GCE

Chemistry A

H432/03: Unified chemistry

A Level

Mark Scheme for June 2024

OCR (Oxford Cambridge and RSA) is a leading UK awarding body, providing a wide range of qualifications to meet the needs of candidates of all ages and abilities. OCR qualifications include AS/A Levels, Diplomas, GCSEs, Cambridge Nationals, Cambridge Technicals, Functional Skills, Key Skills, Entry Level qualifications, NVQs and vocational qualifications in areas such as IT, business, languages, teaching/training, administration and secretarial skills.

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. **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 **Q3b(iv)** and **Q5b(ii)**.

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 

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

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.

Question			Answer	Marks	Guidance
			• **The start of Q1a shows pages 18 and 20 of the QP.** • **These pages MUST be annotated to show that they have been looked at. Use 'BP' OR 'SEEN' when pages 18 and 20 contain no responses.** • **LINK Pages 18 and 20 NOW before starting to mark Q1a.**		
1	(a)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF pH = 13.6(0), award 2 marks** --- $K_w = [H^+] \times 0.400$ **OR** $1.00 \times 10^{-14} = [H^+] \times 0.400$ **OR** $[H^+] = \frac{K_w}{0.400}$ **OR** $[H^+] = \frac{1.00 \times 10^{-14}}{0.400}$ **OR** $[H^+] = 2.5 \times 10^{-14}$ ✓ pH = –log 2.5×10^{-14} = 13.6(0) ✓ **ALLOW** 13.6…… up to calculator value of 13.60205999 correctly rounded	**2**	**ALLOW ECF** from incorrect $[H^+]$ calculated from $[OH^-]$ **AND** K_w …….for pH > 7 **ONLY** **ALLOW** method based on pOH: **pOH** = –log 0.400 = 0.40 ✓ *Calculator: 0.39794…* pH = 14 – 0.40 = 13.6(0) ✓
	(b)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF pH = 1.12, award 1 mark** --- pH = –log 0.075 = **1.12** ✓ ***2 DP required***	**1**	

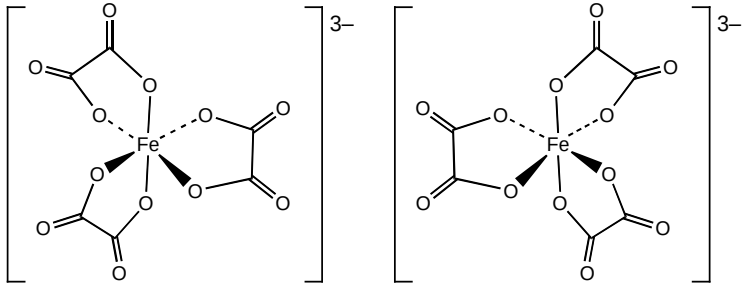
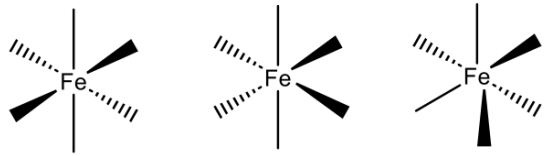
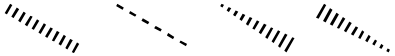
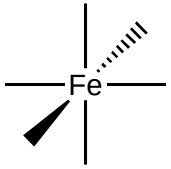
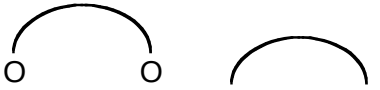
Question	Answer	Marks	Guidance
(c)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF pH = 4.28, award 2 marks** --- $1.75 \times 10^{-5} = \frac{[H^+] \times 0.100}{0.300}$ **OR** $[H^+] = \frac{1.75 \times 10^{-5} \times 0.300}{0.100}$ **OR** $[H^+] = 5.25 \times 10^{-5}$ (mol dm^{-3}) ✓ pH = –log 5.25×10^{-5} = 4.28 ✓ ***2 DP required***	**2**	**COMMON ERRORS** **1 mark for 5.23** inverted [HA] and [A$^-$] $[H^+] = \frac{1.75 \times 10^{-5} \times 0.100}{0.300}$ **OR** $5.83\ldots \times 10^{-6}$ × pH = –log $5.83\ldots \times 10^{-6}$ = **5.23** ✓ **ECF** **1 mark for 4.46** [HA] = 0.2 instead of 0.3 $[H^+] = \frac{1.75 \times 10^{-5} \times 0.200}{0.100}$ **OR** 3.5×10^{-5} × pH = –log 3.5×10^{-5} = **4.46** ✓ **ECF** Other **ECF** available from **ONE** transcription error **ONLY, e.g.** 1.57×10^{-5} for $K_a = 1.75 \times 10^{-5}$ **Zero marks for square root approach** **e.g. via** $K_a = \frac{[H^+]^2}{0.300}$ **Zero marks for [A$^-$] : [HA] = 0.1 : 0.1** **i.e.** $[H^+] = \frac{1.75 \times 10^{-5} \times 0.100}{0.100}$ **=** 1.75×10^{-5} × **pH = 4.76** × **ALLOW Henderson-Hasselbalch for both marks:** e.g. pH = 4.76 + log $\frac{0.100}{0.300}$ **OR** pH = –log(1.75×10^{-5}) + log $\frac{0.100}{0.300}$ ✓ **OR** pH = –log(1.75×10^{-5}) – log $\frac{0.300}{0.100}$ pH = **4.28** ✓

