

Markscheme

May 2019

Chemistry

Higher level

Paper 2

19 pages

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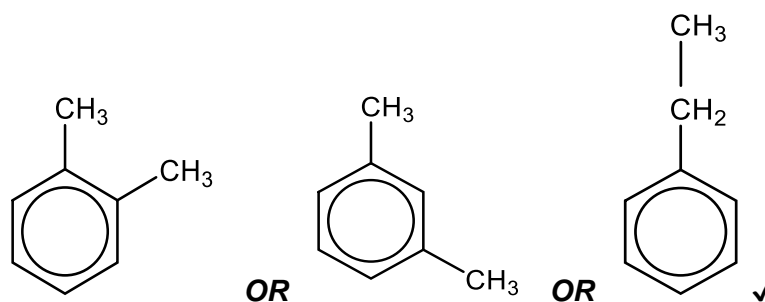
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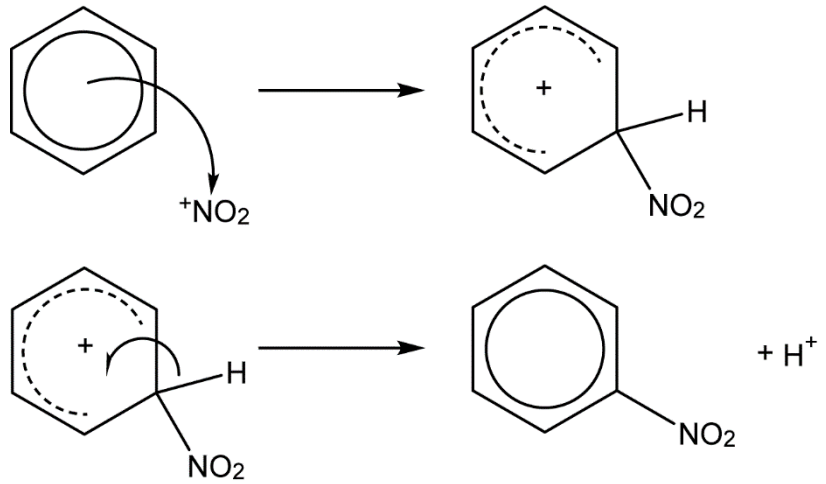
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Question			Answers	Notes	Total
1.	a		<p>Number of signals: 2 ✓</p> <p>Ratio: 3:2 OR 6:4 ✓</p>	<p>Accept any correct integer or fractional ratio. Accept ratios in reverse order.</p>	2
1.	b				1
1.	c	i	$2\text{H}_2\text{SO}_4 + \text{HNO}_3 \rightleftharpoons \text{NO}_2^+ + 2\text{HSO}_4^- + \text{H}_3\text{O}^+ \checkmark$	<p>Accept a single arrow instead of an equilibrium sign.</p> <p>Accept "$\text{H}_2\text{SO}_4 + \text{HNO}_3 \rightleftharpoons \text{NO}_2^+ + \text{HSO}_4^- + \text{H}_2\text{O}$".</p> <p>Accept "$\text{H}_2\text{SO}_4 + \text{HNO}_3 \rightleftharpoons \text{H}_2\text{NO}_3^+ + \text{HSO}_4^-$".</p> <p>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.</p>	1

(continued...)

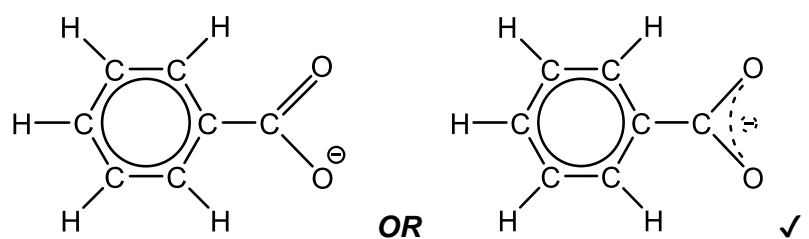
(Question 1 continued)

Question			Answers	Notes	Total
1.	c	ii	 <p>curly arrow going from benzene ring to N «of $^+\text{NO}_2/\text{NO}_2^+$» ✓</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 AND H^+ ✓</p>	<p>Accept mechanism with corresponding Kekulé structures.</p> <p>Do not 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 "$\text{C}_6\text{H}_5\text{NO}_2 + \text{H}_2\text{SO}_4$" if HSO_4^- 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 OR high temperature \checkmark	Do not penalize missing radical symbol on Br. Accept "homolytic fission of bromine" for M1.	2
1.	d	ii	$\text{H}_3\text{C}-\text{C}_6\text{H}_4-\text{CH}_2\text{Br} \checkmark$ 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 AND there is no chiral carbon OR no AND there is no carbon with four different substituents/groups \checkmark	Accept "no AND no asymmetric carbon atom".	1

