<table>
<tr><th colspan="3">Question</th><th>Expected answers</th><th>Marks</th><th>Additional guidance</th></tr>
<tr><td>1</td><td>a</td><td></td><td>graph:
Rate does not change with concentration
AND zero-order with respect to I_2 ✓

initial rates data:
Mark independently

When $[(CH_3)_2CO] \times 2$, rate × 2 (2^1) ✓
1st order with respect to $(CH_3)_2CO$ ✓

When [HCl] x 2.5, rate × 2.5 ✓
1st order with respect to HCl ✓</td><td></td><td>ANNOTATIONS MUST BE USED

ALLOW (straight) line with zero gradient AND zero-order
ALLOW horizontal line AND zero-order
IGNORE just ‘constant line’ OR just ’straight line’
also fits 1st order

CARE with comparisons in opposite direction
ALLOW $[(CH_3)_2CO] \times 0.5$, rate × 0.5 (0.5^1)

ALLOW [HCl] × 0.4, rate × 0.4 (0.4^1)
ALLOW H^+ for HCl

CARE: Comparison of Experiments 1 and 3 may be valid despite BOTH concentrations changing</td></tr>
<tr><td></td><td></td><td></td><td>Rate equation and rate constant:

rate = $k[(CH_3)_2CO(aq)]\,[HCl(aq)]$ ✓
$k = \dfrac{rate}{[(CH_3)_2CO(aq)]\,[HCl(aq)]}$ OR
$\dfrac{2.10 \times 10^{-9}}{(1.50 \times 10^{-3}) \times (2.00 \times 10^{-2})}$ ✓

= 7(.00) × 10^{-5} OR 0.00007(00) ✓

units: $dm^3\ mol^{-1}\ s^{-1}$ ✓</td><td>9</td><td>ALLOW ECF from incorrect orders
In rate equation, square brackets are required

rate = $k[(CH_3)_2CO(aq)][HCl(aq)][I_2(aq)]^0$
ALLOW H^+ for HCl
IGNORE state symbols, even if wrong

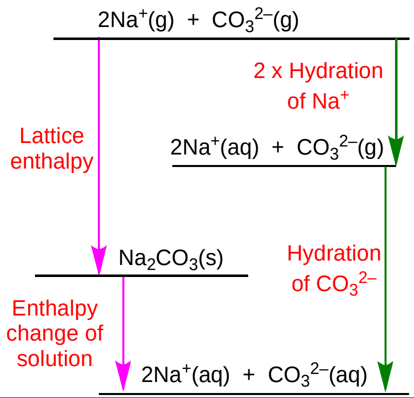
ALLOW ECF for units ‘correct’ for incorrect expression used to calculate k, e.g. upside down or wrong orders
$\dfrac{[(CH_3)_2CO(aq)]\,[H^+(aq)]}{rate}$ ✗ units: $mol\ s\ dm^{-3}$ ✓</td></tr>
</table>

Question			Expected answers	Marks	Additional guidance
1	b		**step 1**: $H_2(g)$ + $ICl(g)$ $\longrightarrow$ $HCl(g)$ + $HI(g)$ LHS of step 1 ✓ **step 2**: $HI(g)$ + $ICl(g)$ $\longrightarrow$ $HCl(g)$ + $I_2(g)$ products of step 1 **AND** step 2 ✓	2	State symbols **NOT** required **2nd mark** can **ONLY** be awarded provided that • **1st mark** has been awarded • **step 1 AND step 2** add up to the overall equation. e.g. **ALLOW** $\longrightarrow$ $H_2ICl(g)$ **step 2**: $H_2ICl(g)$ + $ICl(g)$ $\longrightarrow$ $2HCl(g)$ + $I_2(g)$ In **step 2**, **ALLOW** inclusion of extra species on **both** sides of the equation **only** if they cancel, e.g. $HI(g)$ + $HCl(g)$ + $ICl(g)$ $\longrightarrow$ $2HCl(g)$ + $I_2(g)$
			Total	**11**	

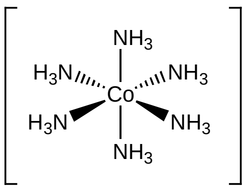
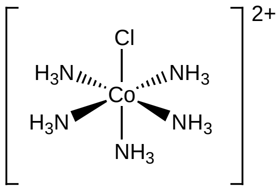
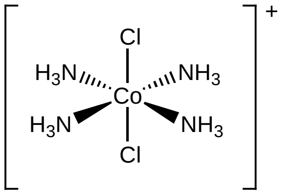
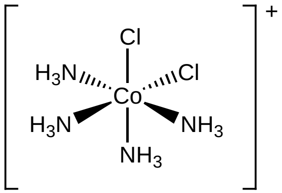
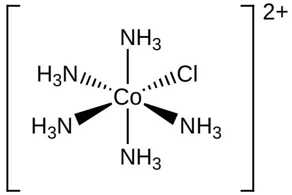
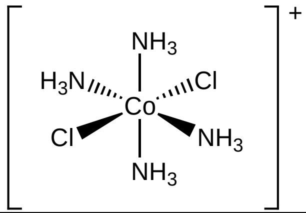
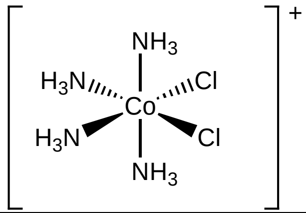
Question			Expected answers	Marks	Additional guidance
2	a		(The enthalpy change that accompanies) the formation of **one mole** of a(n ionic) compound ✓ from its **gaseous ions** ✓ (under standard conditions)	2	**IGNORE** 'Energy needed' **OR** 'energy required' **ALLOW** as alternative for compound: lattice, crystal, substance, solid, product **Note**: 1st mark requires **1 mole** **2nd mark** requires **gaseous ions** **IF** candidate response has '1 mole of gaseous ions', award 2nd mark but **NOT** 1st mark **IGNORE** reference to 'constituent elements' **IGNORE**: $2Na^+(g) + O^{2-}(g) \longrightarrow Na_2O(s)$ *Question asks for a definition, not an equation*
	b	i	**C** (or 2**C**) **A** **B** **D** **G** **E** (or 2**E**) **F** All seven correct ✓✓✓ Five **OR** six correct ✓✓ Three **OR** four correct ✓	3	**ALLOW** **496 (OR** 992**)** **–141** **790** **249** **G OR Lattice enthalpy/LE** [**OR** answer to **(ii)**] **108** (**OR** 216) **–414**
		ii	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = –2520 (kJ mol^{-1}) award 2 marks** -- $-414 = (2 \times 108) + 249 + (2 \times 496) + (-141) + 790\ ) + \Delta H_{LE}$ **OR** $\Delta H_{LE} = -414 - [\ (2 \times 108) + 249 + (2 \times 496) + (-141) + 790\ ]$ ✓ $= -414 - 2106 =$ **-2520** (kJ mol^{-1}) ✓	2	**IF** there is an alternative answer, check **the list below for marking of answers from common errors** -- **ALLOW** for **1 mark**: –1692 wrong sign for 414 –1916 2 × 108 and 2 × 496 not used for Na^+ –2412 2 × 108 not used for Na^+ –2024 2 × 496 not used for Na^+ +2520 wrong sign for final answer –2802 sign changed for 1st electron affinity of oxygen –2395.5 atomisation of oxygen halved

