Mark Scheme

Question	Answer	Marks	Guidance
1	A	**1**	
2	B	**1**	
3	C	**1**	ALLOW +6 in the box

Mark Scheme

Question			Answer	Marks		Guidance
4	(a)		*Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** A comprehensive conclusion, using all quantitative data, to calculate the energy change and ΔH values for reactions 3.1 and 3.2 **AND** linking ΔH data using Hess' Law *There is a well-developed line of reasoning which is clear and logically structured. The working throughout is clearly shown. All values calculated with reasonable numbers of SF and correct signs mostly shown, allowing for ECF.* **Level 2 (3–4 marks)** Attempts to describe all three scientific points but explanations may be incomplete. **OR** Explains two scientific points thoroughly with few omissions. *There is a line of reasoning with some logical structure. There may be minor errors in energy change and errors in the calculations of ΔH for reaction 3.1 or reaction 3.2.* **Level 1 (1–2 marks)** Processes raw mass and temperature data and obtains a calculated value for the energy change using $mc\Delta T$ **OR** attempts to obtain values for two scientific points but explanations may be incomplete *There is an attempt at a logical structure with a line of reasoning to obtain a value for energy change. There may be minor errors in calculation of energy change.* **0 marks –** *No response or no response worthy of credit.*	**6**		**Indicative scientific points may include:** **1. Masses and ΔT from raw results** • $m(Na_2O)$ = 1.24 (g) • m(solution) = 25.75 (g) • ΔT = 35.0 (ºC) **Energy change from $mc\Delta T$** • energy released in J **OR** kJ = 25.75 × 4.18 × 35.0 = 3767 (J) **OR** 3.767 (kJ) *(3.767225 unrounded)* --- **2. $\Delta_r H$ for reaction 3.2** • $n(Na_2O) = \frac{1.24}{62.0}$ = 0.0200 (mol) • $\Delta_r H$ value $-\frac{3767}{0.0200}$ = –188 (kJ mol^{-1}) *(–188.36125 unrounded)* --- **3. $\Delta_r H$ for reaction 3.1** • ΔH value for **reaction 3.1** clearly linked to ΔH for **reaction 3.2** and **reaction 3.3** in energy cycle or an expression: ΔH**(3.1)** = ΔH**(3.2)** + 2ΔH**(3.3)** • ΔH**(3.1)** = –188 + (2 × –57.6) = –188 – 115.2 = –303(.2) (kJ mol^{-1}) *(–303.56125 unrounded)* **Note** Throughout, **ALLOW ECF** from previous value **ALLOW** omission of trailing zeroes ---

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	(b)		% uncertainties to at least *1 SF, rounded or truncated* --- **ONE** correct % uncertainty ✓ **BOTH** correct % uncertainties ✓ --- ***mass***: $\frac{0.005 \times 2}{1.24} \times 100$ = 0.8/0.81 **OR** 0.80 (truncated) ΔT: $\frac{0.1 \times 2}{35.0} \times 100$ = 0.6 / 0.57 (%) ✓ *Calculator values:* mass: 0.8064516129 ΔT: 0.5714285714	**2**		**ALLOW** error for uncertainty --- **ALLOW ECF** from mass and ΔT in **2(a)** **IGNORE** % uncertainty of mass of solution --- **ALLOW one** mark for: • 2 calculations with both ×2 factors missing i.e. mass 0.3% **AND** ΔT 0.4% • Not converting to %s using ×2 factors i.e. 0.008 **AND** 0.006
	(c)		**ALLOW** uncertainty **OR** error throughout Greater mass of Na_2O **OR** more Na_2O ✓ For mass, **ALLOW** amount/moles/quantity larger ΔT **OR** reduces % uncertainty in ΔT ✓	**2**		**ALLOW** up to 2 marks based on a single mass measurement: one mass measurement **OR** measure mass directly ✓ *e.g. tare balance* % uncertainty reduced by **half** ✓ --- **IGNORE** • repeat and take average • read to more figures *(same apparatus)* • increase volume (*reduces mass error but increases ΔT error*) • use a cooling curve • use a lid

