GCE

Chemistry A

H432/01: Periodic table, elements and physical chemistry

A Level

Mark Scheme for June 2022

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It is also responsible for developing new specifications to meet national requirements and the needs of students and teachers. OCR is a not-for-profit organisation; any surplus made is invested back into the establishment to help towards the development of qualifications and support, which keep pace with the changing needs of today's society.

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.

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:

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:

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 

11. Annotations available in RM Assessor

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

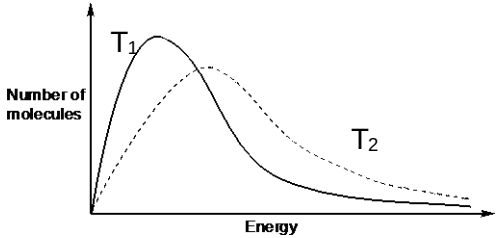
You should ensure also that you are familiar with the administrative procedures related to the marking process. These are set out in the OCR booklet **Instructions for Examiners**. If you are examining for the first time, please read carefully **Appendix 5 Introduction to Script Marking: Notes for New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

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

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		

SECTION B

Question			Answer	Marks	AO element	Guidance
16	(a)	(i)	 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 ✓ Drawing of correct Boltzmann distributions at **two** different temperatures with one termperature identified. ✓ (At higher temperature) **more** molecules/particles have energy above activation energy ✓	3	AO1.1 ×3	**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 **ALLOW** T2 as 'higher termperature' 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 **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 **DO NOT ALLOW** lowers E_a **DO NOT ALLOW** atoms for molecules **IGNORE** (more) successful collisions

Question			Answer	Marks	AO element	Guidance
	(a)	(ii)	**Orders** **(Expt 1+2)** When [NO] × 2, rate × 4 **AND** 2nd order with respect to NO ✓ **(Expt 2+3)** When [NO] × 2 **AND** [CO] × 4, rate × 16 **AND** 1st order with respect to CO ✓ **Rate Equation** rate = k [NO]^2[CO] ✓ **Value of *k*** $k = \frac{1.85 \times 10^{-4}}{(2.75 \times 10^{-4})^2 \times 7.25 \times 10^{-4}}$ = **3.37 × 10^6** ✓ **Units of *k*** dm^6 mol^{-2} s^{-1} ✓	**5**	**AO3.1** **AO3.2** **AO2.6** **AO1.2 ×2**	**ALLOW ORA** throughout e.g. expt 2+1 [NO] halves, rate quarters etc. **IGNORE** [CO] constant **ALLOW** if working shown with the table. **ALLOW** if seen in 2 steps i.e. When [NO] × 2, rate x 4 AND [CO] × 4, intermediate rate × 4. **ALLOW** comparing **Expt 1+3** When [NO] × 4 AND [CO] × 4, rate × 64 **AND** 1st order with respect to CO **ALLOW ECF** from incorrect orders **ALLOW** rate = k [NO]^2[CO]^1 **ALLOW** rate equation with correct numbers substituted **ALLOW** 3.36 x 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 x10^6 **IGNORE** rounding errors past **3SF** **ALLOW** units in any order e.g. mol^{-2} dm^6 s^{-1} **ALLOW ECF** from incorrect rate equation.

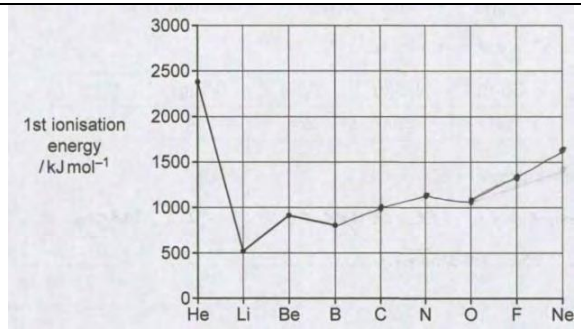
Question			Answer	Marks	AO element	Guidance
						Common errors **4 marks (including units)** 4.65 x 10^9 mol $^{-3}$ dm^9 s^{-1} (use of 2nd order with respect to CO) 2446 mol^{-1} dm^3 s^{-1} (use of zero order wrt CO)
	(b)		$2NO_2$ **<u>only</u>** on LHS of step 1 ✓ Rest of mechanism ✓	**2**	**AO3.1 ×2**	M2 dependent on M1 ***Examples:*** *Step 1* : $2NO_2 \rightarrow NO + NO_3$ *Step 2* : $NO_3 + CO \rightarrow NO_2 + CO_2$ **OR** *Step 1* : $2NO_2 \rightarrow N_2O_4$ *Step 2* : $N_2O_4 + CO \rightarrow NO + NO_2 + CO_2$ **OR** *Step 1* : $2NO_2 \rightarrow N_2 + 2O_2$ *Step 2* : $N_2 + 2O_2 + CO \rightarrow NO + NO_2 + CO_2$ **OR** *Step 1* : $2NO_2 \rightarrow 2NO + O_2$ *Step 2* : $NO + O_2 + CO \rightarrow NO_2 + CO_2$
			Total	**10**		