Question			Expected answers	Marks	Additional guidance
					Any other number: **CHECK** for **ECF** from 1st marking point for expressions with **ONE** error only
2	c		**ALLOW** reverse argument throughout (**ORA**) ***Comparison of size AND charge of cations*** Mg^{2+} is smaller **AND** Mg^{2+} has a greater charge **OR** Mg^{2+} has **a** greater charge density ✓ ***Comparison of size of anions*** S^{2-} is larger **OR** S^{2-} has a smaller charge density ✓ ***Comparison of attraction of a cation and an anion*** Mg^{2+} has stronger attraction **OR** Na^{+} has weaker attraction **AND** S^{2-} has weaker attraction **OR** O^{2-} has stronger attraction ✓	**3**	***ANNOTATIONS MUST BE USED*** **NOTE**: For **ALL** marking points, assume that the following refer to 'ions', Mg^{2+}, etc. For 'ions', **ALLOW** 'atoms' For Mg^{2+}, Na^{+}, O^{2-} and S^{2-}, **ALLOW** symbols: Mg, Na, O and S **ALLOW** names: magnesium, sodium, oxygen, oxide, sulfur, sulfide **BUT DO NOT ALLOW** molecules *i.e.* **ALLOW** Mg has a smaller (atomic) radius **IGNORE** idea of close packing of ions --- **ORA**: Na^{+} is larger **AND** Na^{+} has a smaller charge **OR** Na^{+} has a smaller charge density ✓ **IGNORE** just Mg^{2+} is small *comparison required* **ORA** O^{2-} is smaller **OR** O^{2-} has a larger charge density ✓ **IGNORE** just S^{2-} is large *comparison required* **ALLOW** pull for attraction **ALLOW** 'attracts with more force' for greater attraction **BUT** … **IGNORE** just 'greater force' (*could be repulsion*) **OR** comparison of bond strength/energy to break bonds **IGNORE** comparisons of numbers of ions

Question			Expected answers	Marks	Additional guidance
	d	i	Cycle needs **formation** of CO_3^{2-} ions (from C and O) ✓ *i.e.* ***NOT*** *breaking up of* CO_3^{2-} *ion*	1	**ALLOW** carbonate ion contains C and O **ALLOW** carbonate ion contains 2 elements **IGNORE** sodium carbonate contains 3 elements **IGNORE** carbonate ion has covalent bonds
2	d	ii	See also **Appendix 1** at end of mark scheme **Mark allocation** **1 –** $2Na^+(g)$ + $CO_3^{2-}(g)$ on a top line **AND** $Na_2CO_3(s)$ on a lower line **AND** 'Lattice enthalpy' label (as below) links the lines ✓ **2 –** $2Na^+(g)$ + $CO_3^{2-}(g)$ on a top line **AND** $2Na^+(aq)$ + $CO_3^{2-}(g)$ on a middle line **AND** $2Na^+(aq)$ + $CO_3^{2-}(aq)$ on a lower line **AND** 'ΔH hydration' labels (as below) link the lines ✓ **NOTE:** For hydration labels, see diagram below **2** x hydration of Na^+ **OR** hydration of **2** x Na^+ is **required** 3 – ΔH solution' label **BELOW** $Na_2CO_3(s)$ **AND ALL** arrows in correct directions ✓	3	***ANNOTATIONS MUST BE USED*** **MARK AS FOLLOWS** **1.** Mark the cycle **2. IF** there is **no cycle**, mark the equation below -- **State symbols** are required for **ALL** species **IGNORE** direction of any arrows until **MARK 3** **ALLOW** $Na_2CO_3(aq)$ on a lower line as an alternative for $2Na^+(aq)$ + $CO_3^{2-}(aq)$ **ALLOW** CO_3^{2-} hydrated first: i.e. $2Na^+(g)$ + $CO_3^{2-}(aq)$ on middle line **ALLOW** two hydration stages combined i.e. $2Na^+(g)$ + $CO_3^{2-}(g)$ on a top line **AND** $2Na^+(aq)$ + $CO_3^{2-}(aq)$ on a lower line **AND BOTH** 'Hydration' labels link the lines ✓ **IF** cycle shown using $NaCO_3$, Na^+ and CO_3^- **ALLOW ECF** for third marking point only **NOTE: DO NOT ALLOW ECF** from any other species **For simple energy cycles** a maximum of 2 marks only can be awarded **–** See **APPENDIX 1** -- **For an equation,** only **1 mark** can be awarded Lattice enthalpy = $-\Delta H$(solution) Na_2CO_3 + [2 x ΔH(hydration) Na^+] + ΔH(hydration) CO_3^{2-}

