

Markscheme

May 2017

Chemistry

Higher level

Paper 2

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Question			Answers	Notes	Total
1.	a	i	$n(\text{Ag}) = \frac{3.275 \text{ g}}{107.87 \text{ g mol}^{-1}} \Rightarrow 0.03036 \text{ «mol»}$ <p>AND</p> $n(\text{O}) = \frac{3.760 \text{ g} - 3.275 \text{ g}}{16.00 \text{ g mol}^{-1}} = \frac{0.485}{16.00} \Rightarrow 0.03031 \text{ «mol»} \checkmark$ $\frac{0.03036}{0.03031} \approx 1 \text{ / ratio of Ag to O approximately } 1 : 1, \text{ so}$ <p>AgO ✓</p>	<p>Accept other valid methods for M1.</p> <p>Award [1 max] for correct empirical formula if method not shown.</p>	2
1	a	ii	<p>temperature too low</p> <p>OR</p> <p>heating time too short</p> <p>OR</p> <p>oxide not decomposed completely ✓</p> <p>heat sample to constant mass «for three or more trials» ✓</p>	<p>Accept "not heated strongly enough".</p> <p>If M1 as per markscheme, M2 can only be scored for constant mass technique.</p> <p>Accept "soot deposition" (M1) and any suitable way to reduce it (M2).</p> <p>Accept "absorbs moisture «from atmosphere» (M1) and "cool in dessicator" (M2).</p> <p>Award [1 max] for reference to "impurity" AND design improvement.</p>	2
1	b		<p>A_r closer to 107/less than 108 «so more ^{107}Ag»</p> <p>OR</p> <p>A_r less than the average of (107 + 109) «so more ^{107}Ag» ✓</p>	<p>Accept calculation that gives greater than 50% ^{107}Ag.</p>	1

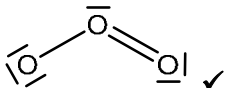
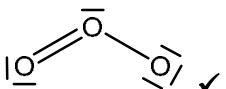
Question			Answers			Notes	Total
1	c	i	Flask containing	Colour of solution	Product formula	<p><i>Do not accept name for the products.</i></p> <p><i>Accept "Na⁺ + OH⁻" for NaOH.</i></p> <p><i>Ignore coefficients in front of formula.</i></p>	3
			Na ₂ O	blue	NaOH ✓		
			P ₄ O ₁₀	AND yellow ✓	H ₃ PO ₄ ✓		
1	c	ii	<p>«molten» Na₂O has mobile ions/charged particles AND conducts electricity ✓</p> <p>«molten» P₄O₁₀ does not have mobile ions/charged particles AND does not conduct electricity/is poor conductor of electricity ✓</p>			<p><i>Do not award marks without concept of mobile charges being present.</i></p> <p><i>Award [1 max] if type of bonding or electrical conductivity correctly identified in each compound.</i></p> <p><i>Do not accept answers based on electrons.</i></p> <p><i>Award [1 max] if reference made to solution.</i></p>	2
1	d		<p>electrons in discrete/specific/certain/different shells/energy levels ✓</p> <p>energy levels converge/get closer together at higher energies</p> <p>OR</p> <p>energy levels converge with distance from the nucleus ✓</p>			<p><i>Accept appropriate diagram for either M1, M2 or both.</i></p> <p><i>Do not give marks for answers that refer to the lines in the spectrum.</i></p>	2

