



Markscheme

November 2018

Chemistry

Higher level

Paper 2

23 pages

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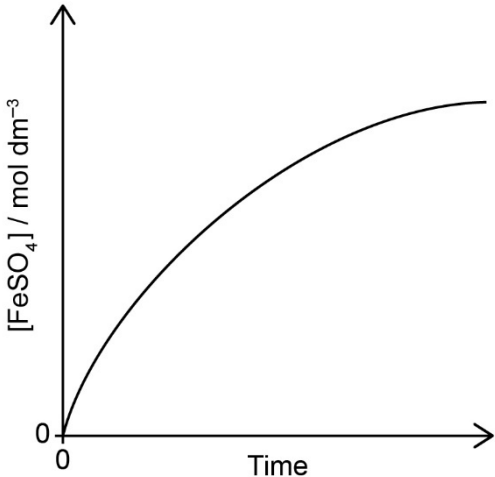
Question			Answers	Notes	Total
1.	a	i	$n_{\text{CuSO}_4} \llcorner = 0.0800 \text{ dm}^3 \times 0.200 \text{ mol dm}^{-3} \llcorner = 0.0160 \text{ mol}$ AND $n_{\text{Fe}} \llcorner = \frac{3.26 \text{ g}}{55.85 \text{ g mol}^{-1}} \llcorner = 0.0584 \text{ mol}$ ✓ CuSO ₄ is the limiting reactant ✓	Do not award M2 if mole calculation is not shown.	2
1.	a	ii	ALTERNATIVE 1: $\llcorner 0.0160 \text{ mol} \times 63.55 \text{ g mol}^{-1} = \llcorner 1.02 \text{ g} \llcorner$ ✓ $\llcorner \frac{0.872 \text{ g}}{1.02 \text{ g}} \times 100 = \llcorner 85.5 \llcorner \llcorner$ ✓ ALTERNATIVE 2: $\llcorner \frac{0.872 \text{ g}}{63.55 \text{ g mol}^{-1}} = \llcorner 0.0137 \llcorner \llcorner$ ✓ $\llcorner \frac{0.0137 \text{ mol}}{0.0160 \text{ mol}} \times 100 = \llcorner 85.6 \llcorner \llcorner$ ✓	Accept answers in the range 85–86 %. Award [2] for correct final answer.	2

Question			Answers	Notes	Total
1.	b	i	<p>ALTERNATIVE 1:</p> <p>$q = \llcorner 80.0 \text{ g} \times 4.18 \text{ J g}^{-1} \text{ K}^{-1} \times 7.5 \text{ K} \Rightarrow 2.5 \times 10^3 \llcorner \text{J} \llcorner / 2.5 \llcorner \text{kJ} \llcorner \checkmark$</p> <p>$\llcorner \text{per mol of CuSO}_4 = \frac{-2.5 \text{ kJ}}{0.0160 \text{ mol}} = -1.6 \times 10^2 \text{ kJ mol}^{-1} \llcorner$</p> <p>$\llcorner \text{for the reaction} \llcorner \Delta H = -1.6 \times 10^2 \llcorner \text{kJ} \llcorner \checkmark$</p> <p>ALTERNATIVE 2:</p> <p>$q = \llcorner 80.0 \text{ g} \times 4.18 \text{ J g}^{-1} \text{ K}^{-1} \times 7.5 \text{ K} \Rightarrow 2.5 \times 10^3 \llcorner \text{J} \llcorner / 2.5 \llcorner \text{kJ} \llcorner \checkmark$</p> <p>$\llcorner n_{\text{Cu}} = \frac{0.872}{63.55} = 0.0137 \text{ mol} \llcorner$</p> <p>$\llcorner \text{per mol of CuSO}_4 = \frac{-2.5 \text{ kJ}}{0.0137 \text{ mol}} = -1.8 \times 10^2 \text{ kJ mol}^{-1} \llcorner$</p> <p>$\llcorner \text{for the reaction} \llcorner \Delta H = -1.8 \times 10^2 \llcorner \text{kJ} \llcorner \checkmark$</p>	<p><i>Award [2] for correct final answer.</i></p>	2
1.	b	ii	<p>density «of solution» is 1.00 g cm^{-3}</p> <p>OR</p> <p>specific heat capacity «of solution» is $4.18 \text{ J g}^{-1} \text{ K}^{-1}$/that of «pure» water</p> <p>OR</p> <p>reaction goes to completion</p> <p>OR</p> <p>iron/CuSO₄ does not react with other substances \checkmark</p>	<p><i>The mark for “reaction goes to completion” can only be awarded if 0.0160 mol was used in part (b)(i).</i></p> <p><i>Do not accept “heat loss”.</i></p>	1

(continued...)

