

# Markscheme

May 2019

Chemistry

Higher level

Paper 2

19 pages

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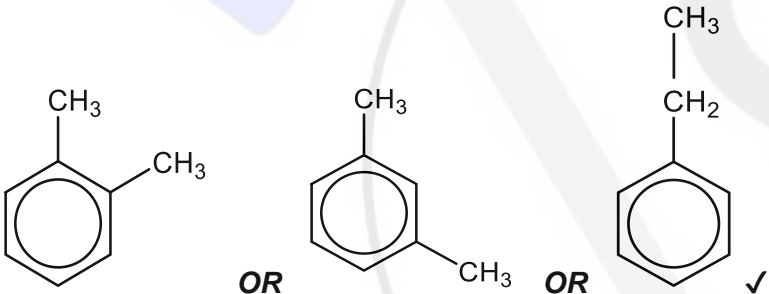
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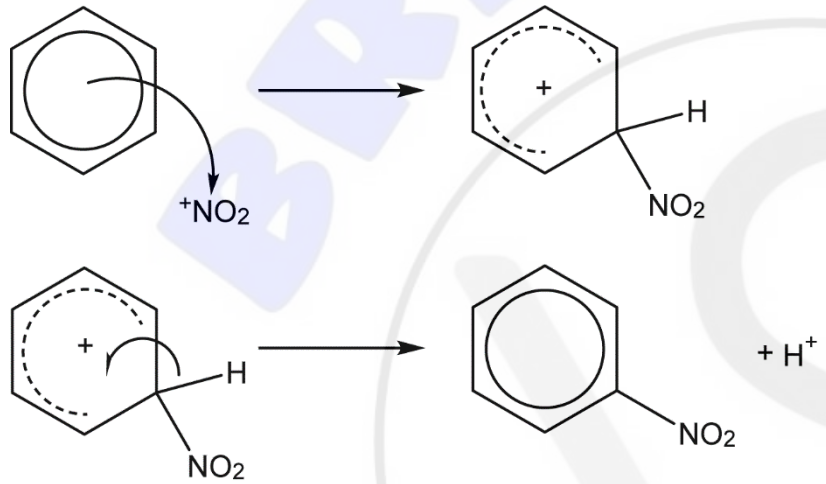
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Question			Answers	Notes	Total
1.	a		Number of signals: 2 ✓  Ratio: 3:2 <b>OR</b> 6:4 ✓	Accept any correct integer or fractional ratio. Accept ratios in reverse order.	2
1.	b				1
1.	c	i	$2\text{H}_2\text{SO}_4 + \text{HNO}_3 \rightleftharpoons \text{NO}_2^+ + 2\text{HSO}_4^- + \text{H}_3\text{O}^+ \checkmark$	Accept a single arrow instead of an equilibrium sign. Accept " $\text{H}_2\text{SO}_4 + \text{HNO}_3 \rightleftharpoons \text{NO}_2^+ + \text{HSO}_4^- + \text{H}_2\text{O}$ ". Accept " $\text{H}_2\text{SO}_4 + \text{HNO}_3 \rightleftharpoons \text{H}_2\text{NO}_3^+ + \text{HSO}_4^-$ ". Accept equivalent two step reactions in which sulfuric acid first behaves as a strong acid and protonates the nitric acid, before behaving as a dehydrating agent removing water from it.	1

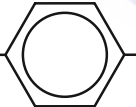
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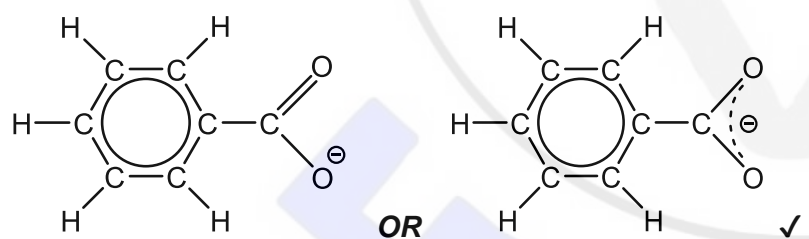
(Question 1 continued)