Question	Answer	Marks	Guidance
(d)	**Calculation** ***2 marks*** $n(Cu(NO_3)_2 \cdot 3H_2O) = 0.200 \times \frac{100}{1000}$ **OR** $2(.00) \times 10^{-2}$ (mol) **OR** 0.02(00) ✓ Mass $Cu(NO_3)_2 \cdot 3H_2O = 2.00 \times 10^{-2} \times 241.5$ = **4.83** (g) ✓ **2 or more DP to match balances** **Method** ***3 marks*** **Dissolve** solid in (distilled) **water** (less than 100 cm^3) (in beaker) ✓ Transfer (solution) to **volumetric** flask **AND** Wash/rinse (from beaker to flask) ✓ Make up to mark/up to 100 cm^3 with (distilled water) **AND** Invert flask (several times to ensure mixing) ✓	**5**	**FULL ANNOTATIONS MUST BE USED** **ALLOW ECF throughout** --- **ALLOW ECF** from incorrect $n(Cu(NO_3)_2 \cdot 3H_2O)$ 4.83 g subsumes 1st mark **ALLOW** small amount/some **DO NOT ALLOW** 100 cm^3 or more of water **IGNORE** solvent **ALLOW** graduated flask **ASSUME** that wash/rinse is to a volumetric flask **ALLOW** swirl/shake --- **ALLOW** preparation of solutions > 100 cm^3 **4 marks** e.g. for 250 cm^3 $n(Cu(NO_3)_2 \cdot 3H_2O) = 0.200 \times \frac{250}{1000}$ **OR** 0.05 (mol) **×** Mass $Cu(NO_3)_2 \cdot 3H_2O = 0.05 \times 241.5$ = **12.075** (g) ✓ Then method adapted for 250 cm^3 volumetric flask e.g. Make up to 250 cm^3 with water

Question			Answer	Marks	Guidance
2	(a)	(i)	Bonds are breaking **AND** endothermic **OR** energy is required/needed ✓ **IGNORE** 'overcome' for 'break'	1	**IGNORE** 'more energy needed to break bonds than released in making bonds' *Unclear whether response refers to bond breaking or overall enthalpy change*
	(a)	(ii)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF bond enthalpy = (+)413 (kJ mol^{-1}) award 3 marks** --- *Energy for bonds made (3 × H–H + 1 × C≡O)* ***1 mark*** 3 × 436 + 1 × 1077 **OR** 1308 + 1077 **OR** **2385** (kJ) ✓ **IGNORE** sign *4C–H bond enthalpy correctly calculated* ***1 mark*** 4 × C–H bond enthalpy = 195 + 2385 – (2 × O–H) = 195 + 2385 – 2 × 464 = 195 + 2385 – 928 = **1652** (kJ mol^{-1}) ✓ **IGNORE** sign *C–H bond enthalpy correctly calculated* ***1 mark*** **This mark is **NOT** available from **TWO** previous errors **OR** from ΔH = 195 **not** being used ** C–H bond enthalpy = $\frac{1652}{4}$ = (+)**413** kJ mol^{-1} ✓ **For the final answer,** **DO NOT ALLOW** value with a negative sign --- **COMMON ERRORS** **–413** → 2 marks *Wrong sign for answer* **304** → 2 marks *2 mol of H_2 instead of 3 mol:* 2 × 436 + 1 × 1077 = 872 + 1077 = 1949 × 195 + 1949 – 928 = 1216 ECF ✓ 1216/4 = **304** ECF ✓	3	**COMMON ERRORS** **ECF for other numbers** **315.5 OR 316** → 2 marks *Wrong sign for 195* Bonds made = 2385 ✓ –195 + 2385 – 928 = 1262 × 1262/4 = **315.5 OR 316** ✓ **ECF** **877** → 2 marks *Wrong sign for 928* Bonds made = 2385 ✓ 195 + 2385 + 928 = 3508 × 3508/4 = **877** ✓ **ECF** **364** → 1 mark *Missing ΔH, (195)* *Potentially 2 errors: missing 195 and sign for 195* Bonds made = 2385 ✓ 2385 – 928 = 1457 × 1457/4 = **364/ 364.3 /364.25** × **NO ECF** **779.5 OR 780** → 1 mark *Wrong sign for 928 **AND** 195* Bonds made = 2385 ✓ –195 + 2385 + 928 = 3118 × 3118/4 = **779.5** × **NO ECF** **529** → 2 marks *1 O–H instead of 2 O–H:* Bonds made = 2385 ✓ 195 + 2385 – 464 = 2116 × 2116/4 = **529** ✓ **ECF** **181** → 2 marks *4 O–H instead of 2 O–H:* Bonds made = 2385 ✓ 195 + 2385 – 1856 = 724 × 724/4 = **181** ✓ **ECF**

