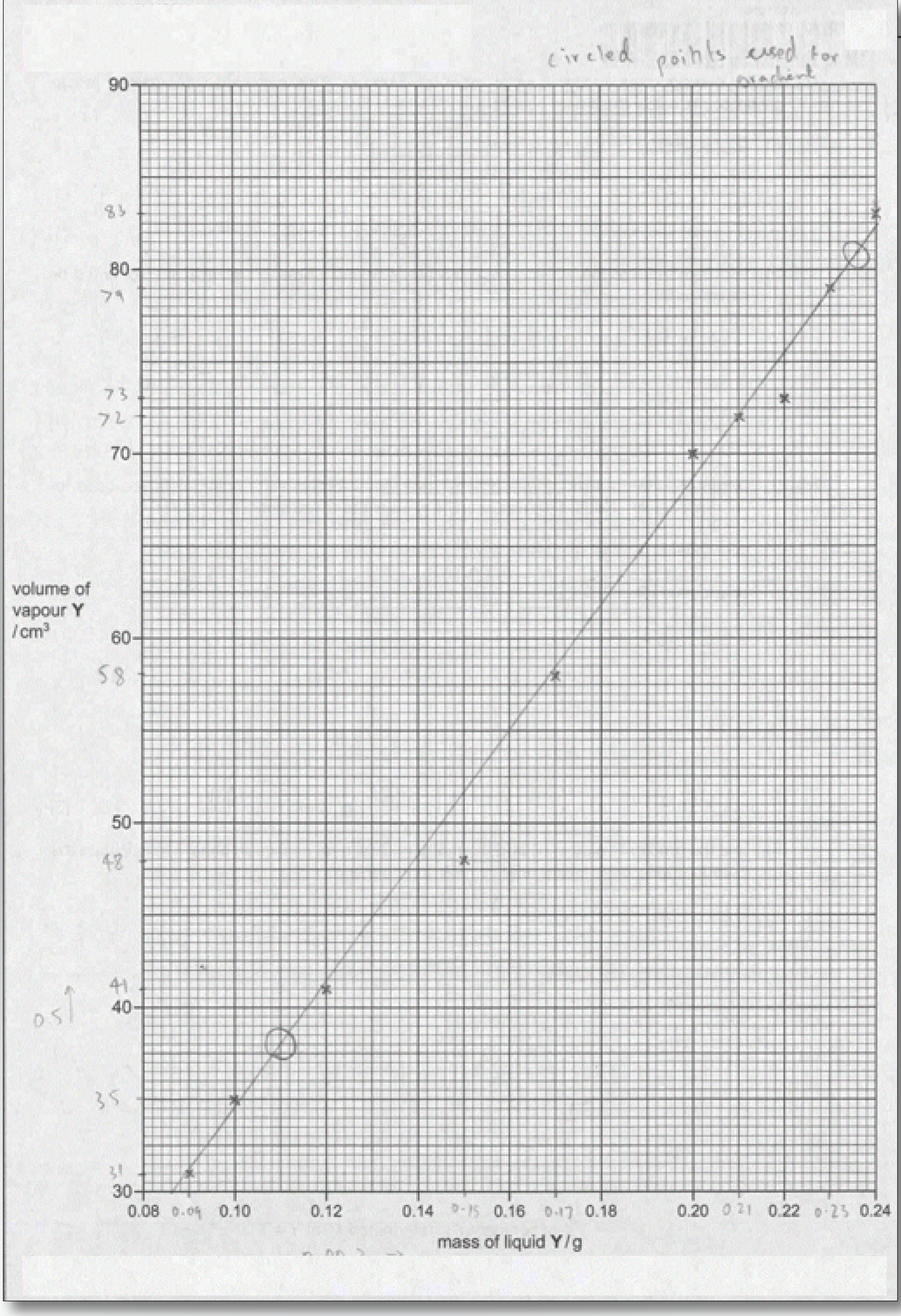
(d)(i)	correct co-ordinates. correct calculation of the gradient must be three significant figures	[1 [1]
(d)(ii)	Calculation of Mr = 3.07×10^4 / gradient in 2(d)(i) Answer	[1]
(e)	Mr (from mass spectrum) = 84 OR empirical formula = CH_2 OR ratio of C and H seen as 1:2 Y is C_6H_{12}	[1]
		Total: [12]

EXAMINER COMMENTS

MARK SCHEME

Select page
HIGH
MIDDLE
LOW



Your Mark

2(a) ☐

2(b) ☐

2(c)(i) ☐

2(c)(ii) ☐

2(d)(i) ☐

2(d)(ii) ☐

2(e) ☐

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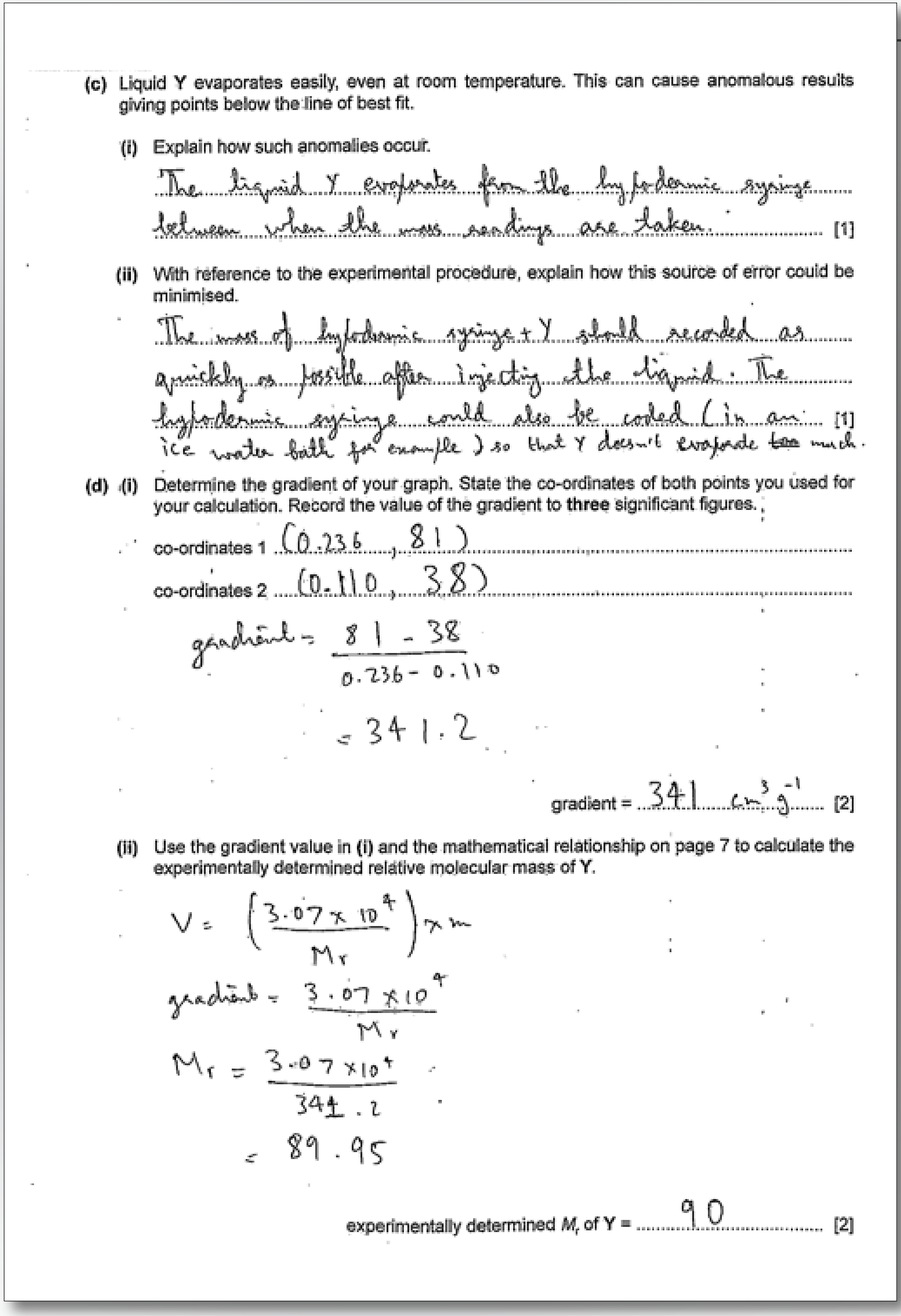
EXAMINER COMMENTS
MARK SCHEME



(c) Liquid Y evaporates easily, even at room temperature. This can cause anomalous results giving points below the line of best fit.