Question		Answers	Notes	Total
2.	a	<p>Any wavenumber in the following ranges:</p> <p>2500–3000 «cm⁻¹» ✓</p> <p>1700–1750 «cm⁻¹» ✓</p> <p>2850–3090 «cm⁻¹» ✓</p>		1
2.	b	X-ray «crystallography/spectroscopy» ✓		1
2.	c	<p>Any one of:</p> <p>«regular» hexagon</p> <p>OR</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>OR</p> <p>bond order 1.5 ✓</p>		1
2.	d		<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		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: $[H^+] \llcorner = 10^{-2.95} \llcorner = 1.122 \times 10^{-3} \llcorner \llcorner \text{mol dm}^{-3} \llcorner \llcorner \checkmark$ $\llcorner [OH^-] = \frac{1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}}{1.22 \times 10^{-3} \text{ mol dm}^{-3}} \llcorner \llcorner = 8.91 \times 10^{-12} \llcorner \llcorner \text{mol dm}^{-3} \llcorner \llcorner \checkmark$ ALTERNATIVE 2: pOH = «14 – 2.95 =» 11.05 ✓ $\llcorner [OH^-] = 10^{-11.05} \llcorner \llcorner = 8.91 \times 10^{-12} \llcorner \llcorner \text{mol dm}^{-3} \llcorner \llcorner \checkmark$	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 ₆ H ₅ COOH» 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		<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>OR</p> <p>all are s^1 ✓</p>		1
3.	c	<p>«3-D/giant» regularly repeating arrangement «of ions»</p> <p>OR</p> <p>lattice «of ions» ✓</p> <p>electrostatic attraction between oppositely charged ions</p> <p>OR</p> <p>electrostatic attraction between Na^+ and O^{2-} ions ✓</p>	<p>Do not 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>«$\Delta H_{\text{atomisation}}(\text{O}) + 1\text{st EA} + 2\text{nd EA} = 249 \text{ kJ mol}^{-1} - 141 \text{ kJ mol}^{-1} + 753 \text{ kJ mol}^{-1}$ \Rightarrow «+»861 «kJ mol⁻¹» ✓</p> <p>$\text{Na}(\text{s}) \rightarrow \text{Na}^+(\text{g})$ $\Delta H_{\text{atomisation}}(\text{Na}) + 1\text{st IE} = 107 \text{ kJ mol}^{-1} + 496 \text{ kJ mol}^{-1} \Rightarrow$ «+»603 «kJ mol⁻¹» ✓</p>		2
3.	d	ii	<p>lattice enthalpy = $861 \text{ «kJ mol}^{-1}\text{»} + 2 \times 603 \text{ «kJ mol}^{-1}\text{»} - (-414 \text{ «kJ mol}^{-1}\text{») ✓$</p> <p>«= +» 2481 «kJ mol⁻¹» ✓</p>	<p>Award [2] for correct final answer.</p> <p>If given values are used: M1: lattice enthalpy = $850 \text{ «kJ mol}^{-1}\text{»} + 2 \times 600 \text{ «kJ mol}^{-1}\text{»} - (-414 \text{ «kJ mol}^{-1}\text{») ✓$ M2: «= +» 2464 «kJ mol⁻¹»</p>	2
3.	d	iii	<p>K^+ ion is larger than Na^+ OR smaller attractive force because of greater distance between ion «centres» ✓</p>		1

(continued...)

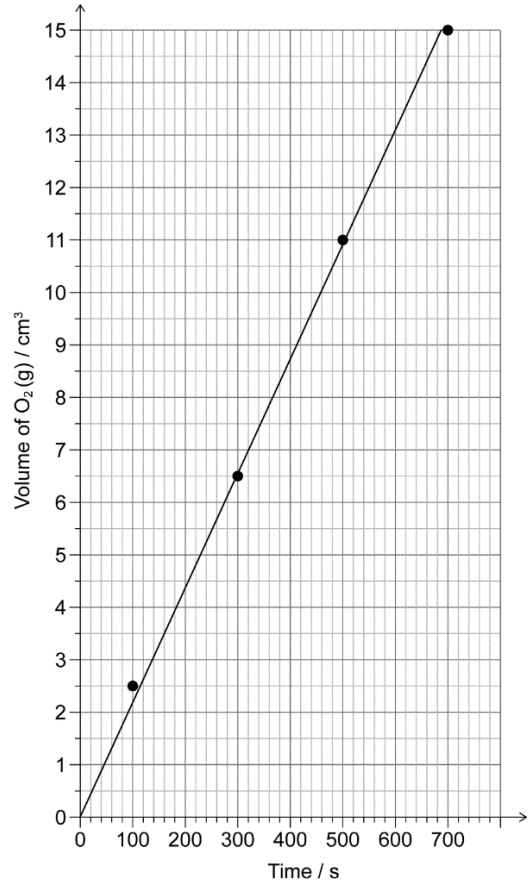
(Question 3 continued)