Question			Answer	Marks	Guidance
	(a)	(iii)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF energy released = 7.15×10^5 kJ, award 2 marks** --- $n(H_2) = \frac{60.0 \times 10^3}{24.0}$ = **2500** (mol) ✓ Energy released = 2500×285.8 = **7.15×10^5** kJ ✓ **3SF AND standard form** required **IGNORE** sign i.e. **ALLOW** + **OR** – **OR** no sign	**2**	**ALLOW ECF ONLY** from incorrect $n(H_2)$ based on with incorrect unit conversion from m^3 e.g. $n(H_2) = \frac{60.0 \times 10^2}{24.0}$ = 250 (mol) ✗ $250 \times 285.8 = 7.15 \times 10^4$ kJ ECF ✓ So **ALLOW** 1 mark for: $\pm 7.15 \times 10^x$ (unit conversion) 7.145×10^5 *(not 3SF)* 715000 *(not standard form)* --- **ALLOW** use of ideal gas equation with a sensible temperature (290–298K) and pressure (100/101/101325 kPa) e.g. e.g. At 293K and 100 kPa, $n(H_2) = \frac{100 \times 10^3 \times 60.0}{8.314 \times 293}$ = 2463… (mol) → 2463×285.8 = **7.04×10^5** kJ e.g. At 298K and 100 kPa, $n(H_2) = \frac{100 \times 10^3 \times 60.0}{8.314 \times 298}$ = 2421.7… (mol) → 2421.7×285.8 = **6.92×10^5** kJ **ALLOW** use of 8.31 for *R (same answers)* 293K → 2464.24×285.8 = **7.04×10^5** kJ 298K → 2422.89×285.8 = **6.92×10^5** kJ

Question			Answer	Marks	Guidance
	(b)	(i)	$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$ ✓	1	***ALL** 3 state symbols required*
	(b)	(ii)	***n*(AgNO$_3$) 1 mark** $= 2.50 \times 10^{-2} \times 60.0/1000 = 1.5(0) \times 10^{-3}$ (mol) ✓ **Essential mark** **Formula 2 marks** **Ratio** 5.00×10^{-4} mol **A** contains $1.5(0) \times 10^{-3}$ mol Cl **OR** ratio A : Cl = $1.5(0) \times 10^{-3} \div 5.00 \times 10^{-4} = 1 : 3$ ✓ **Formula** $= AlCl_3$ ✓ Automatically subsumes 1:3 ratio mark **ALLOW** Al_2Cl_6 **ALLOW** PCl_3	3	**Check equation from 2b(i) at top of response** --- **ALLOW** 1:3 or 3:1 ratio seen anywhere, e.g. XCl_3 **ALLOW ECF** from formula of silver chloride in **2b(i)** e.g. From $AgCl_2$ *n*(Cl) = **2** × $1.5(0) \times 10^{-3} = 3.(00) \times 10^{-3}$ (mol) ratio = 1 : 6 Formula = SCl_6
	(c)	(i)	$C_{13}H_{19}N_3O_7$ ✓	1	**ALLOW** elements in formula in any order e.g. $C_{13}H_{19}O_7N_3$
	(c)	(ii)	4 ✓	1	
	(c)	(iii)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF difference = 61.7, award 2 marks** --- M_r of **C** = 380 **OR** M_r of **D** = 441.7 ✓ Correct difference = 441.7 – 380 = **61.7** ✓ ***AWARD** mark for **correct answer of 61.7 only***	2	**ALLOW** other approaches based on different atoms in **C** and **D**, e.g. Difference = $7 \times (32.1 - 16) - 3 \times (31 - 14)$ $= 112.7 - 51 = \mathbf{61.7}$ ✓ --- **Check answer from 2c(i) at top of response for ECF** **ALLOW ECF** from incorrect formula from **2c(i)** e.g. From $C_{12}H_{16}N_3O_6$ M_r of **C** = 349 **OR** M_r of **D** = 394.6 ✓ **ECF** difference = 394.6 – 349 = **45.6** ✓ **ECF**