Question			Expected answers	Marks	Additional guidance
					**OR** Lattice enthalpy + ΔH(solution) Na_2CO_3 = 2 x ΔH(hydration) Na^+ + ΔH(hydration) CO_3^{2-} ✓ **IGNORE** state symbols for equation approach
			Total	**14**	

Question			Expected answers	Marks	Additional guidance
3	**a**		Co: $(1s^22s^22p^6)3s^23p^63d^74s^2$ ✓ Co^{3+}: $(1s^22s^22p^6)3s^23p^63d^6$ ✓	**2**	**ALLOW** $(1s^22s^22p^6)3s^23p^64s^23d^7$ (i.e. 4s before 3d) **ALLOW** upper case D, etc. and subscripts, e.g. $[Ar]4S_23D_7$ If included, **ALLOW** $4s^0$
	b		catalyst **OR** coloured ✓	**1**	**IGNORE** forms different oxidation states
	c		Donates an electron/lone pair to a metal ion **OR** forms a coordinate bond to a metal ion ✓	**1**	**ALLOW** donates an electron pair/lone pair to a metal/transition element **ALLOW** dative (covalent) bond for coordinate bond
	d	**i**	$Co(OH)_2$ ✓ precipitation ✓	**2**	Mark independently **ALLOW** $Co(OH)_2(H_2O)_4$ **ALLOW** precipitate (reaction)
		ii	$CoCl_4^{2-}$ ✓ ligand substitution ✓	**2**	Mark independently **ALLOW** ligand exchange **DO NOT ALLOW** just substitution

Question			Expected answers	Marks	Additional guidance
3	e	i	 ✓  ✓  ✓  ✓	4	***ANNOTATIONS MUST BE USED*** **CARE**: Cl can be on any position, e.g. for **B**  complex ions in **C** and **D** can be other way around In one complex ion, the 2 Cls must be opposite one another In the other complex ion, the 2 Cls must be next to one another **CARE**: Cl atoms can be on any position, e.g. for **C** and **D**  
			Marking sequence **See also Appendix 2 for examples** **1.** Mark any correct complex ions first Do **not** look at these complex ions again **2.** Mark with crosses any complex ions with incorrect ligands. This could include Cl in complex **A**, and NH_3Cl and $NH_3^+Cl^-$, but **NOT** NH_3------ connectivity on the **LEFT** only and **NOT** Cl^- and **NOT** just NH_3^+ Do **not** look at these complex ions again **3.** In the remaining complex ions, identify errors in ligands (See Appendix 2): e.g. • NH_3 ligands bonded to an H on the **LEFT** only: NH_3----- *(connectivity error)* • Cl^- • NH_3^+ Mark these complex ions to maximise errors but treat any incorrectly bonded NH_3, Cl^- and NH_3 as **ECF**		

Question			Expected answers	Marks	Additional guidance
			SEE APPENDIX 2 FOR EXAMPLES		
3	**e**	**ii**	143.4 **OR** 107.9 + 35.5 (g mol^{-1}) used *i.e. molar mass AgCl* **OR** amount of AgCl = 0.02(000) mol ✓ **Ratio** ratio complex : **Cl^-** = 1 : 2 **OR** 0.01 : 0.02 ✓ **Identification – available from 1 : 2 ratio OR 2Cl^-** Therefore the complex is **B** ✓	**3**	**DO NOT ALLOW** $AgCl_2$ **DO NOT ALLOW** $\frac{2.868}{0.01}$ *0.01 linked to AgCl, not complex* **ALLOW** this mark **ONLY** for evidence of Cl^- ***Quality of Written Communication*** Identification as **B** is dependent on correct 1 : 2 ratio **OR 2**Cl^- for this mark
			Total	**15**	

Question			Expected answers	Marks	Additional guidance
4	a	i	A strong acid completely dissociates **AND** a weak acid partially dissociates ✓	1	**ALLOW** ionises for dissociates
		ii	(K_a =) $\dfrac{[H^+]\,[NO_2^-]}{[HNO_2]}$ ✓	1	**DO NOT ALLOW** $\dfrac{[H^+]^2}{[HNO_2]}$ Square brackets **are required**
		iii	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 1.89 award **2 marks** **IF** answer = 1.9 award **1 mark** --- pH = –log 0.0129 = **1.89** ✓✓ **OR** pH = –log 0.0129 = **1.9** ✓ ***not** two decimal places*	2	**IF** there is an alternative answer to more decimal places, check calculator value -- **Working to get to 0.0129 (mol dm^{-3})** **Not required and no credit** $[H^+] = \sqrt{K_a \times [HNO_2]}$ **=** $\sqrt{4.43 \times 10^{-4} \times 0.375}$ **ALLOW 1 mark** for an answer with more than 2 decimal places that rounds back to 1.89
		iv	HNO_3 + HNO_2 ⇌ NO_3^- + $H_2NO_2^+$ ✓ Acid 1 Base 2 Base 1 Acid 2 ✓	2	State symbols **NOT** required **ALLOW** 1 **AND** 2 labels the other way around. **ALLOW** 'just acid' and 'base' labels if linked by lines so that it is clear what the acid–base pairs are **IF** proton transfer is wrong way around **ALLOW** 2nd mark for idea of acid–base pairs, *i.e.* HNO_3 + HNO_2 ⇌ $H_2NO_3^+$ + NO_2^- ✗ Base 2 Acid 1 Acid 2 Base 1 ✓ **NOTE** For the 2nd marking point (acid–base pairs), this is the **ONLY** acceptable **ECF**