(i) Explain how such anomalies occur.

The liquid Y evaporates from the hypodermic syringe between when the mass readings are taken. [1]

(ii) With reference to the experimental procedure, explain how this source of error could be minimised.

The mass of hypodermic syringe + Y should recorded as quickly as possible after injecting the liquid. The hypodermic syringe could also be cooled (in an ice water bath for example) so that Y doesn't evaporate ~~too~~ much. [1]

(d) (i) Determine the gradient of your graph. State the co-ordinates of both points you used for your calculation. Record the value of the gradient to **three** significant figures.

co-ordinates 1 (0.236 , 81)

co-ordinates 2 (0.110 , 38)

$$\text{gradient} = \frac{81 - 38}{0.236 - 0.110}$$

$$= 341.2$$

gradient = $341\ cm^3 g^{-1}$ [2]

(ii) Use the gradient value in (i) and the mathematical relationship on page 7 to calculate the experimentally determined relative molecular mass of Y.

$$V = \left(\frac{3.07 \times 10^4}{M_r}\right) \times m$$

$$\text{gradient} = \frac{3.07 \times 10^4}{M_r}$$

$$M_r = \frac{3.07 \times 10^4}{341.2}$$

$$= 89.95$$

experimentally determined M_r of Y = 90 [2]

Select page

HIGH MIDDLE LOW

Your Mark

2(a) ☐

2(b) ☐

2(c)(i) ☐

2(c)(ii) ☐

2(d)(i) ☐

2(d)(ii) ☐

2(e) ☐

Q2 Mark scheme

Expected answer

(a)

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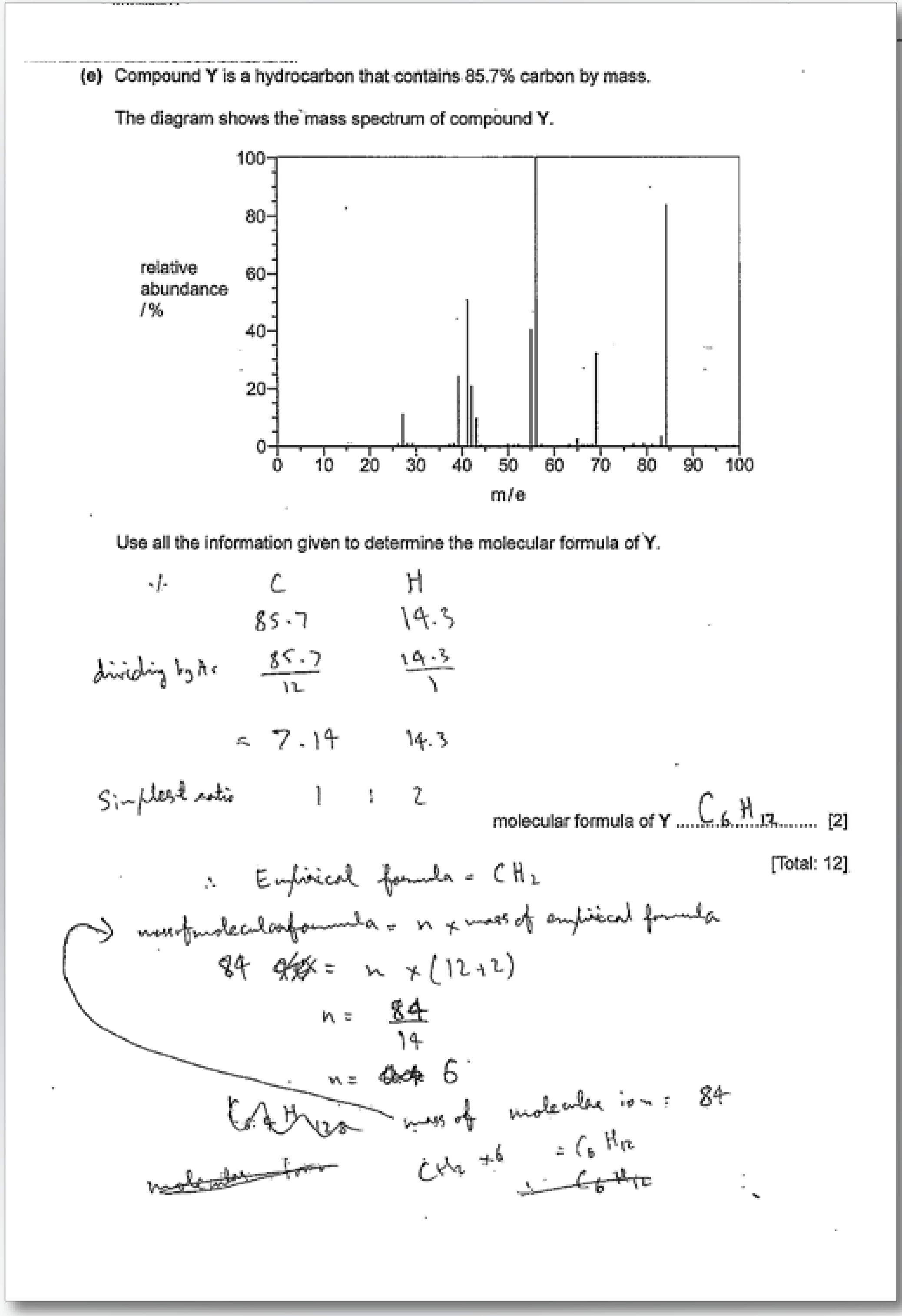
EXAMINER COMMENTS

MARK SCHEME



(e) Compound Y is a hydrocarbon that contains 85.7% carbon by mass.

The diagram shows the mass spectrum of compound Y.

Use all the information given to determine the molecular formula of Y.

%	C	H
	85.7	14.3
dividing by Ar	$\frac{85.7}{12}$	$\frac{14.3}{1}$
	= 7.14	14.3
Simplest ratio	1 :	2

molecular formula of Y ......C_6H_{12}...... [2]

[Total: 12]

∴ Empirical formula = CH_2

mass of molecular formula = n × mass of empirical formula

84 ~~[illegible]~~ = n × (12+2)

