CAMBRIDGE
OCR

GCE

Chemistry A

H432/01: Periodic table, elements and physical chemistry

A Level

Mark Scheme for June 2026

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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 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. These are posted on the RM Cambridge Assessment Support Portal http://www.rm.com/support/ca

3. Log-in to RM Assessor and mark the **required number** of practice responses ("scripts") and the **number of required** 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 40% 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 or the RM Assessor messaging system, or by email.

5. **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. There is a NR (No Response) option. Award NR (No Response)
   - if there is nothing written at all in the answer space
   - OR if there is a comment which does not in any way relate to the question (e.g. 'can't do', 'don't know')
   - OR if there is a mark (e.g. a dash, a question mark) which isn't an attempt at the question.

   Note: Award 0 marks – for an attempt that earns no credit (including copying out the question).
   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 e-mail.

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 **18a** and **21c(i).**

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



If a candidate has achieved 5 marks then they have reached Level 3 but with one mark omitted. 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 SEEN

11. **Annotations**

Annotation	Meaning
	Correct response
	Incorrect response
A	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

Annotation	Meaning
SEEN	Noted but no credit given
I	Ignore
BP	Blank page

12. **Subject Specific Marking Instructions**

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

Annotation	Meaning
/; OR	alternative and acceptable answers for the same marking point
✓	Separates marking points
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.

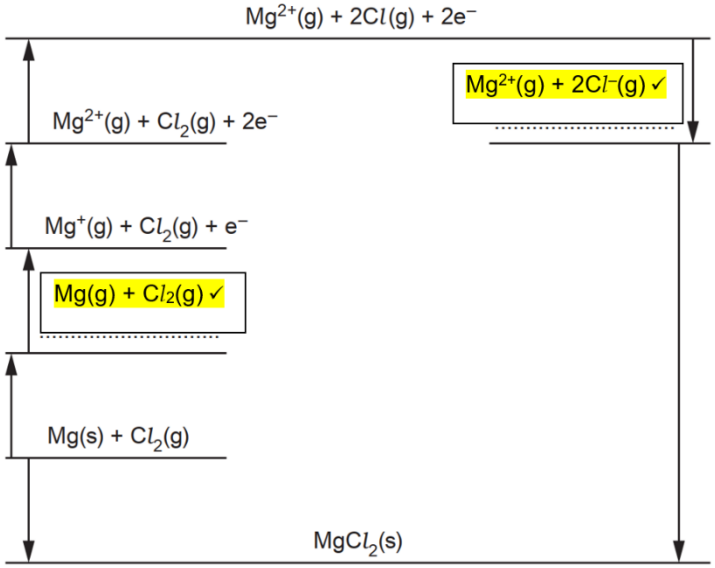
SECTION A

Question	Answer	Marks	Guidance
1	D	1	
2	D	1	
3	C	1	
4	C	1	
5	B	1	
6	D	1	
7	A	1	
8	C	1	
9	B	1	
10	D	1	
11	B	1	
12	C	1	
13	C	1	
14	D	1	**ALLOW** '1' instead of 'D'
15	A	1	
	Total	15	

SECTION B

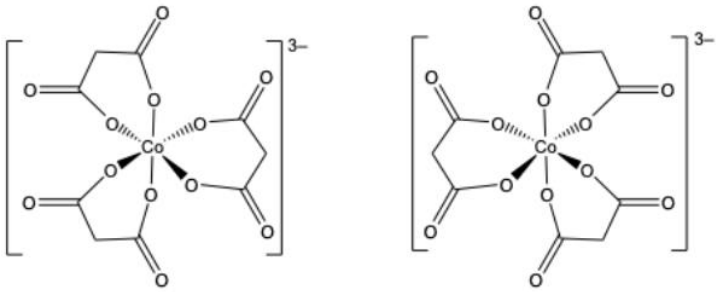
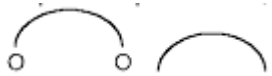
Question			Answer	Mark	Guidance
16	(a)	(i)	$Al^{2+}(g) \rightarrow Al^{3+}(g) + e^{-}$ ✓	1	**ALLOW** $Al^{2+}(g) - e^{-} \rightarrow Al^{3+}(g)$ **ALLOW** e for e^{-} **IGNORE** state symbols on electron
		(ii)	**Gradual increase between 1st and 3rd IE:** 2nd and 3rd electrons removed from **more** positively charged **ion** **OR** successive ions get smaller/have a smaller radius **OR** proton:electron ratio increases ✓ **Large increase between 3rd and 4th IE:** 4th electron removed from a **shell closer** to the nucleus **OR** first three electrons are removed from **shell** 3 but 4th electron is removed from shell 2 ✓ Greater **attraction** between nucleus (and outer electron) ✓	3	**Comparison** should be used for each mark **IGNORE** atomic (radius) for marking point 1 **ALLOW** Electron removed from **2**p rather than **3**s **IGNORE** subshell/energy level/orbital **DO NOT ALLOW** references to atoms (electron removed from ion) for mark 2 **Seen in either explanation** **IGNORE** 'pull' for attraction