Question			Answers	Notes	Total
2.	a	i	$\text{Sn}^{2+}(\text{aq}) \rightarrow \text{Sn}^{4+}(\text{aq}) + 2\text{e}^{-}$ ✓	Accept equilibrium sign. Accept $\text{Sn}^{2+}(\text{aq}) - 2\text{e}^{-} \rightarrow \text{Sn}^{4+}(\text{aq})$	1
2	a	ii	$\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 14\text{H}^{+}(\text{aq}) + 3\text{Sn}^{2+}(\text{aq}) \rightarrow 2\text{Cr}^{3+}(\text{aq}) + 7\text{H}_2\text{O}(\text{l}) + 3\text{Sn}^{4+}(\text{aq})$ ✓	Accept equilibrium sign.	1
2	a	iii	$\ll [\text{K}_2\text{Cr}_2\text{O}_7] = \frac{13.239 \text{ g}}{294.20 \text{ g mol}^{-1} \times 0.100 \text{ dm}^3} \Rightarrow 0.450 \ll \text{mol dm}^{-3} \gg$ ✓		1
2	a	iv	$n(\text{Sn}^{2+}) = \ll 0.450 \text{ mol dm}^{-3} \times 0.01324 \text{ dm}^3 \times \frac{3 \text{ mol}}{1 \text{ mol}} \Rightarrow 0.0179 \ll \text{mol} \gg$ ✓ $\ll [\text{Sn}^{2+}] = \frac{0.0179 \text{ mol}}{0.0100 \text{ dm}^3} \Rightarrow 1.79 \ll \text{mol dm}^{-3} \gg$ ✓	Award [2] for correct final answer.	2
2	a	v	hydroxyl/OH OR aldehyde/CHO ✓	Accept "hydroxy/alcohol" for "hydroxyl". Accept amino/amine/ NH_2 .	1
2	b	i	$\ll E^{\ominus} \Rightarrow +0.85 \ll \text{V} \gg$ ✓	Accept 0.85 V.	1
2	b	ii	$\Delta G^{\ominus} \ll = -nFE^{\ominus} \gg = -2 \ll \text{mol e}^{-} \gg \times 96500 \ll \text{C mol}^{-1} \gg \times 0.85 \ll \text{V} \gg$ ✓ $\ll \Delta G^{\ominus} \Rightarrow -164 \ll \text{kJ} \gg$ ✓	Accept " $\ll + \gg 164 \ll \text{kJ} \gg$ " as question states energy released. Award [1 max] for " $+$ " or " $-$ " 82 $\ll \text{kJ} \gg$. Do not accept answer in J.	2
2	b	iii	incompletely filled d-orbitals ✓ colour depends upon the energy difference between the split d-orbitals ✓ variable/multiple/different oxidation states ✓ different $\ll \text{nature/identity of} \gg$ ligands ✓ different number of ligands ✓		3 max

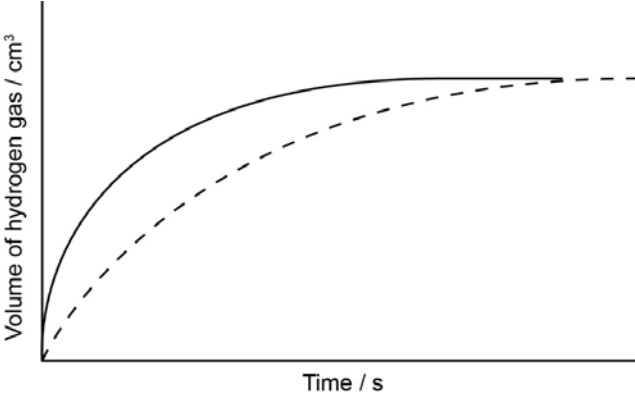
Question		Answers	Notes	Total
2	c	Zn/zinc is a stronger reducing agent than Fe/iron OR Zn/zinc is oxidized instead of Fe/iron OR Zn/zinc is the sacrificial anode ✓	Accept “Zn is more reactive than Fe”. Accept “Zn oxide layer limits further corrosion”. Do not accept “Zn layer limits further corrosion”.	1

