GCE

Chemistry A

H432/01: Periodic table, elements and physical chemistry

Advanced GCE

Mark Scheme for Autumn 2021

Oxford Cambridge and RSA Examinations

This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

Tuesday 5 October 2021 –Afternoon

A Level Chemistry A

H432/01 Periodic table, elements and physical chemistry

MARK SCHEME

Duration: 2 hours 15 minutes

MAXIMUM MARK 100

Last updated: 17/10/2021
Post-standardisation

This document consists of 27 pages

1. Annotations

Annotation	Meaning
✓	Correct response
✗	Incorrect response
^	Omission mark
BOD	Benefit of doubt given
CON	Contradiction
RE	Rounding error
SF	Error in number of significant figures
ECF	Error carried forward
L1	Level 1
L2	Level 2
L3	Level 3
NBOD	Benefit of doubt not given
SEEN	Noted but no credit given
I	Ignore

2. Abbreviations, annotations and conventions used in the detailed Mark Scheme (to include abbreviations and subject-specific conventions).

Annotation	Meaning
/	alternative and acceptable answers for the same marking point
✓	Separates marking points
DO NOT ALLOW	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
( )	Words which are not essential to gain credit
__	Underlined words must be present in answer to score a mark
ECF	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

Question	Answer	Marks	AO element	Guidance
1	C	1	AO1.1	
2	B	1	AO1.2	
3	D	1	AO2.6	
4	B	1	AO2.2	
5	D	1	AO2.6	
6	C	1	AO2.6	
7	A	1	AO1.1	
8	B	1	AO2.2	
9	B	1	AO2.2	
10	A	1	AO2.6	
11	A	1	AO1.2	
12	C	1	AO1.2	
13	D	1	AO1.1	Accept 1
14	B	1	AO2.1	
15	C	1	AO2.3	
	Total	15		

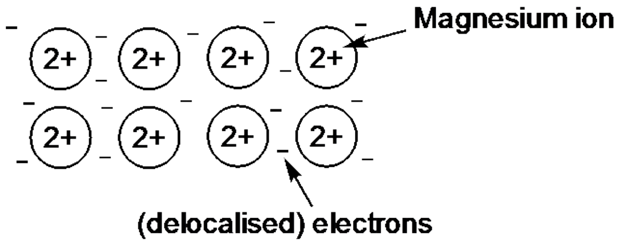
<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>AO element</th><th>Guidance</th></tr>
<tr><td>16</td><td>(a)</td><td></td><td>

Diagram with regular arrangement of labelled ‘Mg^{2+} ions’ OR ‘2+ ions’
AND attempt to show electrons ✓

Labelled electrons between other species
AND
statement anywhere of delocalised electrons (can be in text or in diagram)

Electrons move ✓</td><td>3</td><td></td><td>Regular arrangement must have at least two rows of correctly charged ions and a minimum of two ions per row

ALLOW as label: +2 ions OR + 2 cations OR +2/2+ seen within circle

ALLOW e^- or ‘e’ as a label for electron

IGNORE “–“ for electron label

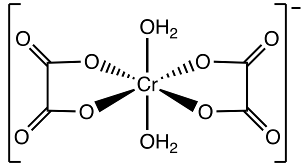
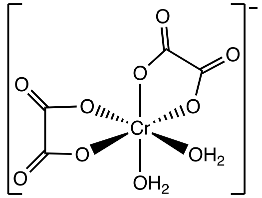
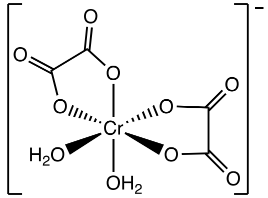
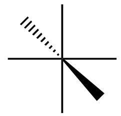
ALLOW mobile/flow for move