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	(d)	(i)	sodium nitrate(III)	1		**ALLOW** sodium nitrite **OR** sodium nitrite(III)
	(d)	(ii)	Sodium/Na oxidised from 0 to +1 ✓ Nitrogen/N reduced from +3 to 0 ✓	2		**ALLOW** 1+ for +1 and 3+ for +3 **ALLOW** N_2 for nitrogen **ALLOW** 1 mark for elements **AND** all oxidation numbers correct, but N on oxidised line and Na on reduced line '+' is required in +3 and +1 oxidation numbers
	(d)	(iii)	$2NaNO_2 + 6Na \rightarrow 4Na_2O + N_2$ ✓ **IGNORE** state symbols	1		**ALLOW** multiples, e.g. $NaNO_2 + 3Na \rightarrow 2Na_2O + ½N_2$
			Total	14		

Mark Scheme

Question	Answer	Marks	AO element	Guidance
5	**C**	**1**	AO2.2	
6	**B**	**1**	AO1.2	
7	**D**	**1**	AO1.2	
8	**C**	**1**	AO2.6	

Mark Scheme

Question			Answer	Marks	AO element	Guidance
9	(a)		**Equation**: $Mg + 2CH_3COOH \rightarrow (CH_3COO)_2Mg + H_2$ ✓	3	2.6	**ALLOW** $Mg(CH_3COO)_2$ **ALLOW** multiples **IGNORE** Oxidation numbers in formulae **IGNORE** state symbols
			Oxidation: Mg from 0 to +2 ✓		1.2	Mark independently from equation
			Reduction: H from +1 to 0 ✓		1.2	**ALLOW** 1 mark for correct oxidation numbers but incorrectly linked to redox.
	(b)		$HCOOH + CH_3COOH \rightleftharpoons HCOO^- + CH_3COOH_2^+$ ✓ **A1 B2 B1 A2** **OR** **A2 B1 B2 A1** ✓ **CARE:** Both + and – charges required for products in equilibrium **DO NOT AWARD** the 2nd mark from an equilibrium expression that omits either charge	2	1.2×2	**IGNORE** state symbols (even if wrong) **IF** proton transfer is wrong way around **ALLOW** 2nd mark for idea of acid–base pairs, ***i.e.*** $HCOOH + CH_3COOH \rightleftharpoons HCOOH_2^+ + CH_3COO^-$ **B2 A1 A2 B1** **NOTE** For the 2nd marking point (acid–base pairs), this is the **ONLY** acceptable **ECF** ***i.e. NO ECF*** *from impossible chemistry*
	(c)	(i)	$[H^+] = 10^{-2.72}$ **OR** 1.905×10^{-3} (mol dm^{-3}) ✓ $[CH_3COOH] = \frac{(1.905 \times 10^{-3})^2}{1.78 \times 10^{-5}}$ ✓ (= 0.204 mol dm^{-3})	2	2.4×2	**ALLOW** 2SF up to calculator value of $1.905460718 \times 10^{-3}$ **ALLOW** use of [HA] Mark is for working.

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(ii)	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer =** 2.4×10^{-2} (mol dm^{-3}) **award 4 marks** --- **Calculation of H^+ in buffer** $[H^+]_{buffer} = 10^{-4.00}$ **OR** 1×10^{-4} (mol dm^{-3}) ✓ **Calculation of CH_3COOH in buffer** $n(CH_3COOH)$ **OR** $[CH_3COOH]_{buffer}$ $= \frac{0.204}{1000} \times 400$ **OR** 8.16×10^{-2} ✓ **Calculation of $[CH_3COO^-]$ in buffer (in 1 dm^3)** $[CH_3COO^-]_{buffer} = 1.78 \times 10^{-5} \times \frac{8.16 \times 10^{-2}}{1 \times 10^{-4}}$ **OR** 1.5×10^{-2} (mol dm^{-3}) ✓ **Calculation of original $[CH_3COO^-]$ (in 600 cm^3)** $[CH_3COO^-]_{initial} = (\frac{1.45248 \times 10^{-2} \times 1000}{600})$ $= 2.4 \times 10^{-2}$ (mol dm^{-3}) ✓ --- **4** 3.3×3 3.4×1	**ALLOW ECF** **ALLOW** [HA] and [A^-] in working **ALLOW** 1.5×10^{-2} up to calculator value 1.45248×10^{-2} (mol dm^{-3}) **ALLOW** 2.4×10^{-2} up to calculator value 2.4208×10^{-2} (mol dm^{-3}) **COMMON ERRORS BUT CHECK WORKING** $[CH_3COO^-]_{initial} = 8.7 \times 10^{-3}$ 3 marks *600 and 1000 inverted* $[CH_3COO^-]_{initial} = 3.6 \times 10^{-6}$ 3 marks *$[CH_3COOH] : [H^+]$ inverted* $[CH_3COO^-]_{initial} = 1.3 \times 10^{-6}$ 2 marks *$[CH_3COOH] : [H^+]$ inverted AND 600 and 1000 inverted* No volumes used = 3.6×10^{-2} 2 marks