Question			Answers	Notes	Total
3.	a	i	$K_c = \frac{[PCl_3][Cl_2]}{[PCl_5]} \checkmark$		1
3	a	ii	decrease in temperature \checkmark endothermic «reaction» AND «equilibrium» shifts to the left/reactants OR endothermic «reaction» AND K_c decreases OR endothermic «reaction» AND concentration of PCl_5 increased/concentration of PCl_3 and Cl_2 decreased OR «equilibrium» shifts in the exothermic direction \checkmark	Do not accept “temperature change”. Accept “ ΔH positive” in place of “endothermic”. Accept “products” instead of “ PCl_3 and Cl_2 ”.	2
3	b		Lewis structure: $\begin{array}{c} \overline{\text{Cl}} - \overline{\text{P}} - \overline{\text{Cl}} \\ \\ \overline{\text{Cl}} \end{array} \checkmark$ Molecular geometry: trigonal/triangular pyramidal \checkmark Bond angles: $< 109.5^\circ \checkmark$	Penalize missing lone pairs once only between this question and 4(b)(ii). Accept any combination of lines, dots or crosses to represent electrons. Do not apply ECF. Do not accept answer equal to or less than 90° . Literature value is 100.1° .	3

Question			Answers	Notes	Total
4.	a	i	triple bond in nitrogen «molecule» AND single bond in hydrazine ✓ triple bond is stronger than single bond OR more shared «pairs of» electrons make bond stronger/attract nuclei more ✓	<i>Accept bond enthalpy values from data booklet (158 and 945 kJ mol⁻¹).</i>	2
4	a	ii	hydrogen bonding «between molecules, dinitrogen tetraoxide does not» ✓		1
4	a	iii	N_2H_4 : -2 AND N_2O_4 : +4 ✓		1
4	a	iv	N_2H_4 AND oxidized/oxidation state increases OR N_2H_4 AND loses hydrogen OR N_2H_4 AND reduces/removes oxygen from N_2O_4 ✓	<i>Accept “N_2H_4 AND gives electrons «to N_2O_4»”.</i>	1

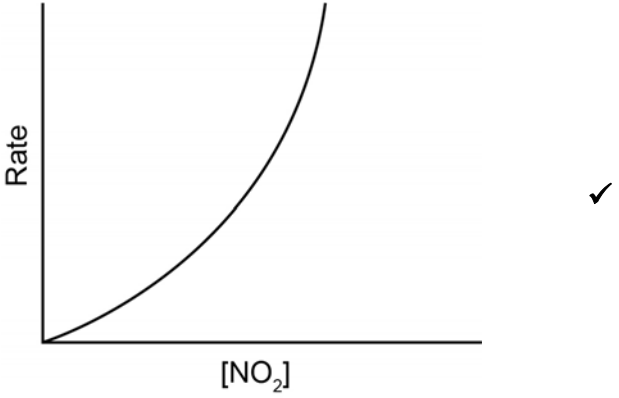
Question			Answers	Notes	Total
4	b	i	<p>lone pair on p orbital «of O atom» overlaps/delocalizes with pi electrons «from double bond» ✓</p> <p>both O–O bonds have equal bond length</p> <p>OR</p> <p>both O–O bonds have same/1.5 bond order</p> <p>OR</p> <p>both O–O are intermediate between O–O AND O=O ✓</p> <p>both O–O bonds have equal bond energy ✓</p>	<p>Accept “p/pi/π electrons are delocalized/not localized”.</p>	3
4	b	ii	<p>ALTERNATIVE 1:</p>  <p>FC: -1 AND +1 AND 0 ✓</p> <p>ALTERNATIVE 2:</p>  <p>FC: 0 AND +1 AND -1 ✓</p>	<p>Accept any combination of lines, dots or crosses to represent electrons.</p> <p>Do not accept structure that represents 1.5 bonds.</p> <p>Do not penalize missing lone pairs if already penalized in 3(b).</p> <p>If resonance structure is incorrect, no ECF.</p> <p>Any one of the structures with correct formal charges for [2 max].</p>	2