$n = \frac{84}{14}$

n = ~~[illegible]~~ 6

~~C_6H_{12}~~ mass of molecular ion = 84

~~molecular form~~ $CH_2 \times 6$ = C_6H_{12}

~~∴ C_6H_{12}~~

Select page

HIGH **MIDDLE** **LOW**

Your Mark

2(a) ☐

2(b) ☐

2(c)(i) ☐

2(c)(ii) ☐

2(d)(i) ☐

2(d)(ii) ☐

2(e) ☐

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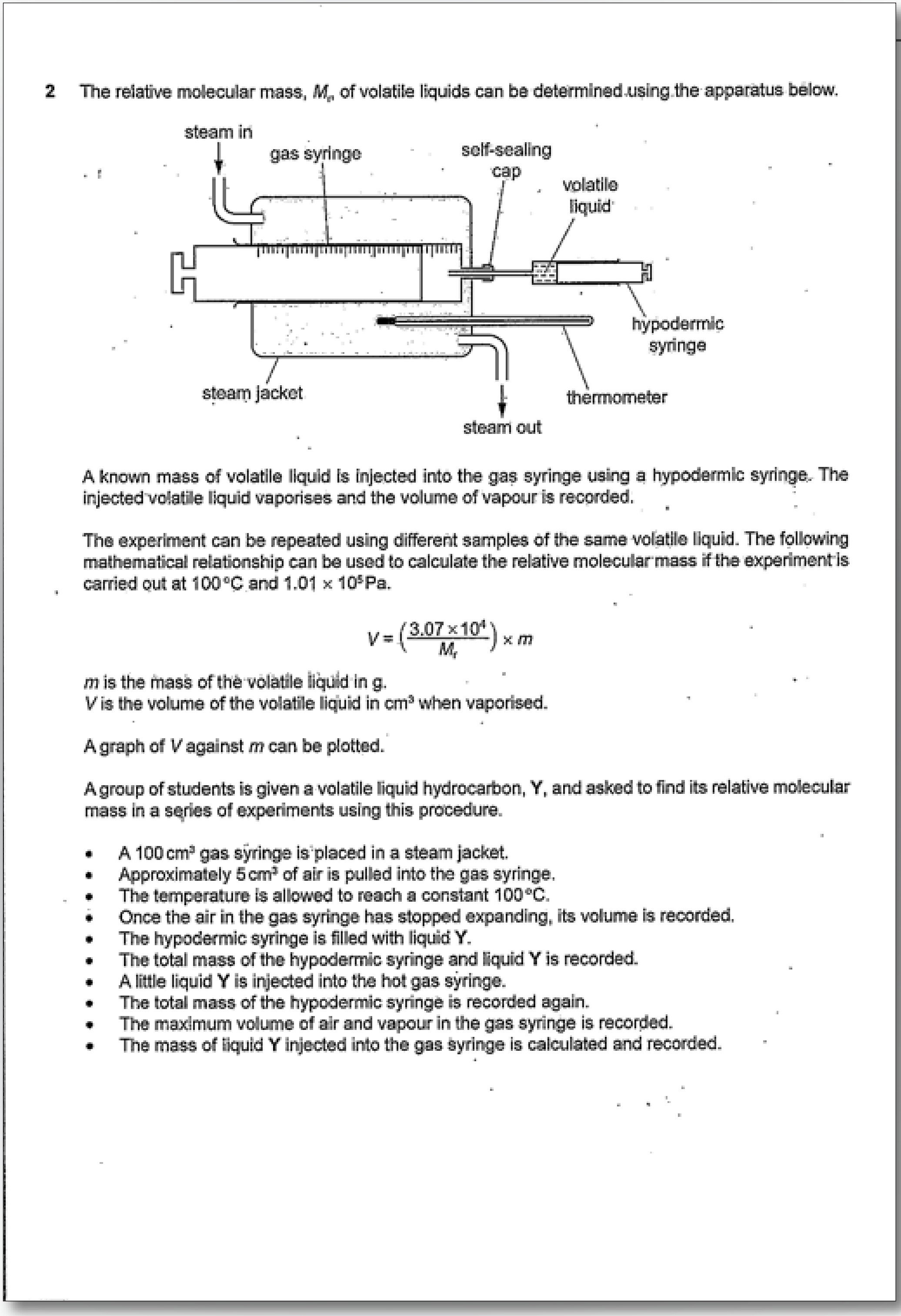

2 The relative molecular mass, M_r of volatile liquids can be determined using the apparatus below.

A known mass of volatile liquid is injected into the gas syringe using a hypodermic syringe. The injected volatile liquid vaporises and the volume of vapour is recorded.

The experiment can be repeated using different samples of the same volatile liquid. The following mathematical relationship can be used to calculate the relative molecular mass if the experiment is carried out at 100 °C and 1.01 × 10^5 Pa.

$$V = \left(\frac{3.07 \times 10^4}{M_r}\right) \times m$$

m is the mass of the volatile liquid in g.
V is the volume of the volatile liquid in cm^3 when vaporised.

A graph of V against m can be plotted.

A group of students is given a volatile liquid hydrocarbon, **Y**, and asked to find its relative molecular mass in a series of experiments using this procedure.

- A 100 cm^3 gas syringe is placed in a steam jacket.
- Approximately 5 cm^3 of air is pulled into the gas syringe.
- The temperature is allowed to reach a constant 100 °C.
- Once the air in the gas syringe has stopped expanding, its volume is recorded.
- The hypodermic syringe is filled with liquid **Y**.
- The total mass of the hypodermic syringe and liquid **Y** is recorded.
- A little liquid **Y** is injected into the hot gas syringe.
- The total mass of the hypodermic syringe is recorded again.
- The maximum volume of air and vapour in the gas syringe is recorded.
- The mass of liquid **Y** injected into the gas syringe is calculated and recorded.

Your Mark

2(a) ☐
2(b) ☐
2(c)(i) ☐
2(c)(ii) ☐
2(d)(i) ☐
2(d)(ii) ☐
2(e) ☐

Q2 Mark scheme

Expected answer

(a)

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0.12	41
0.22	73

All mass values. **[1]**
All volume values. **[1]**

(b)
Candidate's points plotted correctly from table in 2(a). **[1]**
Line of best fit drawn. **[1]**

(c)(i)
Y evaporates from the (hypodermic) syringe
OR
Y evaporates before injection
OR
Y evaporates before weighing / after injection **[1]**

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OR
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OR
Minimising length of time between each weighing **[1]**

(d)(i)
correct co-ordinates. **[1**
correct calculation of the gradient
must be three significant figures **[1]**

(d)(ii)
Calculation of Mr = 3.07×10^4 / gradient in 2(d)(i)
Answer **[1]**

(e)
Mr (from mass spectrum) = 84
OR
empirical formula = CH_2
OR
ratio of C and H seen as 1:2
Y is C_6H_{12} **[1]**

Total: [12]

EXAMINER COMMENTS
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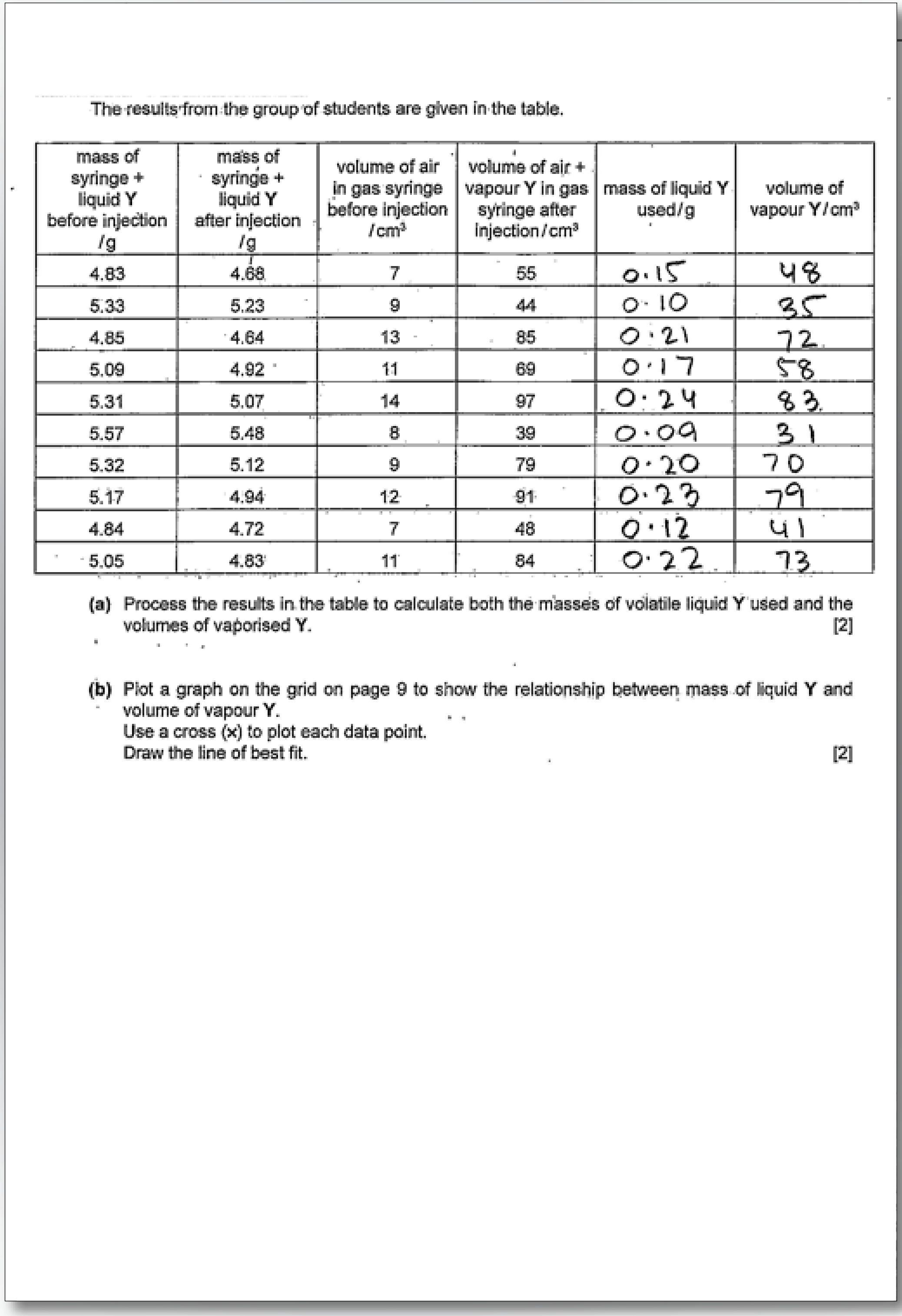