Question			Answers	Notes	Total
1.	c	ii	 <p>curly arrow going from benzene ring to N «of <math>^+\text{NO}_2/\text{NO}_2^+</math>» ✓</p> <p>carbocation with correct formula and positive charge on ring ✓</p> <p>curly arrow going from C–H bond to benzene ring of cation ✓</p> <p>formation of organic product nitrobenzene <b>AND</b> <math>\text{H}^+</math> ✓</p>	<p>Accept mechanism with corresponding Kekulé structures.</p> <p>Do <b>not</b> accept a circle in M2 or M3.</p> <p>Accept first arrow starting either inside the circle or on the circle.</p> <p>If Kekulé structure used, first arrow must start on the double bond.</p> <p>M2 may be awarded from correct diagram for M3.</p> <p>M4: Accept "<math>\text{C}_6\text{H}_5\text{NO}_2 + \text{H}_2\text{SO}_4</math>" if <math>\text{HSO}_4^-</math> used in M3.</p>	4

(continued...)

(Question 1 continued)

Question			Answers	Notes	Total
1.	d	i	$\text{Br}_2 \rightarrow 2\text{Br}\cdot \checkmark$ «sun»light/UV/hv <b>OR</b> high temperature $\checkmark$	Do <b>not</b> penalize missing radical symbol on Br. Accept "homolytic fission of bromine" for M1.	2
1.	d	ii	$\text{H}_3\text{C}$ —  — $\text{CH}_2\text{Br}$ $\checkmark$ HBr $\checkmark$	Accept condensed formulae, such as $\text{CH}_3\text{C}_6\text{H}_4\text{CH}_2\text{Br}$ .	2
1.	e		no <b>AND</b> there is no chiral carbon <b>OR</b> no <b>AND</b> there is no carbon with four different substituents/groups $\checkmark$	Accept "no <b>AND</b> no asymmetric carbon atom".	1

Question		Answers	Notes	Total
2.	a	<p>Any wavenumber in the following ranges:</p> <p>2500–3000 «cm<sup>-1</sup>» ✓</p> <p>1700–1750 «cm<sup>-1</sup>» ✓</p> <p>2850–3090 «cm<sup>-1</sup>» ✓</p>		1
2.	b	X-ray «crystallography/spectroscopy» ✓		1
2.	c	<p>Any one of:</p> <p>«regular» hexagon</p> <p><b>OR</b></p> <p>all «H–C–C/C–C–C» angles equal/120° ✓</p> <p>all C–C bond lengths equal/intermediate between double and single</p> <p><b>OR</b></p> <p>bond order 1.5 ✓</p>		1
2.	d	 <p><b>OR</b></p>	<p>Accept Kekulé structures.</p> <p>Negative sign must be shown in correct position.</p>	1

(continued...)

(Question 2 continued)