(Question 1b continued)

Question			Answers	Notes	Total
1.	b	iii	<p>ALTERNATIVE 1:</p> $\llcorner 0.2^{\circ}\text{C} \times \frac{100}{7.5^{\circ}\text{C}} = \gg 3\%/0.03 \checkmark$ $\llcorner 0.03 \times 160 \text{ kJ} \gg = \llcorner \pm \gg 5 \llcorner \text{kJ} \gg \checkmark$ <p>ALTERNATIVE 2:</p> $\llcorner 0.2^{\circ}\text{C} \times \frac{100}{7.5^{\circ}\text{C}} = \gg 3\%/0.03 \checkmark$ $\llcorner 0.03 \times 180 \text{ kJ} \gg = \llcorner \pm \gg 5 \llcorner \text{kJ} \gg \checkmark$	<p>Accept values in the range 4.1–5.5 «kJ».</p> <p>Award [2] for correct final answer.</p>	2

Question			Answers	Notes	Total
1.	c	i	 <p>initial concentration is zero AND concentration increases with time ✓ decreasing gradient as reaction proceeds ✓</p>		2
1.	c	ii	<p>«draw a» tangent to the curve at time = 0 ✓ «rate equals» gradient/slope «of the tangent» ✓</p>	Accept suitable diagram.	2
1.	c	iii	<p>piece has smaller surface area ✓</p> <p>lower frequency of collisions OR fewer collisions per second/unit time ✓</p>	Accept "chance/probability" instead of "frequency". Do not accept just "fewer collisions".	2

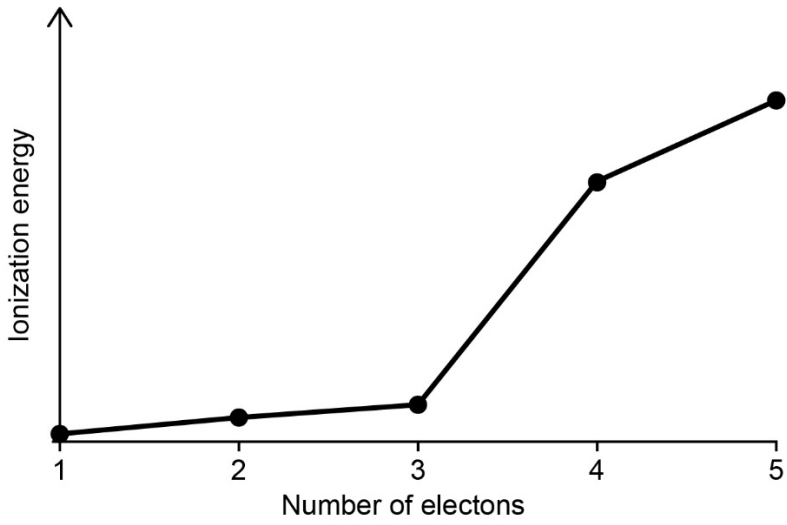
Question		Answers	Notes	Total
1.	d	<p><i>Anode (positive electrode):</i> $2\text{H}_2\text{O}(\text{l}) \rightarrow \text{O}_2(\text{g}) + 4\text{H}^+(\text{aq}) + 4\text{e}^-$ ✓</p> <p><i>Cathode (negative electrode):</i> $2\text{H}_2\text{O}(\text{l}) + 2\text{e}^- \rightarrow \text{H}_2(\text{g}) + 2\text{OH}^-(\text{aq})$ OR $2\text{H}^+(\text{aq}) + 2\text{e}^- \rightarrow \text{H}_2(\text{g})$ ✓</p>	<p>Accept "$4\text{OH}^-(\text{aq}) \rightarrow \text{O}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) + 4\text{e}^-$" OR "$\text{Fe}^{2+}(\text{aq}) \rightarrow \text{Fe}^{3+}(\text{aq}) + \text{e}^-$" for M1.</p> <p>Accept "$\text{Fe}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Fe}(\text{s})$" OR "$\text{SO}_4^{2-}(\text{aq}) + 4\text{H}^+(\text{aq}) + 2\text{e}^- \rightarrow 2\text{H}_2\text{SO}_3(\text{aq}) + \text{H}_2\text{O}(\text{l})$" for M2.</p>	2