The results from the group of students are given in the table.

mass of syringe + liquid Y before injection /g	mass of syringe + liquid Y after injection /g	volume of air in gas syringe before injection /cm³	volume of air + vapour Y in gas syringe after injection /cm³	mass of liquid Y used/g	volume of vapour Y/cm³
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5.05	4.83	11	84	0·22	73

(a) Process the results in the table to calculate both the masses of volatile liquid Y used and the volumes of vaporised Y. [2]

(b) Plot a graph on the grid on page 9 to show the relationship between mass of liquid Y and volume of vapour Y.
Use a cross (x) to plot each data point.
Draw the line of best fit. [2]

Your Mark

2(a)

2(b)

2(c)(i)

2(c)(ii)

2(d)(i)

2(d)(ii)

2(e)

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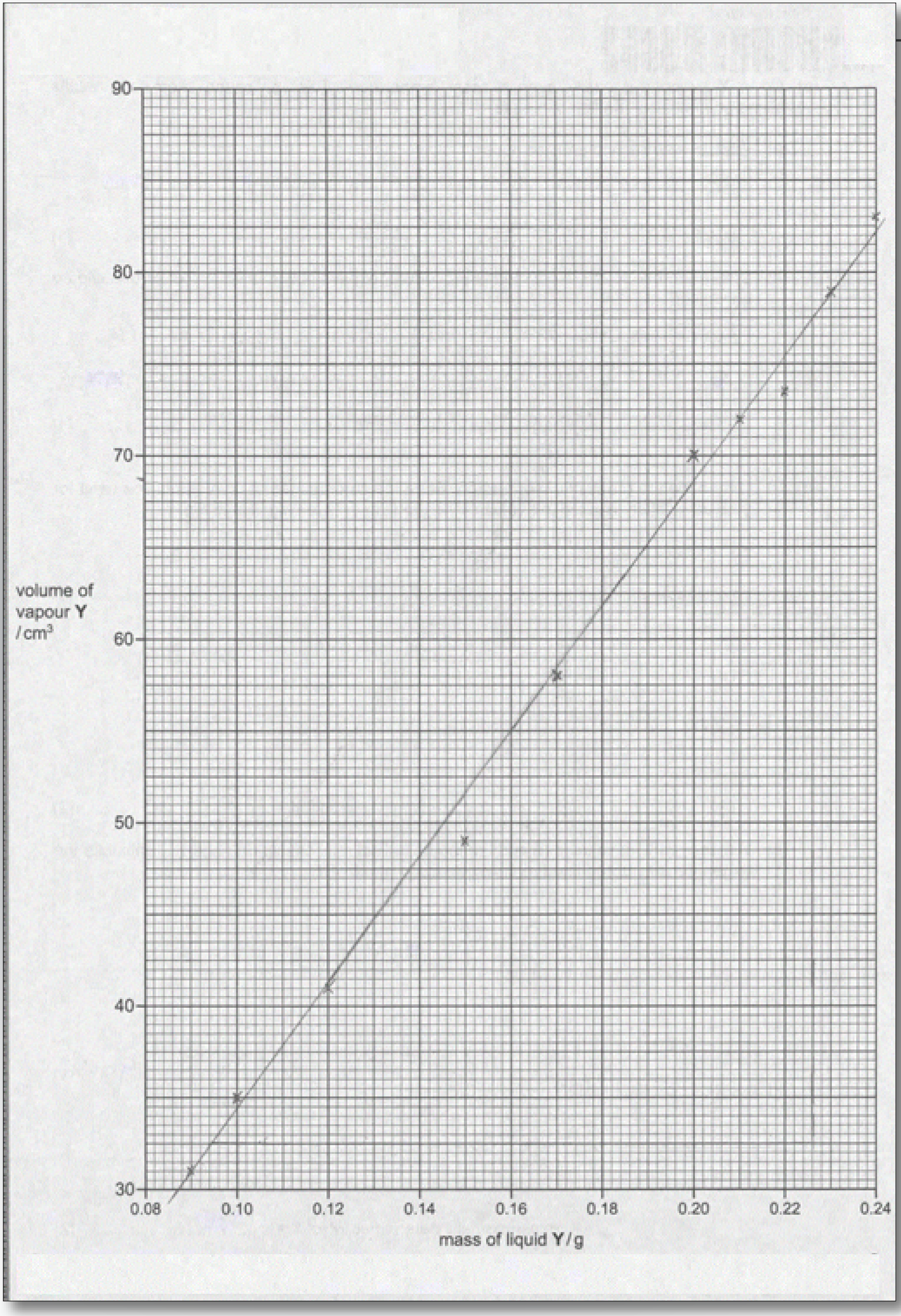