Question			Expected answers	Marks	Additional guidance
					i.e., ***NO ECF*** *from impossible chemistry*
4	b	i	Proton acceptor ✓	1	**ALLOW** H^+ acceptor
		ii	**Marks are for correctly calculated values.** **Working shows how values have been derived.** $[OH^-] = 2 \times 0.04(00) = 0.08(00)$ (mol dm^{-3}) ✓ $[H^+] = \dfrac{1.00 \times 10^{-14}}{0.08(00)}$ **OR** 1.25×10^{-13} (mol dm^{-3}) ✓ pH = $-\log 1.25 \times 10^{-13}$ = **12.90** ✓ -- **pOH variation (also worth 3 marks)** $[OH^-] = 2 \times 0.04(00) = 0.08(00)$ (mol dm^{-3}) ✓ pOH $-\log 0.08(00) = 1.10$ ✓ pH = 14.00 – 1.10 = 12.90 ✓	3	**ALLOW** by **ECF** $\dfrac{1.00 \times 10^{-14}}{\text{calculated value of } [OH^-]}$ **DO NOT ALLOW** 12.9 *not* ***two*** *decimal places* -------------------------------------- **COMMON ERRORS** 12.60 ✓✓ *no × 2 for [OH⁻]* 12.6 ✓ *no × 2 for [OH⁻]* ***AND*** *1 DP only* 12.30 ✓✓ *÷ 2 [OH⁻]* 12.3 ✓ *÷ 2 [OH⁻]* ***AND*** *1 DP only* 1.40 **NO** marks
	c		$Ca(OH)_2 + 2HNO_2 \rightarrow Ca(NO_2)_2 + 2H_2O$ ✓ $H^+ + OH^- \longrightarrow H_2O$ ✓	2	**ALLOW**: $2H^+ + 2OH^- \rightarrow 2H_2O$

Question			Expected answers	Marks	Additional guidance
4	d	i	**Equilibrium** $H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$ ✓		***ANNOTATIONS MUST BE USED*** **Equilibrium sign is required** **IGNORE** $HA \rightleftharpoons H^+ + A^-$ **DO NOT ALLOW** $H_2CO_3 \rightleftharpoons 2H^+ + CO_3^{2-}$ **DO NOT ALLOW** $NaHCO_3 \rightleftharpoons Na^+ + HCO_3^-$ **IGNORE** $H_2O + CO_2 \rightleftharpoons H_2CO_3$
			Action of buffer **Added alkali** H_2CO_3 reacts with added alkali **OR** $H_2CO_3 + OH^- \rightarrow$ **OR** added alkali reacts with H^+ **OR** $H^+ + OH^- \rightarrow$ ✓ Equilibrium $\rightarrow$ right **OR** equilibrium shifts forming H^+ **OR** HCO_3^- ✓		**IF** $HA \rightleftharpoons H^+ + A^-$ **OR** $H_2CO_3 \rightleftharpoons 2H^+ + CO_3^{2-}$ have been used above: **ALLOW** all marks that meet marking alternatives as written **NOTE** The 1st '**added acid**' mark **cannot** then be accessed Equilibrium responses **must** refer back to a written equilibrium **BUT IF** $H_2CO_3 \rightarrow H^+ + HCO_3^-$ shown above, assume that any equilibrium comments apply to the correct equilibrium **IF** more than one equilibrium shown, it **must** be clear which equilibrium is being referred to **ALLOW** added alkali reacts with weak acid ***Quality of Written Communication*** Mark is for linking the action of the buffer in controlling added alkali and hence pH

Question			Expected answers	Marks	Additional guidance
			Added acid HCO_3^- reacts with added acid ✓ Equilibrium → left **OR** equilibrium shifts forming H_2CO_3 ✓	**5**	**HCO_3^-** is **required** for this mark **BUT** … **ALLOW** added acid reacts with conjugate base **ONLY** if HCO_3^- is present in equilibrium with H_2CO_3 **DO NOT ALLOW** salt reacts with added acid
4	d	ii	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = **6.6 : 1** **OR** **1 : 0.15** **CHECK** ratio is HCO_3^- : H_2CO_3 and award **5 marks.** **IF** answer = **0.15 : 1** , **CHECK** ratio is H_2CO_3 : HCO_3^- and award **4 marks** -- In blood at pH 7.40, $[H^+] = 10^{-pH} = 10^{-7.40} = 3.98 \times 10^{-8}$ (mol dm^{-3}) ✓ $K_a = \frac{[H^+]\,[HCO_3^-]}{[H_2CO_3]} = \frac{3.98 \times 10^{-8} \times 10.5}{1}$ **OR** $K_a = 4.18 \times 10^{-7}$ (mol dm^{-3}) ✓ In blood at pH 7.20, $[H^+] = 10^{-pH} = 10^{-7.20} = 6.31 \times 10^{-8}$ (mol dm^{-3}) ✓ $\frac{[HCO_3^-]}{[H_2CO_3]} = \frac{K_a}{[H^+]}$ **OR** $\frac{4.18 \times 10^{-7}}{6.31 \times 10^{-8}}$ ✓ $= \frac{6.6}{1}$ **OR** 6.6 : 1 ✓ (up to calc. value, see below) **ALLOW** any answer with > 1 decimal place that rounds back to 6.62 **OR** 6.63	 **5**	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below --- ***ANNOTATIONS MUST BE USED*** **FOR ALTERNATIVE** using Henderson–Hasselbalch equation below --- **ALLOW** 3.98×10^{-8} up to calculator value of $3.981071706 \times 10^{-8}$ correctly rounded **ALLOW** 6.31×10^{-8} up to calculator value of $6.309573445 \times 10^{-8}$ correctly rounded --- **Common errors** 0.15 : 1 ✓✓✓✓ *Inverse ratio of H_2CO_3 : HCO_3^-* 16.6 : 1 **OR** 0.06 : 1 ✓✓✓✓ *10.5/1 swapped over in 2nd mark giving K_a value of 3.79×10^{-9}* ***ALLOW** answer with > 1 decimal place that rounds back to 16.64 **OR** 16.65*
			ALTERNATIVE approach for concentrations using Henderson–Hasselbalch equation ***(5 marks)*** $pH = pK_a + \log\frac{[HCO_3^-]}{[H_2CO_3]}$ **OR** $-\log K_a + \log\frac{[HCO_3^-]}{[H_2CO_3]}$ ✓ $pK_a = pH - \log\frac{[HCO_3^-]}{[H_2CO_3]} = 7.40 - \log\frac{10.5}{1} = 6.38$ ✓ (subsumes previous mark) Calculator: 6.378810701		