Question		Answers	Notes	Total	
2.	e	<p>electrons delocalized «across the O–C–O system»  <b>OR</b>            resonance occurs ✓</p> <p>122 «pm» &lt; C–O &lt; 143 «pm» ✓</p>	<p>Accept “delocalized <math>\pi</math>-bond”.</p> <p>Accept “bond intermediate between single and double bond” or “bond order 1.5” for M1.</p> <p>Accept any answer in range 123 to 142 pm.</p>	2	
2.	f	i	<p><b>ALTERNATIVE 1:</b>  <math>[H^+] \llcorner = 10^{-2.95} \llcorner = 1.122 \times 10^{-3} \llcorner \llcorner \text{mol dm}^{-3} \llcorner \llcorner \llcorner</math> ✓  <math>\llcorner [OH^-] = \frac{1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}}{1.22 \times 10^{-3} \text{ mol dm}^{-3}} \llcorner \llcorner = 8.91 \times 10^{-12} \llcorner \llcorner \llcorner \llcorner \llcorner \llcorner \llcorner \llcorner \llcorner</math> ✓</p> <p><b>ALTERNATIVE 2:</b>            pOH = «14 – 2.95 =» 11.05 ✓  <math>\llcorner [OH^-] = 10^{-11.05} \llcorner \llcorner = 8.91 \times 10^{-12} \llcorner \llcorner \llcorner \llcorner \llcorner \llcorner \llcorner \llcorner \llcorner</math> ✓</p>	<p>Award [2] for correct final answer.            Accept other methods.</p>	2
2.	f	ii	<p><math>2C_6H_5COOH(s) + 15O_2(g) \rightarrow 14CO_2(g) + 6H_2O(l)</math>            correct products ✓            correct balancing ✓</p>		2
2.	g		<p>Oxidized:            C/carbon «in <math>C_6H_5COOH</math>»  <b>AND</b>            Reduced:            O/oxygen «in <math>O_2</math>» ✓</p>		1
2.	h		«intermolecular» hydrogen bonding ✓	Accept diagram showing hydrogen bonding.	1
2.	i		lithium aluminium hydride/ $LiAlH_4$ ✓		1

Question		Answers	Notes	Total
3.	a		<p>Accept curve showing general trend.</p> <p>Award mark only if the energy difference between the first two points is larger than that between points 2/3 and 3/4.</p>	1
3.	b	<p>same number of electrons in outer shell</p> <p><b>OR</b></p> <p>all are <math>s^1</math> ✓</p>		1
3.	c	<p>«3-D/giant» regularly repeating arrangement «of ions»</p> <p><b>OR</b></p> <p>lattice «of ions» ✓</p> <p>electrostatic attraction between oppositely charged ions</p> <p><b>OR</b></p> <p>electrostatic attraction between <math>\text{Na}^+</math> and <math>\text{O}^{2-}</math> ions ✓</p>	<p>Do <b>not</b> accept “ionic” without description.</p>	2

(continued...)

(Question 3 continued)

Question			Answers	Notes	Total
3.	d	i	$\frac{1}{2} \text{O}_2(\text{g}) \rightarrow \text{O}^{2-}(\text{g})$ <p>«<math>\Delta H_{\text{atomisation}}(\text{O}) + 1\text{st EA} + 2\text{nd EA} = 249 \text{ kJ mol}^{-1} - 141 \text{ kJ mol}^{-1} + 753 \text{ kJ mol}^{-1}</math>  <math>\Rightarrow</math> «+»861 «kJ mol<sup>-1</sup>» ✓</p> <p><math>\text{Na}(\text{s}) \rightarrow \text{Na}^+(\text{g})</math>  «<math>\Delta H_{\text{atomisation}}(\text{Na}) + 1\text{st IE} = 107 \text{ kJ mol}^{-1} + 496 \text{ kJ mol}^{-1} \Rightarrow</math> «+»603 «kJ mol<sup>-1</sup>» ✓</p>		2
3.	d	ii	<p>lattice enthalpy = 861 «kJ mol<sup>-1</sup>» + 2 × 603 «kJ mol<sup>-1</sup>» - (-414 «kJ mol<sup>-1</sup>») ✓</p> <p>«= +» 2481 «kJ mol<sup>-1</sup>» ✓</p>	<p>Award <b>[2]</b> for correct final answer.</p> <p>If given values are used:  M1: lattice enthalpy = 850 «kJ mol<sup>-1</sup>» + 2 × 600 «kJ mol<sup>-1</sup>» - (-414 «kJ mol<sup>-1</sup>») ✓  M2: «= +» 2464 «kJ mol<sup>-1</sup>»</p>	2
3.	d	iii	<p>K<sup>+</sup> ion is larger than Na<sup>+</sup>  <b>OR</b>  smaller attractive force because of greater distance between ion «centres» ✓</p>		1

(continued...)