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Your Mark

2(a) ☐

2(b) ☐

2(c)(i) ☐

2(c)(ii) ☐

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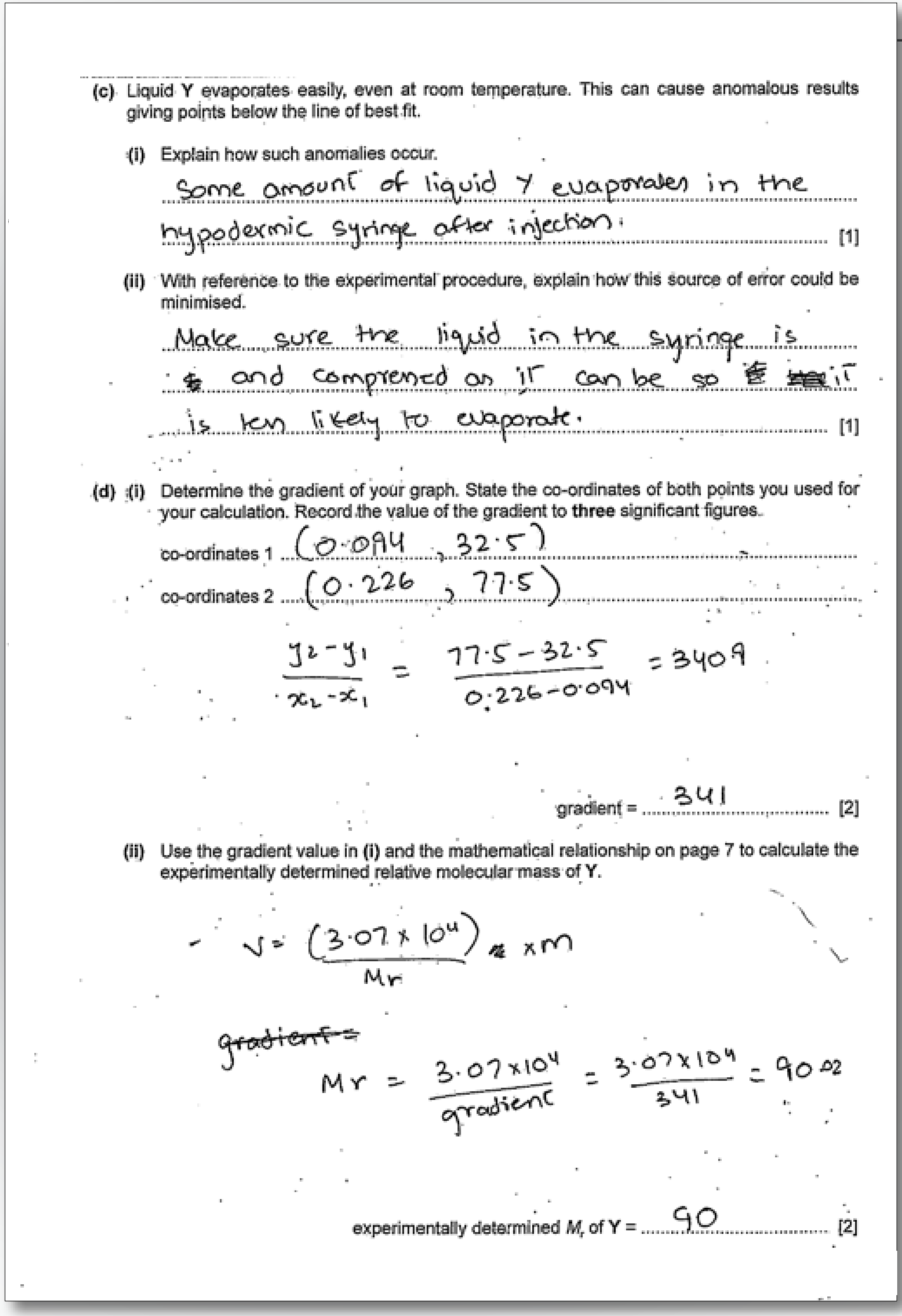

(c) Liquid **Y** evaporates easily, even at room temperature. This can cause anomalous results giving points below the line of best fit.

(i) Explain how such anomalies occur.

Some amount of liquid Y evaporates in the hypodermic syringe after injection. [1]

(ii) With reference to the experimental procedure, explain how this source of error could be minimised.

Make sure the liquid in the syringe is ~~[illegible]~~ and compressed as it can be so ~~[illegible]~~ ~~[illegible]~~ it is less likely to evaporate. [1]

(d) **(i)** Determine the gradient of your graph. State the co-ordinates of both points you used for your calculation. Record the value of the gradient to **three** significant figures.

co-ordinates 1 (0.094 , 32.5)

co-ordinates 2 (0.226 , 77.5)

$$\frac{y_2-y_1}{x_2-x_1} = \frac{77.5-32.5}{0.226-0.094} = 3409$$

gradient = 341 [2]

(ii) Use the gradient value in **(i)** and the mathematical relationship on page 7 to calculate the experimentally determined relative molecular mass of **Y**.

$$v = \frac{(3.07 \times 10^4)}{Mr} \times m$$

~~gradient =~~

$$Mr = \frac{3.07\times10^4}{\text{gradient}} = \frac{3.07\times10^4}{341} = 90.02$$

experimentally determined M_r of **Y** = 90 [2]

Select page

HIGH

MIDDLE

LOW

Your Mark

2(a) ☐

2(b) ☐

2(c)(i) ☐

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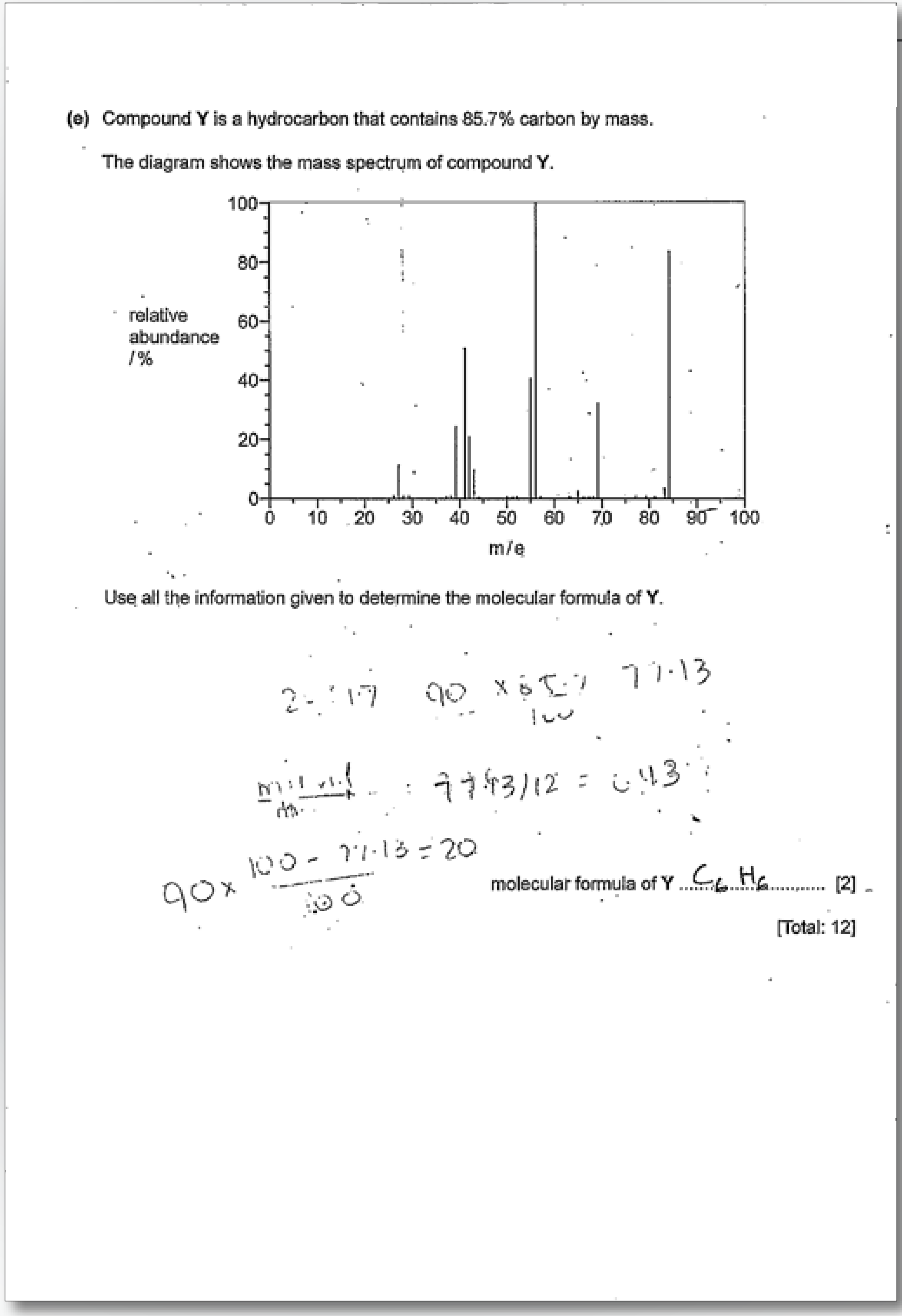

(e) Compound **Y** is a hydrocarbon that contains 85.7% carbon by mass.

The diagram shows the mass spectrum of compound **Y**.

Use all the information given to determine the molecular formula of **Y**.