Question			Answer	Marks	AO element	Guidance
17	(a)	(i)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF *T* = 52.4 ºC OR 52.5 ºC award 4 marks** **IF *T* = 32.4 (ºC) award 3 marks** **----------** ***Correctly calculates n($AgNO_3$)*** $= 0.400 \times \frac{100.0}{1000}$ **OR** 0.04(00) (mol) ✓ ***Energy released per mole of $AgNO_3$ in J OR kJ*** $= \frac{678 \times 0.0400}{2}$ **OR** 13.56 (kJ) **OR** 13560 (J) ✓ ***Correctly calculates ΔT*** $\Delta T = \frac{13560}{100 \times 4.18}$ **OR** 32.4 (ºC) ✓ ***Maximum temperature reached*** = 32.4… + 20.0 = 52.4 ºC ✓ **3 SF required**	4	**AO1.2** **AO2.4** **AO2.8** **AO2.8**	***FULL ANNOTATIONS MUST BE USED*** **----------** **ALLOW ECF** throughout **----------** **ALLOW** 13.6 kJ **OR** 13600 J (to 3SF) **DO NOT ALLOW** < 3 SF **IGNORE** any sign **and** units *i.e.* ***ALLOW*** *correctly calculated value in J* ***OR*** *kJ* **----------** **ALLOW ECF ONLY** from calculated ΔT *+20* ºC **Common errors** **3 marks** **84.9 ºC (not divided $\frac{169.8}{2}$)**

	(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** - $4(\Delta_f H^{\ominus}.NO)$ $= -1172 - 6(-286) + 4(-46)$ $= -1172 + 1716 - 184$ $= (+)360$ (kJ mol^{-1}) ✓ $\Delta_f H^{\ominus}.NO = \frac{360}{4} = (+)90$ (kJ mol^{-1}) ✓	**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)

	(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
		(ii)	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer =** –2587 (kJ mol^{-1}) **award 3 marks** --- $\Delta S^{\ominus}$ $\Delta S^{\ominus}$ = 256 + 4(214) + 8(192) – 4(151) – 8(220) = (+)284 (J K^{-1} mol^{-1}) **OR** (+)0.284 (kJ K^{-1} mol^{-1}) ✓ *Use of* T = 298 (K) **AND** ΔS = 0.284 (kJ K^{-1} mol^{-1}) ✓ $\Delta H = (\Delta G + T\Delta S)$ = –2587 (kJ mol^{-1}) ✓	**3**	**AO2.2** **×3**	**ALLOW ECF throughout** M2 is for unit conversions seen anywhere. **ALLOW 3SF** up to the calculator value -2587.368 (kJ mol^{-1}) **ALLOW ECF** from incorrect unit conversions or incorrect ΔS.

						Common errors **2 marks** -2664.9 (kJ mol^{-1}) (Use of 25^{o}C) 81960 (kJ mol^{-1}) (Use of ΔS 284) 4428 (kJ mol^{-1}) (Use of 25^{o}C and ΔS 284) -2756.632 (kJ mol^{-1}) (Use of ΔS = -0.284)
		(iii)	ΔS is positive/ + **AND** ΔH is negative/ – ✓ ΔG is negative (– at all temperatures) **OR** ΔG is (always) negative/ – ✓	**2**	**AO3.1** **AO3.2**	**ALLOW** ΔH is exothermic **ALLOW** '-TΔS' is negative' *ΔG comment is **dependent** on on the signs assigned to ΔS* **AND** *ΔH (either in answer or from 17 cii).* **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 ΔS is negative/ - **AND** ΔH is negative/ - Reaction is feasible only at low temperatures **IGNORE** ΔS is negative/ - **AND** ΔH is positive/ + (-ΔG given in 17 cii) **----------** **<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 ✓
			Total	**14**		