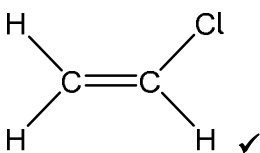
Question			Answers	Notes	Total
4	c		<p>Any two of:</p> <p>IE₄: electron in lower/inner shell/energy level OR IE₄: more stable/full electron shell ✓</p> <p>IE₄: electron closer to nucleus OR IE₄: electron more tightly held by nucleus ✓</p> <p>IE₄: less shielding by complete inner shells ✓</p>	<p>Accept "increase in effective nuclear charge" for M2.</p>	2 max
4	d	i	<p>$Q_c = \frac{0.10}{0.52^2} \Rightarrow 0.37$ ✓</p> <p>reaction proceeds to the left/NO₂(g) «until Q = K_c» OR reverse reaction «favoured» ✓</p>	<p>Do not award M2 without a calculation for M1 but remember to apply ECF.</p>	2
4	d	ii	<p>$\Delta G = 0$ ✓</p> <p>reaction at equilibrium OR rate of forward and reverse reaction is the same OR constant macroscopic properties ✓</p>		2

Question			Answers	Notes	Total
5.	a	i	concentration of acid decreases OR surface area of magnesium decreases ✓	Accept "less frequency/chance/rate/probability/likelihood of collisions". Do not accept just "less acid" or "less magnesium". Do not accept "concentration of reagents decrease".	1
5	a	ii	 <p>Volume of hydrogen gas / cm³</p> <p>Time / s</p> curve starting from origin with steeper gradient AND reaching same maximum volume ✓		1
5	b	i	«rate =>» $k [\text{NO}_2]^2$ ✓	Accept $\text{rate} = k [\text{NO}_2]^2 [\text{CO}]^0$.	1
5	b	ii	«step» I AND CO does not appear in the rate law expression OR «step» I AND only «2 molecules of» NO ₂ appears in rate expression ✓	Do not allow ECF from (i).	1

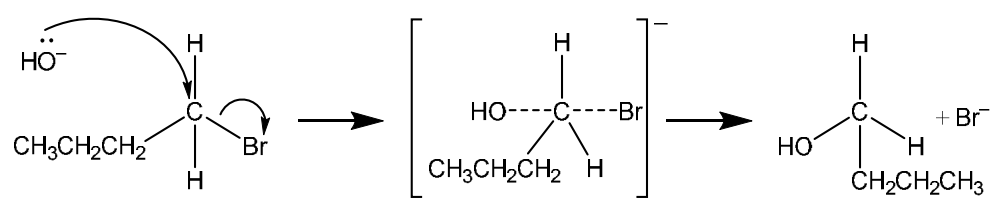
(continued...)

(Question 5b continued)

Question			Answers	Notes	Total
5	b	iii	«IR or UV-vis» spectroscopy OR colorimetry OR colour change «over time» ✓	Accept GC/gas chromatography.	1
5	b	iv	« $E_{a(\text{rev})} = 226 + 132 \Rightarrow 358$ «kJ» ✓	Do not accept –358.	1
5	b	v		Curve must go through origin.	1
5	c		activation energy is independent of temperature ✓	Accept “no relationship”.	1
5	d		$2\text{NO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{HNO}_3(\text{aq}) + \text{HNO}_2(\text{aq})$ OR $4\text{NO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) + \text{O}_2(\text{g}) \rightarrow 4\text{HNO}_3(\text{aq})$ ✓	Accept ionized forms of the acids.	1

Question		Answers	Notes	Total
6.	a	<p><i>Initiation:</i></p> $\text{Cl}-\text{Cl} \rightarrow \text{Cl}\cdot + \text{Cl}\cdot \checkmark$ <p><i>Propagation:</i></p> $\text{Cl}\cdot + \text{CH}_4 \rightarrow \text{Cl}-\text{H} + \cdot\text{CH}_3 \checkmark$ $\text{Cl}-\text{Cl} + \cdot\text{CH}_3 \rightarrow \text{Cl}-\text{CH}_3 + \text{Cl}\cdot \checkmark$	<p><i>Do not penalize missing electron dot on radicals if consistent throughout.</i></p> <p><i>Accept Cl₂, HCl and CH₃Cl without showing bonds.</i></p> <p><i>Do not accept hydrogen radical, H• or H, but apply ECF to other propagation steps.</i></p>	3
6	b	$\llcorner \Delta H^\ominus \Rightarrow -82.0 \llcorner \text{kJ} \llcorner - 92.3 \llcorner \text{kJ} \llcorner - (-74.0 \llcorner \text{kJ} \llcorner) \checkmark$ $\llcorner \Delta H^\ominus \Rightarrow -100.3 \llcorner \text{kJ} \llcorner \checkmark$	<p><i>Award [2] for correct final answer.</i></p>	2
6	c	$\text{H}_2\text{C}=\text{CHCl}$ <p>OR</p> 	<p><i>Accept "CH₂CHCl" or "CHClCH₂".</i></p> <p><i>Do not accept "C₂H₃Cl".</i></p>	1

