Markscheme

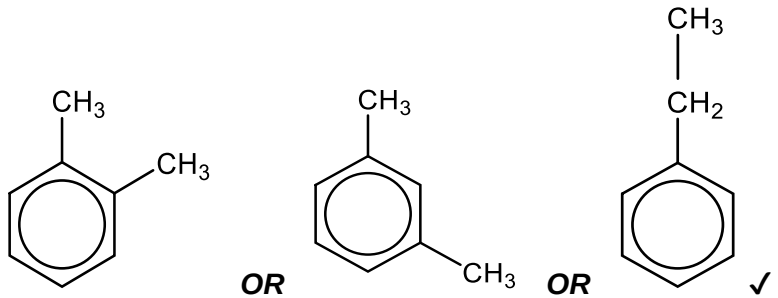
May 2019

Chemistry

Higher level

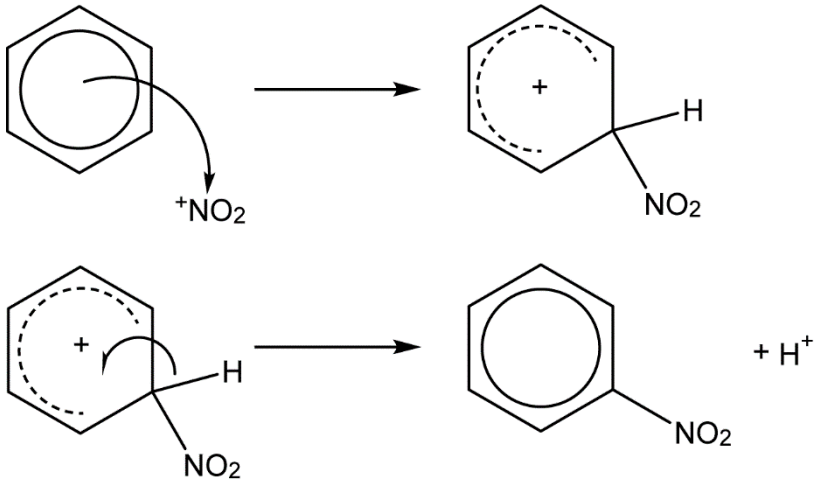
Paper 2

19 pages

Question			Answers	Notes	Total
1.	a		*Number of signals:* 2 ✓ *Ratio:* 3 : 2 ***OR*** 6 : 4 ✓	*Accept any correct integer or fractional ratio.* *Accept ratios in reverse order.*	**2**
1.	b		 ***OR*** ***OR*** ✓		**1**
1.	c	i	$2H_2SO_4 + HNO_3 \rightleftharpoons NO_2^+ + 2HSO_4^- + H_3O^+$ ✓	*Accept a single arrow instead of an equilibrium sign.* *Accept "$H_2SO_4 + HNO_3 \rightleftharpoons NO_2^+ + HSO_4^- + H_2O$".* *Accept "$H_2SO_4 + HNO_3 \rightleftharpoons H_2NO_3^+ + HSO_4^-$".* *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**

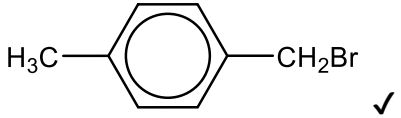
(continued…)

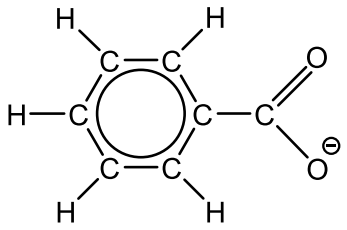
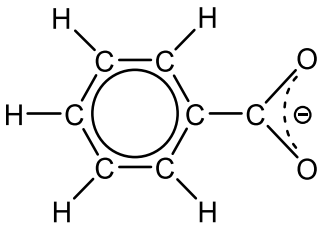
(Question 1 continued)