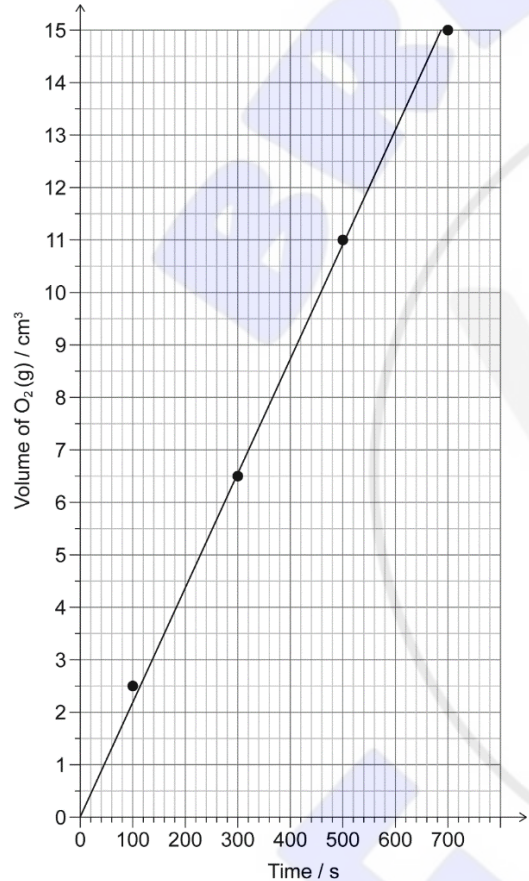
(Question 3 continued)

Question		Answers	Notes	Total
3.	e	<p><i>Sodium oxide:</i>  <math>\text{Na}_2\text{O}(\text{s}) + \text{H}_2\text{O}(\text{l}) \rightarrow 2\text{NaOH}(\text{aq}) \checkmark</math></p> <p><i>Phosphorus(V) oxide:</i>  <math>\text{P}_4\text{O}_{10}(\text{s}) + 6\text{H}_2\text{O}(\text{l}) \rightarrow 4\text{H}_3\text{PO}_4(\text{aq}) \checkmark</math></p> <p><i>Differentiation:</i>                      NaOH/product of <math>\text{Na}_2\text{O}</math> is alkaline/basic/pH &gt; 7 <b>AND</b> <math>\text{H}_3\text{PO}_4</math>/product of <math>\text{P}_4\text{O}_{10}</math> is acidic/pH &lt; 7 <math>\checkmark</math></p>		3
3.	f	<p><math>n(\text{Na}_2\text{O}_2)</math> theoretical yield «= <math>\frac{5.00 \text{ g}}{61.98 \text{ g mol}^{-1}}</math> » = <math>0.0807/8.07 \times 10^{-2}</math> «mol»</p> <p><b>OR</b></p> <p>mass of <math>\text{Na}_2\text{O}_2</math> theoretical yield «= <math>\frac{5.00 \text{ g}}{61.98 \text{ g mol}^{-1}} \times 77.98 \text{ g mol}^{-1}</math> » = 6.291                      «g» <math>\checkmark</math></p> <p>% yield «= <math>\frac{5.50 \text{ g}}{6.291 \text{ g}} \times 100</math>» <b>OR</b> « <math>\frac{0.0705}{0.0807} \times 100</math> » = 87.4 «%» <math>\checkmark</math></p>	Award [2] for correct final answer.	2

(continued...)