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			ALLOW alternative approach based on Henderson–Hasselbalch equation (**ALLOW** $-\log K_a$ for pK_a) e.g. $pH = pK_a + \log\frac{[CH_3COOH]}{[CH_3COO^-]}$ **OR** $pK_a - \log\frac{[CH_3COO^-]}{[CH_3COOH]}$ **OR** $4 = 4.75 + \log\frac{8.16 \times 10^{-2}}{[CH_3COO^-]}$ **OR** $4.75 - \log\frac{[CH_3COO^-]}{8.16 \times 10^{-2}}$ ✓ $\log[CH_3COO^-] = 4 - 4.75 - 1.09 = -1.84$ ✓ $[CH_3COO^-]_{buffer} = 1.5 \times 10^{-2}$ ✓ $[CH_3COO^-]_{initial} = 2.4 \times 10^{-2}$ ✓			**ALLOW** $-\log K_a$ for pK_a ----------
			Total	**12**		

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10	(a)	(i)	**Overall equation AND state symbols:** **M**(s) + 2HCl(aq) → **M**Cl$_2$(aq) + H$_2$(g) ✓ **STATE SYMBOLS required in overall equation ONLY** **Half equations:** Oxidation **M** → **M**$^{2+}$ + 2e$^-$ ✓ Reduction 2H$^+$ + 2e$^-$ → H$_2$ **OR** H$^+$ + e$^-$ → ½H$_2$ ✓	**3**	2.6×3	**All 3 marks are independent.** **IGNORE** charges/oxidation numbers shown around overall *equation.* *Treat as rough working* **ALLOW** overall equation shown with some or all ions that are present e.g. (**with state symbols**) M + 2H$^+$ → M^{2+} + H$_2$ M + 2HCl → M^{2+} + 2Cl$^-$ + H$_2$ M + 2H$^+$ + 2Cl$^-$ → M^{2+} + 2Cl$^-$ + H$_2$ In half equations, **IGNORE** state symbols even is wrong BUT half equations MUST only have species that change. For charges on half equations, **ALLOW** M^{+2} for M^{2+} **OR** H^{+1} for H$^+$ **ALLOW** **M** – 2e$^-$ → **M**$^{2+}$ If **BOTH** half equations are correct but shown with oxidation and reduction the wrong way around, award 1 mark from the 2 marks for half equations
	(a)	(ii)	Bubbles/effervescence/fizzing stops ✓ **M**/metal/solid has disappeared/dissolved ✓	**2**	3.3×2	Responses must imply that all fizzing has stopped and that all the solid has dissolved **i.e.** 'metal disappears' is not quite enough. 'All the metal disappears' is enough **IGNORE** constant mass **IGNORE** no increase in temperature
	(a)	(iii)	H$^+$ + OH$^-$ → H$_2$O ✓	**1**	2.5	**ALLOW** multiples e.g. 2H$^+$ + 2OH$^-$ → 2H$_2$O **IGNORE** state symbols, even if wrong