Question			Answer	Marks	Guidance
3	(a)	(i)	species with **two lone pairs** (of electrons) ✓ forming **dative** (covalent)**/co-ordinate bond(s)** **OR** **donates electrons** to a (central) **metal atom/ion** ✓	2	**ALLOW** species with **lone pairs** that form **two dative/coordinate bonds** ✓✓ **ALLOW non-bonding pair** for **lone pair** **IGNORE** LP for lone pair **IGNORE** donates two pairs of electrons alone
	(a)	(ii)	**Charge** Overall 3– charge shown (outside brackets) on at least **ONE** optical isomer ✓ *3– must apply to the overall charge of structures* **----------** **3D structures**  1 mark for each isomer ✓✓ • Bonds **MUST** go to O^- of $(COO^-)_2$ ligands **DO NOT ALLOW** impossible 3D diagrams, e.g. 	3	**IGNORE** charges or dipoles on atoms within diagrams (even if wrong) Square brackets **NOT** required **ALLOW** unambiguous structures **----------** **ALLOW** –3 for 3– **----------** **3D:** Must contain 2 'out wedges', 2 'in wedges' and 2 lines in plane of paper **OR** 4 lines, 1 'out wedge' and 1 'in wedge': For bond into paper, **ALLOW**:  **ALLOW** following geometry throughout:  **DO NOT ALLOW** 3D structures simplified loop for oxalate, e.g.  For incorrect element in centre, e.g. Cu, **AWARD** 2 marks max

<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>Guidance</th></tr>
<tr><td></td><td>(b)</td><td>(i)</td><td>$Fe^{2+} \rightarrow Fe^{3+} + e^-$ ✓
OR $Fe^{2+} - e^- \rightarrow Fe^{3+}$

$C_2O_4^{2-} \rightarrow 2CO_2 + 2e^-$ ✓
OR $C_2O_4^{2-} - 2e^- \rightarrow 2CO_2$</td><td>2</td><td>For both half-equations,
ALLOW multiples
ALLOW e for e^-
IGNORE state symbols.

ALLOW $C_2O_4^{2-} \rightarrow C_2O_4^- + e^-$
$C_2O_4^{2-} \rightarrow C_2O_4 + 2e^-$
$2H_2O + C_2O_4^{2-} \rightarrow 2CO_3^{2-} + 4H^+ + 2e^-$

ALLOW $2C_2O_4^{2-} \rightarrow C_4O_8^{2-} + 2e^-$</td></tr>
<tr><td></td><td>(b)</td><td>(ii)</td><td>
<table>
<tr><td></td><td>1</td><td>2</td><td>3</td></tr>
<tr><td>Final reading/cm^3</td><td>23.55</td><td>45.40</td><td>22.75</td></tr>
<tr><td>Initial reading/cm^3</td><td>1.90</td><td>23.55</td><td>1.20</td></tr>
<tr><td>Titre/cm^3</td><td>21.65</td><td>21.85</td><td>21.55</td></tr>
</table>
Readings recorded to accuracy of burette
All readings recorded to two decimal places with the last figure either 0 or 5
AND
Final and initial readings in correct rows ✓

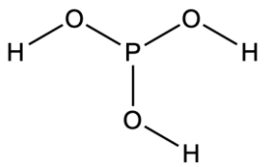
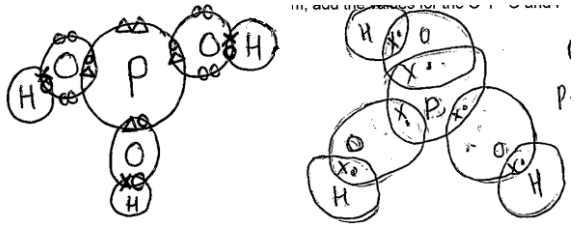
Correct titres
All 3 titres correct to 2 DP: ✓ ✓
2 titres correct to 2 DP: ✓
</td><td>3</td><td></td></tr>
<tr><td></td><td>(b)</td><td>(iii)</td><td>FIRST, CHECK THE ANSWER ON ANSWER LINE
IF % error = 0.46, award 1 mark