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

	(c)			**4**		FULL ANNOTATIONS WITH TICKS, CROSSES, CON, etc MUST BE USED
			Explanation for He *Distance/shielding* (Outer) electrons are in a lower energy/closer shell/smaller atomic radius/fewer shells ✓		**AO1.1**	**ORA** throughout Comparison needed for each mark **ALLOW** change of **shell** (i.e **2**s and **1**s) **IGNORE** 'different **sub**-shell'
			Explanation for Be *Nuclear charge* number of protons/proton number increases **OR** greater **nuclear** charge ✓		**AO1.1**	**IGNORE** atomic number increases **IGNORE** nucleus gets bigger **IGNORE** 'effective nuclear charge increases'
			Distance/shielding (Outer) electrons are in the same shell **OR** sub-shell **OR** (Outer) electrons experience the same/similar shielding **OR** Atomic radius decreases ✓		**AO1.2**	**ALLOW** same orbital **IGNORE** 'there is shielding' **ALLOW** 'greater repulsion from inner shells'
			For either Be or He *Attraction* **Greater** nuclear attraction (on outer electrons) **OR** (outer) electrons attracted more strongly to the nucleus ✓		**AO1.2**	**IGNORE** just 'greater attraction' **OR** greater force **IGNORE '**pull' for 'attraction' **IGNORE** 'held' for attracted, *e.g. IGNORE 'held more strongly*

	(d)		***Sub-shells*** Be electron is in (2)s **AND** B electron is in (2)p ✓ ***Energy levels*** B / (2)p is high**er energy** (level) **OR** Be / (2)s is low**er energy (**level) ✓	**2**	**AO1.2 ×2**	**IGNORE** number before s and p **DO NOT ALLOW** "shell" **IGNORE** block **DO NOT ALLOW** unpaired electron removed more easily (**ORA**) **IGNORE** 'less energy to remove' **IGNORE** comments about distance from nucleus **IGNORE** 2s shielding
			Total	**9**		

Question			Answer	Marks	AO element	Guidance
19	(a)	(i)	**Titres** 22.75 | 22.45 | **22.70** | 22.55 ✓ **Mean titre** $\frac{22.45 + 22.55}{2}$ = 22.5(0) (cm^3) ✓	**2**	**AO1.2 ×2**	**2 DP essential** i.e. last 0 for 22.70 **DO NOT ALLOW** use of trial titre.
		(ii)	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 498 mg award 5 marks - **Number of moles of KOH in titre** $= 0.0600 \times \frac{22.50}{1000}$ **OR** 1.35×10^{-3} (mol) ✓ **Number of moles of acid in 10 cm^3** $= \frac{1.35 \times 10^{-3}}{2}$ **OR** 6.75×10^{-4} (mol) ✓ ***Number of moles of* acid in 250 cm^3** $= 6.75 \times 10^{-4} \times 25$ **OR** 0.016875 (mol) ✓ ***Mass of* acid in 4 tablets** $= 0.016875 \times 118$ **OR** 1.99125 (g) ✓ **Mass in one tablet AND mg conversion** **(**i.e. divide by 4 **AND** x 1000) $= \frac{1.99 \times 10^3}{4} = 498$ (mg) ✓ **Answer must be to 3SF**	**5**	**AO2.8 ×3** **AO3.1** **AO3.2**	**ALLOW ECF** from incorrect titre in 19 (a) (i) **ALLOW ECF** throughout **TAKE CARE: values shown may be truncated calculator values.** Steps can be calculated in any order which will change the intermediate answers**.** Marks are for the processing of the data. **ALLOW 3SF** up to calculated value throughout **BUT** ignore trailing zeros on intermediate values **IGNORE** rounding errors past **3SF** ---------- **Common errors** **5 marks** 503 mg (use of 22.725 cm^3) **4 marks** 996mg (no divided by 2) 19.9mg (no volume conversion i.e. x 25)

