



GCE

Chemistry A

H432/01: Periodic table, elements and physical chemistry

A Level

Mark Scheme for June 2022

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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.

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MARKING INSTRUCTIONS**PREPARATION FOR MARKING****RM ASSESSOR**

1. Make sure that you have accessed and completed the relevant training packages for on-screen marking: *RM Assessor Online Training*; *OCR Essential Guide to Marking*.
2. Make sure that you have read and understood the mark scheme and the question paper for this unit.
3. Log-in to RM Assessor and mark the **required number** of practice responses (“scripts”) and the **required number** of standardisation responses.

MARKING

1. Mark strictly to the mark scheme.
2. Marks awarded must relate directly to the marking criteria.
3. The schedule of dates is very important. It is essential that you meet the RM Assessor 50% and 100% (traditional 50% Batch 1 and 100% Batch 2) deadlines. If you experience problems, you must contact your Team Leader (Supervisor) without delay.
4. If you are in any doubt about applying the mark scheme, consult your Team Leader by telephone, email or via the RM Assessor messaging system.
5. Work crossed out:

Crossed Out Responses

Where a candidate has crossed out a response and provided a clear alternative then the crossed out response is not marked. Where no alternative response has been provided, examiners may give candidates the benefit of the doubt and mark the crossed out response where legible.

Rubric Error Responses – Optional Questions

Where candidates have a choice of question across a whole paper or a whole section and have provided more answers than required, then all responses are marked and the highest mark allowable within the rubric is given. Enter a mark for each question answered into RM assessor, which will select the highest mark from those awarded. *(The underlying assumption is that the candidate has penalised themselves by attempting more questions than necessary in the time allowed.)*

Multiple Choice Question Responses

When a multiple choice question has only a single, correct response and a candidate provides two responses (even if one of these responses is correct), then no mark should be awarded (as it is not possible to determine which was the first response selected by the candidate).

When a question requires candidates to select more than one option/multiple options, then local marking arrangements need to ensure consistency of approach.

Contradictory Responses

When a candidate provides contradictory responses, then no mark should be awarded, even if one of the answers is correct.

Short Answer Questions (requiring only a list by way of a response, usually worth only **one mark per response**)

Where candidates are required to provide a set number of short answer responses then only the set number of responses should be marked. The response space should be marked from left to right on each line and then line by line until the required number of responses have been considered. The remaining responses should not then be marked. Examiners will have to apply judgement as to whether a 'second response' on a line is a development of the 'first response', rather than a separate, discrete response. *(The underlying assumption is that the candidate is attempting to hedge their bets and therefore getting undue benefit rather than engaging with the question and giving the most relevant/correct responses.)*

Short Answer Questions (requiring a more developed response, worth **two or more marks**)

If the candidates are required to provide a description of, say, three items or factors and four items or factors are provided, then mark on a similar basis – that is downwards (as it is unlikely in this situation that a candidate will provide more than one response in each section of the response space.)

Longer Answer Questions (requiring a developed response)

Where candidates have provided two (or more) responses to a medium or high tariff question which only required a single (developed) response and not crossed out the first response, then only the first response should be marked. Examiners will need to apply professional judgement as to whether the second (or a subsequent) response is a 'new start' or simply a poorly expressed continuation of the first response.

6. Always check the pages (and additional objects if present) at the end of the response in case any answers have been continued there. If the candidate has continued an answer there then add a tick to confirm that the work has been seen.

7. Award No Response (NR) if:

- there is nothing written in the answer space.

Award Zero '0' if:

- anything is written in the answer space and is not worthy of credit (this includes text and symbols).

Team Leaders must confirm the correct use of the NR button with their markers before live marking commences and should check this when reviewing scripts.

8. The RM Assessor **comments box** is used by your Team Leader to explain the marking of the practice responses. Please refer to these comments when checking your practice responses. **Do not use the comments box for any other reason.**

If you have any questions or comments for your Team Leader, use the phone, the RM Assessor messaging system, or email.

9. Assistant Examiners will send a brief report on the performance of candidates to their Team Leader (Supervisor) via email by the end of the marking period. The report should contain notes on particular strengths displayed as well as common errors or weaknesses. Constructive criticism of the question paper/mark scheme is also appreciated.

10. For answers marked by levels of response:

Read through the whole answer from start to finish, using the Level descriptors to help you decide whether it is a strong or weak answer. The indicative scientific content in the Guidance column indicates the expected parameters for candidates' answers, but be prepared to recognise and credit unexpected approaches where they show relevance. Using a 'best-fit' approach based on the skills and science content evidenced within the answer, first decide which set of level descriptors, Level 1, Level 2 or Level 3, best describes the overall quality of the answer.

Once the level is located, award the higher or lower mark:

The higher mark should be awarded where the level descriptor has been evidenced and all aspects of the communication statement (in italics) have been met.

The lower mark should be awarded where the level descriptor has been evidenced but aspects of the communication statement (in italics) are missing.

In summary:

The skills and science content determines the level.

The communication statement determines the mark within a level.

Level of response questions on this paper are **20(a)** and **Q22(c)**

The only annotation on a level of response question should be the indication of the level.

A level annotation should be used where all marks for a level have been achieved.

e.g. if a candidate has 6 marks, they would have this annotation on their script:

L3

If a candidate has achieved 5 marks then they have reached Level 3 but will not have met the communication statement.