$\frac{2 \times 0.05}{21.65} \times 100 = 0.46$ (%) ✓ 2 DP minimum
Calculator value: 0.46189…</td><td>1</td><td>Check Titres from 3b(ii) at top of response
----
ALLOW % error from ANY of the 3 titres from 3b(ii)
OR from the mean titre

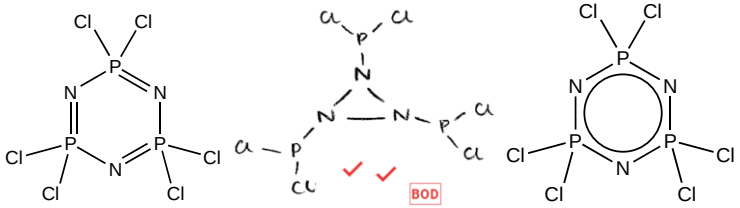
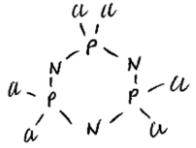
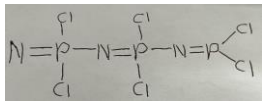
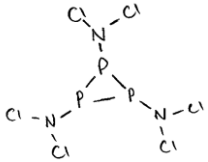
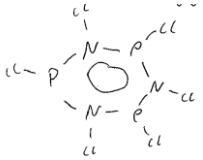
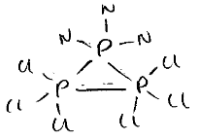
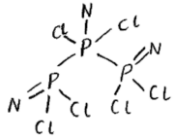
DO NOT ALLOW 0.50%</td></tr>
</table>

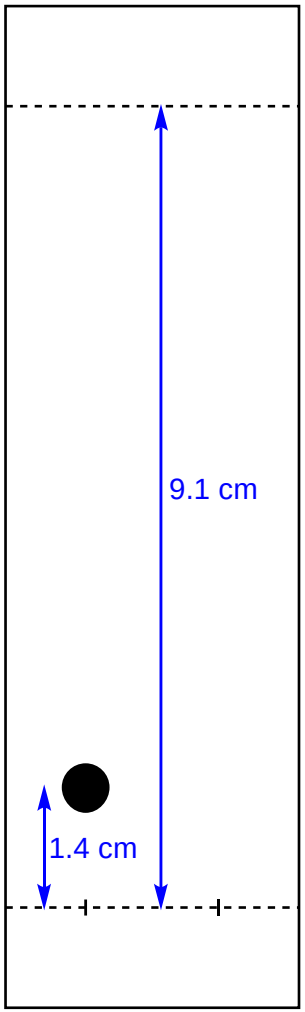
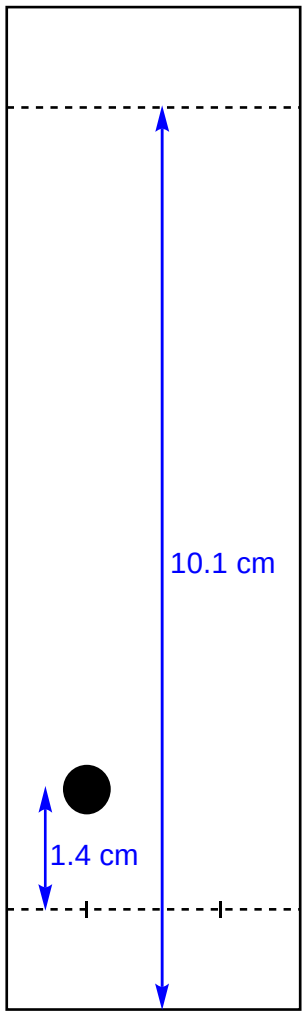
Question			Answer	Marks	Guidance
	(b)*	(iv)	*Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** Analyses the results to calculate the **correct** amount of MnO_4^- using the **correct** mean titre from the candidate's titres **AND** Obtains **correct** value of **x as 2** *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)** Analyses titration results to determine an amount of MnO_4^- from a mean titre of the candidate's titres **AND** amount of FeC_2O_4 in 25.0 cm^3 **OR** 250 cm^3 **OR** uses a mass of FeC_2O_4 to obtain a value of **x** with few errors *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)** Analyses results to determine an amount of MnO_4^- from the candidate's titres **OR** Analyses the information to obtain values of $n(MnO_4^-)$ and $n(FeC_2O_4)$ with some errors. *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**	***For mean titre,** **Check Titres from 3b(ii) at top of response*** **Indicative scientific points may include:** **Mean titre and $n(MnO_4^-)$** Mean titre = $\frac{(21.65 + 21.55)}{2}$ = 21.6(0) (cm^3) $n(MnO_4^-) = 0.0200 \times \frac{21.6(0)}{1000} = 4.32 \times 10^{-4}$ (mol) **Amount of FeC_2O_4 in mol** $n(FeC_2O_4)$ in 25.0 cm^3 = $5/3 \times n(MnO_4^-)$ = $7.2(0) \times 10^{-4}$ (mol) $n(FeC_2O_4)$ in 250 cm^3 = $7.2(0) \times 10^{-3}$ (mol) **Value of x (final answer)** Molar mass $FeC_2O_4 \cdot \mathbf{x}H_2O = \frac{1.295}{7.2(0) \times 10^{-3}}$ = 179.9 Molar mass of $\mathbf{x}H_2O$ = 179.9 – 143.8 = 36.(….) **x** = 36/18 = 2 **Credit other correct methods,** e.g. For value of **x** Mass of $FeC_2O_4 = 7.2(0) \times 10^{-3} \times 143.8 = 1.03536$ g Mass of H_2O = 1.295 **–** 1.035 = 0.25964 g $n(H_2O) = \frac{0.25964}{18}$ = 0.0144 mol $\boldsymbol{x} = \frac{0.0144}{7.2 \times 10^{-3}}$ = **2**