2 - 1·7 90 × 85·7/100 77·13

mol : 77·13/12 = 6·43

90 × 100/100 - 77·13 = 20

molecular formula of Y ....C_6H_6.......... [2]

[Total: 12]

Your Mark

2(a) ☐

2(b) ☐

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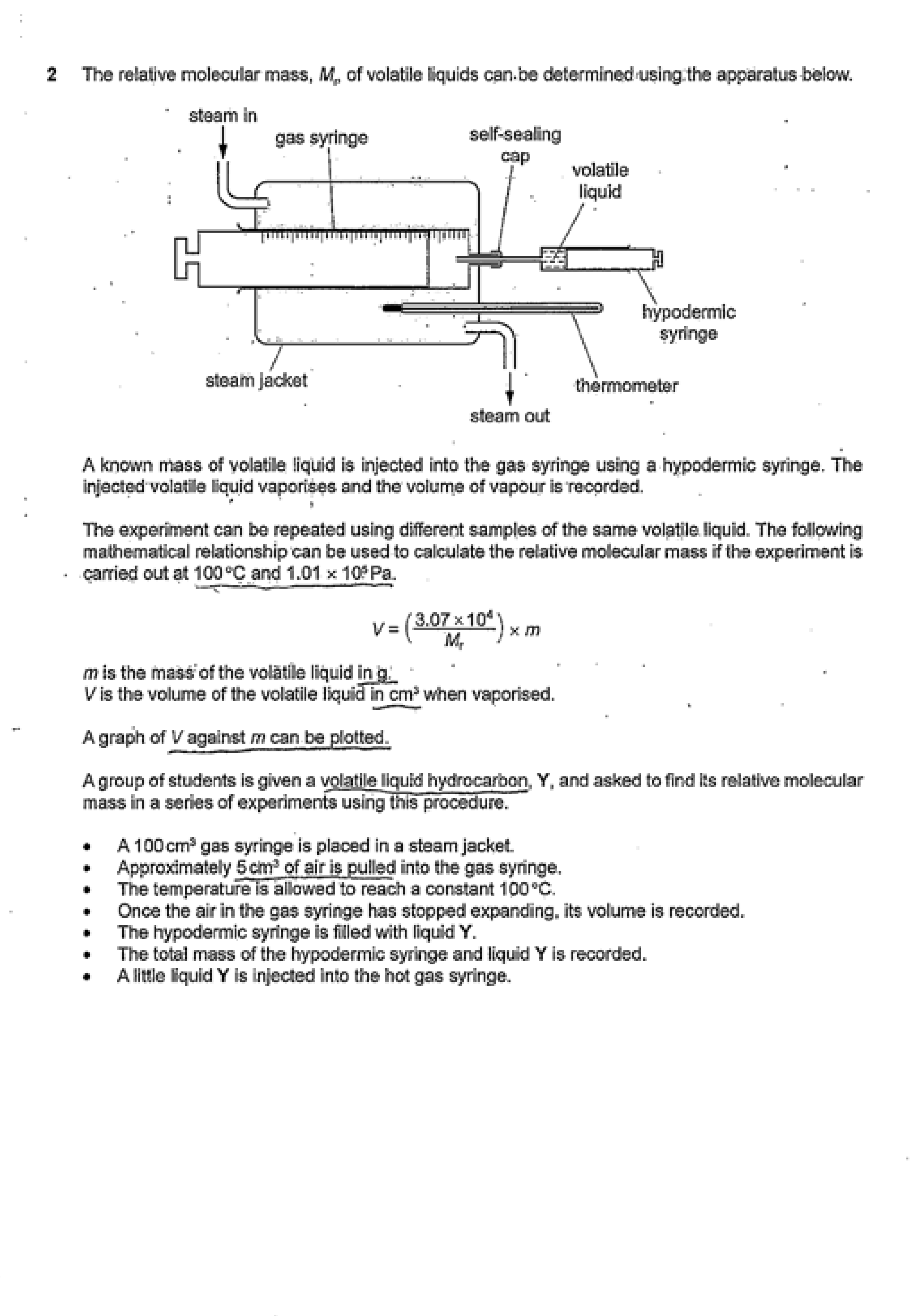

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- A little liquid Y is injected into the hot gas syringe.

Your Mark

2(a) ☐

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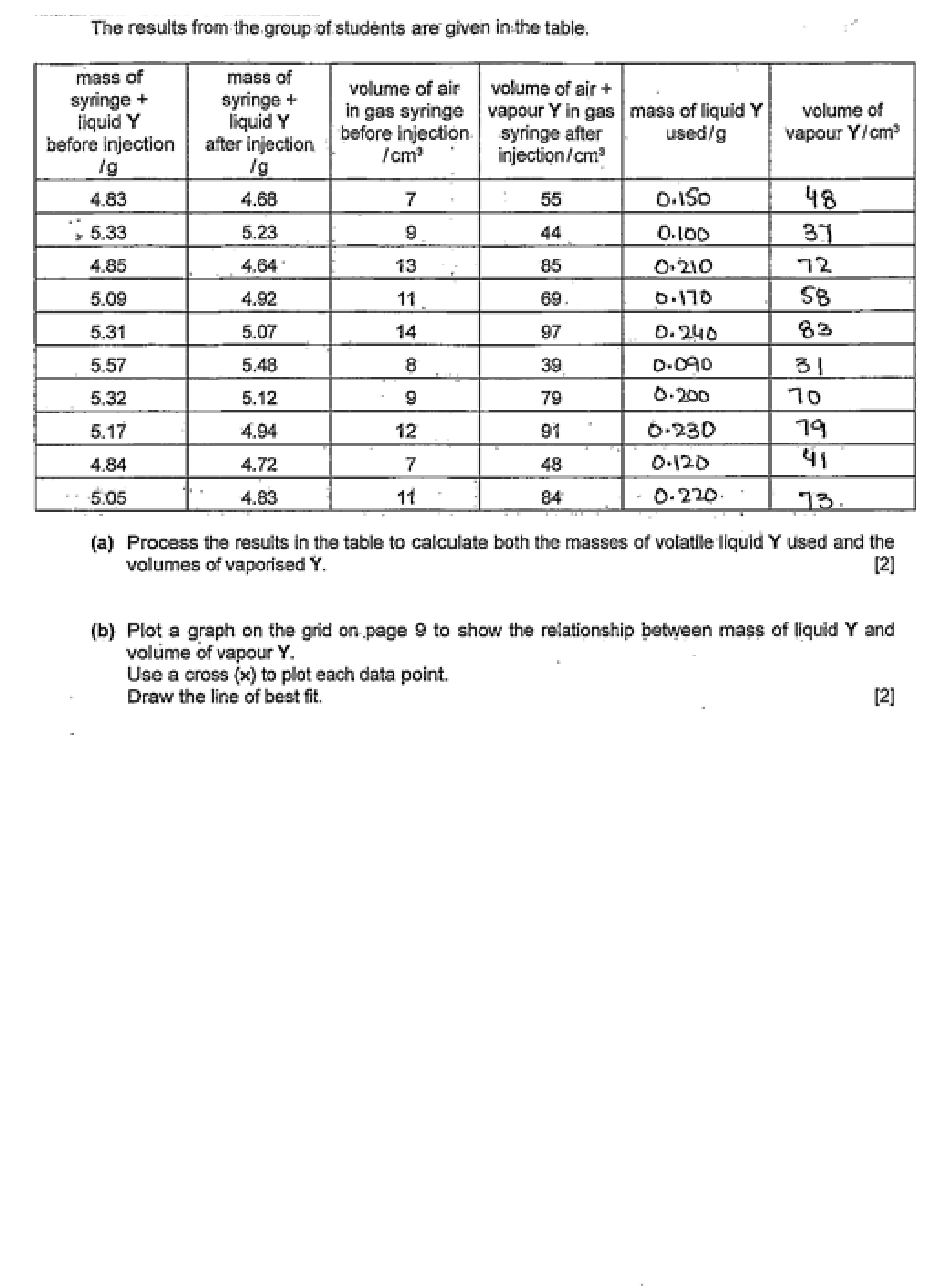

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Your Mark

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2(b) ☐

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2(e) ☐

Q2 Mark scheme

Expected answer

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0.12	41
0.22	73

All mass values. [1]
All volume values. [1]

(b)
Candidate's points plotted correctly from table in 2(a). [1]
Line of best fit drawn. [1]

(c)(i)
Y evaporates from the (hypodermic) syringe
OR
Y evaporates before injection
OR
Y evaporates before weighing / after injection [1]