Question			Expected answers	Marks	Additional guidance
			At pH = 7.20, $\log \frac{[HCO_3^-]}{[H_2CO_3]}$ = pH – pK_a = 7.20 – 6.38 = 0.82 ✓ (subsumes previous mark) $\frac{[HCO_3^-]}{[H_2CO_3]} = 10^{0.82}$ ✓ $= \frac{6.6}{1}$ **OR** 6.6 : 1 ✓		
			Total	**22**	

Question			Expected answers	Marks	Additional guidance
5	a	i	Complete circuit with electrodes to voltmeter **AND** salt bridge between solutions ✓ Fe^{3+}/Fe^{2+} half-cell with Pt electrode **AND** 1 mol dm^{-3}/ 1 M Fe^{2+} and 1 mol dm^{-3}/ 1 M Fe^{3+} ✓ Ni electrode in (1 mol dm^{-3}) Ni^{2+} half-cell ✓	3	circuit shown **must** be complete, *i.e. must be capable of working* salt bridge **must** be labelled. electrodes **AND** salt bridge **must** dip into/touch both solutions **ALLOW** cells drawn either way around **ALLOW** Fe^{3+}/Fe^{2+} 1 mol dm^{-3} / 1 M /1 molar **ALLOW BOTH** solutions same concentration/equimolar **DO NOT ALLOW** 1 mol **OR** 1 dm^{-3} **IGNORE** any temperature or pressure, even if wrong
		ii	1.02 V **AND** – sign ✓ 0.49 V **AND** + sign ✓	2	**IGNORE** any sign **BEFORE** cell potential **ALLOW 1 mark** for correct values **AND** signs **BOTH** the wrong way round: *i.e.*1.02 V **AND** + sign **AND** 0.49 V **AND** – sign
	b		**Cell A** (based on **1** and **2**) $Ni + 2Fe^{3+} \longrightarrow Ni^{2+} + 2Fe^{2+}$ ✓ **Cell B** (based on **1** and **3**) $2Cr + 3Ni^{2+} \longrightarrow 2Cr^{3+} + 3Ni$ ✓ **concentrations** (of the ions in each cell) change **OR** **concentrations** are not standard ✓	3	In equations, **ALLOW** equilibrium sign, $\rightleftharpoons$ instead of $\rightarrow$ **Equations are required** for the first two marking points **ALLOW** $Ni \longrightarrow Ni^{2+} + 2e^{-}$ **ALLOW** $Ni^{2+} + 2e^{-} \longrightarrow Ni$ **ALLOW** any statement that a **concentration** is changing **IGNORE** 'non-standard conditions'
	c	i	$MH + OH^{-} \longrightarrow M + H_2O + e^{-}$ ✓	1	**ALLOW** $MH \longrightarrow M + H^{+} + e^{-}$
		ii	adsorbed (on a solid) **OR** on the surface (of a solid) **OR** as a liquid under pressure ✓	1	**DO NOT ALLOW** adsorbed **into** the solid ***CON*** **DO NOT ALLOW** just 'as a liquid'
			Total	**10**	

Question			Expected answers	Marks	Additional guidance
6	a		$\Delta G = \Delta H - T\Delta S$ ✓	1	
	b		process — sign $2CO(g) + O_2(g) \longrightarrow 2CO_2(g)$ — **−** $NaCl(s) + (aq) \longrightarrow NaCl(aq)$ — **+** $H_2O(l) \longrightarrow H_2O(s)$ — **−** $Mg(s) + H_2SO_4(aq) \longrightarrow MgSO_4(aq) + H_2(g)$ — **+** $CuSO_4(s) + 5H_2O(l) \longrightarrow CuSO_4{\bullet}5H_2O(s)$ — **−** **All 5 correct $\longrightarrow$ 2 marks** ✓✓ **4 correct $\longrightarrow$ 1 mark** ✓	2	
	c		$\Delta S = (4 \times 211 + 6 \times 189) - (4 \times 192 + 5 \times 205)$ ✓ $\Delta S = (+)185\ (J\ K^{-1}\ mol^{-1})$ ✓	2	**ALLOW ECF** from working line above from a single error --------------------------------------- **COMMON ERRORS** $(+)3\ (J\ K^{-1}\ mol^{-1})$ ✓ $(211 + 189) - (192 + 205)$ $-185\ (J\ K^{-1}\ mol^{-1})$ ✓ *incorrect sign*
	d		With increasing temperature $T\Delta S$ is more negative **OR** $T\Delta S$ decreases **OR** $-T\Delta S$ increases **OR** $\|T\Delta S\|$ increases **OR magnitude** of $T\Delta S$ increases ✓ At high temperature $T\Delta S$ is more negative that ΔH **OR** at high T, $T\Delta S$ outweighs/is more significant than ΔH **OR** At low temperature $\Delta H - T\Delta S < 0$ **OR** At high temperature $\Delta H - T\Delta S > 0$ ✓	2	***ANNOTATIONS MUST BE USED*** **DO NOT ALLOW** just $T\Delta S$ increases **DO NOT ALLOW** At high T, '$-T\Delta S$ is greater (than ΔH)' ***APPROACH BASED ON TOTAL ENTROPY:*** With increasing temperature $\Delta H/T$ is less negative **OR** $\Delta H/T$ increases **OR** $-\Delta H/T$ decreases **OR** $\|\Delta H/T\|$ decreases **OR** magnitude of $\Delta H/T$ decreases ✓ **ALLOW** at high temperatures $\Delta S - \Delta H/T < 0$