Question			Answer	Marks	AO element	Guidance
	(b)	(i)	(Glycolic) acid is in **excess/partially neutralised** **AND** glycolate/potassium glycolate (ions) are present/produced ✓	1	AO1.1	**ALLOW** some acid remains **ALLOW** conjugate base for glycolate ions/salt of weak acid **ALLOW** $HOCH_2COO^-$
		(ii)	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 3.93 award 4 marks** **Initial amounts** $n(HOCH_2COOH) = 0.750 \times \frac{60.0}{1000}$ **OR** 0.045(0) (mol) **AND** $n(KOH) = 0.625 \times \frac{40.0}{1000}$ **OR** 0.025(0) ✓ **Amounts in the buffer solution** $n(HOCH_2COOH) = 0.0450 - 0.0250$ **OR** 0.02(00) (mol) **AND** $n(HOCH_2COO^-)$ 0.025(0) (mol) ✓ **pH** $K_a = 10^{-3.83}$ **OR** $1.479 \ldots \times 10^{-4}$ ✓ $[H^+] = \frac{1.479 \ldots \times 10^{-4} \times 0.200}{0.250}$ **OR** 1.183×10^{-4} (mol dm^{-3}) pH = 3.93 (**2 DP**) ✓	4	AO1.2 ×1 AO2.8 ×3	**ALLOW ECF** throughout **ALLOW use of moles for concentration** $[H^+] = \frac{1.479 \ldots \times 10^{-4} \times 0.0200}{0.0250}$ **Common errors** **3 marks** pH = 3.57 not using n(HA) remaining **2 marks** pH = 3.75 using HA and KOH concentrations within question

Question			Answer	Marks	AO element	Guidance
		(iii)	NH_3 / OH^- reacts with H^+ / $HOCH_2COOH$ / (Glycolic) acid ✓ $HOCH_2COOH \rightleftharpoons H^+ + HOCH_2COO^-$ **AND** Equilibrium shifts to the right ✓	**2**	**AO1.2 ×2**	**ALLOW** NH_3 will act as a base (and form NH_4^+) **ALLOW** NH_3 decreases $[H^+]$ **ALLOW** $HA \rightleftharpoons H^+ + A^-$ Equilibrium equation needs to be shown.
			Total	**14**		

Question			Answer	Marks	AO element	Guidance
20	(a)		Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question. **Level 3 (5–6 marks)** Uses correct method to calculate K_c **AND** explains why most operational condition is different with few omissions in the explanation. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** 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. *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** 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 *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.*	**6**	**AO2.4 ×4** **AO1.2 ×2**	**Indicative scientific points may include:** **IGNORE trailing zeroes** **Equilibrium amounts** $n(N_2)$: 1.20 – 0.08 = 1.12, $n(H_2)$: 3.60 – 0.24 = 3.36 **Equilibrium concentrations** $[N_2] = \frac{1.12}{8.00} = 0.140$ (mol dm^{-3}) $[H_2] = \frac{3.36}{8.00} = 0.420$ (mol dm^{-3}) $[NH_3] = \frac{0.160}{8.00} = 0.0200$ (mol dm^{-3}) **Equilibrium expression and K_c value wih units** $K_c = \frac{[NH_3]^2}{[N_2] \times [H_2]^3}$ $K_c = \frac{0.0200^2}{0.140 \times 0.420^3} = 0.0386$ *Calculator: 0.03856417851* **Units:** dm^6 mol^{-2} **Explanation for operational differences.** **Temperature** • Low temperature for maximum yield: (ΔH –ve \ exothermic) • High temperature to increase rate **Pressure** • High pressure for maximum yield (fewer (gaseous) moles/molecules of products) • High pressure expensive to generate **OR** high pressure is a safety hazard

Question			Answer	Marks	AO element	Guidance
			0 marks *No response or no response worthy of credit.*			**Catalyst** • 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' *Implies shift to left* **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**		

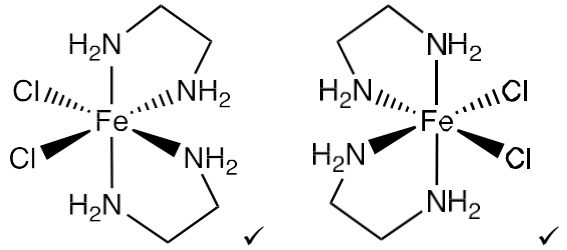
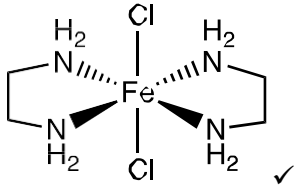
Question			Answer	Marks	AO element	Guidance
21	(a)	(i)	Ca fizzes faster **AND** Ca dissolves/disappears more quickly ✓	1	AO2.3	**CARE** Both needed for **1 mark.** **ORA** **ALLOW AW** **IGNORE** finishes first **IGNORE** more bubbles (need idea of rate) **IGNORE** exothermic
21		(ii)	Oxidation $Mg \rightarrow Mg^{2+} + 2e^-$ ✓ Reduction $2H^+ + 2e^- \rightarrow H_2$ **OR** $H^+ + e^- \rightarrow ½H_2$ ✓	2	AO2.6 ×2	In half equations, **ALLOW** the use of e for e^- **ALLOW** Mg - $2e^- \rightarrow Mg^{2+}$ **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