IGNORE ‘carry charge’</td></tr>
<tr><td></td><td>(b)</td><td>(i)</td><td>$Mg^{3+}(g) \rightarrow Mg^{4+}(g) + e^-$ ✓</td><td>1</td><td>AO1.2</td><td>State symbols required
(ignore states on electrons)
ALLOW $Mg^{3+}(g) - e^- \rightarrow Mg^{4+}(g)$
ALLOW Mg^{+3} (g)
ALLOW e for e^-</td></tr>
<tr><td></td><td>(b)</td><td>(ii)</td><td>Big jump/larger difference between 2 and 3 ✓</td><td>1</td><td>AO1.2</td><td>IGNORE big jump between 10 and 11
DO NOT ALLOW other combinations.</td></tr>
<tr><td></td><td>(b)</td><td>(iii)</td><td>1st AND 3rd AND 4th AND 5th AND 9th AND 11th ✓
i.e.
<table>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td></tr>
<tr><td>✓</td><td></td><td>✓</td><td>✓</td><td>✓</td><td></td><td></td><td></td><td>✓</td><td></td><td>✓</td><td></td></tr>
</table></td><td>1</td><td>AO2.1</td><td></td></tr>
</table>

Question			Answer	Marks	AO element	Guidance
	(c)	(i)	(enthalpy change for) **1 mole** of a compound/substance/solid/solute **dissolving** ✓	1	AO1.1	**IGNORE** 'energy released' **OR** 'energy required' For dissolving, **ALLOW** forms aqueous/hydrated ions **IGNORE** ionic **OR** covalent **DO NOT ALLOW** dissolving elements **DO NOT ALLOW** response that implies formation of **1 mole** of aqueous ions
	(c)	(ii)	$Mg^{2+}(aq) + 2F^{-}(g)$ ✓ $Mg^{2+}(aq) + 2F^{-}(aq)$ ✓	2	AO2.2 ×2	**ALLOW** $Mg^{2+}(g) + 2F^{-}(aq)$ **ALLOW** $MgF_2(aq)$
	(c)	(iii)	–6 (kJ mol^{-1}) ✓ $\Delta_{sol}H$ (MgF_2) = – (–2926) + (2 × –506) + (–1920)	1	AO2.2	**1 mark ONLY**
	(c)	(iv)	**Ionic radius** Halide **ion** gets larger down the group ✓ **Lattice enthalpy** Lattice enthalpy is less exothermic down group **OR** halide ion has less attraction for Mg^{2+} ✓ **Hydration enthalpy** Hydration enthalpy is less exothermic down group **OR** halide ion has less attraction for H_2O ✓ **Enthalpy of solution** Difficult to predict whether lattice enthalpy or hydration enthalpy has bigger effect ✓	4	AO1.2 ×3 AO3.2	**ALLOW ORA** throughout **ALLOW** ions closer together in MgF_2 **OR** further apart in MgI_2 **DO NOT ALLOW** atomic radius **ALLOW** MgI_2 is less exothermic than MgF_2 for LE and hydration enthalpy -as trend 'down the group'. **ALLOW** less negative/more positive **BUT** **IGNORE** is smaller/less
			Total	**14**		

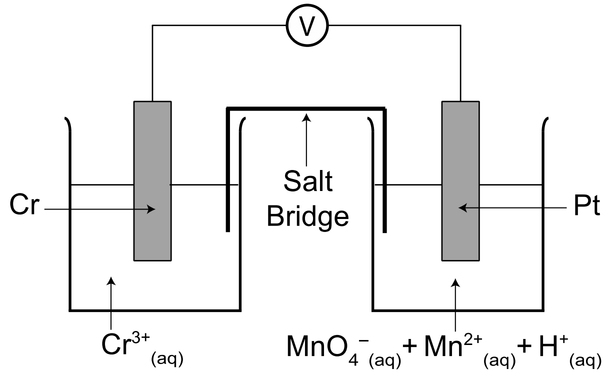
Question			Answer	Marks	AO element	Guidance
17	(a)		***Transition element:*** Has an **ion** with an incomplete/partially-filled d **sub-shell/d-orbital** ✓ ***d-block*** d **sub-shell/d-orbital** is being filled/has highest energy **OR** Electron configurations shown for Sc: $1s^22s^22p^63s^23p^63d^14s^2$ **AND** Zn:$1s^22s^22p^63s^23p^63d^{10}4s^2$ ✓ *Electron configurations of ions* Sc^{3+}: $1s^22s^22p^63s^23p^6$ **AND** d **sub-shell empty / d orbital(s) empty** ✓ Zn^{2+}: $1s^22s^22p^63s^23p^63d^{10}$ **AND** d **sub-shell full / d-orbitals full** ✓	**4**	AO1.1 ×4	***FULL ANNOTATIONS MUST BE USED*** --- **DO NOT ALLOW** d shell **IGNORE** d block **IGNORE** outer electron electron configurations **ALLOW** $4s^0$ **ALLOW** $4s^2$ before 3d, i.e. …..$4s^23d^1$; $4s^23d^{10}$ **IGNORE** other Sc and Zn ions **ALLOW ECF** for short hand notation**.** For Sc^{3+}, **ALLOW** Sc^{+3} **OR** Sc forms a 3+ ion; For Zn^{2+}, **ALLOW** Zn^{+2} **OR** Zn forms a 2+ ion;
	(b)	(i)	**Donates two** electron **pairs** (to a metal ion) **AND** forms **two** coordinate **bonds** (to a metal ion) ✓	**1**	AO1.1 x1	**ALLOW** lone pairs for electron pairs **ALLOW** dative (covalent) bonds for coordinate bonds **TWO** is only needed once if bonds are plural, e.g. **Donates 2** electron **pairs** to form coordinate **bonds** **Donates** electron **pairs** to form **2** coordinate **bonds**