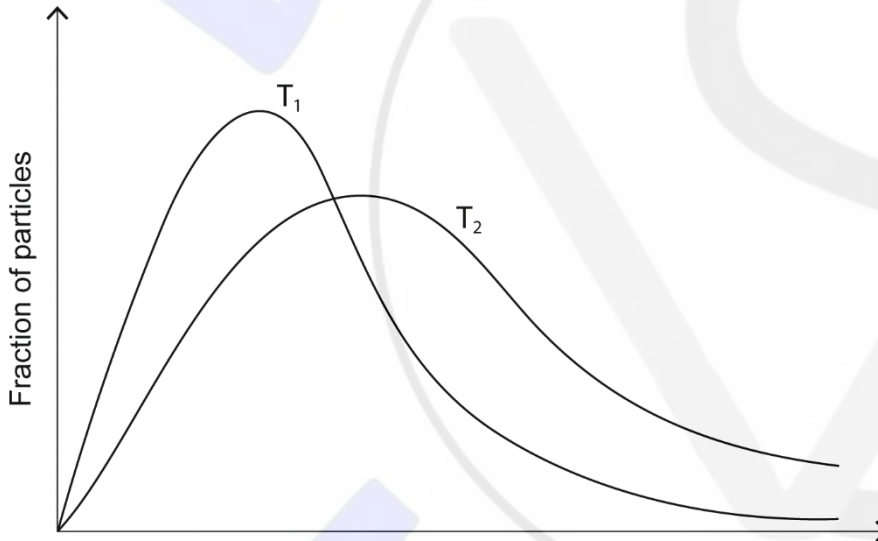
(Question 3 continued)

Question			Answers	Notes	Total
3.	g	i	$\Sigma\Delta H_f \text{ products} = 2 \times (-1130.7) / -2261.4 \text{ «kJ» } \checkmark$ $\Sigma\Delta H_f \text{ reactants} = 2 \times (-510.9) + 2 \times (-393.5) / -1808.8 \text{ «kJ» } \checkmark$ $\Delta H = \text{«}\Sigma\Delta H_f \text{ products} - \Sigma\Delta H_f \text{ reactants} = -2261.4 - (-1808.8) = \text{» } -452.6 \text{ «kJ» } \checkmark$	Award <b>[3]</b> for correct final answer. Award <b>[2 max]</b> for “+ 452.6 «kJ»”.	3
3.	g	ii	only valid for covalent bonds <b>OR</b> only valid in gaseous state $\checkmark$		1
3.	h		bond in O <sub>3</sub> has lower enthalpy <b>AND</b> bond order is 1.5 «not 2» $\checkmark$	Accept “bond in ozone is longer”.	1
3.	i		Any one of: finite volume of particles «requires adjustment to volume of gas» $\checkmark$ short-range attractive forces «overcomes low kinetic energy» $\checkmark$		1 max
3.	j		NaOH $\checkmark$		1
3.	k		IV $\checkmark$		1

Question			Answers	Notes	Total
4.	a		decomposes in light ✓	Accept "sensitive to light".	1
4.	b	i	 <p>points correctly plotted ✓                      best fit line <b>AND</b> extended through (to) the origin ✓</p> <p>Average rate of reaction:                      «slope (gradient) of line =&gt; 0.022 «cm<sup>3</sup> O<sub>2</sub> (g) s<sup>-1</sup>» ✓</p>	Accept range 0.020–0.024 cm <sup>3</sup> O <sub>2</sub> (g) s <sup>-1</sup> .	3

(continued...)

(Question 4 continued)

Question			Answers	Notes	Total
4.	b	ii	<p>Rate equation:  <math>\text{Rate} = k[\text{H}_2\text{O}_2] \times [\text{KI}] \checkmark</math></p> <p>Overall order:                      2 <math>\checkmark</math></p>	Rate constant must be included.	2
4.	b	iii	 <p>peak of <math>T_2</math> to right of <b>AND</b> lower than <math>T_1 \checkmark</math>                      lines begin at origin <b>AND</b> <math>T_2</math> must finish above <math>T_1 \checkmark</math></p>		2

(continued...)