They should have the following annotations on their scripts:

L3 **^**

The same principle should be applied to Level 2 and Level 1.

No marks (0) should have a cross: **×**

Place the annotations alongside the mark for the question.
















On additional pages, annotate using **SEEN**

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11. Annotations available in RM Assessor

Annotation	Meaning
	Correct response
	Incorrect response
	Omission mark
	Benefit of doubt given
	Contradiction
	Rounding error
	Error in number of significant figures
	Error carried forward
	Level 1
	Level 2
	Level 3
	Benefit of doubt not given
	Noted but no credit given
	Ignore
	Blank page

12. 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

13. Subject-specific Marking Instructions

INTRODUCTION

Your first task as an Examiner is to become thoroughly familiar with the material on which the examination depends. This material includes:

- the specification, especially the assessment objectives
- the question paper
- the mark scheme.

You should ensure that you have copies of these materials.

You should ensure also that you are familiar with the administrative procedures related to the marking process. These are set out in the OCR booklet **Instructions for Examiners**. If you are examining for the first time, please read carefully **Appendix 5 Introduction to Script Marking: Notes for New Examiners**.

Please ask for help or guidance whenever you need it. Your first point of contact is your Team Leader.

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SECTION A

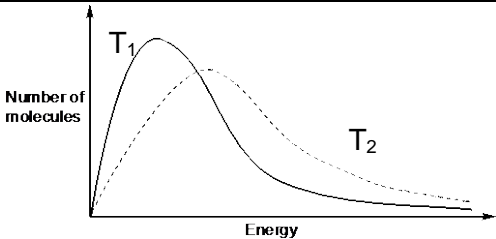
Question	Answer	Marks	AO element	Guidance
1	D	1	2.7	
2	C	1	1.2	
3	B	1	2.2	
4	C	1	2.8	
5	B	1	2.2	
6	B	1	1.2	
7	A	1	2.2	
8	A	1	1.2	
9	A	1	1.1	
10	A	1	2.1	
11	D	1	2.3	
12	C	1	1.2	
13	Award the mark regardless of response.	1	2.2	
14	A	1	1.2	
15	B	1	1.2	
	Total	15		

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SECTION B

Question			Answer	Marks	AO element	Guidance
16	(a)	(i)	 <p> Axes labelled (number of) molecules AND (kinetic) energy AND correct drawing of a Boltzmann distribution i.e. curve must start within the first small square nearest to the origin AND must not touch the x-axis at high energy ✓ </p> <p> Drawing of correct Boltzmann distributions at two different temperatures with one temperature identified. ✓ </p> <p> (At higher temperature) more molecules/particles have energy above activation energy ✓ </p>	3	AO1.1 ×3	<p> ALLOW particles on the y-axis DO NOT ALLOW atoms on y-axis DO NOT ALLOW enthalpy on x-axis DO NOT ALLOW an increase of more than one small square at the high energy end of the curve i.e. allow a small inflection </p> <p> ALLOW T2 as 'higher temperature' Maximum of curve for higher temperature must be to the right AND lower than the maximum of the curve for lower temperature Lines can only cross once </p> <p> ALLOW ORA if states the effect when the temperature is lower ALLOW has enough energy to react ALLOW E_a shown on graph AND greater area under the curve to the right of E_a </p> <p> DO NOT ALLOW lowers E_a DO NOT ALLOW atoms for molecules </p> <p> IGNORE (more) successful collisions </p>

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Question		Answer	Marks	AO element	Guidance
(a)	(ii)	<p>Orders (Expt 1+2) When [NO] \times 2, rate \times 4 AND 2nd order with respect to NO ✓</p> <p>(Expt 2+3) When [NO] \times 2 AND [CO] \times 4, rate \times 16 AND 1st order with respect to CO ✓</p> <p>Rate Equation rate = k [NO]²[CO] ✓</p> <p>Value of k $(k = \frac{1.85 \times 10^{-4}}{(2.75 \times 10^{-4})^2 \times 7.25 \times 10^{-4}})$ $= 3.37 \times 10^6 \text{ ✓}$</p> <p>Units of k $\text{dm}^6 \text{ mol}^{-2} \text{ s}^{-1} \text{ ✓}$</p>	5	<p>AO3.1</p> <p>AO3.2</p> <p>AO2.6</p> <p>AO1.2 $\times 2$</p>	<p>ALLOW ORA throughout e.g. expt 2+1 [NO] halves, rate quarters etc.</p> <p>IGNORE [CO] constant</p> <p>ALLOW if working shown with the table. ALLOW if seen in 2 steps i.e. When [NO] \times 2, rate \times 4 AND [CO] \times 4, intermediate rate \times 4.</p> <p>ALLOW comparing Expt 1+3 When [NO] \times 4 AND [CO] \times 4, rate \times 64 AND 1st order with respect to CO</p> <p>ALLOW ECF from incorrect orders ALLOW rate = k [NO]²[CO]¹ ALLOW rate equation with correct numbers substituted</p> <p>ALLOW 3.36×10^6 from the use of Expt 3 IGNORE errors in working out – the mark is for the value ALLOW 3 SF upto the calculator value 3374180.678 OR 3.374180678×10^6 IGNORE rounding errors past 3SF</p> <p>ALLOW units in any order e.g. $\text{mol}^{-2} \text{ dm}^6 \text{ s}^{-1}$ ALLOW ECF from incorrect rate equation.</p>