Question			Answers	Notes	Total
1.	**c**	**ii**	 curly arrow going from benzene ring to N **«**of $^+NO_2/NO_2^+$**»** ✓ carbocation with correct formula and positive charge on ring ✓ curly arrow going from C–H bond to benzene ring of cation ✓ formation of organic product nitrobenzene ***AND*** H^+ ✓	*Accept mechanism with corresponding Kekulé structures.* *Do **not** accept a circle in M2 or M3.* *Accept first arrow starting either inside the circle or on the circle.* *If Kekulé structure used, first arrow must start on the double bond.* *M2 may be awarded from correct diagram for M3.* *M4: Accept "$C_6H_5NO_2 + H_2SO_4$" if HSO_4^- used in M3.*	**4**

(continued…)

(Question 1 continued)

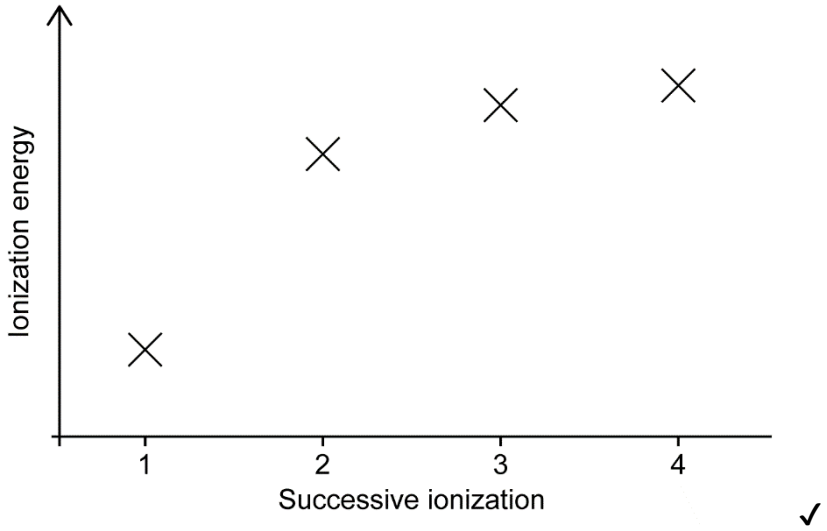
Question			Answers	Notes	Total
1.	**d**	**i**	$Br_2 \rightarrow 2Br\bullet$ ✓ «sun»light/UV/*hv* ***OR*** high temperature ✓	*Do **not** penalize missing radical symbol on Br.* *Accept "homolytic fission of bromine" for M1.*	**2**
1.	**d**	**ii**	 ✓ HBr ✓	*Accept condensed formulae, such as $CH_3C_6H_4CH_2Br$.*	**2**
1.	**e**		no ***AND*** there is no chiral carbon ***OR*** no ***AND*** there is no carbon with four different substituents/groups ✓	*Accept "no **AND** no asymmetric carbon atom".*	**1**

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

(continued…)

(Question 2 continued)