Question			Answer	Marks	AO element	Guidance
		(ii)*	*Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** Reaches a comprehensive conclusion with most detail and few errors to obtain: the formulae of **A** and **B** **AND** ionic equation for ligand substitution **AND** the 3D structures of **B** stereoisomers *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Reaches a sound conclusion with some detail and some errors for the formula of **A OR B** **AND** ionic equation for ligand substitution **OR** the 3D structures of **B** stereoisomers *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** Obtains the correct formula of **A OR B OR** 3D structures of **B** stereoisomers which are mostly correct. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** No response or no response worthy of credit.	6	AO2.2 ×2 AO2.6 ×2 AO3.1 ×2	**Indicative scientific points:** **<u>1. Formula of the hydrated salt A</u>** **Formula of A**: $Cr_2H_{24}O_{24}S_3$ *Example of working* Cr : H : O : S $\frac{17.10}{52.0} : \frac{3.94}{1.0} : \frac{63.13}{16.0} : \frac{15.83}{32.1}$ ***There may be other methods*** ***Detail*** *Hydrated salt =* $Cr_2(SO_4)_3 \bullet 12H_2O$ **<u>2. Formula of B and ionic equation</u>** **Formula of B**: $[Cr(H_2O)_2(C_2O_4)_2]^-$ **Ionic equation** $[Cr(H_2O)_6]^{3+} + 2C_2O_4^{2-} \rightarrow [Cr(H_2O)_2(C_2O_4)_2]^- + 4H_2O$ **ALLOW** ligands in any order, e.g. $[Cr(C_2O_4)_2(H_2O)_2]^-$ ***Detail*** *Use of charges and brackets* **<u>3. 3D structures of B stereoisomers</u>**

Question			Answer	Marks	AO element	Guidance
						   • Consistent use of 2 ‘out wedges’, 2 ‘in wedges’, 2 lines in plane of paper **OR** 4 lines, 1 ‘out wedge’ and 1 ‘in wedge’ **ALLOW** following orientations  ***Detail*** • Most bonding shown from Cr to O of H_2O and O^- $C_2O_4^{2-}$
			Total	**11**		