Question		Answers	Notes	Total
2.	a	<p>«in 100 g sample» $\frac{62.02 \text{ g}}{12.01 \text{ g mol}^{-1}}$ AND $\frac{10.43 \text{ g}}{1.01 \text{ g mol}^{-1}}$</p> <p>OR</p> <p>«in 100 g sample» 5.164 mol C AND 10.33 mol H ✓</p> <p>27.55 %</p> <p>OR</p> <p>1.722 mol O ✓</p> <p>«empirical formula» C₃H₆O ✓</p>		3
2.	b	«absorption at wavenumber 1700–1750 cm ⁻¹ » C=O/carbonyl ✓	<i>Do not accept "ketone" or "aldehyde".</i>	1
2.	c	«m/z => 58 ✓		1
2.	d	<p> $\begin{array}{c} \text{H} \quad \text{O} \quad \text{H} \\ \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{H} \\ \quad \quad \\ \text{H} \quad \quad \text{H} \end{array}$ ✓ </p> <p>CH₃COCH₃/</p>		1

Question			Answers	Notes	Total
3.	a	i	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^5$ OR $[\text{Ar}] 4s^2 3d^{10} 4p^5 \checkmark$	Accept 3d before 4s.	1
3.	a	ii		Accept double-headed arrows.	1

Question			Answers	Notes	Total
3.	b	i	<p>Structure I – follows octet rule:</p> $\left[\begin{array}{c} \ddot{\text{O}}-\ddot{\text{Br}}-\ddot{\text{O}}: \\ \downarrow \\ \ddot{\text{O}}: \end{array} \right]^- / \left[\begin{array}{c} \ddot{\text{O}}-\ddot{\text{Br}}-\ddot{\text{O}}: \\ \\ \ddot{\text{O}}: \end{array} \right]^- \quad \checkmark$ <p>Structure II – does not follow octet rule:</p> $\left[\begin{array}{c} \ddot{\text{O}}-\ddot{\text{Br}}=\ddot{\text{O}} \\ \\ \ddot{\text{O}}: \end{array} \right]^- \quad \text{OR} \quad \left[\begin{array}{c} \ddot{\text{O}}-\ddot{\text{Br}}=\ddot{\text{O}} \\ \\ \ddot{\text{O}}: \end{array} \right]^- \quad \checkmark$	Accept dots, crosses or lines to represent electron pairs.	2
3.	b	ii	<p>«structure I» formal charge on Br = +2 OR «structure II» formal charge on Br = 0/+1 ✓</p> <p>structure II is preferred AND it produces formal charge closer to 0 ✓</p>	Ignore any reference to formal charge on oxygen.	2

Question			Answers	Notes	Total
3.	c		<p><i>Geometry:</i> trigonal/pyramidal ✓</p> <p><i>Reason:</i> three bonds AND one lone pair OR four electron domains ✓</p> <p><i>O–Br–O angle:</i> 107° ✓</p>	<p>Accept “charge centres” for “electron domains”.</p> <p>Accept answers in the range 104–109°.</p>	3
3.	d	i	$\text{BrO}_3^- (\text{aq}) + 6\text{e}^- + 6\text{H}^+ (\text{aq}) \rightarrow \text{Br}^- (\text{aq}) + 3\text{H}_2\text{O} (\text{l})$ <p>correct reactants and products ✓ balanced equation ✓</p>	Accept reversible arrows.	2
3.	d	ii	$\text{BrO}_3^- (\text{aq}) + 6\text{Fe}^{2+} (\text{aq}) + 6\text{H}^+ (\text{aq}) \rightarrow \text{Br}^- (\text{aq}) + 3\text{H}_2\text{O} (\text{l}) + 6\text{Fe}^{3+} (\text{aq}) \checkmark$		1
3.	d	iii	$E^\ominus_{\text{reaction}} = \llcorner +1.44 \text{ V} - 0.77 \text{ V} \Rightarrow 0.67 \llcorner \text{ V} \llcorner \checkmark$ $\Delta G^\ominus = \llcorner -nFE^\ominus_{\text{reaction}} = -6 \times 96500 \text{ C mol}^{-1} \times 0.67 \text{ V} \Rightarrow -3.9 \times 10^5 \llcorner \text{ J} \llcorner \checkmark$		2
3.	e		<p>both are paramagnetic ✓ «both» contain unpaired electrons ✓</p>	Accept orbital diagrams for both ions showing unpaired electrons.	2