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Question			Answer	Marks	AO element	Guidance
						Common errors 4 marks (including units) $4.65 \times 10^9 \text{ mol}^{-3} \text{ dm}^9 \text{ s}^{-1}$ (use of 2 nd order with respect to CO) $2446 \text{ mol}^{-1} \text{ dm}^3 \text{ s}^{-1}$ (use of zero order wrt CO)
	(b)		2NO_2 only on LHS of step 1 ✓ Rest of mechanism ✓	2	AO3.1 ×2	M2 dependent on M1 Examples: <i>Step 1:</i> $2\text{NO}_2 \rightarrow \text{NO} + \text{NO}_3$ <i>Step 2:</i> $\text{NO}_3 + \text{CO} \rightarrow \text{NO}_2 + \text{CO}_2$ OR <i>Step 1:</i> $2\text{NO}_2 \rightarrow \text{N}_2\text{O}_4$ <i>Step 2:</i> $\text{N}_2\text{O}_4 + \text{CO} \rightarrow \text{NO} + \text{NO}_2 + \text{CO}_2$ OR <i>Step 1:</i> $2\text{NO}_2 \rightarrow \text{N}_2 + 2\text{O}_2$ <i>Step 2:</i> $\text{N}_2 + 2\text{O}_2 + \text{CO} \rightarrow \text{NO} + \text{NO}_2 + \text{CO}_2$ OR <i>Step 1:</i> $2\text{NO}_2 \rightarrow 2\text{NO} + \text{O}_2$ <i>Step 2:</i> $\text{NO} + \text{O}_2 + \text{CO} \rightarrow \text{NO}_2 + \text{CO}_2$
			Total	10		

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Question			Answer	Marks	AO element	Guidance
17	(a)	(i)	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE IF $T = 52.4\text{ }^{\circ}\text{C}$ OR $52.5\text{ }^{\circ}\text{C}$ award 4 marks IF $T = 32.4\text{ }^{\circ}\text{C}$ award 3 marks</p> <hr/> <p>Correctly calculates $n(\text{AgNO}_3)$ $= 0.400 \times \frac{100.0}{1000}$ OR $0.04(00)$ (mol) ✓</p> <p>Energy released per mole of AgNO_3 in J OR kJ $= \frac{678 \times 0.0400}{2}$ OR 13.56 (kJ) OR 13560 (J) ✓</p> <p>Correctly calculates ΔT $\Delta T = \frac{13560}{100 \times 4.18}$ OR 32.4 ($^{\circ}\text{C}$) ✓</p> <p>Maximum temperature reached $= 32.4\dots + 20.0 = 52.4\text{ }^{\circ}\text{C}$ ✓ 3 SF required</p>	4	<p>AO1.2</p> <p>AO2.4</p> <p>AO2.8</p> <p>AO2.8</p>	<p>FULL ANNOTATIONS MUST BE USED</p> <hr/> <p>ALLOW ECF throughout</p> <hr/> <p>ALLOW 13.6 kJ OR 13600 J (to 3SF) DO NOT ALLOW < 3 SF IGNORE any sign and units <i>i.e. ALLOW correctly calculated value in J OR kJ</i></p> <hr/> <p>ALLOW ECF ONLY from calculated $\Delta T + 20\text{ }^{\circ}\text{C}$</p> <p>Common errors 3 marks $84.9\text{ }^{\circ}\text{C}$ (not divided $\frac{\Delta H}{2}$)</p>

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	(a)	(ii)	Maximum temperature is the same AND Half the energy/ moles AND half the mass/volume	1	AO3.4	ALLOW response that links the same proportionality/ratio of volume/mass and energy/moles ALLOW if seen by a calculation
	(b)	(i)	(Enthalpy change) when 1 mole of a compound is formed from its elements ✓	1	AO1.1 ×1	ALLOW energy required OR energy released ALLOW one mole of product/substance DO NOT ALLOW 1 mole of element DO NOT ALLOW is formed from its gaseous elements when 1 mole of a solid compound when 1 mole of a gaseous compound
		(ii)	FIRST, CHECK THE ANSWER ON ANSWER LINE If answer = (+)90 award 2 marks ----- $4(\Delta_f H^\ominus \text{.NO}) = -1172 - 6(-286) + 4(-46)$ $= -1172 + 1716 - 184$ $= (+)360 \text{ (kJ mol}^{-1}\text{)} \checkmark$ $\Delta_f H^\ominus \text{.NO} = \frac{360}{4} = (+)90 \text{ (kJ mol}^{-1}\text{)} \checkmark$	2	AO2.2 ×2	ALLOW ECF providing all values are used ALLOW one transcription error in the values used for M2 Common error 1 mark -90 (wrong sign)

