OCR
RECOGNISING ACHIEVEMENT

GCE

Chemistry A

Advanced GCE

Unit **F325:** Equilibria, Energetics and Elements

Mark Scheme for January 2012

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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.

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Annotations available in Scoris.

Annotation	Meaning
	Benefit of doubt given
	Contradiction
	Incorrect response
	Error carried forward
	Ignore
	Not answered question
	Benefit of doubt not given
	Power of 10 error
	Omission mark
	Rounding error
	Error in number of significant figures
	Correct response

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

Annotation	Meaning
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

12. The following questions should be annotated with ticks, crosses, etc. Annotations should be placed to clearly show where they apply within the body of the text (i.e. not in margins)

Question 1(a); Question 2(c), 2d(ii); Question 3e(i); Question 4d(i), 4d(ii); Question 6d; Question 7(a); Question 8(c)

All the Additional Pages in the examination script must be checked to see if any candidates include any answers.

- When you open question **1(a)** you will see a view of page 22, one of the Additional Pages.
- If the page is blank then, using the marking mode, annotate the page with an omission mark, ^.
- Scroll down to page 23 and annotate with a ^ if the page is blank.
- Scroll down to page 24 and annotate with a ^ if the page is blank.

- If pages 22, 23 or 24 are not blank then use the paper clip icon to link the pages to the correct questions.
- You may need to contact your Team Leader if you do not know how to do this.

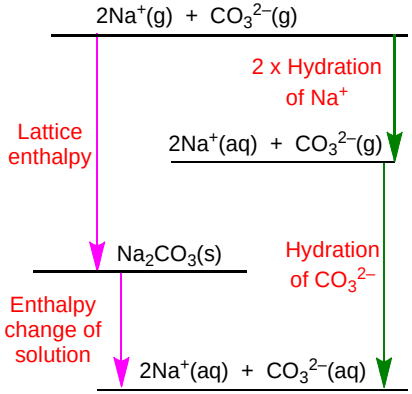
Question			Expected answers	Marks	Additional guidance
1	a		***graph:*** Rate does not change with concentration **AND** zero-order with respect to I_2 ✓ ***initial rates data:*** Mark independently When $[(CH_3)_2CO]$ × 2, rate × 2 (2^1) ✓ 1st order with respect to $(CH_3)_2CO$ ✓ When [HCl] x 2.5, rate × 2.5 ✓ 1st order with respect to HCl ✓		***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** $[(CH_3)_2CO]$ × 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
			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: $dm^3\ mol^{-1}\ s^{-1}$ ✓	**9**	**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} ✓

Question			Expected answers	Marks	Additional guidance
1	b		**step 1**: $H_2(g)$ + ICl(g) $\longrightarrow$ LHS of step 1 ✓ $\longrightarrow$ HCl(g) + HI(g) **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**	

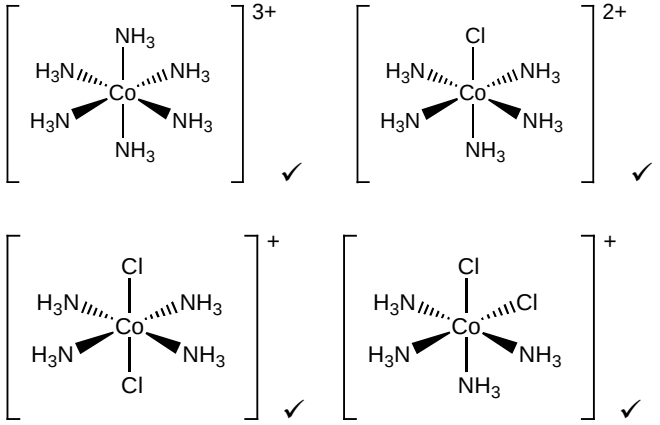
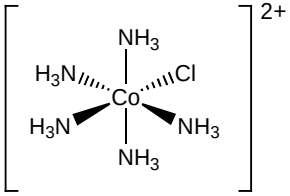
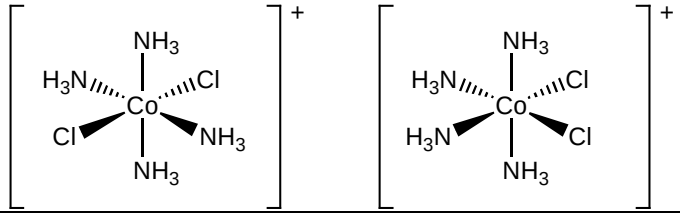
Question			Expected answers	Marks	Additional guidance
2	a		(The enthalpy change that accompanies) the formation of **one mole** of a(n ionic) compound ✓ from its **gaseous ions** ✓ (under standard conditions)	2	**IGNORE** 'Energy needed' **OR** 'energy required' **ALLOW** as alternative for compound: 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**)		***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
			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 ✓		**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*
			Comparison of size of anions S^{2-} is larger **OR** S^{2-} has a smaller charge density ✓		**ORA** O^{2-} is smaller **OR** O^{2-} has a larger charge density ✓ **IGNORE** just S^{2-} is large *comparison required*
			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**	**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: $(1s^2 2s^2 2p^6)3s^2 3p^6 3d^7 4s^2$ ✓ Co^{3+}: $(1s^2 2s^2 2p^6)3s^2 3p^6 3d^6$ ✓	2	**ALLOW** $(1s^2 2s^2 2p^6)3s^2 3p^6 4s^2 3d^7$ (i.e. 4s before 3d) **ALLOW** upper case D, etc. and subscripts, e.g. $[Ar]4S_2 3D_7$ 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	$(K_a =) \frac{[H^+]\,[NO_2^-]}{[HNO_2]}$ ✓	1	**DO NOT ALLOW** $\frac{[H^+]^2}{[HNO_2]}$ 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}) ✓ $[H^+] = \frac{1.00 \times 10^{-14}}{0.08(00)}$ **OR** 1.25×10^{-13} (mol dm^{-3}) ✓ pH = –log 1.25×10^{-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** $\frac{1.00 \times 10^{-14}}{\text{calculated value of } [OH^-]}$ **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 → 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, ⇌ instead of → **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 ⟶ 2 marks** ✓✓ **4 correct ⟶ 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** $\lvert T\Delta S\rvert$ 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** $\lvert\Delta H/T\rvert$ 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 x 543/1000 ✓ $T = \frac{\Delta H}{\Delta S}$ = 493 x 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 × 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**	