Question		Answers	Notes	Total
4.	a	nuclear charge/number of protons/ Z_{eff} increases «causing a stronger pull on the outer electrons» ✓ same number of shells/«outer» energy level/shielding ✓	Accept "atomic number" for "number of protons".	2
4.	b	isoelectronic/same electronic configuration/«both» have 2.8 ✓ more protons in Na^+ ✓		2
4.	c	 <p>Sketch showing: largest increase between third and fourth ionization energies ✓ $IE_1 < IE_2 < IE_3 < IE_4 < IE_5$ ✓</p>		2

Question		Answers	Notes	Total
4.	d	<p>Fe^{2+} AND smaller size/radius</p> <p>OR</p> <p>Fe^{2+} AND higher charge density ✓</p> <p>stronger interaction with «polar» water molecules ✓</p>	<i>M1 not needed for M2.</i>	2
5.	a	all «species» are in same phase ✓	<p><i>Accept “all species are in same state”.</i></p> <p><i>Accept “all species are gases”.</i></p>	1
5.	b	negative AND fewer moles/molecules «of gas» in the products ✓		1
5.	c	<p>$\Delta G^\ominus = \ll -RT \ln K_c = \gg -8.31 \text{ J K}^{-1} \text{ mol}^{-1} \times 1000 \text{ K} \times \ln 280$</p> <p>OR</p> <p>$\Delta G^\ominus = -4.7 \times 10^4 \text{ «J»} \checkmark$</p> <p>$\ll \Delta G^\ominus = \gg -47 \text{ «kJ»} \checkmark$</p>	<i>Award [2] for correct final answer.</i>	2
5.	d	<p>$\Delta G^\ominus < 0$/spontaneous AND $\Delta S^\ominus < 0$/unfavourable ✓</p> <p>exothermic AND ΔH^\ominus «must be» negative/favourable ✓</p>		2

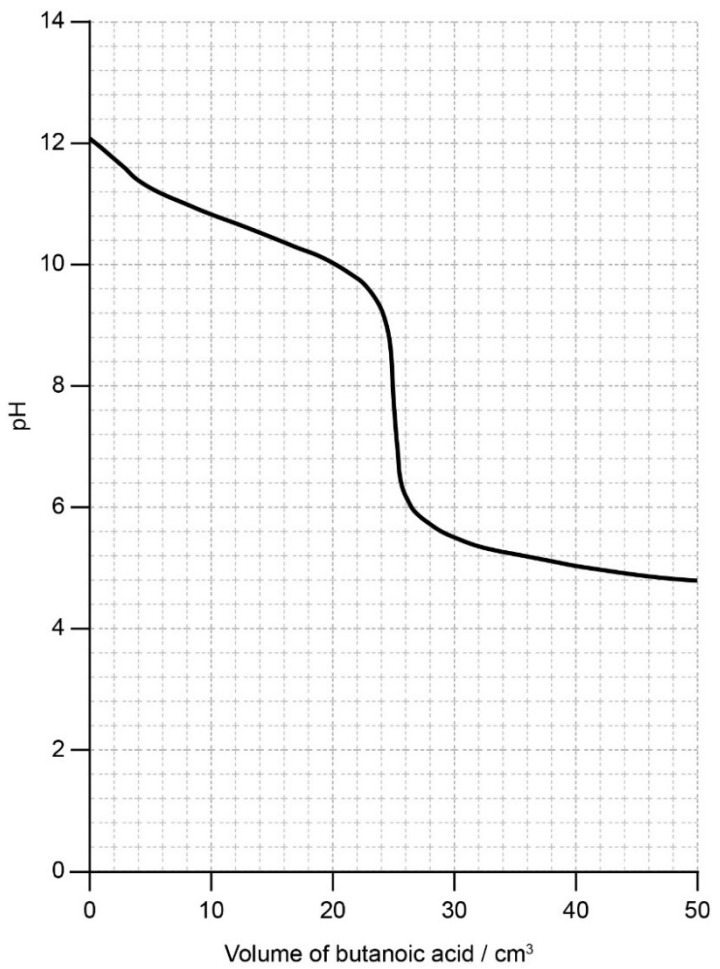
Question		Answers	Notes	Total
5.	e	<p>«reaction quotient/Q => $\frac{[\text{SO}_3]^2}{[\text{SO}_2]^2 [\text{O}_2]} / \frac{0.500^2}{0.200^2 \times 0.300} / 20.8 \checkmark$</p> <p>reaction quotient/Q/20.8/answer < K_c/280</p> <p>OR</p> <p>mixture needs more product for the number to equal $K_c \checkmark$</p> <p>reaction proceeds to the right/products \checkmark</p>	<p><i>Do not award M3 without valid reasoning.</i></p>	3