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	(c)	(i) a measure of the dispersal of energy (in a system) ✓	1	AO1.1	ALLOW a measure/degree of the disorder (of a system) ORA
		<p>(ii) FIRST CHECK THE ANSWER ON ANSWER LINE If answer = -2587 (kJ mol⁻¹) award 3 marks</p> <hr style="border-top: 1px dashed blue;"/> <p>ΔS^\ominus $\Delta S^\ominus = 256 + 4(214) + 8(192) - 4(151) - 8(220)$ $= (+)284$ (J K⁻¹ mol⁻¹) OR $(+)0.284$ (kJ K⁻¹ mol⁻¹) ✓</p> <p><i>Use of</i> T = 298 (K) AND $\Delta S = 0.284$ (kJ K⁻¹ mol⁻¹) ✓</p> <p>$\Delta H = (\Delta G + T\Delta S)$ $= -2587$ (kJ mol⁻¹) ✓</p>	3	AO2.2 ×3	<p>ALLOW ECF throughout</p> <p>M2 is for unit conversions seen anywhere.</p> <p>ALLOW 3SF up to the calculator value -2587.368 (kJ mol⁻¹)</p> <p>ALLOW ECF from incorrect unit conversions or incorrect ΔS.</p>

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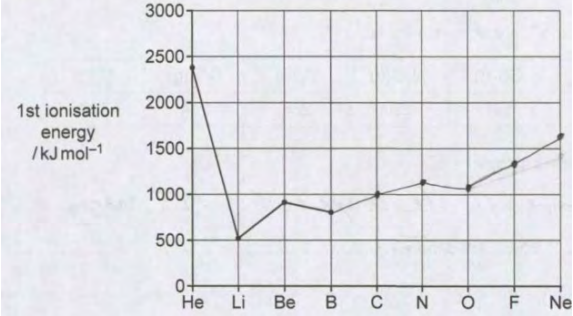
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					<p>Common errors 2 marks -2664.9 (kJ mol⁻¹) (Use of 25°C) 81960 (kJ mol⁻¹) (Use of ΔS 284) 4428 (kJ mol⁻¹) (Use of 25°C and ΔS 284) -2756.632 (kJ mol⁻¹) (Use of ΔS = -0.284)</p>
		(iii)	<p>ΔS is positive/ + AND ΔH is negative/ - ✓ ΔG is negative (- at all temperatures) OR ΔG is (always) negative/ - ✓</p>	2	<p>AO3.1 ALLOW ΔH is exothermic ALLOW '-TΔS' is negative'</p> <p>AO3.2 ΔG comment is dependent on on the signs assigned to ΔS AND ΔH (either in answer or from 17 cii).</p> <p>ALLOW ECF from incorrect signs for ΔS and/or ΔH from c(ii) i.e. ΔS is positive/ + AND ΔH is positive/ + Reaction is feasible only at high temperatures</p> <p>ΔS is negative/ - AND ΔH is negative/ - Reaction is feasible only at low temperatures</p> <p>IGNORE ΔS is negative/ - AND ΔH is positive/ + (-ΔG given in 17 cii)</p> <p>----- <u>Alternative Approach</u> ALLOW use of ΔG=0 for 2 marks i.e. calculates T = - 9109K ✓ It is always feasible above - 9109K / calculated -ve value and all temperatures are above this ✓</p>
			Total	14	

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Question		Answer	Marks	AO element	Guidance
18	(a)	 <p>1st ionisation energy /kJ mol⁻¹</p> <p>He Li Be B C N O F Ne</p> <p>All points show a general increase from B (i.e ignore O) AND Ne lower than He ✓</p> <p>O lower than N AND O is higher than C AND F higher than O ✓</p>	2	AO1.1 AO1.2	
	(b)	<p>8.3×10^{-22} (kJ) ✓</p> <p>From $\frac{500}{6.02 \times 10^{23}}$</p> <p>Answer MUST be to 2 SF AND in standard form.</p>	1	AO2.2	<p>ALLOW use of IEs close to 500 giving a range:</p> <p>8.3×10^{-22} (from 500) to 9.1×10^{-22} (from 550)</p>

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	(c)	<p>Explanation for He <i>Distance/shielding</i> (Outer) electrons are in a lower energy/closer shell/smaller atomic radius/fewer shells ✓</p> <p>Explanation for Be <i>Nuclear charge</i> number of protons/proton number increases OR greater nuclear charge ✓</p> <p><i>Distance/shielding</i> (Outer) electrons are in the same shell OR sub-shell OR (Outer) electrons experience the same/similar shielding OR Atomic radius decreases ✓</p> <p>For either Be or He <i>Attraction</i> Greater nuclear attraction (on outer electrons) OR (outer) electrons attracted more strongly to the nucleus ✓</p>	4	<p>AO1.1</p> <p>AO1.1</p> <p>AO1.2</p> <p>AO1.2</p>	<p>FULL ANNOTATIONS WITH TICKS, CROSSES, CON, etc MUST BE USED</p> <p>ORA throughout Comparison needed for each mark ALLOW change of shell (i.e 2s and 1s) IGNORE 'different sub-shell'</p> <p>IGNORE atomic number increases IGNORE nucleus gets bigger IGNORE 'effective nuclear charge increases'</p> <p>ALLOW same orbital</p> <p>IGNORE 'there is shielding' ALLOW 'greater repulsion from inner shells'</p> <p>IGNORE just 'greater attraction' OR greater force IGNORE 'pull' for 'attraction' IGNORE 'held' for attracted, e.g. IGNORE 'held more strongly'</p>
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	(d)	<p>Sub-shells Be electron is in (2)s AND B electron is in (2)p ✓</p> <p>Energy levels B / (2)p is higher energy (level) OR Be / (2)s is lower energy (level) ✓</p>	2	AO1.2 x2	<p>IGNORE number before s and p DO NOT ALLOW "shell" IGNORE block</p> <p>DO NOT ALLOW unpaired electron removed more easily (ORA) IGNORE 'less energy to remove'</p> <p>IGNORE comments about distance from nucleus IGNORE 2s shielding</p>
		Total	9		