Question			Answer	Mark	Guidance
16	(b)	(i)	Magnesium oxidised from 0 (in Mg) to +2 (in $MgCl_2$/Mg^{2+}) ✓ Hydrogen reduced from +1 (in HCl/H^+) to 0 (in H_2) ✓	2	Treat working on equation as rough working unless no further response has been made **ALLOW** 2+ **DO NOT ALLOW** Mg^{2+} for oxidation number **ALLOW** 1+ **DO NOT ALLOW** H^+ for oxidation number **ALLOW** 1 mark for all four relevant oxidation numbers correct **OR** correct identification of oxidation/reduction
	(b)	(ii)	Cl_2 (g) + $2I^-$ (aq) → $2Cl^-$ (aq) + I_2 (aq) ✓ Chlorine is more reactive than iodine **AND** **gains** electrons more easily **OR** forms negative/1– ion more easily ✓ Cl has a smaller atomic radius/less shielding **AND** greater (nuclear) attraction (for electron) ✓	3	**ALLOW** multiples **IGNORE** state symbols **ALLOW** ORA **ALLOW** Chlorine is more reactive than iodine **AND** is a stronger oxidising agent/more easily reduced **IGNORE** attracts **IGNORE** ideas of electron affinity **IGNORE** ideas of displacement reaction **DO NOT ALLOW** more energy “required” **ALLOW** ORA **IGNORE** explanation in terms of electronegativity

Question			Answer	Mark	Guidance
	(c)	(i)	**CARE: Two points required for 1 mark** --- Standard conditions: 1 atm/100 kPa and 298 K/25 °C Standard state: the (physical) state of a substance under standard conditions ✓	1	**ALLOW** 101 kPa, 1.01x 10^5 Pa, 1 x 10^5 Pa, 1 bar **IGNORE** concentration **ALLOW** element/compound **AW** for substance **IGNORE** RTP **IGNORE** room temperature
	(c)	(ii)	Correct cycle with all equations for energy changes labelled  	2	**State symbols are required**

Question			Answer	Mark	Guidance
	(c)	(iii)	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 123 (kJ mol^{-1}) award 2 marks** --- **2($\Delta_{at}H$)** = – (+1451) – (+738) – (+148) + (–641) – (–2526) – (2 x –349) ✓ **$\Delta_{at}H$** = 123 (kJ mol^{-1}) ✓	2	**For other answers**, check for a single transcription error or calculation error which could merit 1 mark if all values have been used –641 = 148 + 738 + 1451 + 2(**$\Delta_{at}H$**) + 2(–349) + –2526 **Common errors for 1 mark:** –2403 (use of +2526) –575 (use of 2x +349) –123 (wrong sign) –51.5 (use of 1x –349) +246 (no divide by 2) +271 (use of –148) +764 (use of +641) +861 (use of –738) +1574 (use of –1451) **DO NOT ALLOW** any answer which involves two errors