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	(a)	(iv)	**Mean titre** **1 mark** $= \frac{(27.30 + 27.20)}{2} = 27.25$ (cm^3) ✓ **Analysis of results** **5 marks** n(NaOH) $= 27.25 \times \frac{0.320}{1000} = 8.72 \times 10^{-3}$ (mol) ✓ n(HCl) in 25.0 cm^3 = n(NaOH) n(HC*l*) in 250 cm^3 $= 8.72 \times 10^{-3} \times 10 = 8.72 \times 10^{-2}$ (mol) ✓ n(HC*l*) that reacted with **M** $= 0.210 - 8.72 \times 10^{-2} = 0.1228$ (mol) ✓ n(**M**) that reacted $= \frac{0.1228}{2} = 0.0614$ (mol) ✓ A_r of **M** $= \frac{6.90}{0.0614} = 112.4$ **AND M** = cadmium/Cd ✓	**6**	2.8×5 3.2	***FULL ANNOTATIONS MUST BE USED*** --- **Common error:** Incorrect mean from all 3 titres = 27.35 cm^3 **Use ECF throughout** Intermediate values for working to **at least 3 SF.** **TAKE CARE:** Value written down may be truncated calculator value. Depending on rounding, either can be credited. **ALLOW** 0.123 (mol) i.e. 3SF **ALLOW** 0.0615 (mol) **IF** 0.1228 rounded to 0.123 **ALLOW** 112.2 from 0.0615 **AND** Cd **ALLOW** A_r to nearest whole number **ALLOW ECF** for metal closest to calculated A_r **DO NOT ALLOW** Ga **OR** Sc (Form 3+ ions only)
			COMMON ERRORS: Mean of 27.35 (use of all 3 titres) → 8.752×10^{-3} → 8.752×10^{-2} → 0.12248 → 0.06124 → 112.7 **AND** Cd: *5 marks* No ÷2 to *obtain n(M)* → 56.2 **AND** Fe (from 27.25) *5 marks* → 56.3 **AND** Fe (from 27.35) *4 marks* *No subtraction from 0.210* → $8.72 \times 10^{-2}/2$ → 4.36×10^{-2} → $\frac{6.90}{4.36 \times 10^{-2}}$ → 158.2 to 158.3 **AND** Tb *5 marks*			No ×10 to *obtain n(HCl) in 250 cm^3* *5 marks* $0.210 - 8.72 \times$ **10^{-3}** $= 0.20128$ **OR** 0.201 $n(M) = 0.20128/2 = 0.10064$ $A_r = 6.90/0.10064 = 68.56$ → Zn *No ×10 and no ÷ 2* *4 marks* $0.210 - 8.72 \times$ **10^{-3}** $= 0.20128$ $A_r = 6.9/0.20128 = 34.28$ → Ca *Omitting initial titration calculation* *Zero marks* $0.210/2 = 0.105$ → $6.9/0.105 = 65.71$ → Zn

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	(b)	**(i)**	$n(CO_2) = \frac{2.75}{44} = 0.0625$ (mol) ✓	**1**	2.8	
	(b)	**(ii)**	$n(\mathbf{X}_2CO_3) = 0.0625$ (mol) **OR** 0.0625 used in molar mass expression below ✓ Molar mass of $\mathbf{X}_2CO_3$ $= \frac{14.57}{0.0625} = 233.12$ (g mol^{-1}) ✓ Metal **X** = Rubidium/Rb ✓	**3**	1.2 2.8 3.2	**ALLOW ECF** from **4b(i)** **ALLOW** to nearest whole number **DO NOT ALLOW** strontium/Sr *wrong carbonate formula* --- **ALLOW ECF** for **X** from calculated molar mass **ONLY IF X** is a Group 1 metal **OR** Ag **Working:** Mass of **X** in $\mathbf{X}_2CO_3$ = 233.14 – 60 = 173.12 **OR** 173 A_r of **X** $= \frac{173.12}{2}$ **OR** 86.56 **OR** 85.6 **OR** 87
	(c)	**(i)**	Reweigh to constant mass ✓	**1**	3.4	**ALLOW** response implying leaving for longer and monitoring by reweighing to constant mass, e.g. Leave flask until the mass does not change **IGNORE** 'leave for longer' **OR** wait till fizzing stops *Needs link to constant mass* **ALLOW** Collect gas until gas volume is constant
	(c)	**(ii)**	Mass (CO_2) **OR** $n(CO_2)$ loss would be smaller **OR** Mass X_2CO_3 **OR** $n(X_2CO_3)$ reacted (seems to be) less ✓ Molar mass would be greater ✓	**2**	3.1 3.2	
			Total	**19**		