(c)(ii)
(Stop evaporation by)
Keeping the syringe as cool as possible
OR
Closing off the needle end to stop evaporation
OR
Minimising length of time between each weighing [1]

(d)(i)
correct co-ordinates. [1
correct calculation of the gradient
must be three significant figures [1]

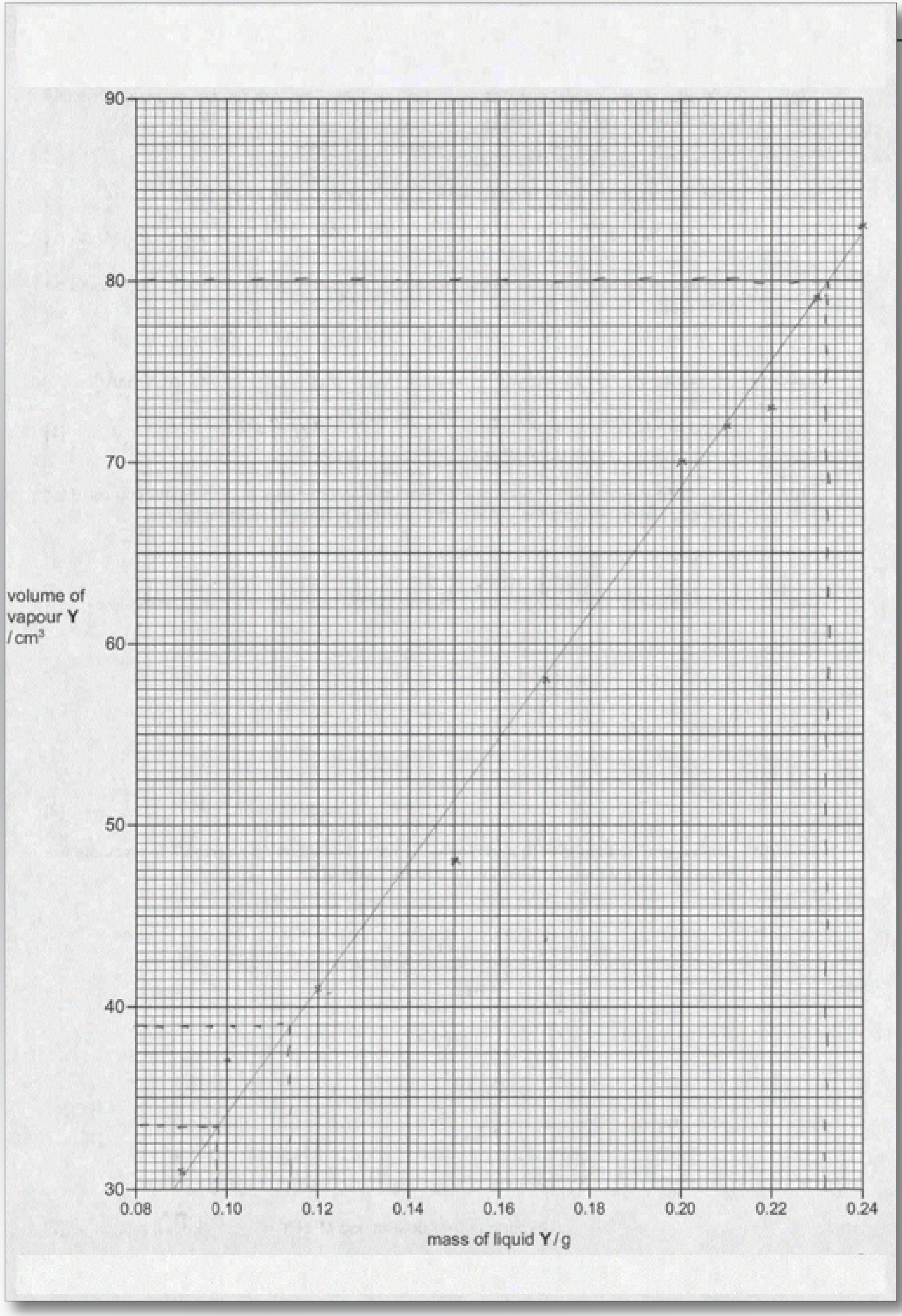
(d)(ii)
Calculation of Mr = 3.07×10^4 / gradient in 2(d)(i)
Answer [1]

(e)
Mr (from mass spectrum) = 84
OR
empirical formula = CH_2
OR
ratio of C and H seen as 1:2
Y is C_6H_{12} [1]

Total: [12]

EXAMINER COMMENTS

MARK SCHEME



Select page

HIGH MIDDLE LOW

Your Mark

2(a) ☐
2(b) ☐
2(c)(i) ☐
2(c)(ii) ☐
2(d)(i) ☐
2(d)(ii) ☐
2(e) ☐

Q2	Mark scheme	
	Expected answer	
(a)		

Mass of liquid Y used / g	Volume of vapour Y / cm^3
0.15	48
0.10	35
0.21	72
0.17	58
0.24	83
0.09	31
0.20	70
0.23	79
0.12	41
0.22	73

(a)	All mass values.	[1]
	All volume values.	[1]
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(c)(i)	Y evaporates from the (hypodermic) syringe OR Y evaporates before injection OR Y evaporates before weighing / after injection	[1]
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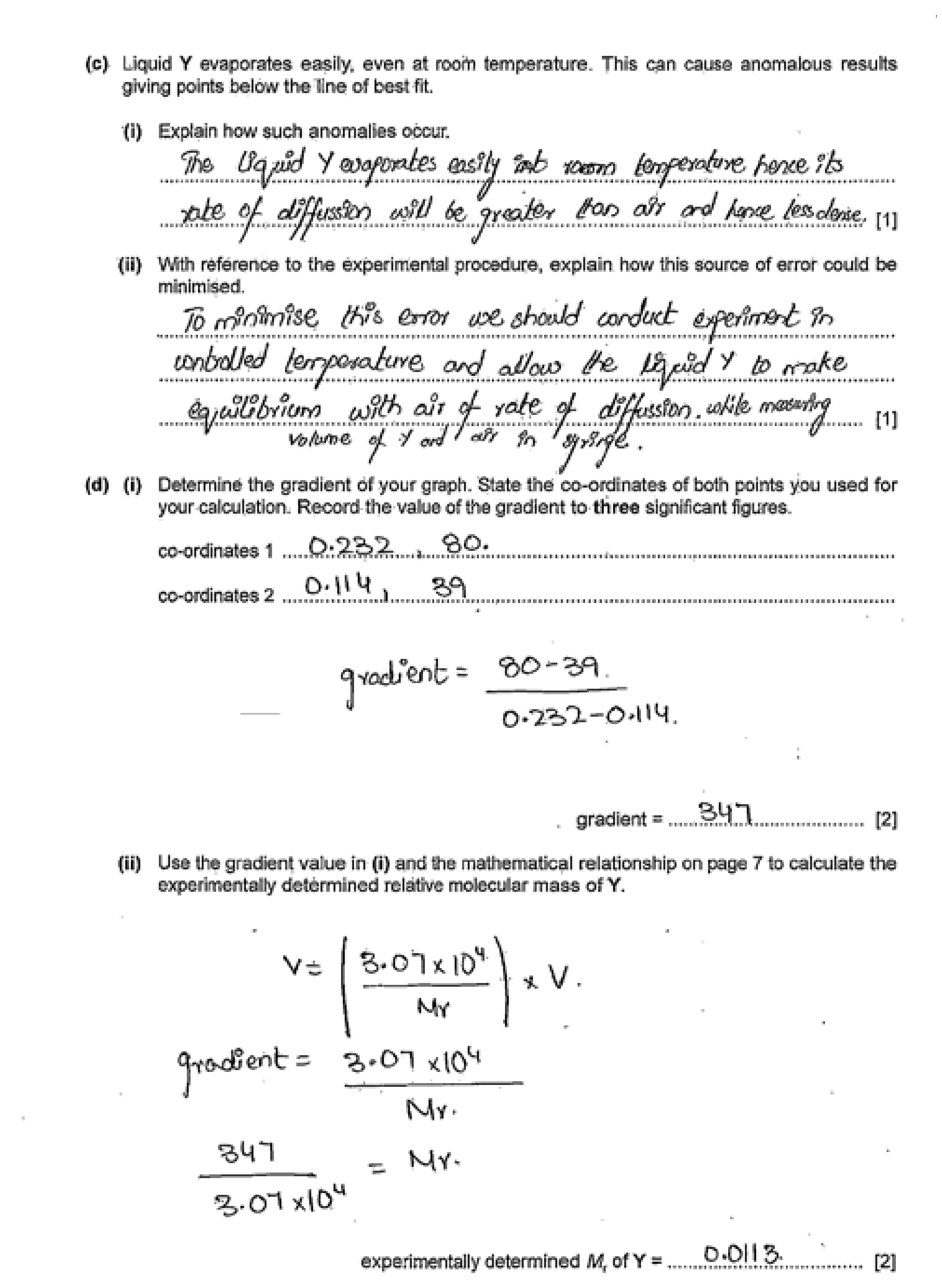
(d)(i)	correct co-ordinates.	[1
	correct calculation of the gradient must be three significant figures	[1]
(d)(ii)	Calculation of Mr = 3.07×10^4 / gradient in 2(d)(i)	
	Answer	[1]
(e)	Mr (from mass spectrum) = 84 OR empirical formula = CH_2 OR ratio of C and H seen as 1:2 Y is C_6H_{12}	[1]
		Total: [12]