Question			Expected answers	Marks	Additional guidance
7	a		**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** $dm^3\ mol^{-1}$ ✓	**5**	**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
			Common errors for 4 calculation marks **– Remember there is another mark for units** 7.81 x 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**		

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 ***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**	

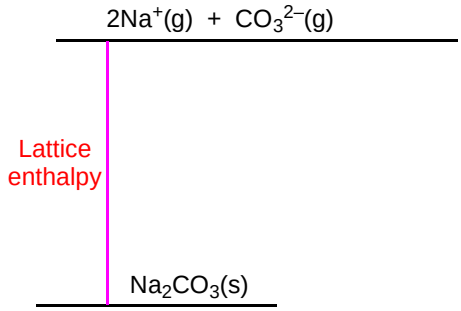
Question			Expected answers	Marks	Additional guidance
8	a		$Fe_2O_3 + 6H^+ \longrightarrow 2Fe^{3+} + 3H_2O$ ✓	1	**ALLOW** $Fe_2O_3 + 6HCl \longrightarrow 2FeCl_3 + 3H_2O$ **OR** $Fe_2O_3 + 6HCl \longrightarrow 2Fe^{3+} + 6Cl^- + 3H_2O$ **ALLOW** correct multiples **IGNORE** state symbols **DO NOT ALLOW** 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 = $0.0200 \times \frac{26.5}{1000}$ $= 5.30 \times 10^{-4}$ (mol) ✓ amount Fe^{2+} = **6** × 5.30 x 10^{-4} $= 3.18 \times 10^{-3}$ mol ✓ amount Fe^{2+} in original 250 cm^3 = **10** × 3.18 x 10^{-3} $= 3.18 \times 10^{-2}$ (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

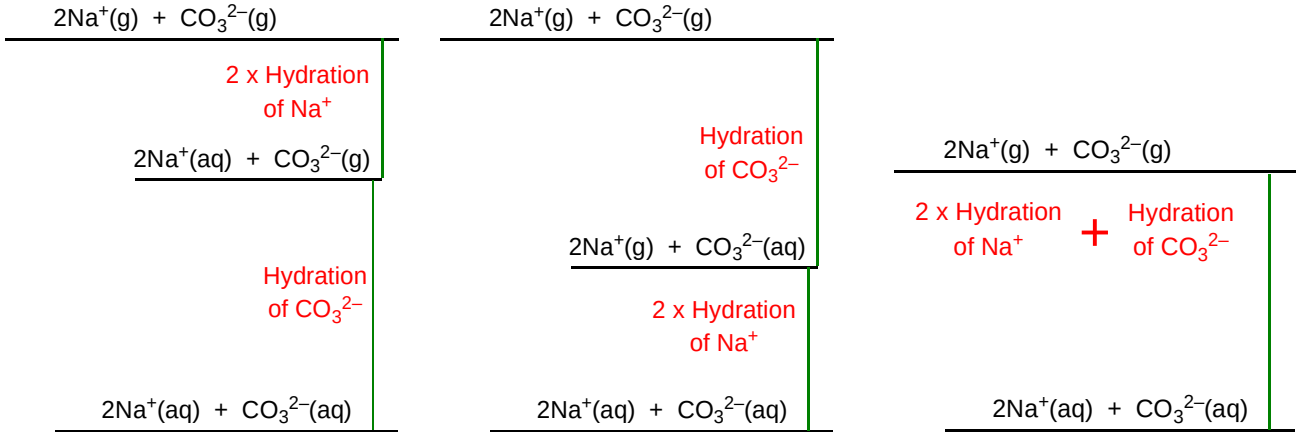
Question			Expected answers	Marks	Additional guidance
8	d		E^{-o-} for MnO_4^- is more positive/greater than Cl_2 **OR** E^{-o-} for $Cr_2O_7^{2-}$ is less positive/smaller than Cl_2 ✓ MnO_4^- reacts with Cl^- **OR** HCl (forming Cl_2 gas) **OR** $Cr_2O_7^{2-}$ does **not** react with Cl^- ions ✓	**2**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