Question			Answers	Notes	Total
2.	**e**		electrons delocalized **«**across the O–C–O system**»** ***OR*** resonance occurs ✓ 122 **«**pm**»** < C–O < 143 **«**pm**»** ✓	*Accept "delocalized π-bond".* *Accept "bond intermediate between single and double bond" or "bond order 1.5" for M1.* *Accept any answer in range 123 to 142 pm.*	**2**
2.	**f**	**i**	***ALTERNATIVE 1:*** $[H^+]$ **«**$= 10^{-2.95}$**»** $= 1.122 \times 10^{-3}$ **«**mol dm^{-3}**»** ✓ **«**$[OH^-] = \frac{1.00 \times 10^{-14}\ mol^2\ dm^{-6}}{1.22 \times 10^{-3}\ mol\ dm^{-3}}$ **=»** 8.91×10^{-12} **«**mol dm^{-3}**»** ✓ ***ALTERNATIVE 2:*** pOH = **«**14 − 2.95 **=»** 11.05 ✓ **«**$[OH^-] = 10^{-11.05}$ **=»** 8.91×10^{-12} **«**mol dm^{-3}**»** ✓	*Award **[2]** for correct final answer.* *Accept other methods.*	**2**
2.	**f**	**ii**	$2C_6H_5COOH\,(s) + 15O_2\,(g) \rightarrow 14CO_2\,(g) + 6H_2O\,(l)$ correct products ✓ correct balancing ✓		**2**
2.	**g**		*Oxidized:* C/carbon **«**in C_6H_5COOH**»** ***AND*** *Reduced:* O/oxygen **«**in O_2**»** ✓		**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		 ✓	*Accept curve showing general trend.* *Award mark only if the energy difference between the first two points is larger than that between points 2/3 and 3/4.*	**1**
3.	b		same number of electrons in outer shell ***OR*** all are s^1 ✓		**1**
3.	c		**«**3-D/giant**»** regularly repeating arrangement **«**of ions**»** ***OR*** lattice **«**of ions**»** ✓ electrostatic attraction between oppositely charged ions ***OR*** electrostatic attraction between Na^+ and O^{2-} ions ✓	*Do **not** accept "ionic" without description.*	**2**

(continued…)

(Question 3 continued)

Question			Answers	Notes	Total
3.	**d**	**i**	$\frac{1}{2}\ O_2(g) \rightarrow O^{2-}(g)$ **«**$\Delta H_{atomisation}$ (O) + 1st EA + 2nd EA = 249 kJ mol^{-1} − 141 kJ mol^{-1} + 753 kJ mol^{-1} =**» «**+**»**861 **«**kJ mol^{-1}**»** ✓ $Na(s) \rightarrow Na^+(g)$ **«**$\Delta H_{atomisation}$ (Na) + 1st IE = 107 kJ mol^{-1} + 496 kJ mol^{-1} =**» «**+**»**603 **«**kJ mol^{-1}**»** ✓		**2**
3.	**d**	**ii**	lattice enthalpy = 861 **«**kJ mol^{-1}**»** + 2 × 603 **«**kJ mol^{-1}**»** −(−414 **«**kJ mol^{-1}**»**) ✓ **«**= +**»** 2481 **«**kJ mol^{-1}**»** ✓	*Award **[2]** for correct final answer.* *If given values are used:* *M1: lattice enthalpy = 850 **«**kJ mol^{-1}**»** + 2 × 600 **«**kJ mol^{-1}**»** −(−414 **«**kJ mol^{-1}**»**)* *M2: **«**= +**»** 2464 **«**kJ mol^{-1}**»***	**2**
3.	**d**	**iii**	K^+ ion is larger than Na^+ ***OR*** smaller attractive force because of greater distance between ion «centres» ✓		**1**

(continued…)

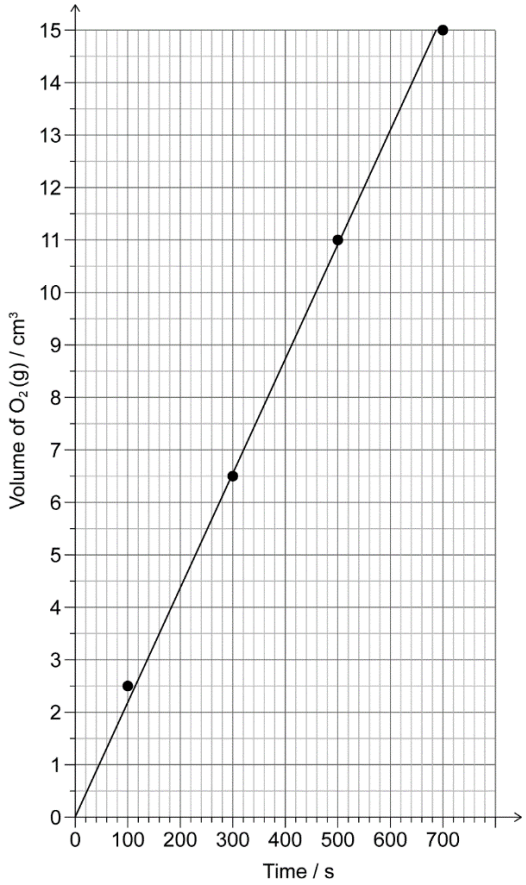
(Question 3 continued)