Question			Answer	Marks	AO element	Guidance
18	(a)		Formula: $CuCO_3$ ✓ $CuCO_3 + 2HNO_3 \rightarrow Cu(NO_3)_2 + CO_2 + H_2O$ ✓	2	AO1.2 AO2.6	**IGNORE state symbols** **ALLOW** formula within equation. **ALLOW** other copper(II) compounds which can react with nitric acid to form a gas e.g. CuS, $CuSO_3$ for mark 1, with correct equation for mark 2. e.g.$CuSO_3 + 2HNO_3 \rightarrow Cu(NO_3)_2 + SO_2 + H_2O$
	(b)		$2Cu^{2+}(aq) + 4I^{-}(aq) \rightarrow 2CuI(s) + I_2(aq)$ ✓	1	AO2.6	**ALLOW** multiples State symbols are required
	(c)		starch (solution) **AND** blue-black to colourless ✓	1	AO1.2	**ALLOW** blue **OR** black **OR** purple for colour of mixture **ALLOW** blue colour disappears (to colourless) **IGNORE** 'clear' **IGNORE** 'colorimetry
	(d)		**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 1.35 award 4 marks** -- $n(S_2O_3^{2-}) = 0.0200 \times \frac{26.55}{1000}$ $= 5.31 \times 10^{-4}$ (mol) ✓ $n(I_2) = 2.655 \times 10^{-4}$ **OR** $n(Cu^{2+}) = 5.31 \times 10^{-4}$ (mol) ✓ $m(Cu/Cu^{2+})$ in ore $= 63.5 \times 5.31 \times 10^{-4}$ $= 0.0337.....$ (g) ✓ percentage $= \frac{0.0337....}{2.50} \times 100$ $= 1.35$ (%) ✓ (**3SF** required)	4	AO2.8 ×5	***FULL ANNOTATIONS MUST BE USED*** -- **ALLOW ECF** throughout If 1:2 ratio for $I_2:Cu^{2+}$ not used check ratio in b) and allow **ECF** **IGNORE** rounding errors after 3 SF Calculator: 0.0337185 **ALLOW** 3 SF (0.0337) up to calculator value **ECF** dependent on the use of a calculated mass of Cu/Cu^{2+}

Question			Answer	Marks	AO element	Guidance
	(e)	(i)	Lower **AND** smaller titre ✓	1	AO3.4	**ALLOW** less I_2 produced / less $\mathbf{Cu^{2+}}$ reacts
		(ii)	The same **AND** burette measures by difference ✓	1	AO3.4	**ALLOW AW**
	(f)		Any two of the following: Make up a (standard solution) from Step 2 to a stated volume (e.g. 250 cm^3) **OR** Repeat titrations **AND** Take mean of concordant/closest titres/ identify anomalies **OR** lower $[S_2O_3]^{2-}$ to increase titre volume (to reduce the percentage error). **OR** higher $[S_2O_3]^{2-}$ so not to refill the burette. **OR** Use a 3 dec place balance (to reduce the percentage error).	2	AO3.4 x 2	
			Total	**12**		

Question			Answer	Marks	AO element	Guidance
19	(a)	(i)	**Complete** circuit with voltmeter **AND** labelled salt bridge linking two half-cells ✓  Cr electrode in Cr^{3+} ✓ Pt electrode in MnO_4^- **AND** H^+ **AND** Mn^{2+} ✓	3	AO1.2 ×3	Half cells can be drawn in either order Half cells must show electrodes dipping into solutions **ALLOW** small gaps in circuit **IGNORE** any stated concentrations **IGNORE** state symbols In salt bridge, **ALLOW** any stated ion that may be present, e.g. Cr^{3+}, MnO_4^-, Mn^{2+}, H^+
	(a)	(ii)	$5Cr + 3MnO_4^- + 24H^+ \rightarrow 5Cr^{3+} + 3Mn^{2+} + 12H_2O$ ✓	1	AO2.6	**IGNORE** state symbols **ALLOW** multiples
	(b)	(i)	Mn is oxidised from +6 (in MnO_4^{2-}) to +7 (in MnO_4^-) ✓ Mn is reduced from +6 (in MnO_4^{2-}) to +4 (in MnO_2) ✓	2	AO2.1 ×2	**IGNORE** '6' (signs required) **ALLOW** after number, e.g. 5+ **ALLOW** 1 mark for correct oxidation numbers but not linked to oxidation/reduction. **IGNORE** any reference to electron loss/gain (even if wrong)