Question		Answers	Notes	Total
3.	e	<p><i>Sodium oxide:</i> $\text{Na}_2\text{O} (\text{s}) + \text{H}_2\text{O} (\text{l}) \rightarrow 2\text{NaOH} (\text{aq}) \checkmark$</p> <p><i>Phosphorus(V) oxide:</i> $\text{P}_4\text{O}_{10} (\text{s}) + 6\text{H}_2\text{O} (\text{l}) \rightarrow 4\text{H}_3\text{PO}_4 (\text{aq}) \checkmark$</p> <p><i>Differentiation:</i> NaOH/product of Na_2O is alkaline/basic/pH > 7 AND H_3PO_4/product of P_4O_{10} is acidic/pH < 7 \checkmark</p>		3
3.	f	<p>$n(\text{Na}_2\text{O}_2)$ theoretical yield «= $\frac{5.00 \text{ g}}{61.98 \text{ g mol}^{-1}}$ » = $0.0807/8.07 \times 10^{-2}$ «mol»</p> <p>OR</p> <p>mass of Na_2O_2 theoretical yield «= $\frac{5.00 \text{ g}}{61.98 \text{ g mol}^{-1}} \times 77.98 \text{ g mol}^{-1}$ » = 6.291 «g» \checkmark</p> <p>% yield «= $\frac{5.50 \text{ g}}{6.291 \text{ g}} \times 100$» OR « $\frac{0.0705}{0.0807} \times 100$ » = 87.4 «%» \checkmark</p>	Award [2] for correct final answer.	2

(continued...)

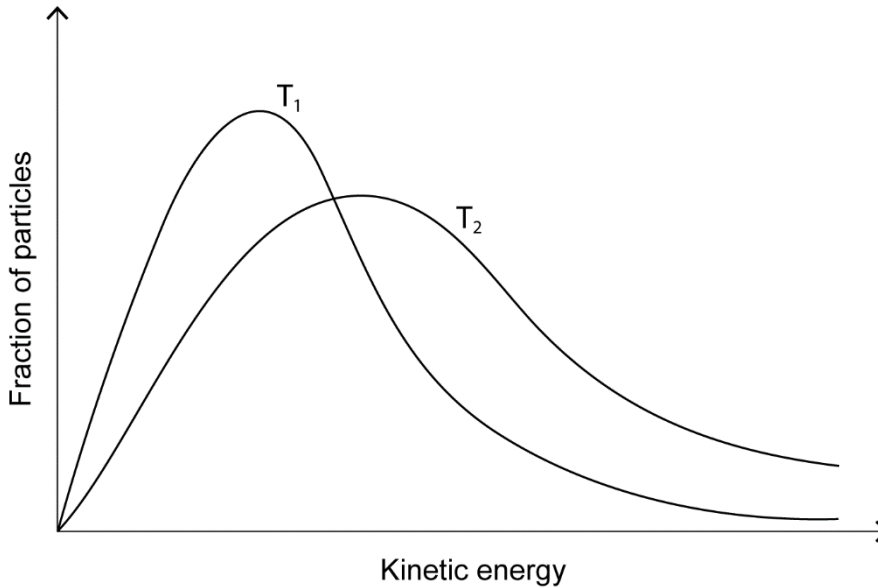
(Question 3 continued)

Question			Answers	Notes	Total
3.	g	i	$\Sigma\Delta H_f$ products = $2 \times (-1130.7) / -2261.4$ «kJ» ✓ $\Sigma\Delta H_f$ reactants = $2 \times (-510.9) + 2 \times (-393.5) / -1808.8$ «kJ» ✓ $\Delta H = \langle \Sigma\Delta H_f$ 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	 <p>points correctly plotted ✓ best fit line AND extended through (to) the origin ✓</p> <p>Average rate of reaction: «slope (gradient) of line => 0.022 «cm³ O₂ (g) s⁻¹» ✓</p>	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	<p>Rate equation: $\text{Rate} = k[\text{H}_2\text{O}_2] \times [\text{KI}] \checkmark$</p> <p>Overall order: 2 \checkmark</p>	Rate constant must be included.	2
4.	b	iii	 <p>peak of T_2 to right of AND lower than $T_1 \checkmark$ lines begin at origin AND T_2 must finish above $T_1 \checkmark$</p>		2

(continued...)