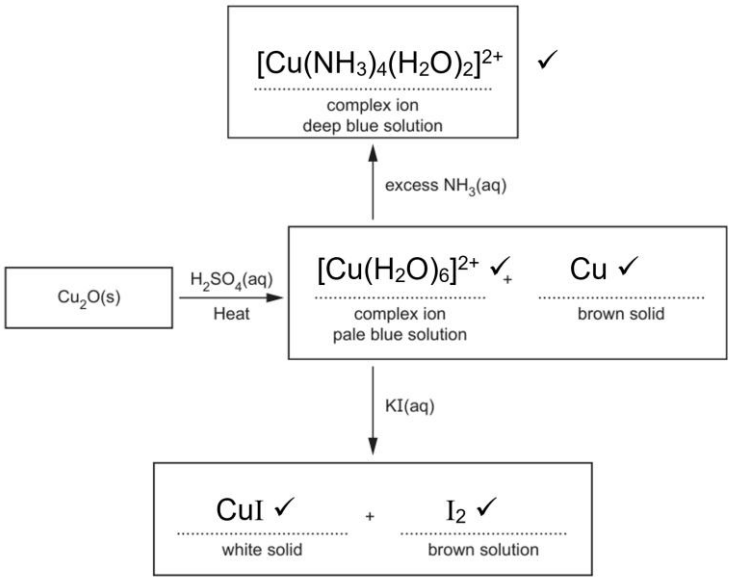
Question			Answer	Mark	Guidance
17	(a)		(An element with an) ion/atom with an incomplete/partially filled d-sub-shell/orbital ✓	1	**ALLOW** **Transition element IUPAC definition**: An element whose atom has an incomplete d sub-shell, or which can give rise to cations with an incomplete d sub-shell **IGNORE** any number before d-subshell/orbital **DO NOT ALLOW** d shell
17	(b)	(i)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^7$ ✓	1	**ALLOW** upper case D, etc and subscripts **ALLOW** inclusion of $4s^0$ **DO NOT ALLOW** [Ar] as shorthand for $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$
		(ii)	$[Co(H_2O)_6]^{2+} + 4Cl^- \rightarrow [CoCl_4]^{2-} + 6H_2O$ ✓ Ligand substitution✓	2	**ALLOW** $CoCl_4^{2-}$ for $[CoCl_4]^{2-}$ **ALLOW** CO for Co **DO NOT ALLOW** $[Co(H_2O)_6]^{2+} + 4HCl \rightarrow 4H^+ + [CoCl_4]^{2-} + 6H_2O$ (question asks for ionic) **ALLOW** Ligand exchange or **AW**

Question			Answer	Mark	Guidance
		(iii)	can **donate** electron **pairs** (to a metal ion/metal/Co/Co^{3+}) **AND** forms **two** coordinate/dative (covalent) **bonds** ✓ **Structures** ✓✓  Bonds **MUST** go to O^- of ligands	3	**ALLOW** lone pairs for electron pairs **TWO** is only needed once if bonds are plural e.g. **donates 2** electron **pairs** to form coordinate **bonds** **OR donates** electron **pairs** to form **2** coordinate **bonds** Square brackets **NOT** required For $^-OOCCH_2COO^-$, **ALLOW** skeletal, structural, displayed formula **ALLOW ECF** for missing CH_2 **OR** using C=O making the dative bond **IGNORE** charges in structures Do **NOT ALLOW** simplified loops for propanedioate e.g. 

Question			Answer	Mark	Guidance
17	c	(i)*	Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question **Level 3 (5–6 marks)** Correctly explains three scientific points with only minor omissions *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)** Correctly explains MOST of two scientific points **OR** Correctly explains SOME of all three scientific points *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)** Correctly explains MOST of one scientific point **OR** Attempts to correctly explain SOME of two scientific points *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.*	6	**Indicative scientific points may include:** **<u>Scientific point 1</u>** **Why ΔH and ΔS are both positive** **ΔH** Bonds are being broken that require/takes in energy **ALLOW** Bonds broken are stronger than the bonds formed/ more energy is required to break bonds than is released in forming bonds **ΔS** Increasing disorder/dispersal of energy because gas forms **<u>Scientific point 2</u>** **Show that the reaction is feasible at 450K** $\Delta G = \Delta H - T\Delta S$ $= 299 - ((754 \times 450) \div 1000)$ $= -40.3$ kJ mol^{-1} $\Delta G < 0$, so feasible **OR** $\Delta G = 0$ when $\Delta H = T\Delta S$ $T = \Delta H \div \Delta S = 397$ K so feasible as 450 > 397 K **<u>Scientific point 3</u>** **Effect of temperature – comments of** $T\Delta S$ and $\Delta H/\Delta G$ the idea: At lower temperature ΔH outweighs $T\Delta S$ to make $\Delta G > 0$ **Examples of statements could include:**