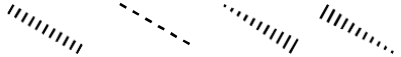
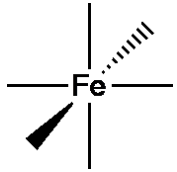
	(b)	**(i)**	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 2.53(g) award 5 marks** **----------** **[H^+]** = $10^{-13.12}$ **OR** 7.58…....× 10^{-14} (mol dm^{-3}) ✓ **[OH^-]** = $\frac{1 \times 10^{-14}}{7.58\ldots\ldots \times 10^{-14}}$ **OR** 0.1318 …….. (mol dm^{-3}) ✓ ***n*(OH⁻) in 250 cm³** = $\frac{0.1318\ldots..}{4}$ **OR** 0.0329…..... (mol) ✓ ***n*(Ba(OH)₂) or n(BaO)** = $\frac{0.0329\ldots\ldots}{2}$ **OR** 0.0164……(mol) ✓ **Mass of BaO =** 0.0164….. × 153.3 = 2.53 (g) **3SF** ✓	**5**	**AO2.4 ×5**	**ALLOW ECF and 3SF throughout.** **ALLOW** calculation process in any order. **IGNORE** rounding errors past **3SF** **----------** Calculator: 7.58577575 × 10^{-14} Calculator: 0.1318256739 **ALLOW** alternative approach using pOH for first 2 marks. p[OH^-] = 14 – 13.12 = 0.88 [OH^-] = $10^{-0.88}$ = 0.1318….. Calculator: 0.03295641846 0.033(0) comes from [OH^-] = 0.132 Calculator: 0.01647820923 Calculator: 2.526109475 **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 **3 marks** 5.65g not dividing by 2 and using Mr for $Ba(OH)_2$

		(ii)	$Ba^{2+}(aq) + 2H^{+}(aq) + SO_4^{2-}(aq) + 2OH^{-}(aq) \rightarrow BaSO_4(s) + 2H_2O(l)$ ✓	**1**	**AO3.2**	**ALLOW** multiples **ALLOW** $H^{+}(aq) + OH^{-}(aq) \rightarrow H_2O(l)$ **OR** $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$
	(c)	**(i)**	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 731(g) award 3 marks** **----------** ***n*(Z)** $n\ (Ca_5NH_4(NO_3)_{11}\cdot 10H_2O) = \frac{1500}{1080.5}$ **OR** 1.388246… ✓ **Mass of limestone** $n(CaCO_3) = 1.388246\ldots \times 5$ **OR** 6.94123… **AND** mass $CaCO_3 = 6.94123\ldots \times 100.1$ **OR** 694.8 g ✓ mass limestone $= \frac{694.8 \times 100}{95.0} = 731$ g (**3SF**) ✓	**3**	**AO2.6 ×3**	**ALLOW ECF throughout** **ALLOW** calculation process in any order. **IGNORE** rounding errors past **3SF** **DO NOT ALLOW** 100 for M_r of $CaCO_3$ **Common errors** **2 marks** 146g no x 5 for moles of $CaCO_3$ 660g use of 95.0/100 29.3g divide by 5 rather than x5

		(ii)	$Mg_3Ca(CO_3)_4$ (s) + 8HC*l*(aq) → 3MgCl_2(aq) + CaCl_2(aq)+ 4H_2O(l) + 4CO_2(g) Correct formulae ✓ Balanced **AND** state symbols ✓	**2**	**AO2.6 ×2**	**ALLOW** multiples **M2** dependent on **M1** **IGNORE** incorrect state symbol for $Mg_3Ca(CO_3)_4$
			TOTAL	**13**		

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

Question			Answer	Marks	AO element	Guidance
		(ii)	**Empirical formula** $FeC_4H_{16}N_4Cl_2$ (any order) **AND** charge = (1)+ ✓ **Structures** i.e. Optical isomers (*cis*)  ✓ *i.e. trans* isomer  ✓	**4**	**AO1.2 ×1** **AO3.1 ×3**	**DO NOT ALLOW** $Fe(NH_2CH_2CH_2NH_2)Cl_2$ for empirical formula **ALLOW** any order --- **TAKE CARE**: structures may be in different orientations and in different order **IGNORE** charges **(anywhere)** **IF** connectivity between Fe **AND** N of NH_2 is incorrect then penalise first time **ONLY**