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Question		Answer	Marks	AO element	Guidance
	(b)	(i)			
		(i)	1	AO1.1	<p>ALLOW some acid remains</p> <p>ALLOW conjugate base for glycolate ions/salt of weak acid</p> <p>ALLOW HOCH₂COO⁻</p>
		(ii)	4	<p>AO1.2 x1</p> <p>AO2.8 x3</p>	<p>ALLOW ECF throughout</p> <p>ALLOW use of moles for concentration</p> $[H^+] = \frac{1.479 \dots \times 10^{-4} \times 0.0200}{0.0250}$ <p>Common errors 3 marks pH = 3.57 not using n(HA) remaining</p> <p>2 marks pH = 3.75 using HA and KOH concentrations within question</p>
		<p>FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 3.93 award 4 marks</p> <p>-----</p> <p>Initial amounts</p> $n(\text{HOCH}_2\text{COOH}) = 0.750 \times \frac{60.0}{1000} \quad \text{OR } 0.045(0) \text{ (mol)}$ $\text{AND } n(\text{KOH}) = 0.625 \times \frac{40.0}{1000} \quad \text{OR } 0.025(0) \checkmark$ <p>Amounts in the buffer solution</p> $n(\text{HOCH}_2\text{COOH}) = 0.0450 - 0.0250 \quad \text{OR } 0.02(00) \text{ (mol)}$ $\text{AND } n(\text{HOCH}_2\text{COO}^-) \quad \quad \quad 0.025(0) \text{ (mol)} \checkmark$ <p>pH</p> $K_a = 10^{-3.83} \quad \text{OR } 1.479 \dots \times 10^{-4} \checkmark$ $[H^+] = \frac{1.479 \dots \times 10^{-4} \times 0.200}{0.250} \quad \text{OR } 1.183 \times 10^{-4} \text{ (mol dm}^{-3}\text{)}$ <p>pH = 3.93 (2 DP) ✓</p>			

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Question			Answer	Marks	AO element	Guidance
		(iii)	<p>$\text{NH}_3 / \text{OH}^-$ reacts with $\text{H}^+ / \text{HOCH}_2\text{COOH} /$ (Glycolic) acid ✓</p> <p>$\text{HOCH}_2\text{COOH} \rightleftharpoons \text{H}^+ + \text{HOCH}_2\text{COO}^-$ AND Equilibrium shifts to the right ✓</p>	2	AO1.2 x2	<p>ALLOW NH_3 will act as a base (and form NH_4^+) ALLOW NH_3 decreases $[\text{H}^+]$</p> <p>ALLOW $\text{HA} \rightleftharpoons \text{H}^+ + \text{A}^-$ Equilibrium equation needs to be shown.</p>
			Total	14		

Question		Answer	Marks	AO element	Guidance
20	(a)	<p>Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.</p> <p>Level 3 (5–6 marks) Uses correct method to calculate K_c AND explains why most operational condition is different with few omissions in the explanation.</p> <p><i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i></p> <p>Level 2 (3–4 marks) Uses correct method to calculate K_c with few errors OR Derives a correct expression for K_c with an attempt at the K_c calculation AND explains why an operational condition is different with some omissions.</p> <p><i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i></p> <p>Level 1 (1–2 marks) Derives a correct expression for K_c AND explains why one operational condition is different with some omissions. OR explains why most operational conditions are different</p> <p><i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i></p>	6	AO2.4 ×4 AO1.2 ×2	<p>Indicative scientific points may include: IGNORE trailing zeroes</p> <p><u>Equilibrium amounts</u> $n(\text{N}_2): 1.20 - 0.08 = 1.12$, $n(\text{H}_2) : 3.60 - 0.24 = 3.36$</p> <p><u>Equilibrium concentrations</u></p> $[\text{N}_2] = \frac{1.12}{8.00} = 0.140 \text{ (mol dm}^{-3}\text{)}$ $[\text{H}_2] = \frac{3.36}{8.00} = 0.420 \text{ (mol dm}^{-3}\text{)}$ $[\text{NH}_3] = \frac{0.160}{8.00} = 0.0200 \text{ (mol dm}^{-3}\text{)}$ <p><u>Equilibrium expression and K_c value with units</u></p> $K_c = \frac{[\text{NH}_3]^2}{[\text{N}_2] \times [\text{H}_2]^3}$ $K_c = \frac{0.0200^2}{0.140 \times 0.420^3} = 0.0386$ <p><i>Calculator: 0.03856417851 Units: dm⁶ mol⁻²</i></p> <p><u>Explanation for operational differences.</u></p> <p><u>Temperature</u></p> <ul style="list-style-type: none"> • Low temperature for maximum yield: (ΔH –ve \ exothermic) • High temperature to increase rate <p><u>Pressure</u></p> <ul style="list-style-type: none"> • High pressure for maximum yield (fewer (gaseous) moles/molecules of products) • High pressure expensive to generate OR high pressure is a safety hazard