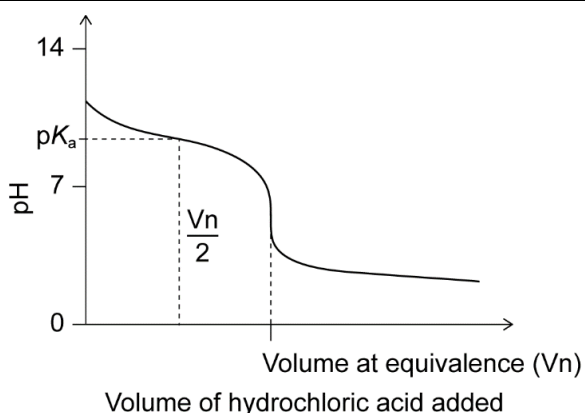
(Question 4 continued)

Question			Answers	Notes	Total
4.	b	iv	E_a marked on graph ✓ explanation in terms of more “particles” with $E \geq E_a$ 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		$M(\text{H}_2\text{O}_2) \llcorner = 2 \times 1.01 + 2 \times 16.00 \llcorner = 34.02 \llcorner \text{g} \llcorner \checkmark$ $\llcorner \% \text{H}_2\text{O}_2 = 3 \times \frac{34.02}{314.04} \times 100 \llcorner = \llcorner 32.50 \llcorner \% \llcorner \checkmark$	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 ₂ (g)/chlorine <u>gas</u> OR Cl ₂ (g)/chlorine <u>gas</u> is toxic ✓	Accept “ethanoic acid produces H ⁺ ions” Accept “ethanoic acid/vinegar reacts with NaOCl”. Do not accept “2CH ₃ COOH + NaOCl + NaCl → 2CH ₃ COONa + Cl ₂ + H ₂ O” as it does not refer to equilibrium. Accept suitable molecular or ionic equations for M1 and M3.	3
5.	c	i	$\begin{array}{c} \text{H} : \ddot{\text{N}} : \ddot{\text{Cl}} : \\ \quad \quad \quad \cdot \\ \text{H} \end{array}$ <p style="text-align: right;">✓</p>	Accept any combination of dots/crosses or lines to represent electron pairs.	1
5.	c	ii	sp 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	 <p>correct shape of graph AND vertical drop at V_n ✓ $pK_a = pH$ at $\frac{V_n}{2}$ /half neutralization/half equivalence ✓</p>	<p>M1: must show buffer region at $pH > 7$ and equivalence point at $pH < 7$. Graph must start below $pH = 14$.</p>	2
5.	d	ii	<p>methyl orange OR bromophenol blue OR bromocresol green OR 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 [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		$1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 \checkmark$		1
6.	b		«frequency/wavelength of visible» light absorbed by electrons moving between d levels/orbitals \checkmark colour due to remaining frequencies OR complementary colour transmitted \checkmark		2
6.	c		${}_{26}^{54}\text{Fe} \checkmark$		1
6.	d		$\llcorner A_r \Rightarrow 54 \times 0.0584 + 56 \times 0.9168 + 57 \times 0.0217 + 58 \times 0.0031$ OR $\llcorner A_r \Rightarrow 55.9111 \checkmark$ $\llcorner A_r \Rightarrow 55.91 \checkmark$	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	<p>lemon juice is the electrolyte OR lemon juice allows flow of ions OR 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 OR each half-cell/metal has a different redox/electrode potential ✓</p> <p>iron is oxidized OR $\text{Fe} \rightarrow \text{Fe}^{2+} + 2\text{e}^-$ OR $\text{Fe} \rightarrow \text{Fe}^{3+} + 3\text{e}^-$ OR iron is anode/negative electrode of cell ✓</p> <p>copper is cathode/positive electrode of cell OR reduction occurs at the cathode OR $2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2$ ✓</p> <p>electrons flow from iron to copper ✓</p>		2

(continued...)

(Question 6 continued)

Question			Answers	Notes	Total
6.	f	i	$\ll E^\ominus = +0.34 \text{ V} - (-0.45 \text{ V}) = +\gg 0.79 \text{ «V» } \checkmark$		1
6.	f	ii	$\ll \Delta G^\ominus = -nFE^\ominus = -2 \text{ mol} \times 96\,500 \text{ C mol}^{-1} \times \frac{0.79 \text{ JC}^{-1}}{1000} \Rightarrow -152 \text{ «kJ» } \checkmark$	Accept range 150–153 kJ.	1
6.	f	iii	$\ll \ln K_c = -\frac{\Delta G^\ominus}{RT} = -\frac{-152 \times 10^3 \text{ J mol}^{-1}}{8.31 \text{ JK}^{-1} \text{ mol}^{-1} \times 298 \text{ K}} \Rightarrow 61.38 \checkmark$ $K = 4.5 \times 10^{26} \checkmark$	Accept answers in range 2.0×10^{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): $\text{Ag}^+ (\text{aq}) + \text{e}^- \rightarrow \text{Ag} (\text{s}) \checkmark$ 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