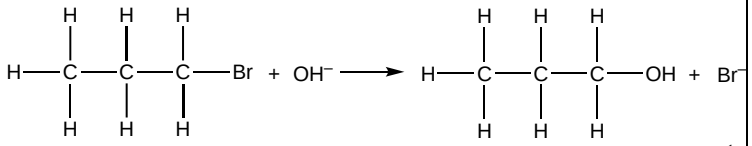
Question	Answer	Marks	Guidance
			Responses using 25.0 cm^3 rather than the titres are limited to **Level 1** For communication, a typical 'logical structure' would label **most** calculation steps in response e.g. *Communication strand met* $KMnO_4$ mean titre: $\frac{21.65 + 21.55}{2} = 21.6\ cm^3$ $n(KMnO_4) = 21.6 \times 10^{-3} \times 0.02$ $= 4.32 \times 10^{-4}$ $n(FeC_2O_4 \cdot xH_2O) = \frac{4.32 \times 10^{-4}}{3} \times 5$ $= 7.2 \times 10^{-4}$ in $25\ cm^3$ $n = 7.2 \times 10^{-3}$ in $250\ cm^3$ $n = \frac{mass}{mr}$ $mr = \frac{mass}{n} = \frac{1.295}{7.2 \times 10^{-3}} = 179.86$ *Communication strand **not** met* $\frac{21.60}{1000} \times 0.02 = 4.32 \times 10^{-4}$ mol $\left(\frac{4.32 \times 10^{-4}}{3}\right) \times 5 = 7.2 \times 10^{-4}$ mol in $25\ cm^3$ $(7.2 \times 10^{-4}) \times 10 = 7.2 \times 10^{-3}$ mol in $250\ cm^3$ $\frac{1.295}{7.2 \times 10^{-3}} = 179.86$

Question			Answer	Marks	Guidance
4	(a)	(i)	In (Equilibrium) **1,** $H_2PO_4^-$/It acts as a base **AND** accepts/gains H^+/a proton **OR** $H_2PO_4^-$ forms H_3PO_4 ✓ In (Equilibrium) **2** $H_2PO_4^-$/It acts as an acid, **AND** donates/loses H^+/a proton **OR** $H_2PO_4^-$ forms HPO_4^{2-} ✓	**2**	**ALLOW** description for 1 or 2 as long as unambiguous, e.g. Equation 1, etc **IGNORE** missing charge on $H_2PO_4^-$ throughout **IGNORE** reference to HPO_4^{2-} acting as an acid/base **OR** Equilibrium **3** *Question is about $H_2PO_4^-$* **ALLOW** 'dissociates into H^+ and HPO_4^{2-}' **IGNORE** 'partially'
	(a)	(ii)	Diagram showing **all** bonds correctly ✓  • 3 bonds only around each P • 2 bonds only around each O • Each O bonded to an H **Bond angles** O–P–O = 107º ✓ P–O–H = 104.5º ✓	**3**	**IGNORE** geometry **ALLOW** dot and cross diagram showing 2 shared electrons for each bond ……. and **IGNORE** any lone pairs **e.g.**  Unambiguous bond angles may be shown on dot and cross diagram **ALLOW** 106–108º **ALLOW** 104–105º
	(a)	(iii)	phosphoric(III) **acid** ✓ *Oxidation number **MUST** be in correct place*	**1**	**DO NOT ALLOW** phosphoric acid (III) **DO NOT ALLOW** phosphorous acid