Question			Answers	Notes	Total
7.	a	i	Number of hydrogen environments: 3 ✓ Ratio of hydrogen environments: 2:3:9 ✓ Splitting patterns: «all» singlets ✓	Accept any equivalent ratios such as 9:3:2. Accept “no splitting”.	3
7	a	ii	carbonyl OR C=O ✓	Accept “ketone” but not “aldehyde”.	1
7	a	iii	$ \begin{array}{ccccccc} & & \text{CH}_3 & & \text{O} & & \\ & & & & & & \\ \text{H}_3\text{C} & - & \text{C} & - & \text{CH}_2 & - & \text{C} & - & \text{CH}_3 \\ & & & & & & & & \\ & & \text{CH}_3 & & & & & & \end{array} $ ✓✓	Accept (CH ₃) ₃ CCH ₂ COCH ₃ . Award [1] for any aldehyde or ketone with C ₇ H ₁₄ O structural formula.	2
7	b	i	hexane AND hex-1-ene ✓	Accept “benzene AND hexane AND hex-1-ene”.	1
7	b	ii	CH ₃ CH ₂ CH ₂ CH ₂ CHBrCH ₃ ✓	Accept displayed formula but not molecular formula.	1
7	c	i	Reagents: «concentrated» sulfuric acid AND «concentrated» nitric acid ✓ Name of mechanism: electrophilic substitution ✓		2
7	c	ii	benzene has «delocalized» π bonds «that are susceptible to electrophile attack» AND alkanes do not ✓	Do not accept “benzene has single and double bonds”.	1

Question		Answers	Notes	Total
7	d	 <p>curly arrow going from lone pair/negative charge on O in OH^- to C ✓ curly arrow showing Br leaving ✓ representation of transition state showing negative charge, square brackets and partial bonds ✓</p>	<p>Accept OH^- with or without the lone pair. Do not allow curly arrows originating on H in OH^-. Accept curly arrows in the transition state. Do not penalize if HO and Br are not at 180°. Do not award M3 if OH-C bond is represented. Award [2 max] if wrong isomer is used.</p>	3

Question			Answers	Notes	Total												
8.	a	i	H ₂ O/water ✓	Accept "hydroxide ion/OH ⁻ ".	1												
	a	ii	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 33%;">Acid</th> <th style="width: 33%;">AND</th> <th style="width: 33%;">Base</th> </tr> </thead> <tbody> <tr> <td>HOCl</td> <td></td> <td>OCl⁻</td> </tr> <tr> <td>OR</td> <td></td> <td></td> </tr> <tr> <td>H₂O</td> <td></td> <td>OH⁻ ✓</td> </tr> </tbody> </table>	Acid	AND	Base	HOCl		OCl ⁻	OR			H ₂ O		OH ⁻ ✓		1
Acid	AND	Base															
HOCl		OCl ⁻															
OR																	
H ₂ O		OH ⁻ ✓															
	b	i	«0.100 mol dm ⁻³ × 0.0250 dm ³ = 0.00250 «mol» ✓		1												
	b	ii	« $M = \frac{0.510\text{g}}{0.00250\text{mol}} \Rightarrow 204 \text{ «g mol}^{-1}\text{»}$ ✓		1												
	b	iii	« $1.00 \times 10^{-14} = [\text{H}^+] \times 0.100$ » 1.00 × 10 ⁻¹³ «mol dm ⁻³ » ✓		1												
	b	iv	weak AND pH at equivalence greater than 7 OR weak acid AND forms a buffer region ✓		1												
	b	v	calorimetry OR measurement of heat/temperature OR conductivity measurement ✓	Accept "indicator" but not "universal indicator".	1												
	b	vi	«pK _a = pH at half-equivalence ⇒ 5.0		1												