Question			Expected answers	Marks	Additional guidance
					OR ΔS is more negative than $\Delta H/T$ **OR** ΔS outweighs/ is more significant than $\Delta H/T$
6	e		(For feasibility,) $\Delta G < 0$ **OR** $\Delta G = 0$ **OR** $0 < \Delta H - T\Delta S$ **OR** $0 = \Delta H - T\Delta S$ **OR** $0 = 493 - T \times 543/1000$ ✓ $T = \dfrac{\Delta H}{\Delta S} = 493 \times 1000/543$ ✓ = 908 K ✓ Units of temperature are **required**	3	**ALLOW** total entropy statement: ΔS(total) = 0 **OR** ΔS(total) >0 **ALLOW** $0 = 493 - T \times 543$ ✓ *i.e.* This *mark focuses on* ΔG ***OR*** $\Delta H - T\Delta S$ *being = 0 and* ***NOT*** *on conversion of* ΔS *value into kJ* K^{-1} mol^{-1} **Mark temperature given on answer line** **ALLOW** 3 SF up to calculator value 907.9189687 correctly rounded, e.g. 907.9, 907.92 **ALLOW** temperature in ºC: i.e. **ALLOW** by subtraction of 273: 635, 634.9, 634.91 ^{o}C **ALLOW** by subtraction of 273.15: 635, 634.8, 634.77 ^{o}C up to calculator value correctly rounded **ALLOW** C for ºC; ºK for K **IF** ΔS has not been converted to kJ, **DO NOT ALLOW** 2nd mark **BUT** … **ALLOW** calculated answer = 493/543 = 0.91 K (calculator: 0.907918968) ***ALLOW 2 marks only for absence of one of the statements required for 1st marking point***
			Total	**10**	

<table>
<tr><th colspan="3">Question</th><th>Expected answers</th><th>Marks</th><th>Additional guidance</th></tr>
<tr><td>7</td><td>a</td><td></td><td>FIRST, CHECK THE ANSWER ON ANSWER LINE
IF numerical value = 7.81×10^{-2} OR 0.0781
AND $[N_2O_4]$ = 0.2(00 mol dm^{-3} AND $[NO_2]$ =1.6(0),
award 4 calculation marks
and check for the mark for correct units

Equilibrium amount of N_2O_4
0.400 mol N_2O_4 ✓

Equilibrium concentrations
$[N_2O_4]$ = 0.200 mol dm^{-3} AND $[NO_2]$ = 1.60 mol dm^{-3} ✓

K_c expression
$K_c = \frac{[N_2O_4]}{[NO_2]^2}$ (Square brackets essential) OR $\frac{0.200}{1.60^2}$ ✓

Calculation
= 7.81×10^{-2} ✓

Units
$dm^3\ mol^{-1}$ ✓</td><td>5</td><td>IF there is an alternative answer, check to see if there is any ECF credit possible using working below
----
ANNOTATIONS MUST BE USED

ALLOW ECF for equilibrium amounts ÷ 2

ALLOW 3 SF up to calculator value of 0.078125 correctly rounded
ALLOW ECF using calculated equilibrium concentrations

For units, ALLOW $mol^{-1}\ dm^3$
ALLOW ECF from incorrect K_c expression</td></tr>
<tr><td></td><td></td><td></td><td colspan="3">Common errors for 4 calculation marks
– Remember there is another mark for units

7.81×10^{-2} from wrong concs ✓✓ + units look for $[N_2O_4]$ = 0.8 AND $[NO_2]$ = 3.2
0.03906 ✓ ✓✓ + units no conversion of both moles to concentration
0.01953 ✓✓✓ + units no conversion of NO_2 moles to concentration
0.3125 ✓✓✓ + units moles of N_2O_4 taken as 3.2/2
12.8 ✓✓✓ + units: mol dm^{-3} K_c expression upside down
0.125 ✓✓✓ + units; none $[NO_2]$ instead of $[NO_2]^2$ 'No units' MUST be stated

0.15625 MARK BY ECF as there are many different routes to this answer</td></tr>
</table>

Question			Expected answers	Marks	Additional guidance
7	b		***Each marking point is independent***		
			Effect on K_c K_c does not change (with pressure) ✓		**ALLOW** K_c **only** changes with temperature **IGNORE** K_c changes with temperature
			Comparison of conc terms after increase in pressure $[NO_2]^2$ increases more than $[N_2O_4]$ **OR** concentration (term) on bottom (of K_c) increases more that concentration (term) on top (of K_c) ✓		**ALLOW** $\frac{[N_2O_4]}{[NO_2]^2} < K_c$ **OR** $\frac{[N_2O_4]}{[NO_2]^2}$ decreases **IGNORE** K_c decreases
			Changes in concentrations linked to K_c (amount /concentration of) N_2O_4 increases **AND** (amount /concentration of) NO_2 decreases **AND** to maintain/restore $\boldsymbol{K_c}$ ✓	3	**ALLOW** top of K_c expression increases and bottom decreases until K_c is reached **ALLOW** equilibrium shifts to right to maintain/restore K_c **IGNORE** just 'restores equilibrium' **K_c IS REQUIRED** **IGNORE** just 'equilibrium shifts to right **IGNORE** le Chatelier response: 'equilibrium shifts to right' because there are fewer moles of gas on right-hand side
			Total	**8**	