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Question			Answer	Marks	AO element	Guidance
			0 marks <i>No response or no response worthy of credit.</i>			<u>Catalyst</u> <ul style="list-style-type: none"> Allows a lower temperature to be used for maximum yield. Reducing fuel expense OR increasing rate
	(b)	(i)	Equilibrium (position) shifts to the left (as T is decreased) AND (forward) reaction is endothermic ✓	1	AO1.2	ALLOW 'favours backward reaction' <i>Implies shift to left</i> ALLOW 'shifts in exothermic direction' BUT only if (forward) reaction stated as endothermic
		(ii)	Student 2 is correct AND same number of gas particles/ gas(eous) molecules/moles of gas on each side (of equation) ✓	1	AO3.2	ALLOW AW that suggests student 2 is correct
			Total	8		

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Question			Answer	Marks	AO element	Guidance
21	(a)	(i)	Ca fizzes faster AND Ca dissolves/disappears more quickly ✓	1	AO2.3	CARE Both needed for 1 mark . ORA ALLOW AW IGNORE finishes first IGNORE more bubbles (need idea of rate) IGNORE exothermic
21		(ii)	Oxidation $\text{Mg} \rightarrow \text{Mg}^{2+} + 2\text{e}^-$ ✓ Reduction $2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2$ OR $\text{H}^+ + \text{e}^- \rightarrow \frac{1}{2}\text{H}_2$ ✓	2	AO2.6 ×2	In half equations, ALLOW the use of e for e ⁻ ALLOW $\text{Mg} - 2\text{e}^- \rightarrow \text{Mg}^{2+}$ IGNORE state symbols even is wrong BUT half equations MUST only have species that change. For charges on half equations, ALLOW Mg ⁺² for Mg ²⁺ OR H ⁺¹ for H ⁺ 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

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	(b)	(i)	<p>FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 2.53(g) award 5 marks</p> <p>-----</p> <p>$[H^+] = 10^{-13.12}$ OR $7.58..... \times 10^{-14}$ (mol dm⁻³) ✓</p> <p>$[OH^-] = \frac{1 \times 10^{-14}}{7.58..... \times 10^{-14}}$ OR 0.1318 (mol dm⁻³) ✓</p> <p>$n(OH^-)$ in 250 cm³ = $\frac{0.1318.....}{4}$ OR $0.0329.....$ (mol) ✓</p> <p>$n(Ba(OH)_2)$ or $n(BaO) = \frac{0.0329.....}{2}$ OR $0.0164.....$ (mol) ✓</p> <p>Mass of BaO = $0.0164..... \times 153.3 = 2.53$ (g) 3SF ✓</p>	5	AO2.4 ×5	<p>ALLOW ECF and 3SF throughout. ALLOW calculation process in any order. IGNORE rounding errors past 3SF</p> <p>-----</p> <p>Calculator: $7.58577575 \times 10^{-14}$</p> <p>Calculator: 0.1318256739</p> <p>ALLOW alternative approach using pOH for first 2 marks.</p> <p>$p[OH^-] = 14 - 13.12 = 0.88$ $[OH^-] = 10^{-0.88} = 0.1318.....$</p> <p>Calculator: 0.03295641846 0.033(0) comes from $[OH^-] = 0.132$</p> <p>Calculator: 0.01647820923</p> <p>Calculator: 2.526109475</p> <p>Common errors 4 marks 5.05g Not dividing by 2 2.82g Use of M_r for $Ba(OH)_2$ 5.06g rounds to 0.132 in M2 then not dividing by 2</p> <p>3 marks 5.65g not dividing by 2 and using M_r for $Ba(OH)_2$</p>
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		(ii)	$\text{Ba}^{2+}(\text{aq}) + 2\text{H}^{+}(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) + 2\text{OH}^{-}(\text{aq})$ $\rightarrow \text{BaSO}_4(\text{s}) + 2\text{H}_2\text{O}(\text{l}) \checkmark$	1	AO3.2	<p>ALLOW multiples</p> <p>ALLOW</p> $\text{H}^{+}(\text{aq}) + \text{OH}^{-}(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l})$ <p>OR</p> $\text{Ba}^{2+}(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) \rightarrow \text{BaSO}_4(\text{s})$						
	(c)	(i)	<p>FIRST CHECK THE ANSWER ON ANSWER LINE</p> <p>If answer = 731(g) award 3 marks</p> <p>-----</p> <p>n(Z)</p> $n(\text{Ca}_5\text{NH}_4(\text{NO}_3)_{11} \cdot 10\text{H}_2\text{O}) = \frac{1500}{1080.5} \text{ OR } 1.388246\dots$ <p>✓</p> <p>Mass of limestone</p> $n(\text{CaCO}_3) = 1.388246\dots \times 5 \text{ OR } 6.94123\dots$ <p>AND</p> $\text{mass CaCO}_3 = 6.94123\dots \times 100.1 \text{ OR } 694.8 \text{ g } \checkmark$ $\text{mass limestone} = \frac{694.8 \times 100}{95.0} = 731 \text{ g (3SF) } \checkmark$	3	AO2.6 x3	<p>ALLOW ECF throughout</p> <p>ALLOW calculation process in any order.</p> <p>IGNORE rounding errors past 3SF</p> <p>DO NOT ALLOW 100 for M_r of CaCO_3</p> <p>Common errors</p> <p>2 marks</p> <table style="width: 100%; border: none;"> <tr> <td style="width: 50%;">146g</td> <td style="width: 50%;">no x 5 for moles of CaCO_3</td> </tr> <tr> <td>660g</td> <td>use of 95.0/100</td> </tr> <tr> <td>29.3g</td> <td>divide by 5 rather than x5</td> </tr> </table>	146g	no x 5 for moles of CaCO_3	660g	use of 95.0/100	29.3g	divide by 5 rather than x5
146g	no x 5 for moles of CaCO_3											
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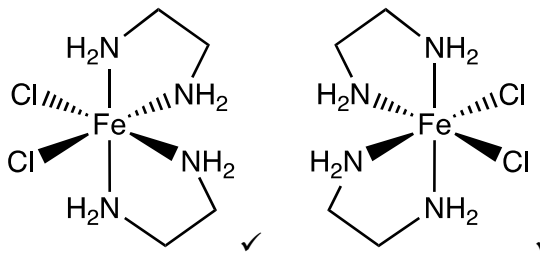
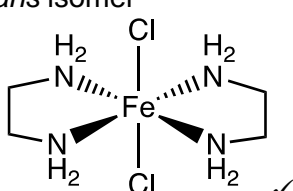
		(ii)	$\text{Mg}_3\text{Ca}(\text{CO}_3)_4(\text{s}) + 8\text{HCl}(\text{aq}) \rightarrow$ $3\text{MgCl}_2(\text{aq}) + \text{CaCl}_2(\text{aq}) + 4\text{H}_2\text{O}(\text{l}) + 4\text{CO}_2(\text{g})$ <p>Correct formulae ✓</p> <p>Balanced AND state symbols ✓</p>	2	AO2.6 x2	<p>ALLOW multiples</p> <p>M2 dependent on M1</p> <p>IGNORE incorrect state symbol for $\text{Mg}_3\text{Ca}(\text{CO}_3)_4$</p>
			TOTAL	13		