Question			Answers	Notes	Total
6.	a	i	<p><i>Butanoic acid:</i></p> $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{CH}_3\text{CH}_2\text{CH}_2\text{COO}^-(\text{aq}) + \text{H}_3\text{O}^+(\text{aq}) \checkmark$ <p><i>Ethylamine:</i></p> $\text{CH}_3\text{CH}_2\text{NH}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{CH}_3\text{CH}_2\text{NH}_3^+(\text{aq}) + \text{OH}^-(\text{aq}) \checkmark$		2
6.	a	ii	<p><i>Diagram showing:</i> dotted line along O-C-O AND negative charge</p>	Accept correct diagrams with pi clouds.	1
6.	a	iii	-1 \checkmark		1
6.	b	i	$\llcorner = \frac{1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}}{0.00192 \text{ mol dm}^{-3}} \llcorner = 5.21 \times 10^{-12} \llcorner \text{ mol dm}^{-3} \llcorner \checkmark$		1

(continued...)

(Question 6b continued)

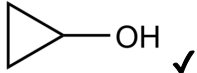
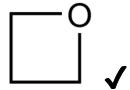
Question			Answers	Notes	Total
6.	b	ii	<p>«$pK_b = 3.35, K_b = 10^{-3.35} = 4.5 \times 10^{-4}$»</p> <p>«$C_2H_5NH_2 + H_2O \rightleftharpoons C_2H_5NH_3^+ + OH^-$»</p> <p>$K_b = \frac{[OH^-][CH_3CH_2NH_3^+]}{[CH_3CH_2NH_2]}$</p> <p>OR</p> <p>«$K_b \Rightarrow 4.5 \times 10^{-4} = \frac{[OH^-][CH_3CH_2NH_3^+]}{0.250}$</p> <p>OR</p> <p>«$K_b \Rightarrow 4.5 \times 10^{-4} = \frac{x^2}{0.250} \checkmark$</p> <p>«$x = [OH^-] \Rightarrow 0.011 \text{ «mol dm}^{-3}\text{»} \checkmark$</p> <p>«$pH = -\log \frac{1.00 \times 10^{-14}}{0.011} \Rightarrow 12.04$</p> <p>OR</p> <p>«$pH = 14.00 - (-\log 0.011) \Rightarrow 12.04 \checkmark$</p>	Award [3] for correct final answer.	3

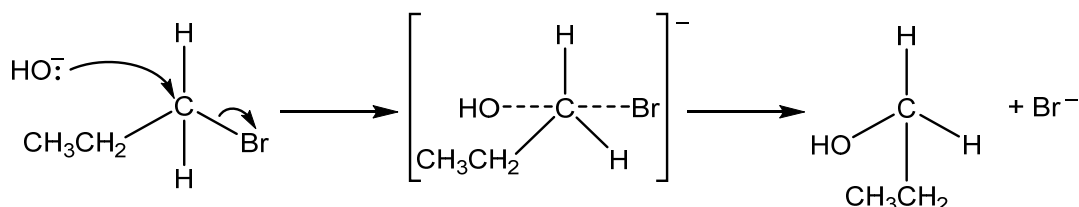
Question		Answers	Notes	Total
6.	c	 <p>decreasing pH curve ✓ pH close to 7 (6–8) at volume of 25 cm³ butanoic acid ✓ weak acid/base shape with no flat «strong acid/base» parts on the curve ✓</p>		3

Question			Answers	Notes	Total
6.	d		<p>Any two of:</p> <p>butanoic acid forms more/stronger hydrogen bonds ✓</p> <p>butanoic acid forms stronger London/dispersion forces ✓</p> <p>butanoic acid forms stronger dipole–dipole interaction/force ✓</p>	<p>Accept “butanoic acid forms dimers”.</p> <p>Accept “butanoic acid has larger M_r/hydrocarbon chain/number of electrons” for M2.</p> <p>Accept “butanoic acid has larger «permanent» dipole/more polar” for M3.</p>	2 max
6.	e	i	lithium aluminium hydride/ LiAlH_4 ✓		1
6.	e	ii	butan-1-ol/1-butanol/ $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$ ✓		1