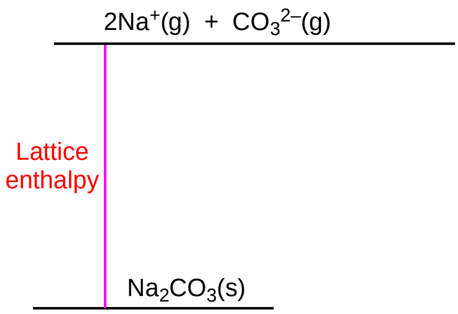
Question			Expected answers	Marks	Additional guidance
8	a		$Fe_2O_3 + 6H^+ \longrightarrow 2Fe^{3+} + 3H_2O$ ✓	1	**ALLOW** $Fe_2O_3 + 6HCl \longrightarrow 2FeCl_3 + 3H_2O$ **OR** $Fe_2O_3 + 6HCl \longrightarrow 2Fe^{3+} + 6Cl^- + 3H_2O$ **ALLOW** correct multiples **IGNORE** state symbols **DO NOT ALLOW** Fe_2Cl_6 as a product
	b		$Sn^{2+} + 2Fe^{3+} \longrightarrow Sn^{4+} + 2Fe^{2+}$ ✓ $6Fe^{2+} + Cr_2O_7^{2-} + 14H^+ \longrightarrow 6Fe^{3+} + 2Cr^{3+} + 7H_2O$ ✓	2	**IGNORE** state symbols **ALLOW** overall equations: $SnCl_2 + 2FeCl_3 \longrightarrow SnCl_4 + 2FeCl_2$ $6FeCl_2 + K_2Cr_2O_7 + 14HCl \rightarrow 6FeCl_3 + 2CrCl_3 + 2KCl + 7H_2O$ **ALLOW** correct multiples

Question			Expected answers	Marks	Additional guidance
8	c		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 54.6%, award **5 marks** -- **Amount Fe^{2+} in 250 cm^3 solution – 3 marks** amount $Cr_2O_7^{2-}$ used = $0.0200 \times \frac{26.5}{1000}$ = 5.30×10^{-4} (mol) ✓ amount Fe^{2+} = **6** × 5.30 x 10^{-4} = 3.18×10^{-3} mol ✓ amount Fe^{2+} in original 250 cm^3 = **10** × 3.18 x 10^{-3} = 3.18×10^{-2} (mol) ✓		***ANNOTATIONS MUST BE USED*** **IF** there is an alternative answer, 1st check common errors below. Then see if there is any **ECF** credit possible using working below -- **Working must be to at least 3 SF throughout** **BUT** ignore trailing zeroes, *i.e.* for 0.490 allow 0.49 **ALLOW ECF** from different Fe^{2+} ratio in equation from **8(b)** **BUT** still **ALLOW** 6 : 1 even from different ratio in equation If no equation use actual 6 : 1 ratio **DO NOT AWARD** 'ratio mark' at all for use of 1 : 1 ratio *– makes problem easier* **ECF** 10 × answer above
			% Fe in ore – 2 marks mass of Fe in ore = 55.8 × 3.18 × 10^{-2} g = 1.77444 g ✓		**ECF** 55.8 × answer above **IF** answer above has **not** been used **AND** × 55.8, **DO NOT ALLOW** this mark but do **ALLOW** final % **IF** answer above **AND** 55.8 are **BOTH not** used, then **DO NOT ALLOW ANY** further marks
			percentage Fe in ore = $\frac{1.77444}{3.25} \times 100$ = 54.6% ✓	**5**	**ECF** $\frac{\text{answer above}}{3.25} \times 100$ **ALLOW** 54.5% (from 1.77 g) **AND** any answer with > 1 decimal place that rounds back to 54.5 **OR** 54.6
					COMMON ERRORS 5.46 ✓✓✓✓ *× 10 omitted* 51.5 ✓✓✓✓ *titre taken as 25.0* 156.2 ✓✓✓✓ *× 159.6 instead of 55.8* 15.62 ✓✓✓ *× 159.6 and × 10 omitted* 45.5 ✓✓✓✓ *5 : 1 ratio* 1.52 ✓✓✓✓ ÷ 6 instead of × 6

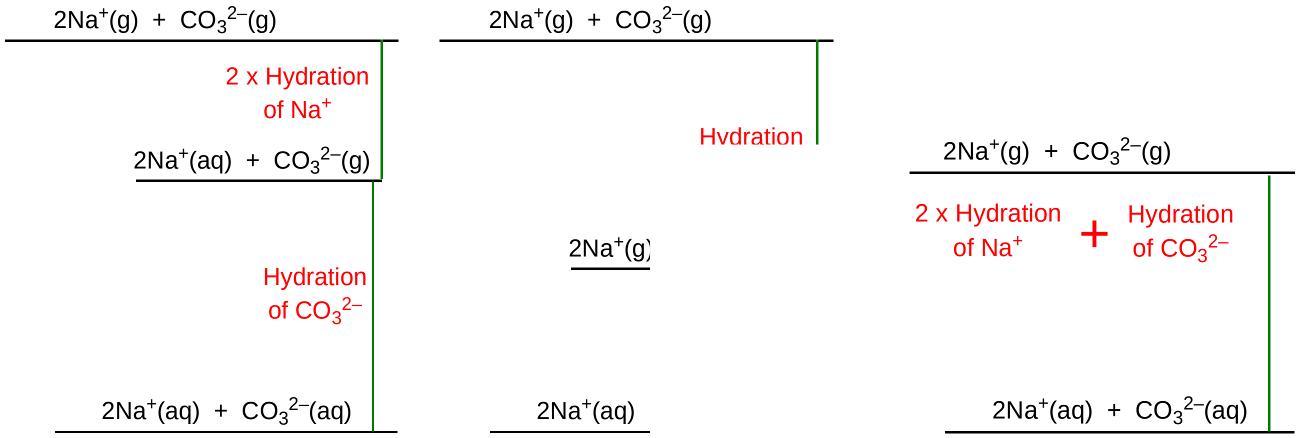
Question			Expected answers	Marks	Additional guidance
8	d		$E^{\ominus}$ for MnO_4^- is more positive/greater than Cl_2 **OR** $E^{\ominus}$ for $Cr_2O_7^{2-}$ is less positive/smaller than Cl_2 ✓ MnO_4^- reacts with Cl^- **OR** HCl (forming Cl_2 gas) **OR** $Cr_2O_7^{2-}$ does **not** react with Cl^- ions ✓	2	**ORA:** $E^{\ominus}$ for Cl_2 is less positive/smaller than MnO_4^- **OR** $E^{\ominus}$ for Cl_2 is more positive/greater than $Cr_2O_7^{2-}$
			Total	**10**	