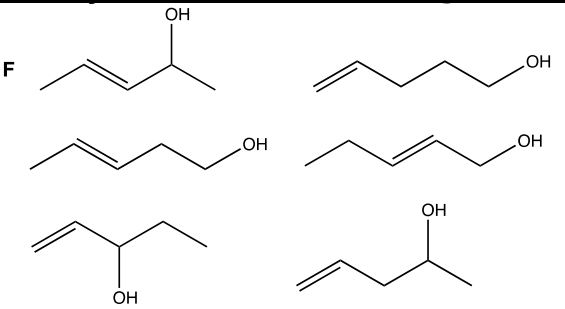
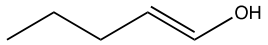
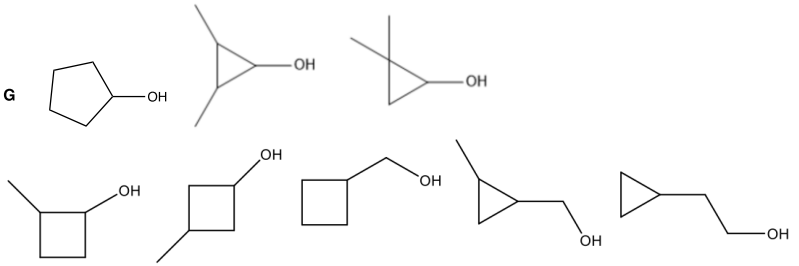
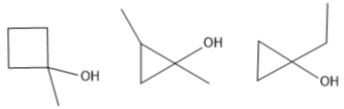
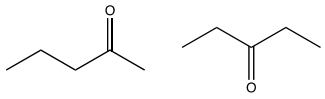
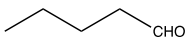
Question			Answer	Marks	Guidance
	(b)	(i)	$4PH_3 + 8O_2 \rightarrow P_4O_{10} + 6H_2O$ ✓	1	**ALLOW** multiples **ALLOW** $2PH_3 + 4O_2 \rightarrow P_2O_5 + 3H_2O$ **IGNORE** state symbols, even if wrong
	(b)	(ii)	$6AgNO_3 + (1)PH_3 + 3H_2O \rightarrow 6Ag + (1)H_3PO_3 + 6HNO_3$ ✓ Ag is reduced from +1 to 0 ✓ P is oxidised from –3 to +3 ✓ **IGNORE** oxidation numbers written around equation *Treat as rough working* **IGNORE** reference to electrons *Question states oxidation numbers*	3	**ALLOW** equation with '1' omitted, i.e. $6AgNO_3 + PH_3 + 3H_2O \rightarrow 6Ag + H_3PO_3 + 6HNO_3$ ✓ **BUT DO NOT ALLOW** '0' **ALLOW** 1 mark for **BOTH** correct oxidation number changes with 'reduced' and 'oxidised' omitted **OR** 'oxidised and reduced the wrong way round + signs required for +1 and +3 For oxidation numbers, **ALLOW** 1+, 3– and 3+
	(c)	(i)	$3PCl_5 + 3NH_4Cl \rightarrow P_3N_3Cl_6 + 12HCl$ ✓	1	**ALLOW** multiples **IGNORE** state symbols, even if wrong
	(c)	(ii)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF % by mass = 26.72, award 2 marks** **IF % by mass = 26.7, award 1 mark** --- M_r of $P_3N_3Cl_6$ = 348(.0) ✓ % by mass of P = $\frac{31.0 \times 3}{348} \times$ **100** = **26.72** ✓ **2 DP required**	2	**ALLOW** 1 mark total for 26.7 *Question asks for 2 DP* **ALLOW ECF** from incorrect M_r **ALLOW** 1 mark for 8.91 (omission of ×3): $\frac{31.0}{348} \times$ **100** = **8.91**

Question			Answer	Marks	Guidance
	(c)	(iii)	(P–N) bond lengths are different ✓ **OR** enthalpy change of hydrogenation is more exothermic (than delocalised structure) **OR** reacts with bromine/electrophiles/by addition	1	**Throughout, ORA** for delocalised structure **IGNORE** C–C bond lengths are different **IGNORE** hydration **ALLOW** decolourises bromine (without a catalyst/halogen carrier) **IGNORE** more reactive without example **IGNORE** alternating single and double bonds
	(c)	(iv)	Structure shown with molecular formula $P_3N_3Cl_6$ **1st mark** • Each P bonded to 2 Cl atoms • Each P bonded to N **AND** Cl • Each N has *at least* 2 bonds • Each Cl has 1 bond ✓ **2nd mark** (dependent on 1st mark) • Each N has 3 bonds • Each P has 3 **OR** 5 bonds ✓ **IGNORE** charges Examples for 2 marks 	2	1st mark *Meets criteria for 1st mark*   **ZERO** marks *N bonded to Cl*   *N atom(s) with 1 bond only*  