Question			Answer	Marks	AO element	Guidance
22	(a)	(i)	<p>(N) donates two electron pairs (to a metal ion/metal/Fe^{3+})</p> <p>AND</p> <p>forms two coordinate / dative (covalent) bonds ✓</p>	1	AO1.2	<p>ALLOW lone pairs for electron pairs</p> <p>TWO is only needed once if bonds are plural e.g. donates 2 electron pairs to form coordinate bonds</p> <p>OR donates electron pairs to form 2 coordinate bonds.</p>

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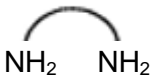


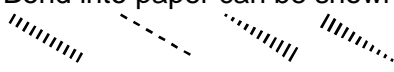
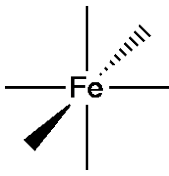
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Question	Answer	Marks	AO element	Guidance
(ii)	<p>Empirical formula $\text{FeC}_4\text{H}_{16}\text{N}_4\text{Cl}_2$ (any order) AND charge = (1)+ ✓</p> <p>Structures</p> <p>i.e. Optical isomers (<i>cis</i>)</p>  <p>i.e. <i>trans</i> isomer</p> 	4	<p>AO1.2 x1</p> <p>AO3.1 x3</p>	<p>DO NOT ALLOW $\text{Fe}(\text{NH}_2\text{CH}_2\text{CH}_2\text{NH}_2)\text{Cl}_2$ for empirical formula</p> <p>ALLOW any order</p> <p>-----</p> <p>TAKE CARE: structures may be in different orientations and in different order</p> <p>IGNORE charges (anywhere)</p> <p>IF connectivity between Fe AND N of NH_2 is incorrect then penalise first time ONLY</p>

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Question	Answer	Marks	AO element	Guidance
	<p>For $\text{NH}_2\text{CH}_2\text{CH}_2\text{NH}_2$, ALLOW skeletal, structural, displayed formula AND C-C without Hs and </p> <p>IF NH_2 shown with incorrect number of H, eg. N  N, penalise first time ONLY</p> <p>IF ALL 3 isomers are 'correct', but 2 x CI AND no Ns, e.g.  AWARD 1 mark</p>			<p>Each structure to contain 2 'out wedges', 2 'in wedges' and 2 lines in plane of paper OR 4 lines, 1 'out wedge' and 1 'in wedge':</p> <p>Bond into paper can be shown as:</p>  <p>ALLOW</p> 
(b)	(i)	1	AO2.6	<p>IGNORE state symbols, even if wrong</p> <p>ALLOW</p> $[\text{Fe}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^- \rightarrow \text{Fe}(\text{OH})_2(\text{H}_2\text{O})_4 + 2\text{H}_2\text{O}$ <p>OR</p> $[\text{Fe}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^- \rightarrow \text{Fe}(\text{OH})_2 + 6\text{H}_2\text{O}$