Question		Answers	Notes	Total
	c	$K_a = 10^{-4.35} / 4.46683 \times 10^{-5} \checkmark$ $[H_3O^+] = \sqrt{4.46683 \times 10^{-5} \times 1.60 \times 10^{-3}} / \sqrt{7.1469 \times 10^{-8}} / 2.6734 \times 10^{-4} \text{ «mol dm}^{-3}\text{»} \checkmark$ $pH = \text{«-log } \sqrt{7.1469 \times 10^{-8}} \Rightarrow 3.57 \checkmark$	<p>Award [3] for correct final answer to two decimal places.</p> <p>If quadratic equation used, then: $[H_3O^+] = 2.459 \times 10^{-4} \text{ «mol dm}^{-3}\text{»}$ and $pH = 3.61$</p>	3

Question			Answers	Notes	Total
9.	a	i	$\Delta H = 177.0 - \frac{189.2}{2} - 285.5 \text{ «kJ» } \checkmark$ $\text{«}\Delta H \text{»} = -203.1 \text{ «kJ» } \checkmark$	<p>Accept other methods for correct manipulation of the three equations.</p> <p>Award [2] for correct final answer.</p>	2
	a	ii	$203.1 \text{ «kJ»} = 0.850 \text{ «kg»} \times 4.18 \text{ «kJ kg}^{-1} \text{ K}^{-1}\text{»} \times \Delta T \text{ «K»}$ <p>OR</p> $\text{«}\Delta T \text{»} = 57.2 \text{ «K» } \checkmark$ $\text{«}T_{\text{final}} = (57.2 + 21.8)^\circ\text{C} \text{»} = 79.0^\circ\text{C} \text{»} / 352.0 \text{ «K»} \checkmark$ <p>If 200.0 kJ was used:</p> $200.0 \text{ «kJ»} = 0.850 \text{ «kg»} \times 4.18 \text{ «kJ kg}^{-1} \text{ K}^{-1}\text{»} \times \Delta T \text{ «K»}$ <p>OR</p> $\text{«}\Delta T \text{»} = 56.3 \text{ «K» } \checkmark$ $\text{«}T_{\text{final}} = (56.3 + 21.8)^\circ\text{C} \text{»} = 78.1 \text{ «}^\circ\text{C} \text{»} / 351.1 \text{ «K»} \checkmark$	<p>Award [2] for correct final answer.</p> <p>Accept two, three or four significant figures.</p> <p>Unit, if specified, must be consistent with value stated.</p>	2
	b	i	$\text{«}\Delta S^\ominus \text{»} = 270 \text{ «J K}^{-1} \text{ mol}^{-1}\text{»} - 267 \text{ «J K}^{-1} \text{ mol}^{-1}\text{»} - 131 \text{ «J K}^{-1} \text{ mol}^{-1}\text{»} \checkmark$ $\text{«}\Delta S^\ominus \text{»} = -128 \text{ «J K}^{-1} \text{ mol}^{-1}\text{»} \checkmark$	<p>Award [2] for correct final answer.</p>	2
	b	ii	<p>«non spontaneous if» $\Delta G^\ominus = \Delta H^\ominus - T\Delta S^\ominus > 0$</p> <p>OR</p> $\Delta H^\ominus > T\Delta S^\ominus \checkmark$ $\text{«}T \text{ above» } \frac{-124.4 \text{ «kJ mol}^{-1}\text{»}}{-0.128 \text{ «kJ K}^{-1} \text{ mol}^{-1}\text{»}} = 972 \text{ «K» } \checkmark$	<p>Award [2] for correct final answer.</p> <p>Accept 699 °C.</p> <p>Do not award M2 for any negative T value.</p>	2