Question			Answers	Notes	Total
3.	**e**		*Sodium oxide:* $Na_2O\,(s) + H_2O\,(l) \rightarrow 2NaOH\,(aq)$ ✓ *Phosphorus(V) oxide:* $P_4O_{10}\,(s) + 6H_2O\,(l) \rightarrow 4H_3PO_4\,(aq)$ ✓ *Differentiation:* NaOH/product of Na_2O is alkaline/basic/pH > 7 ***AND*** H_3PO_4/product of P_4O_{10} is acidic/pH < 7 ✓		**3**
3.	**f**		$n(Na_2O_2)$ theoretical yield **«**$= \frac{5.00\,g}{61.98\,g\,mol^{-1}}$**»** $= 0.0807/8.07 \times 10^{-2}$ **«mol»** ***OR*** mass of Na_2O_2 theoretical yield **«**$= \frac{5.00\,g}{61.98\,g\,mol^{-1}} \times 77.98\,g\,mol^{-1}$**»** $= 6.291$ **«g»** ✓ % yield **«**$= \frac{5.50\,g}{6.291\,g} \times 100$**» *OR* «** $\frac{0.0705}{0.0807} \times 100$**»** $= 87.4$ **«%»** ✓	*Award **[2]** for correct final answer.*	**2**

(continued…)

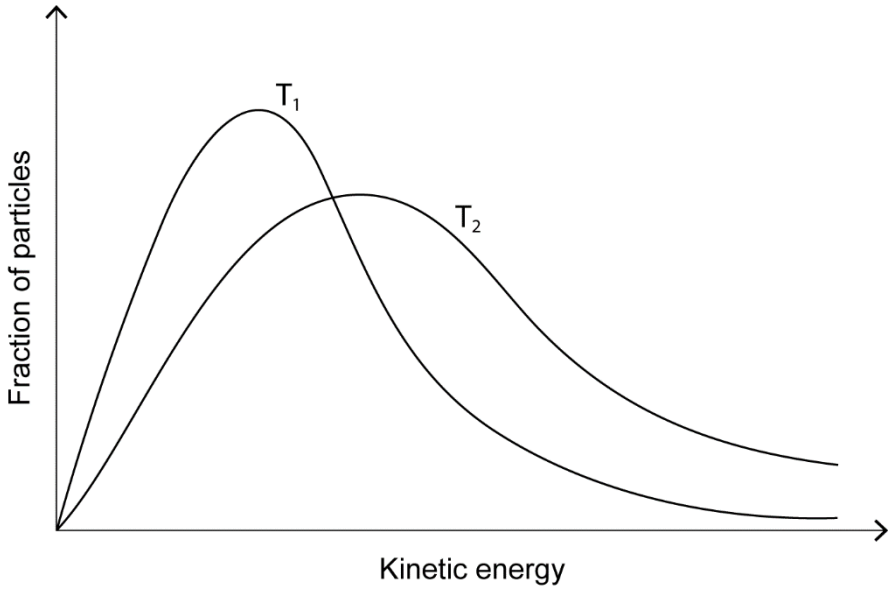
(Question 3 continued)