EXAMINER COMMENTS MARK SCHEME



(c) Liquid **Y** evaporates easily, even at room temperature. This can cause anomalous results giving points below the line of best fit.

(i) Explain how such anomalies occur.

The liquid Y evaporates easily at room temperature hence its rate of diffusion will be greater than air and hence less dense. [1]

(ii) With reference to the experimental procedure, explain how this source of error could be minimised.

To minimise this error we should conduct experiment in controlled temperature and allow the liquid Y to make equilibrium with air of rate of diffusion. while measuring volume of Y and air in syringe. [1]

(d) (i) Determine the gradient of your graph. State the co-ordinates of both points you used for your calculation. Record the value of the gradient to **three** significant figures.

co-ordinates 1 0.232 , 80.

co-ordinates 2 0.114 , 39

$$\text{gradient} = \frac{80-39}{0.232-0.114}$$

gradient = 347 [2]

(ii) Use the gradient value in (i) and the mathematical relationship on page 7 to calculate the experimentally determined relative molecular mass of Y.

$$V = \left(\frac{3.07\times10^4}{Mr}\right)\times V.$$

$$\text{gradient} = \frac{3.07\times10^4}{Mr.}$$

$$\frac{347}{3.07\times10^4} = Mr.$$

experimentally determined M_r of Y = 0.0113 [2]

Select page

HIGH

MIDDLE

LOW

Your Mark

2(a) ☐

2(b) ☐

2(c)(i) ☐

2(c)(ii) ☐

2(d)(i) ☐

2(d)(ii) ☐

2(e) ☐

Q2 Mark scheme

Expected answer

(a)

Mass of liquid Y used / g	Volume of vapour Y / cm^3
0.15	48
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(d)(ii)	Calculation of Mr = 3.07×10^4 / gradient in 2(d)(i) Answer	[1]
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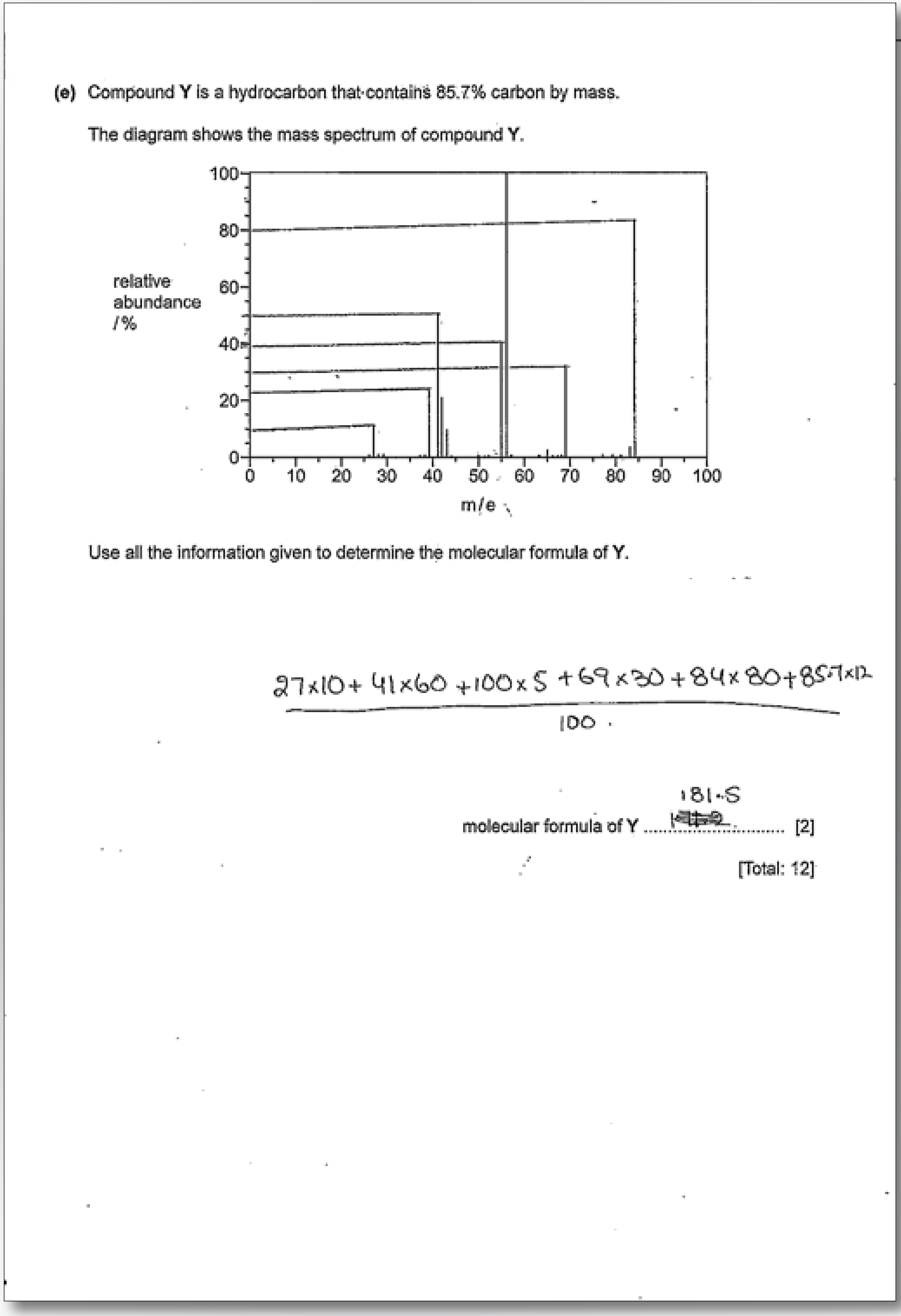
EXAMINER COMMENTS

MARK SCHEME



(e) Compound **Y** is a hydrocarbon that contains 85.7% carbon by mass.

The diagram shows the mass spectrum of compound **Y**.

Use all the information given to determine the molecular formula of **Y**.

$$\frac{27\times10+41\times60+100\times5+69\times30+84\times80+85.7\times12}{100}$$

181.5

molecular formula of Y ....[illegible].......... [2]

[Total: 12]

Select page

HIGH

MIDDLE

LOW

Your Mark

2(a) ☐

2(b) ☐

2(c)(i) ☐

2(c)(ii) ☐

2(d)(i) ☐

2(d)(ii) ☐

2(e) ☐

<table>
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EXAMINER COMMENTS

MARK SCHEME

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