Question			Answer	Mark	Guidance
					TΔS, temperature and feasibility Value of TΔS becomes more positive with temperature increase As temperature increases/above 397 K, ΔG is –ve **OR** ΔG<0 so feasible –TΔS becomes more negative with temperature increase As temperature decreases/below 397 K, ΔG is +ve **OR** ΔG>0 so not feasible **ALLOW** ΔH–TΔS for ΔG i.e. At high temperatures, ΔH–TΔS<0 **OR** ΔH<TΔS At low temperatures ΔH–TΔS>0 **OR** ΔH>TΔS ΔH-TΔS less positive with increasing temperature ΔH–TΔS from +ve to –ve with increasing temperature **ALLOW** use of two correct numerical examples for ΔG calculations for two different temperatures that may include the ΔG calculation from indicative point 2 Aspects of communication might include • Explains clearly that the sign of ΔG depends on the balance between ΔH and TΔS which alters with changing temperature • Explains why ΔH and ΔS are both positive in terms of the actual species in the reaction • Shows clear working in the calculation(s) • Units for calculated answers (especially ΔG)

Question			Answer	Mark	Guidance
	(c)	(ii)	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer for mass = 16.8 (g) award 3 marks** --- $n\ (H_2O) = \frac{6.05}{18} = 0.336$ mol ✓ $n\ (CuSO_4 \bullet 5H_2O) = \frac{0.336}{5} = 0.0672$ mol ✓ $m(CuSO_4 \bullet 5H_2O) = 0.0672 \times 249.6 = 16.8$ g ✓ **3 SF required**	3	**ALLOW ECF** **ALLOW** 3 SF up to calculator value for intermediates. M2 subsumes M1 Alternative for M3: $m(CuSO_4) = 0.0672 \times 159.6 = 10.73$ **AND** $m(CuSO_4 \bullet 5H_2O) = 10.73 + 6.05 = 16.8$ **Common errors for 2 marks:** 10.7 (use of 159.6) 16.78 (more than 3SF) 16.9 (rounding to 2SF too early and using alternative M3 method) 17.0 (rounding to 2SF too early) 59.7 (no divide by 5 and using alternative M3 method) 83.9 (no divide by 5) 274 (multiply by 5 and using alternative M3 method) 419 (multiply by 5)

Question			Answer	Mark	Guidance
	(c)	(iii)		5	Brackets required for $[Cu(NH_3)_4(H_2O)_2]^{2+}$ and $[Cu(H_2O)_6]^{2+}$ **ALLOW** $[Cu(H_2O)_2(NH_3)_4]^{2+}$ **IGNORE** state symbols **IGNORE** names (question asks for formulae) **DO NOT ALLOW** incorrect charge on complex ion

Question			Answer	Mark	Guidance
18	(a) *		Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question **Level 3 (5–6 marks)** Tests for NH_4^+, Fe^{3+} **AND** SO_4^{2-} Correctly describes all three scientific points with only minor omissions *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)** Correctly describes MOST of two scientific points **OR** Correctly describes SOME of all three scientific points *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)** Correctly describes MOST of one scientific point **OR** Attempts to correctly describe SOME of two scientific points *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence* **0 marks** *No response or no response worthy of credit*	6	**Indicative scientific points** **For ammonium ions:** **Test** Any named strong alkali e.g. NaOH **DO NOT ALLOW** ammonia Use damp red litmus/universal indicator paper **Expected observations** (gives off a gas) which turns the indicator paper blue/purple/alkali **DO NOT ALLOW** if indicator is placed in solution **Equations** $NH_4^+(aq) + OH^-(aq) \rightarrow NH_3(g) + H_2O(l)$ **ALLOW** ⇌ **For iron(III) ions:** **Test** Add NaOH (aq) **OR** NH_3 (aq) **OR** OH^- (aq) **Expected observations** Orange/brown/red precipitate/solid or alternative shade of brown **Equation** $Fe^{3+}(aq) + 3OH^-(aq) \rightarrow Fe(OH)_3(s)$ **OR** $[Fe(H_2O)_6]^{3+}(aq) + 3OH^-(aq) \rightarrow Fe(OH)_3(H_2O)_3(s) + 3H_2O(l)$ **OR** $[Fe(H_2O)_6]^{3+}(aq) + 3OH^-(aq) \rightarrow Fe(H_2O)_3(OH)_3(s) + 3H_2O(l)$