Question			Answer	Marks	AO element	Guidance
			For $NH_2CH_2CH_2NH_2$, **ALLOW** skeletal, structural, displayed formula **AND** C-C without Hs and  **IF** NH_2 shown with incorrect number of H, eg.  , penalise first time **ONLY** **IF ALL** 3 isomers are 'correct', but **2 x Cl AND** no Ns, e.g.  **AWARD** 1 mark			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': Bond into paper can be shown as:  **ALLOW** 
	(b)	**(i)**	$Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2$ ✓	**1**	**AO2.6**	**IGNORE** state symbols, even if wrong **ALLOW** $[Fe(H_2O)_6]^{2+} + 2OH^- \rightarrow Fe(OH)_2(H_2O)_4 + 2H_2O$ **OR** $[Fe(H_2O)_6]^{2+} + 2OH^- \rightarrow Fe(OH)_2 + 6H_2O$

Question			Answer	Marks	AO element	Guidance
		(ii)	**Explanation of the brown precipitate** The brown ppt is $Fe(OH)_3$ **OR** $Fe(OH)_2$ loses electrons/ $Fe(OH)_2$ oxidised ✓ **Comparison of *E* values** (*E* of) Fe/Redox system 1 is more negative/less positive (than *E* of O_2/redox system 2) **OR** (*E* of) O_2/Redox system 2 is more positive/less negative (than *E* of Fe/redox system 1) ✓ **Equilibrium shift** More negative/less positive **OR** Fe system **OR** Redox system 1 shifts left **OR** More Positive/less negative **OR** O_2 system **OR** Redox system 2 shifts right ✓ **Equation** $4Fe(OH)_2(s) + O_2(g) + 2H_2O(l) \rightarrow 4Fe(OH)_3(s)$ ✓	4	AO3.1 ×4	**ORA** **ALLOW** Fe^{2+} is oxidised to Fe^{3+} **ALLOW** Fe **ALLOW** E_{cell} is (+) 0.96V **IGNORE** 'lower/higher' **For equilibrium shift** **ALLOW** E_{cell} is +ve therefore the reaction is feasible. **OR** Direction of half equation correctly written. **ALLOW** multiples **ALLOW** equilibrium **IGNORE** state symbols, even if wrong **DO NOT ALLOW** uncancelled species

Question	Answer	Marks	AO element	Guidance
(c)	Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question. **Level 3 (5–6 marks)** Reaches a comprehensive conclusion 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 *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Reaches a 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 *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.*	6	**AO3.1 ×3** **AO3.2 ×3**	**Indicative scientific points may include** **B** $CuCl_4^{2-}$ **OR** $[CuCl_4]^{2-}$ **C** $[Cu(H_2O)_6]^{2+}$ **OR** $CuSO_4$ **D** SO_2 **E** $Cu(NO_3)_2$ **OR** $[Cu(H_2O)_6]^{2+}$ **F** CuI **G** I_2 **Experiment 1** **Equation** $[Cu(H_2O)_6]^{2+} + 4Cl^- \rightarrow [CuCl_4]^{2-} + 6H_2O$ $[Cu(H_2O)_6]^{2+} + 4HCl \rightarrow [CuCl_4]^{2-} + 6H_2O + 4H^+$ **Experiment 2** **Evidence** $n(\mathbf{D}) = \frac{45}{24000} = 1.875 \times 10^{-3}$ Molar mass (**D**) $= \frac{0.12}{1.875 \times 10^{-3}} = 64$ **Equation** $Cu + 2H_2SO_4 \rightarrow CuSO_4 + SO_2 + 2H_2O$ **Oxidation numbers** Cu 0 → Cu +2; S +6 → S +4

Question			Answer	Marks	AO element	Guidance
			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. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*			**Experiment 3** **Equation** $CuO + 2HNO_3 \rightarrow Cu(NO_3)_2 + H_2O$ $2Cu^{2+} + 4I^- \rightarrow 2CuI + I_2$ **OR** $2Cu(NO_3)_2 + 4KI \rightarrow 2CuI + I_2 + 4KNO_3$ **Oxidation numbers** Cu +2 → Cu +1; I –1 to 0

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