APPENDIX 1

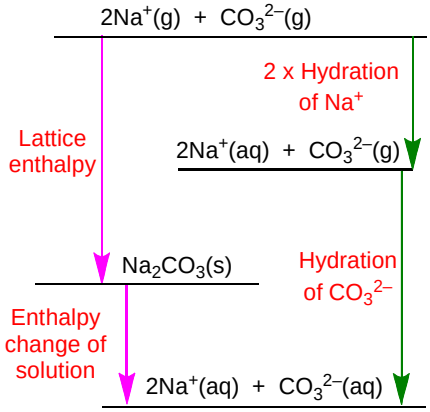
MARK 1



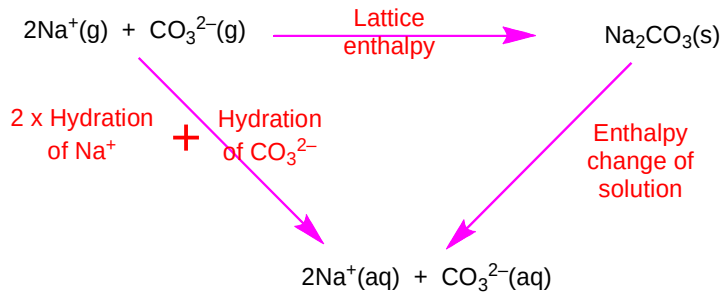
MARK 2



MARK 3



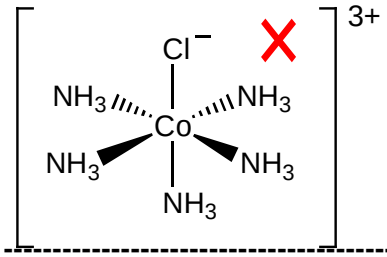
A simple energy cycle can be awarded 2 marks only



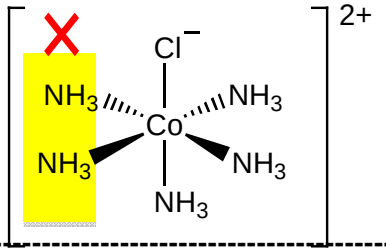
Mark 1 All species, state symbols and labels
Mark 2 Arrows added in correct directions

APPENDIX 2

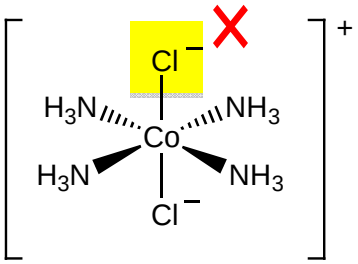
Example 1



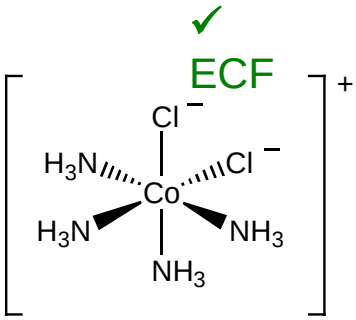
---- **A**



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

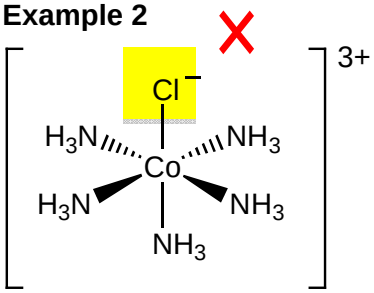
B has connectivity **and** Cl^- errors

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

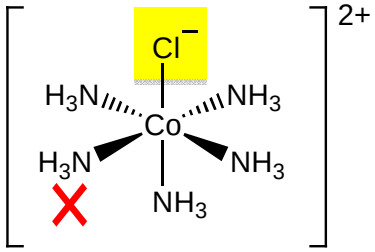
In **B**, either connectivity **OR** Cl^- could have been penalised Choose which to penalise based on maximising identification of errors

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**

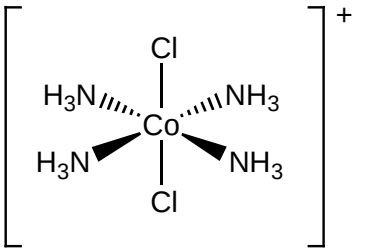
Example 2



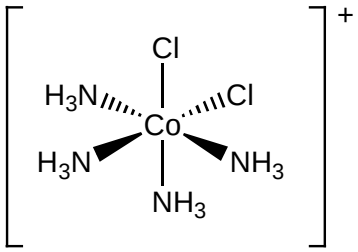
A



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

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