Question			Answer	Mark	Guidance
					For sulfate ions: **Test** Add barium nitrate/$Ba(NO_3)_2$ (aq) or $BaCl_2$ (aq)/ Ba^{2+} (aq) **Expected observations** white precipitate/solid **Equation** Ba^{2+} (aq) + SO_4^{2-} (aq) $\rightarrow BaSO_4$ (s) **ALLOW combined equation for addition of OH^-** NH_4^+ (aq) + Fe^{3+} (aq) + $4OH^-$ (aq) $\rightarrow$ NH_3 (g) + H_2O (l) + $Fe(OH)_3$ (s) **IGNORE** comments of no observation for the carbonate Aspects of the communication statement might typically have been met in response when: • sentences are clearly structured in a logical order which would make it easy to follow the practical steps • state symbols in equations are correct • Additional incorrect tests and/or observations are not included e.g. halide tests as Ag_2CO_3 can be formed as a white ppt

Question			Answer	Mark	Guidance
18	(b)	(i)	Strongest reducing agent = V ✓ Strongest oxidising agent = VO_2^+ (and H^+) ✓	2	**IGNORE** state symbols even if incorrect. **DO NOT ALLOW** $V^{2+}(aq) + 2e^- \rightleftharpoons V(s)$ **DO NOT ALLOW** $VO_2^+(aq) + 2H^+(aq) + e^- \rightleftharpoons VO^{2+}(s) + H_2O(l)$
18	(b)	(ii)	**First reaction:** **Colour change** Violet (V^{2+}) to Green (V^{3+}) ✓ **Comparison of *E* values** System 2 (V^{3+}/V^{2+}) is more negative/less positive than 0.54 **OR** I_2/I^- ✓ **Second reaction:** Green to blue **AND** System 3 (VO^{2+}/V^{3+}) is more negative/less positive than 0.54 **OR** I_2/I^- ✓ **Equilibrium shift related to *E* values** (more negative) systems 2 **AND** 3 shift left ✓ **Final colour change** Brown **AND** I_2 does not react with VO^{2+} **OR** System 4 (VO_2^+/VO^{2+}) is less negative/more positive than 0.54 **OR** I_2/I^- (and reaction finishes) ✓	5	FULL ANNOTATIONS MUST BE USED --- **Discussion of system 1 – CON mark 1** **ALLOW** E_{cell} = 0.80 V for V^{2+}/I_2 **ALLOW** system 2 is negative **AND** I_2/I^- system is positive **IGNORE** higher/lower, larger/smaller E value **ALLOW** E_{cell} = 0.20 V for V^{3+}/I_2 **ALLOW equations for equilibrium shifts** $I_2 + 2V^{2+} \rightarrow 2V^{3+} + 2I^-$ **AND** $2H_2O + I_2 + 2V^{3+} \rightarrow 2VO^{2+} + 4H^+ + 2I^-$ **ALLOW** shades of brown **ALLOW** E_{cell} = –0.46 V for VO^{2+}/I_2 **DO NOT ALLOW** further colour change to yellow (VO_2^+)

Question			Answer	Mark	Guidance
19	(a)	(i)	**Temperature: 1 mark** (Forward) reaction is endothermic **OR** (Forward) reaction takes in heat ✓ **Pressure: 1 mark** More moles (of gas) on product side **OR** 2 (gaseous) moles form 4 (gaseous) moles ✓ **OPTIMUM EQUILIBRIUM CONDITIONS: 1 mark** High temperature **AND** low pressure ✓ **OPERATONAL CONDITIONS: 1 mark** High temperature uses more fuel/energy **AND** Low pressure means slower rate ✓	4	**FULL ANNOTATIONS MUST BE USED** --- Marking points are independent **ALLOW** reverse arguments **ALLOW** increasing temperature **AND** decreasing pressure **ALLOW ORA** **ALLOW** less frequent collisions (for low pressure) **IGNORE** expensive **IGNORE** use of catalyst **IGNORE** safety issues **IGNORE** electricity