Question		Answers	Notes	Total
7.	a	«electrophilic» addition/A _E OR reduction ✓	Accept “hydrogenation”.	1
7.	b	«(-286 kJ) + (-1411 kJ) => -1697 «kJ» ✓		1
7.	c	«-1697 kJ + 1561 kJ => -136 «kJ» OR « $\Delta H^\ominus = \Delta H_f^\ominus (\text{products}) - \Delta H_f^\ominus (\text{reactants}) = -84 \text{ kJ} - 52 \text{ kJ} => -136 \text{ «kJ»} \checkmark$ » ✓		1

Question		Answers	Notes	Total
7.	d	<p><i>Accurate:</i></p> <p>no approximations were made in the cycle</p> <p>OR</p> <p>values are specific to the compounds</p> <p>OR</p> <p>Hess's law is a statement of conservation of energy</p> <p>OR</p> <p>method is based on a law</p> <p>OR</p> <p>data in table has small uncertainties ✓</p> <p><i>Approximate:</i></p> <p>values were experimentally determined/had uncertainties</p> <p>OR</p> <p>each value has been determined to only three/four significant figures</p> <p>OR</p> <p>different sources have «slightly» different values for enthalpy of combustion</p> <p>OR</p> <p>law is valid until disproved</p> <p>OR</p> <p>law of conservation of energy is now conservation of mass-energy</p> <p>OR</p> <p>small difference between two quite large terms «leads to high percentage uncertainty» ✓</p>		2

Question			Answers	Notes	Total
8.	a		angle between bonds is 60°/strained/smaller than 109.5° ✓		1
8.	b	i	<p>Any two of:</p> <p>CH₃COCH₃ ✓</p> <p>CH₃CH₂CHO ✓</p> <p>CH₂=CHCH₂OH ✓</p> <p>CH₃OCH=CH₂ ✓</p> <p> ✓</p> <p> ✓</p>	<p>Accept displayed or condensed structural formulas or skeletal formulas.</p> <p>Accept CH(OH)=CHCH₃ and CH₂=C(OH)CH₃.</p>	2
8.	b	ii	<p>no AND only one «axial/methyl/CH₃» substituent «at the ring»</p> <p>OR</p> <p>no AND two «axial» substituents required «for cis/trans-isomers» ✓</p>	Accept “no AND «O in the ring and» one carbon has two H atoms”.	1
8.	c		<p>Chemical shift:</p> <p>3.7–4.8 «ppm» ✓</p> <p>Splitting pattern:</p> <p>doublet ✓</p>		2

Question		Answers	Notes	Total
9.	a	polarity/polar «molecule/bond» OR carbon-halogen bond is weaker than C-H bond ✓		1
9.	b	primary AND Br/bromine is attached to a carbon bonded to two hydrogens OR primary AND Br/bromine is attached to a carbon bonded to one C/R/alkyl «group» ✓	Accept "primary AND Br/bromine is attached to the first carbon in the chain".	1
9.	c	 <p>curly arrow going from lone pair/negative charge on O in HO⁻ to C ✓</p> <p>curly arrow showing Br leaving ✓</p> <p>representation of transition state showing negative charge, square brackets and partial bonds ✓</p> <p>formation of organic product CH₃CH₂CH₂OH AND Br⁻ ✓</p>	<p>Do not allow curly arrow originating on H in HO⁻.</p> <p>Accept curly arrow either going from bond between C and Br to Br in 1-bromopropane or in the transition state.</p> <p>Do not penalize if HO and Br are not at 180° to each other.</p> <p>Do not award M3 if OH-C bond is represented.</p>	4
9.	d	«Lewis» base AND donates a pair of electrons ✓		1

Question		Answers	Notes	Total
9.	e	<p>Any two of:</p> <p>choose «most» appropriate reaction «for preparing the target compound» ✓</p> <p>design/discover new reactions/reagents ✓</p> <p>apply this knowledge to other areas of chemistry/science ✓</p> <p>«retro-»synthesis «more effective» ✓</p> <p>control/predict «desired» products ✓</p> <p>control rate of reaction «more effectively» ✓</p> <p>satisfy intellectual curiosity ✓</p> <p>predicting how changing reagents/conditions might affect reaction ✓</p> <p>suggesting intermediates/transition states ✓</p>	Accept other reasonable answers.	2 max

10.	a	<p>B: reactant ✓</p> <p>D: intermediate ✓</p>		2
10.	b	rate = $k[A][B]$ ✓		1
10.	c	1.80 «mol dm ⁻³ s ⁻¹ » ✓		1