Question			Answers	Notes	Total
3.	**g**	**i**	$\Sigma\Delta H_f$ products = 2 × (–1130.7) / –2261.4 **«**kJ**»** ✓ $\Sigma\Delta H_f$ reactants = 2 × (–510.9) + 2 × (–393.5) / –1808.8 **«**kJ**»** ✓ ΔH = **«**$\Sigma\Delta H_f$ products – $\Sigma\Delta H_f$ reactants = –2261.4 –(–1808.8) =**»** –452.6 **«**kJ**»** ✓	*Award **[3]** for correct final answer.* *Award **[2 max]** for "+ 452.6 «kJ»".*	**3**
3.	**g**	**ii**	only valid for covalent bonds ***OR*** only valid in gaseous state ✓		**1**
3.	**h**		bond in O_3 has lower enthalpy ***AND*** bond order is 1.5 **«**not 2**»** ✓	*Accept "bond in ozone is longer".*	**1**
3.	**i**		*Any one of:* finite volume of particles **«**requires adjustment to volume of gas**»** ✓ short-range attractive forces **«**overcomes low kinetic energy**»** ✓		**1 max**
3.	**j**		NaOH ✓		**1**
3.	**k**		IV ✓		**1**

Question			Answers	Notes	Total
4.	a		decomposes in light ✓	*Accept "sensitive to light".*	1
4.	b	i	 points correctly plotted ✓ best fit line ***AND*** extended through (to) the origin ✓ *Average rate of reaction:* **«**slope (gradient) of line =**»** 0.022 **«**cm^3 O_2 (g) s^{-1}**»** ✓	*Accept range 0.020–0.024 cm^3 O_2 (g) s^{-1}.*	3

(continued…)

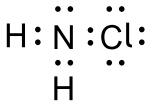
(Question 4 continued)

Question			Answers	Notes	Total
4.	**b**	**ii**	*Rate equation:* Rate = $k[H_2O_2] \times [KI]$ ✓ *Overall order:* 2 ✓	*Rate constant must be included.*	**2**
4.	**b**	**iii**	 peak of T_2 to right of ***AND*** lower than T_1 ✓ lines begin at origin ***AND*** T_2 must finish above T_1 ✓		**2**

(continued…)

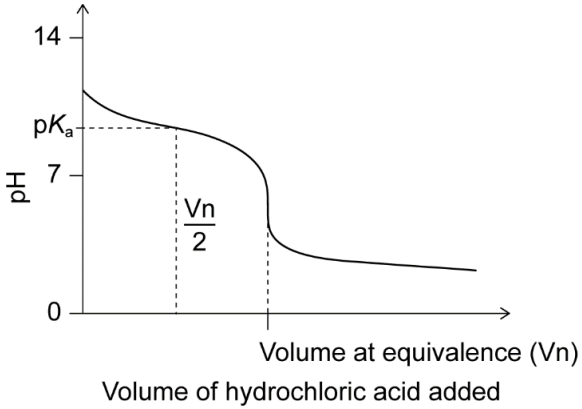
(Question 4 continued)

Question			Answers	Notes	Total
4.	**b**	**iv**	E_a marked on graph ✓ explanation in terms of more "particles" with $E \geq E_a$ ***OR*** greater area under curve to the right of E_a in T_2 ✓		**2**
4.	**b**	**v**	manganese(IV) oxide ***OR*** 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(H_2O_2) **«**= $2 \times 1.01 + 2 \times 16.00$**»** = 34.02 **«**g**»** ✓ **«**% $H_2O_2 = 3 \times \frac{34.02}{314.04} \times 100$ =**»** 32.50 **«**%**»** ✓	*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_2 (g)/chlorine gas ***OR*** Cl_2 (g)/chlorine gas is toxic ✓	*Accept "ethanoic acid produces H^+ ions"* *Accept "ethanoic acid/vinegar reacts with NaOCl".* *Do **not** accept "$2CH_3COOH + NaOCl + NaCl \rightarrow 2CH_3COONa + Cl_2 + H_2O$" as it does not refer to equilibrium.* *Accept suitable molecular or ionic equations for M1 and M3.*	**3**
5.	**c**	**i**	 ✓	*Accept any combination of dots/crosses or lines to represent electron pairs.*	**1**
5.	**c**	**ii**	sp^3 ✓		**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**	 correct shape of graph ***AND*** vertical drop at Vn ✓ pK_a = pH at $\frac{Vn}{2}$/half neutralization/half equivalence ✓	*M1: must show buffer region at pH > 7 and equivalence point at pH < 7.* *Graph must start below pH = 14.*	**2**
5.	**d**	**ii**	methyl orange ***OR*** bromophenol blue ***OR*** bromocresol green ***OR*** methyl red ✓		**1**