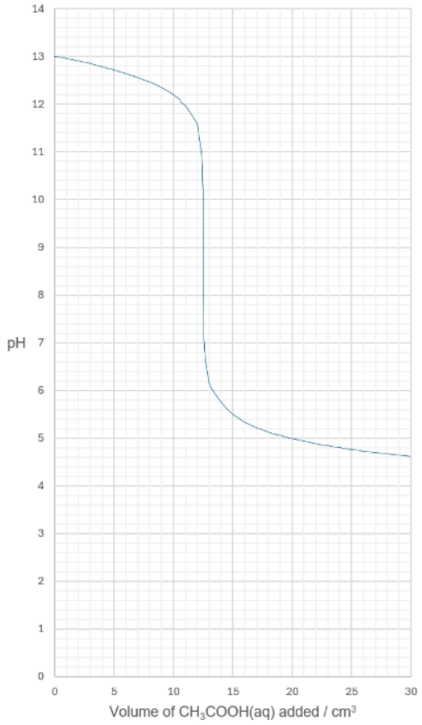
Question			Answer	Mark	Guidance
19	(a)	(ii)	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer for K_c = 0.0382 award 4 marks** --- **Separate mark for units** --- ***Eqm amounts*** $n(H_2)$ = 0.244 **AND** $n(CH_4)$ = 0.650 - 0.122 = 0.528 **AND** $n(CO_2)$ = 0.825 - 0.122 = 0.703 ✓ ***Eqm Concentrations*** **$[H_2]$ = $[CO]$** = $\frac{0.244}{0.5}$ = 0.488 **AND** $[CH_4] = \frac{0.528}{0.5}$ = 1.056 **AND** $[CO_2] = \frac{0.703}{0.5}$ = 1.406 ✓ ***K_c*** $K_c = \frac{[CO]^2[H_2]^2}{[CH_4][CO_2]}$ **OR** = $\frac{0.488^4}{(1.056 \times 1.406)}$ ✓ = 0.0382 ✓ **3SF** is required ***Units*** $mol^2\ dm^{-6}$ ✓	5	**FULL ANNOTATIONS MUST BE USED** --- **ALLOW** all 4 calculation marks for 0.0379 (rounds $[CH_4]$ and $[CO_2]$ to 3SF) **ALLOW ECF** throughout for calculation provided all 4 species being used **CARE** incorrect answers with more than one error needs to be marked as per **ANSWER** column Common errors for 3 of the calculation marks, with the stated errors: NB addition mark for correct unit 0.00955 (using amounts not concentrations) 0.0264 (no subtraction of 0.122 from CH_4 and CO_2) 0.0601 (no divide by 2 for change to CH_4 and CO_2) 0.160 (no powers in K_c expression) 0.260 (multiply by 2 for change to CH_4 and CO_2) 0.642 (multiply by 2 instead of raised to the power of 2) 1.31 (multiply by 2 in K_c expression instead of raised to the power of 2) 26.2 (K_c expression upside down) **ALLOW** in any order **ALLOW ECF** for inverted K_c expression only: $mol^{-2}\ dm^6$

Question			Answer	Mark	Guidance
	(b)	**(i)**	CH_4 (g) + H_2O (g) → CO (g) + $3H_2$ (g) ✓	1	**ALLOW** multiples **IGNORE** state symbols
		(ii)	CO_2 is **used up** **AND** is a greenhouse gas/reduces global warming/effects of global warming ✓	**1**	**ALLOW** Alternative response: Turning water into steam may require more energy **AND** produces CO_2 **AND** increases greenhouse gas. **DO NOT ALLOW** destruction of the ozone layer **DO NOT ALLOW** acid rain **IGNORE** references to temperature