Question			Answer	Marks	AO element	Guidance
	(b)	(ii)	*Explanation using E^o values* (E^o of) system **3** (MnO_4^-/MnO_4^{2-}) is less positive / more negative than system **5** (MnO_4^{2-}/MnO_2)✓ *Equilibrium shift related to E^o values* system **3** (MnO_4^-/MnO_4^{2-}) shifts left **AND** system **5** (MnO_4^{2-}/MnO_2) shifts right ✓	**2**	AO3.1 ×2	**IGNORE** 'lower/higher' **ALLOW** reverse argument: System 5 more positive than system 3, etc Must be comparative **ALLOW** response in terms of E_{cell} E = (+)1.14 V for system 5 – system 3 Shift dependent on systems 3 and 5 correctly identified
	(c)	(i)	$H_2 + 2OH^- \rightarrow 2H_2O + 2e^-$ ✓	**1**	AO2.6	**ALLOW** multiples **ALLOW** $H_2 + 2OH^- - 2e^- \rightarrow 2H_2O$ **ALLOW** equation with equilibrium sign
	(c)	(ii)	(0.40 – 1.23 =) –0.83 (V) ✓	**1**	AO1.2	
	(c)	(iii)	Fuel reacts with oxygen/oxidant to give **electrical** energy/voltage ✓	**1**	AO1.1	**ALLOW** named fuel. e.g. hydrogen/H_2; ethanol; methanol, etc **ALLOW** fuel cell requires <u>continuous</u> supply of fuel **AND** oxygen/an oxidant **OR** fuel cell operates <u>continuously</u> as long as a fuel **AND** oxygen/an oxidant are added **IGNORE** 'reactants' 'products' and comments about pollution and efficiency
			Total	**11**		

Question			Answer	Marks	AO element	Guidance
20	(a)		rate of forwards reaction = rate of backwards reaction **OR** concentrations/pressure/temperature are constant /do not change ✓	1	AO1.1	 **DO NOT ALLOW** "are the same"
	(b)	(i)	$\Delta G = \Delta H - T\Delta S = -114 - (298 \times -0.147)$ ✓ $= -70.194$ (kJ mol^{-1}) **AND** statement of $\Delta G < 0$ **OR** ΔG is –ve **OR** $\Delta H < T\Delta S$ ✓	2	AO2.2 ×2	**ALLOW** $-114000 - (298 \times -147)$ **ALLOW** –70 up to calculator value of –70.194 correctly rounded, i.e. –70 **OR** –70.2 **OR** –70.19 **ALLOW** -70000 up to -70194 (J mol^{-1}) **ALLOW ECF** for an incorrectly calculated **negative** value of ΔG linked to feasibility statement **IGNORE** rounding after 3 SF **ORA** for comment about – sign required for feasibility
	(b)	(ii)	776 (K) ✓ i.e. Maximum temperature = $\frac{\Delta H}{\Delta S} = \frac{-114}{-0.147}$ = 776 (K) **3 SF required** (appropriate from supplied data)	1	AO2.2	

Question			Answer	Marks	AO element	Guidance
	(c)	(i)	**FIRST, CHECK FOR VALUE OF K_p.** **IF** answer = 20.7 (MPa^{-1}), award **4 marks** --- *Equilibrium amounts* n(NO) = 0.4 (mol) **AND** $n(O_2)$ = 0.9 (mol) **AND** $n(NO_2)$ = 1.2 (mol) ✓ *Total moles at equilibrium* n_{tot} = 2.5(mol) ✓ *Partial pressures* $p(NO) = \frac{0.4}{2.5} \times 1.21 = 0.1936$ (MPa) **AND** $p(O_2) = \frac{0.9}{2.5} \times 1.21 = 0.4356$ (MPa) **AND** $p(NO_2) = \frac{1.2}{2.5} \times 1.21 = 0.5808$ (MPa) ✓ *K_p value* $K_p = \frac{0.5808^2}{0.1936^2 \times 0.4356}$ = 20.7 **to 3 SF** (MPa^{-1}) ✓	**4**	AO2.4 ×4	***FULL ANNOTATIONS MUST BE USED*** --- **ALLOW ECF throughout** **ALLOW** 20.6 from 3 SF partial pressures, 0.194, 0.436 and 0.581 **IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below --- **Look for values to 3 SF here: 0.194, 0.436 and 0.581** **ALLOW** **25.0 as ECF (**from omission of partial pressures for **3 marks)**