(continued…)

(Question 5d continued)

Question			Answers	Notes	Total
5.	**d**	**iii**	$NH_3(aq) + H^+(aq) \rightarrow NH_4^+(aq)$ ✓ $NH_4^+(aq) + OH^-(aq) \rightarrow NH_3(aq) + H_2O(l)$ ✓	*Accept reaction arrows or equilibrium signs in both equations.* *Award **[1 max]**, 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**		$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6$ ✓		**1**
6.	**b**		**«**frequency/wavelength of visible**»** light absorbed by electrons moving between d levels/orbitals ✓ colour due to remaining frequencies ***OR*** complementary colour transmitted ✓		**2**
6.	**c**		$^{54}_{26}Fe$ ✓		**1**
6.	**d**		**«**A_r =**»** $54 \times 0.0584 + 56 \times 0.9168 + 57 \times 0.0217 + 58 \times 0.0031$ ***OR*** **«**A_r =**»** 55.9111 ✓ **«**A_r =**»** 55.91 ✓	*Award **[2]** for correct final answer.* *Do **not** accept data booklet value (55.85).*	**2**

(continued…)

(Question 6 continued)

Question			Answers	Notes	Total
6.	**e**		lemon juice is the electrolyte ***OR*** lemon juice allows flow of ions ***OR*** each nail/metal forms a half-cell with the lemon juice ✓ *Any one of:* iron is higher than copper in the activity series ***OR*** each half-cell/metal has a different redox/electrode potential ✓ iron is oxidized ***OR*** $Fe \rightarrow Fe^{2+} + 2e^-$ ***OR*** $Fe \rightarrow Fe^{3+} + 3e^-$ ***OR*** iron is anode/negative electrode of cell ✓ copper is cathode/positive electrode of cell ***OR*** reduction occurs at the cathode ***OR*** $2H^+ + 2e^- \rightarrow H_2$ ✓ electrons flow from iron to copper ✓		**2**

(continued…)

(Question 6 continued)

Question			Answers	Notes	Total
6.	**f**	**i**	«$E^{\ominus} = +0.34\,\text{V} - (-0.45\,\text{V}) = +$»0.79 «V» ✓		**1**
6.	**f**	**ii**	«$\Delta G^{\ominus} = -nFE^{\ominus} = -2\,\text{mol} \times 96\,500\,\text{C mol}^{-1} \times \frac{0.79\,\text{J C}^{-1}}{1000} =$» –152 «kJ» ✓	*Accept range 150–153 kJ.*	**1**
6.	**f**	**iii**	«$\ln K_c = -\frac{\Delta G^{\ominus}}{RT} = -\frac{-152 \times 10^3\,\text{J mol}^{-1}}{8.31\,\text{J K}^{-1}\,\text{mol}^{-1} \times 298\,\text{K}} =$» 61.38 ✓ $K = 4.5 \times 10^{26}$ ✓	*Accept answers in range 2.0×10^{26} to 5.5×10^{26}.* *Do **not** award M2 if answer not given to two significant figures.* *If –140 kJ mol^{-1} used, answer is 3.6×10^{24}.*	**2**
7.			*Cathode (negative electrode):* $Ag^+(aq) + e^- \rightarrow Ag(s)$ ✓ *Anode (positive electrode):* $2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$ ✓	*Accept $4OH^-(aq) \rightarrow O_2(g) + 2H_2O(l) + 4e^-$.* *Accept multiple or fractional coefficients in both half-equations.*	**2**