Question			Answer	Mark	Guidance
20	(a)		pH = 0.46 ✓ **2DP required**	1	This is the only correct answer
20	(b)	(i)	(a base that) completely/fully dissociates/ionises to release OH^- ions (when added to water) **OR** Proton/H^+ acceptor ✓	1	
	(b)	(ii)	$2HNO_3 + Ba(OH)_2 \rightarrow 2H_2O + Ba(NO_3)_2$ **OR** $H^+ + OH^- \rightarrow H_2O$ ✓	1	**IGNORE** state symbols **ALLOW** multiples
20	(b)	(iii)	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer for pH = 12.81 award 5 marks** --- **Initial amounts** $n(HNO_3)$ = = 0.080 × 0.025 = **0.002** $n(Ba(OH)_2)$ = 0.050 × 0.100 = **0.005** ✓ **Final amounts** ($n(Ba(OH)_2)$ **reacted** = $\frac{0.002}{2}$ = 0.001) $n(Ba(OH)_2)$ **unreacted** = 0.005 – 0.001= **0.004** ✓	5	**FULL ANNOTATIONS MUST BE USED** --- **ALLOW ECF** throughout Including incorrectly balanced equation from b ii) **Alternative method for first two marks** **Initial amounts** $n(H^+)$ = 0.080 × 0.025 = **0.002** **AND** $n(OH^-)$ = 0.050 × **2 × 0.100** = **0.010** **Final amounts** $n(OH^-)$ = 0.010 – 0.002 = **0.008 mol**

Question	Answer	Mark	Guidance
	Concentration of OH^- ions ($n(OH^-) = 0.004 \times 2 = 0.008$) $[OH^-] = \frac{0.008}{0.125} =$ **0.064** mol dm^{-3} ✓ **pH** $[H^+] = \frac{1 \times 10^{-14}}{0.064}$ **OR** pOH = 1.19 $= 1.56 \times 10^{-13}$ mol dm^{-3} ✓ pH = 14 –1.19 pH = 12.81 ✓ = 12.81		**Concentration of OH^- ions** $[OH^-] = \frac{0.008}{0.125} =$ **0.064** mol dm^{-3} **ALLOW** alternative approaches **CARE** incorrect answers with more than one error needs to be marked as per **ANSWER/GUIDANCE** column Common errors (only for correctly balanced equation) Common errors for 4 of the calculation marks, with the stated error(s): **Common errors for 4 marks** 11.60 (2 mol of $Ba(OH)_2$ reacts with 1 mol of HNO_3) 11.60 (2 mol of $Ba(OH)_2$ reacts with 1 mol of HNO_3 and 2 $Ba(OH)_2$ only release 1 OH^-) **11.90** (no conversion to conc i.e. no dividing by 0.125) 12.20 ($[Ba(OH)_2]$ dividing by 2 to get $[OH^-]$) 12.38 (1 mol of $Ba(OH)_2$ releases 1 mol of OH^-) 12.38 (1 mol of $Ba(OH)_2$ reacts with 1 mol of HNO_3 and each $Ba(OH)_2$ only releases 1 OH^-)

Question			Answer	Mark	Guidance
					12.51 (1 mol of $Ba(OH)_2$ reacts with 2 mol of HNO_3 and 1 mol of $Ba(OH)_2$ releases 1 mol of OH^-) 12.68 (1 mol of $Ba(OH)_2$ reacts with 1 mol of HNO_3) 12.90 (no subtraction for mark 2) **Common errors for 3 marks** 11.78 (1 mol of $Ba(OH)_2$ reacts with 1 mol of HNO_3 and no conversion to concentration i.e. no dividing by 0.125) **11.90** (2 mol of $Ba(OH)_2$ reacts with 1 mol of HNO_3 and each $Ba(OH)_2$ only releases 1 OH^-) 12.08 (1 mol of $Ba(OH)_2$ reacts with 1 mol of HNO_3 and 2 $Ba(OH)_2$ only release 1 OH^-)
20	**(c)**		***Order of pH*** $NH_3(aq) < KOH < Ba(OH)_2$ ✓ ***Explanation*** Aqueous ammonia is a weak alkali/base **OR** only <u>partially</u> dissociates/ (to produce OH^-) ✓ KOH (and $Ba(OH)_2$) are strong bases/fully dissociate/[KOH] = [OH^-] **AND** $Ba(OH)_2$ produces two (mol of) OH^- ions per (mol of) $Ba(OH)_2$ ✓	3	**Mark independently** **IGNORE** weak<u>est/weak</u>er base for <u>weak base</u> **DO NOT ALLOW** acidic pH **IGNORE** strong<u>est/strong</u>er base for <u>strong</u> base **ALLOW AW** e.g. dibasic/diprotic base **ALLOW** correct calculation KOH pH13.00 **AND** $Ba(OH)_2$ pH13.30 **ALLOW**