Question			Answer	Marks	AO element	Guidance
	(c)	(ii)	<table><tr><th>Change</th><th>K_p</th><th>Equilibrium amount of NO_2</th><th>Initial rate</th></tr><tr><td>**Temperature increased**</td><td>smaller</td><td>smaller</td><td>greater</td></tr><tr><td>**Pressure increase**</td><td>same</td><td>greater</td><td>greater</td></tr><tr><td>**Catalyst added**</td><td>same</td><td>same</td><td>greater</td></tr><tr><td></td><td>✓</td><td>✓</td><td>✓</td></tr></table>	**3**	AO1.2 ×3	Mark by **COLUMN** **ALLOW** obvious alternatives for greater/smaller/same, e.g. increases/decreases/ more/less
			Total	**11**		

Question			Answer	Marks	AO element	Guidance
21	(a)	(i)	*(Expt 1 and 2)* $[S_2O_3^{2-}]$ halves, ($[H^+]$ constant), **AND** rate halves **AND** first order (with respect to $[S_2O_3^{2-}]$)✓ *(Expt 2 and 3)* $[S_2O_3^{2-}]$ quarter **AND** $[H^+]$ halves, **AND** rate quarters **AND** zero order (with respect to $[H^+]$)✓	2	AO3.1 ×2	**ALLOW ORA i.e.** *(Expt 2 and 1)* $[S_2O_3^{2-}]$ doubles, ($[H^+]$ constant), **AND** rate doubles **AND** first order with respect to $[S_2O_3^{2-}]$ **ALLOW** comparison of Expt 1 and 3: $[S_2O_3^{2-}]$ × 1/8 **AND** $[H^+]$ halves, **AND** rate × 1/8 **AND** zero order with respect to $[H^+]$
	(a)	(ii)	$S_2O_3^{2-}$ as only reactant species in step 1 ✓ Rest of mechanism correct ✓	2	AO3.2 ×2	Step 1: $S_2O_3^{2-} \rightarrow S + SO_3^{2-}$ Step 2 $SO_3^{2-} + 2H^+ \rightarrow SO_2 + H_2O$ **OR** Step 1 $S_2O_3^{2-} \rightarrow SO_2 + SO^{2-}$ Step 2 $SO^{2-} + 2H^+ \rightarrow S + H_2O$ **Check with Team Leader for other equations**
	(b)	(i)	**Gradient** gradient in range of –5700 to –6100✓ ***E*a calculation** E_a = (–) gradient × 8.314 *e.g. from –5900, E_a = (+) 49052.6 (J mol^{-1})* ✓ E_a to **3SF** and in kJ mol^{-1} ✓ e.g. 49.1 (kJ mol^{-1})	3	AO2.8 ×3	***FULL ANNOTATIONS MUST BE USED*** -- Marks are for intermediate calculations **ALLOW ECF** from an incorrect gradient **ALLOW ECF** on missing × 10^{-3}, e.g. **ALLOW** 2 marks for: gradient = –5.9, leading to E_a = 49.0526 (J mol^{-1}) **AND** 0.0491 (kJ mol^{-1}) **DO NOT ALLOW** a negative E_a

Question			Answer	Marks	AO element	Guidance
	(b)	**(ii)**	ln *A* is intercept at 0 when 1/*T* **OR** x axis is 0 ✓	**1**	AO3.2	
		(iii)	*ln k* ln *k* = –2.59 ✓ *Temperature* $1/T = 3.10 \times 10^{-3}$ (s^{-1}) *T* = 49.6 ºC ✓	**2**	AO3.1 AO3.2	Correct T scores 2 marks **ALLOW ECF** for 1/T from incorrect lnK **shown on the graph** **ALLOW in the range** $1/T = 3.09 – 3.11$ ($\times 10^{-3}$ s^{-1}) T = 48.5 to 50.6 ºC **ALLOW** *T* = 50 ºC
			Total	**10**		