Question			Answer	Marks	Guidance
5	(a)	(i)	R_f ~ $\frac{1.4}{\mathbf{9.1}}$ in cm **OR** $\frac{14}{\mathbf{91}}$ in mm **= 0.15** ✓ *Working required* ***Check for ~ 9.1 as denominator***  	1	**ALLOW** 0.12 – 0.18 (i.e. ±0.03) **DO NOT ALLOW** $\frac{1.4}{\mathbf{10.1}}$ = 0.14 ***10.1*** *measured from bottom of plate to solvent front* 

Question			Answer	Marks	Guidance
	(a)	(ii)	 ✓ Correct balanced equation **ALLOW** OH^- above the arrow **DO NOT ALLOW** if a **CON** reagent is present, e.g. an acid For OH^- and Br^- **ALLOW** KOH and KBr **OR** NaOH and NaBr **BUT DO NOT ALLOW** K–OH *implies covalent bond*	1	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **DO NOT ALLOW Missing H atoms** **DO NOT ALLOW** H_2O and HBr *Question asks for **alkaline** hydrolysis* **DO NOT ALLOW** C_3H_7, i.e. C_3H_7Br **OR** C_3H_7OH *Structure asked for in Question* **IGNORE** connectivity, e.g. **ALLOW** **BUT DO NOT ALLOW —HO**
	(a)	(iii)	**Difference** propan-1-ol/product/bottom spot is smaller **OR** 1-chloropropane/reactant/top spot bigger ✓ **Reasons** C–Cl bond is stronger than C–Br **AND** 1-chloropropane reacts slower/is less reactive ✓ **Use of propan-1-ol** shows **formation** of propan-1-ol **OR** shows when reaction has **finished** **OR** monitors **course/progress** of reaction ✓	3	**FULL ANNOTATIONS MUST BE USED** **ALLOW ECF and ORA throughout** --- **IGNORE** references to halogens as elements: *i.e.* chlorine is less reactive than bromine etc. **DO NOT ALLOW** chloride, bromide **DO NOT ALLOW** 1-chloropropane has larger bond enthalpy *C–Cl bond required* **IGNORE** 1-chloroproane has different R_f value **IGNORE** 'as a control' **OR** 'as a comparison' …….. with no further explanation

Question			Answer	Marks	Guidance
	(b)	(i)	Green solution Cr^{3+} **OR** $[Cr(H_2O)_6]^{3+}$ ✓ Orange solution $Cr_2O_7^{2-}$ ✓ Formulae **AND** charges must be correct	**2**	**Green solution** **IGNORE** H^+ **ALLOW** $Cr_2(SO_4)_3$ **OR** $CrCl_3$ **OR** Cr^{+3} **Orange solution** **IGNORE** H^+ **ALLOW** $K_2Cr_2O_7$ **OR** $Na_2Cr_2O_7$ **DO NOT ALLOW** Cr^{6+} **ALLOW** 1 mark for correct formulae but wrong way round

Question			Answer	Marks	Guidance
	(b)*	**(ii)**	*Please refer to the marking instructions on page 6 of this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** Reaches a comprehensive conclusion to determine possible **correct** structures for **ALL** of **F**, **G**, **H and I** **AND ALL** functional groups of **F**, **G**, **H** and **I** *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 possible **correct** structures for **two** of **F**, **G**, **H** and **I** **AND most** functional groups of **F**, **G**, **H** and **I** *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)** Reaches a simple conclusion to determine a possible **correct** structure for **one** of **F**, **G**, **H** and **I** **OR some** functional groups of **F**, **G**, **H** and **I** *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:* **Identity of F, G, H** and **I showing CORRECT structures** **F**  **ALLOW** enols for **F**, e.g.  **G**  For **G**, **DO NOT ALLOW** tertiary –OH. e.g.  **H**  **I**  **IGNORE** names, even if incorrect

Question			Answer	Marks	Guidance
					For communication, a typical 'logical structure' would link functional groups to **SOME** of the test results, e.g. **2,4-DNP** **H** and **I** have carbonyl group/aldehyde or ketone **$H^+/Cr_2O_7^{2-}$** **F**, **G** and **I** are primary or secondary alcohols or aldehydes **Bromine** **F** is unsaturated/has C=C **Tollens** **I** is aldehyde ***Correct functional groups may be shown in correct structures***

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