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Question	Answer	Marks	AO element	Guidance
	<p>(ii) Explanation of the brown precipitate The brown ppt is Fe(OH)₃ OR Fe(OH)₂ loses electrons/ Fe(OH)₂ oxidised ✓</p> <p>Comparison of <i>E</i> values (<i>E</i> of) Fe/Redox system 1 is more negative/less positive (than <i>E</i> of O₂/redox system 2) OR (<i>E</i> of) O₂/Redox system 2 is more positive/less negative (than <i>E</i> of Fe/redox system 1) ✓</p> <p>Equilibrium shift More negative/less positive OR Fe system OR Redox system 1 shifts left OR More Positive/less negative OR O₂ system OR Redox system 2 shifts right ✓</p> <p>Equation $4\text{Fe(OH)}_2(\text{s}) + \text{O}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) \rightarrow 4\text{Fe(OH)}_3(\text{s})$ ✓</p>	4	AO3.1 x4	<p>ORA</p> <p>ALLOW Fe²⁺ is oxidised to Fe³⁺</p> <p>ALLOW Fe ALLOW E_{cell} is (+) 0.96V IGNORE 'lower/higher'</p> <p>For equilibrium shift ALLOW E_{cell} is +ve therefore the reaction is feasible. OR Direction of half equation correctly written.</p> <p>ALLOW multiples ALLOW equilibrium IGNORE state symbols, even if wrong DO NOT ALLOW uncanceled species</p>

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Question	Answer	Marks	AO element	Guidance														
(c)	<p>Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.</p> <p>Level 3 (5–6 marks) Reaches a comprehensive conclusion to determine the correct formulae of almost all of B, C, D, E, F and G. AND most correct equations and identifies some changes in oxidation number AND Calculation of M_r of the gas</p> <p><i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i></p> <p>Level 2 (3–4 marks) Reaches a conclusion to determine the correct formulae of at least half of B, C, D, E, F and G. AND EITHER some correct equations OR Any one correct equation and a relevant change in oxidation number OR any one correct equation and a correct calculation of the M_r</p> <p><i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i></p>	6	AO3.1 ×3 AO3.2 ×3	<p>Indicative scientific points may include</p> <table border="1" data-bbox="1671 304 2051 762"> <thead> <tr> <th></th> <th>Formula</th> </tr> </thead> <tbody> <tr> <td>B</td> <td>CuCl_4^{2-} OR $[\text{CuCl}_4]^{2-}$</td> </tr> <tr> <td>C</td> <td>$[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$ OR CuSO_4</td> </tr> <tr> <td>D</td> <td>SO_2</td> </tr> <tr> <td>E</td> <td>$\text{Cu}(\text{NO}_3)_2$ OR $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$</td> </tr> <tr> <td>F</td> <td>CuI</td> </tr> <tr> <td>G</td> <td>I_2</td> </tr> </tbody> </table> <p>Experiment 1 Equation $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{Cl}^- \rightarrow [\text{CuCl}_4]^{2-} + 6\text{H}_2\text{O}$ $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{HCl} \rightarrow [\text{CuCl}_4]^{2-} + 6\text{H}_2\text{O} + 4\text{H}^+$</p> <p>Experiment 2 Evidence $n(\text{D}) = \frac{45}{24000} = 1.875 \times 10^{-3}$ $\text{Molar mass (D)} = \frac{0.12}{1.875 \times 10^{-3}} = 64$</p> <p>Equation $\text{Cu} + 2\text{H}_2\text{SO}_4 \rightarrow \text{CuSO}_4 + \text{SO}_2 + 2\text{H}_2\text{O}$</p> <p>Oxidation numbers $\text{Cu } 0 \rightarrow \text{Cu } +2; \quad \text{S } +6 \rightarrow \text{S } +4$</p>		Formula	B	CuCl_4^{2-} OR $[\text{CuCl}_4]^{2-}$	C	$[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$ OR CuSO_4	D	SO_2	E	$\text{Cu}(\text{NO}_3)_2$ OR $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$	F	CuI	G	I_2
	Formula																	
B	CuCl_4^{2-} OR $[\text{CuCl}_4]^{2-}$																	
C	$[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$ OR CuSO_4																	
D	SO_2																	
E	$\text{Cu}(\text{NO}_3)_2$ OR $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$																	
F	CuI																	
G	I_2																	

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Question	Answer	Marks	AO element	Guidance
	<p>Level 1 (1–2 marks) Reaches a simple conclusion to determine the correct formulae of some of B, C, D, E, F and G OR The correct formulae for 1 of B, C, D, E, F and G with correct equation or calculation.</p> <p><i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i></p> <p>0 marks <i>No response or no response worthy of credit.</i></p>			<p>Experiment 3 Equation $\text{CuO} + 2\text{HNO}_3 \rightarrow \text{Cu}(\text{NO}_3)_2 + \text{H}_2\text{O}$</p> <p>$2\text{Cu}^{2+} + 4\text{I}^- \rightarrow 2\text{CuI} + \text{I}_2$ OR $2\text{Cu}(\text{NO}_3)_2 + 4\text{KI} \rightarrow 2\text{CuI} + \text{I}_2 + 4\text{KNO}_3$</p> <p>Oxidation numbers $\text{Cu} +2 \rightarrow \text{Cu} +1$; $\text{I} -1$ to 0</p>

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