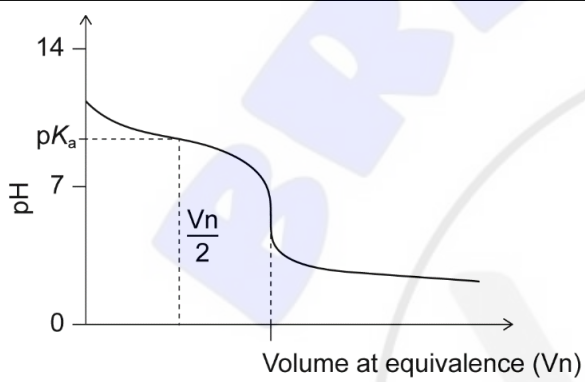
(Question 4 continued)

Question			Answers	Notes	Total
4.	b	iv	$E_a$ marked on graph ✓ explanation in terms of more “particles” with $E \geq E_a$ <b>OR</b> greater area under curve to the right of $E_a$ in $T_2$ ✓		2
4.	b	v	manganese(IV) oxide <b>OR</b> manganese dioxide ✓	Accept “manganese(IV) dioxide”.	1
4.	c		moves «position of» equilibrium to right/products ✓	Accept “reactants are always present as the reaction is in equilibrium”.	1
4.	d		$M(\text{H}_2\text{O}_2) \llcorner = 2 \times 1.01 + 2 \times 16.00 \llcorner = 34.02 \llcorner \text{g} \llcorner \checkmark$ $\llcorner \% \text{H}_2\text{O}_2 = 3 \times \frac{34.02}{314.04} \times 100 \llcorner = \llcorner 32.50 \llcorner \% \llcorner \checkmark$	Award [2] for correct final answer.	2

Question			Answers	Notes	Total
5.	a		partial dissociation «in aqueous solution» ✓		1
5.	b		ethanoic acid/vinegar reacts with NaOH ✓  moves equilibrium to left/reactant side ✓  releases Cl <sub>2</sub> (g)/chlorine <u>gas</u> <b>OR</b> Cl <sub>2</sub> (g)/chlorine <u>gas</u> is toxic ✓	Accept "ethanoic acid produces H <sup>+</sup> ions" Accept "ethanoic acid/vinegar reacts with NaOCl".  Do <b>not</b> accept "2CH <sub>3</sub> COOH + NaOCl + NaCl → 2CH <sub>3</sub> COONa + Cl <sub>2</sub> + H <sub>2</sub> O" as it does not refer to equilibrium. Accept suitable molecular or ionic equations for M1 and M3.	3
5.	c	i	$\begin{array}{c} \text{H} : \ddot{\text{N}} : \ddot{\text{Cl}} : \\   \\ \text{H} \end{array}$ <p style="text-align: right;">✓</p>	Accept any combination of dots/crosses or lines to represent electron pairs.	1
5.	c	ii	sp <sup>3</sup> ✓		1
5.	c	iii	Molecular geometry: «trigonal» pyramidal ✓  H–N–H bond angle: 107° ✓	Accept angles in the range of 100–109.	2
5.	c	iv	covalent/dative/coordinate ✓		1

(continued...)

(Question 5 continued)

Question			Answers	Notes	Total
5.	d	i	 <p>Volume at equivalence (<math>V_n</math>) Volume of hydrochloric acid added</p> <p>correct shape of graph <b>AND</b> vertical drop at <math>V_n</math> ✓ <math>pK_a = \text{pH}</math> at <math>\frac{V_n}{2}</math> /half neutralization/half equivalence ✓</p>	<p>M1: must show buffer region at <math>\text{pH} &gt; 7</math> and equivalence point at <math>\text{pH} &lt; 7</math>. Graph must start below <math>\text{pH} = 14</math>.</p>	2
5.	d	ii	<p>methyl orange <b>OR</b> bromophenol blue <b>OR</b> bromocresol green <b>OR</b> methyl red ✓</p>		1

(continued...)