APPENDIX 1

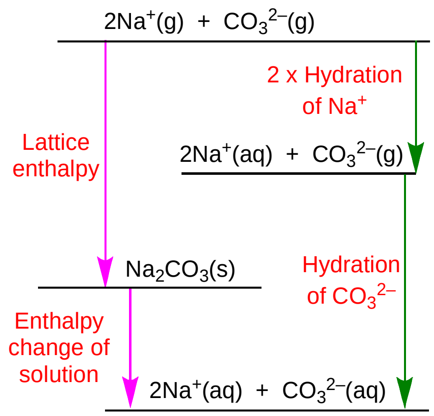
MARK 1



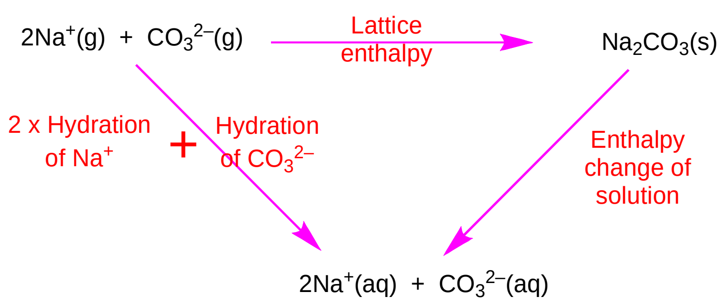
MARK 2



MARK 3



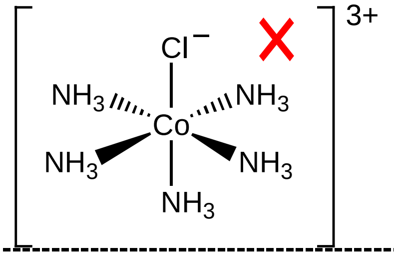
A simple energy cycle can be awarded 2 marks only



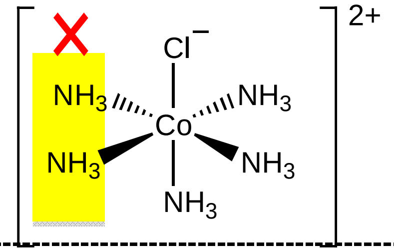
Mark 1 All species, state symbols and labels
Mark 2 Arrows added in correct directions

APPENDIX 2

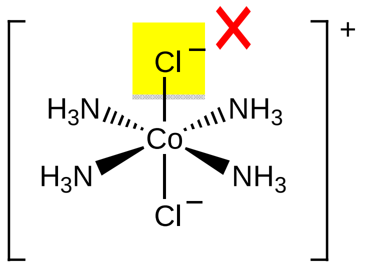
Example 1



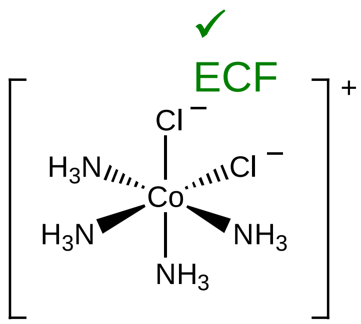
A



B



C



D

No complex ions are correct

A is wrong because a wrong ligand has been attached. This would have been wrong even if Cl had been attached so the Cl^- charge is ignored at this stage

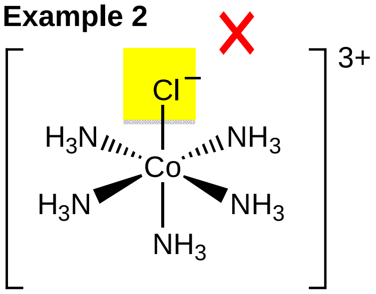
B has connectivity **and** Cl^- errors

C and **D** have Cl^- errors

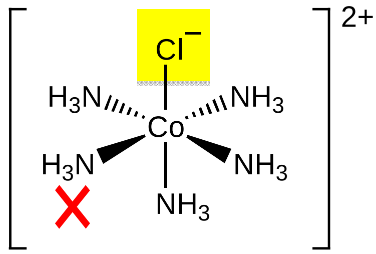
In **B**, either connectivity **OR** Cl^- could have been penalised Choose which to penalise based on maximising identification of errors

If Cl^- had been penalised in **B**, then **C** would have been marked correctly by **ECF**.
But the candidate has clearly made 2 mistakes across **B** and **C** so NH_3 connectivity had been penalised in **B**

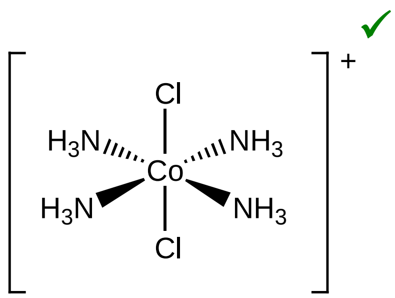
Example 2



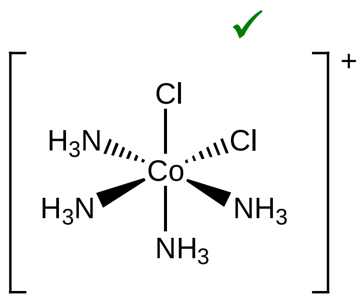
A



B



C



D

C and **D** are correct and they have been marked correct

A is wrong because a wrong ligand has been attached. This would have been wrong even if Cl had been attached so the Cl^- charge is ignored at this stage

In **B**, the only error is Cl^-
A also had Cl^- but the charge had been ignored as Cl was incorrect anyway
B is therefore marked wrong