Question			Answer	Marks	AO element	Guidance
22	(a)		**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 13.15 award 2 marks** --- $[H+] = \frac{1.00 \times 10^{-14}}{0.140} = 7.14..... \times 10^{-14}$ (mol) ✓ pH = –log (7.14….. × 10^{-14}) = 13.15 ✓ **2 DP** required	2	AO2.2 ×2	**ALLOW ECF** providing pH>7 Calculator: 7.142857143 × 10^{-14} **ALLOW** pOH method pOH = –log(0.14) = 0.85……… ✓ pH = 14.00 – (0.85……) = 13.15 ✓
	(b)	(i)	$n(H_2SO_4) = 1.60 \times \frac{25.0}{1000} = 0.04(00)$ (mol) **AND** $n(NaOH) = 1.50 \times \frac{55.0}{1000} = 0.0825$ (mol) ✓ 0.04(00) mol H_2SO_4 reacts with 0.08(00) mol NaOH **OR** 1 mol H_2SO_4 reacts with 2 mol NaOH ✓	2	AO2.2 ×2	**ALLOW** 0.0825>0.08

Question			Answer	Marks	AO element	Guidance
	(b)	(ii)	$q = mc\Delta T$ = 80.0 × 4.18 × 13.0 = 4347.2 (J) **OR** 4.3472 (kJ) ✓ $\Delta H_1 = (-)\dfrac{4.3472}{0.0400}$ = (–)108.68 kJ mol^{-1} ✓ $\Delta_{neut}H = (-)\dfrac{108.68}{2}$ = (–)54.34 kJ mol^{-1} ✓ **– sign** for ΔH *value(s)* ✓	**4**	AO2.4 ×4	**FULL ANNOTATIONS MUST BE USED** --- **ALLOW** 3 SF up to calculated answer throughout **ALLOW ECF** from *q* **DO NOT ALLOW** division by *n*(NaOH) **ALLOW** $\Delta_{neut}H$ from ΔH_1 **/2** **ALLOW** alternative methods
	(b)	(iii)	The same **OR** 13°C ✓ (Double the moles so) **double** the energy is spread over **double** the volume	**2**	AO3.1 ×2	**ALLOW** explanation that uses a calculation based on moles, volumes **ALLOW** mass for volume

Question			Answer	Marks	AO element	Guidance
	(c)*		*Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** Reaches a comprehensive conclusion with most detail and few errors for the formation of the buffer **AND** Calculation of the correct buffer pH **AND** Correct mass of N_2O_3. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Reaches a sound conclusion with some detail and some errors for Formation of buffer **AND** Calculation of the buffer pH **OR** Formation of buffer **AND** Mass of N_2O_3. **OR** Calculation of the buffer pH **AND** Mass of N_2O_3. **OR** Partial explanations of formation of the buffer **AND** buffer pH **AND** Mass of N_2O_3. *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** Attempts, with some success, to: Describe formation of buffer **OR** Calculate buffer pH **OR** Obtain mass of N_2O_3. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** No response or no response worthy of credit.	6	AO1.2 ×2 AO2.6 ×2 AO3.1 ×2	**Indicative scientific points may include:** **<u>1. Formation of buffer</u>** • Acid / HNO_2 is in excess • $HNO_2 + NaOH \rightarrow NaNO_2 + H_2O$ • Partial neutralisation of HNO_2 $\rightarrow$ formation of NO_2^-/ $NaNO_2$ • Buffer contains HNO_2 **AND** NO_2^-/$NaNO_2$ **<u>2. Calculation of buffer pH</u>** • $n(HNO_2)$ added = 0.0500 (mol) • $n(NaOH)$ added = 0.0150 (mol) • $n(NO_2^-)$ formed = 0.0150 (mol) • $n(HNO_2)$ remaining = 0.0500 – 0.0150 = 0.0350 (mol) • $K_a = 10^{-3.34} = 4.57\ldots \times 10^{-4}$ (mol dm^{-3}) • Concentrations = mol (volume 1 dm^3) • $[H^+] = \frac{4.57\ldots \times 10^{-4} \times 0.0350}{0.0150}$ $= 1.0665\ldots. \times 10^{-3}$ (mol dm^{-3}) • pH = 2.97 • pH to 2 dec places **<u>3. Calculation of mass of N_2O_3</u>** • 1 mol $N_2O_3 \rightarrow$ 2 mol HNO_2 **OR** $N_2O_3 + H_2O \rightarrow 2HNO_2$ • $n(HNO_2)$ = 0.0500 (mol) • $n(N_2O_3)$ = 0.0500/2 = 0.0250 (mol) • $m(N_2O_3)$ = 0.0250 × 76 = 1.9(0) g
			Total	16		

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