Question			Answer	Mark	Guidance
					$KOH \rightarrow K^+ + OH^-$ **AND** $Ba(OH)_2 \rightarrow Ba^{2+} + 2OH^-$ **DO NOT ALLOW** ammonia is weak because it does not have any OH^- to dissociate
20	**(d)**	**(i)**	 • Initial pH at 13 ✓ • Vertical part of the curve within half a small square at 12.5 cm^3 ✓	4	**FULL ANNOTATIONS MUST BE USED ON THE GRAPH** --- If pH curve is the wrong way round (i.e. low to high pH) **Award separate marks for:** • the end point (~ 12.5 cm^3) • vertical part with a minimum range of three pH units **AND** middle of vertical section <u>above</u> pH 7 **ALLOW** +/- half small square

Question			Answer	Mark	Guidance
			• **Vertical part** with a minimum range of three pH units **AND** middle of vertical section <u>above</u> pH 7✓ • Ends at pH in range of **5-2** ✓		**IGNORE** extrapolation beyond 30cm^3 or finishing before 30cm^3 if final pH is within range of pH 5-2
		(ii)	**pH** range matches vertical section/rapid **pH** change **OR** end point/colour change matches the equivalence point/ vertical section/rapid **pH** change ✓	1	**ALLOW** suggested range from their curve in d(i) **IGNORE** straight line as alternative for vertical **IGNORE** end point

Question			Answer	Mark	Guidance
21	(a)	(i)	**CARE Two points required for 1 mark** --- (Control variables) **Two** from: ✓ • Amount of catalyst • Temperature • Surface area of catalyst • Volume of solution	1	**ALLOW** mass/mole for amount **IGNORE** volume of catalyst **IGNORE** pressure **IGNORE** same catalyst **DO NOT ALLOW** concentration of H_2O_2 – independent variable **DO NOT ALLOW** concentration of MnO_2/catalyst
21		(ii)	1st order wrt H_2O_2 ✓ **ANY TWO FROM:** ✓ ✓ (Exp 1 and 2) $[H_2O_2]$ x 1.5, rate x 1.5 (Exp 1 and 3) $[H_2O_2]$ x 2.5, rate x 2.5 (Exp 2 and 3) $[H_2O_2]$ x 1.67, rate x 1.67 Rate is proportional to $[H_2O_2]$	3	Treat working on table as rough working unless no further response has been made **ALLOW** alternative mathematical approaches **ALLOW** rate equation for proportional i.e. rate = $k[H_2O_2]$ **ALLOW** both increasing by the same factor as an alternative for directly proportional

Question			Answer	Mark	Guidance
21	(b)	(i)	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 60.6 (kJ mol^{-1}) award 2 marks** --- $E_a = RT(\ln A - \ln k)$ **OR** $-RT(\ln k - \ln A)$ ✓ = 60.6 kJ mol^{-1} ✓	2	**ALLOW** 61 up to calculator answer of 60.63175 **DO NOT ALLOW** a negative activation energy **These are the only acceptable common errors for 1 mark** 9.75 x 10^{-6} (use of $\ln A - \ln k$ / RT) 116 (use of 573 K) 60632 (no conversion to kJ mol^{-1})
21	(b)	(ii)	Step 2 $HO_2 + H_2O_2 \rightarrow H_2O + O_2 + HO$ ✓ Step 4 $H^+ + OH^- \rightarrow H_2O$ ✓	2	**ALLOW** alternative correct equations that **must match** overall equation
21		(iii)	$3Mn^{2+} + 2MnO_4^- \rightarrow 5MnO_2$ ✓ $3Mn^{2+} + 2MnO_4^- + 2H_2O \rightarrow 5MnO_2 + 4H^+$ ✓	2	**IGNORING** any other $H_2O/H^+/e^-$/species i.e. balanced for redox **ALLOW** $3MnO_2 + 2MnO_2$ for $5MnO_2$ **ALLOW** multiples **ALLOW** ⇌

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