(Question 5d continued)

Question			Answers	Notes	Total
5.	d	iii	$\text{NH}_3(\text{aq}) + \text{H}^+(\text{aq}) \rightarrow \text{NH}_4^+(\text{aq}) \checkmark$ $\text{NH}_4^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{NH}_3(\text{aq}) + \text{H}_2\text{O}(\text{l}) \checkmark$	Accept reaction arrows or equilibrium signs in both equations.  Award <b>[1 max]</b> , based on two correct reverse equations but not clearly showing reacting with acid or base but rather dissociation.	2

Question			Answers	Notes	Total
6.	a		$1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 \checkmark$		1
6.	b		«frequency/wavelength of visible» light absorbed by electrons moving between d levels/orbitals $\checkmark$ colour due to remaining frequencies <b>OR</b> complementary colour transmitted $\checkmark$		2
6.	c		${}_{26}^{54}\text{Fe} \checkmark$		1
6.	d		$\llcorner A_r \Rightarrow 54 \times 0.0584 + 56 \times 0.9168 + 57 \times 0.0217 + 58 \times 0.0031$ <b>OR</b> $\llcorner A_r \Rightarrow 55.9111 \checkmark$  $\llcorner A_r \Rightarrow 55.91 \checkmark$	Award <b>[2]</b> for correct final answer. Do <b>not</b> accept data booklet value (55.85).	2

(continued...)

(Question 6 continued)

Question		Answers	Notes	Total
6.	e	<p>lemon juice is the electrolyte  <b>OR</b>                      lemon juice allows flow of ions  <b>OR</b>                      each nail/metal forms a half-cell with the lemon juice ✓</p> <p><i>Any one of:</i>                      iron is higher than copper in the activity series  <b>OR</b>                      each half-cell/metal has a different redox/electrode potential ✓</p> <p>iron is oxidized  <b>OR</b>  <math>\text{Fe} \rightarrow \text{Fe}^{2+} + 2\text{e}^-</math>  <b>OR</b>  <math>\text{Fe} \rightarrow \text{Fe}^{3+} + 3\text{e}^-</math>  <b>OR</b>                      iron is anode/negative electrode of cell ✓</p> <p>copper is cathode/positive electrode of cell  <b>OR</b>                      reduction occurs at the cathode  <b>OR</b>  <math>2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2</math> ✓</p> <p>electrons flow from iron to copper ✓</p>		2

(continued...)

(Question 6 continued)

Question			Answers	Notes	Total
6.	f	i	$\ll E^\ominus = +0.34 \text{ V} - (-0.45 \text{ V}) = +0.79 \text{ V} \gg \checkmark$		1
6.	f	ii	$\ll \Delta G^\ominus = -nFE^\ominus = -2 \text{ mol} \times 96\,500 \text{ C mol}^{-1} \times \frac{0.79 \text{ J C}^{-1}}{1000} \Rightarrow -152 \text{ kJ} \gg \checkmark$	Accept range 150–153 kJ.	1
6.	f	iii	$\ll \ln K_c = -\frac{\Delta G^\ominus}{RT} = -\frac{-152 \times 10^3 \text{ J mol}^{-1}}{8.31 \text{ J K}^{-1} \text{ mol}^{-1} \times 298 \text{ K}} \Rightarrow 61.38 \checkmark$  $K = 4.5 \times 10^{26} \checkmark$	Accept answers in range $2.0 \times 10^{26}$ to $5.5 \times 10^{26}$ .  Do <b>not</b> award M2 if answer not given to two significant figures.  If $-140 \text{ kJ mol}^{-1}$ used, answer is $3.6 \times 10^{24}$ .	2
7.			Cathode (negative electrode): $\text{Ag}^+ (\text{aq}) + \text{e}^- \rightarrow \text{Ag} (\text{s}) \checkmark$  Anode (positive electrode): $2\text{H}_2\text{O} (\text{l}) \rightarrow \text{O}_2 (\text{g}) + 4\text{H}^+ (\text{aq}) + 4\text{e}^- \checkmark$	Accept $4\text{OH}^- (\text{aq}) \rightarrow \text{O}_2 (\text{g}) + 2\text{H}_2\text{O} (\text{l}) + 4\text{e}^-$ .  Accept multiple or fractional coefficients in both half-equations.	2