

# A Level Chemistry A

## H432/03 Unified chemistry

### Sample Question Paper

## Date – Morning/Afternoon

## Version 2.0

Time allowed: 1 hour 30 minutes



**You must have:**

- the Data Sheet for Chemistry A

**You may use:**

- a scientific or graphical calculator



First name						
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Last name						
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Centre number	<input type="text"/>					
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Candidate number	<input type="text"/>				
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### INSTRUCTIONS

- Use black ink. You may use an HB pencil for graphs and diagrams.
- Complete the boxes above with your name, centre number and candidate number.
- Answer **all** the questions.
- Where appropriate, your answers should be supported with working. Marks may be given for a correct method even if the answer is incorrect.
- Write your answer to each question in the space provided.
- Additional paper may be used if required but you must clearly show your candidate number, centre number and question number(s).
- Do **not** write in the bar codes.

### INFORMATION

- The total mark for this paper is **70**.
- The marks for each question are shown in brackets [ ].
- Quality of extended responses will be assessed in questions marked with an asterisk (\*).
- This document consists of **24** pages.

Answer **all** the questions.

1 Give chemical explanations for the following statements.

(a) Bromine has a higher boiling point than chlorine.

.....  
..... [1]

(b) A carton of milk expands on freezing.

.....  
..... [1]

(c) Potassium is placed immediately after argon in the periodic table.

.....  
..... [1]

(d) The reaction of ethane with chlorine under UV radiation is a poor method for preparing a high yield of chloroethane.

.....  
..... [1]

(e) Water has a concentration of approximately  $56 \text{ mol dm}^{-3}$ .

.....  
..... [1]

(f) The carbon–carbon bonds in benzene are all the same length.

.....  
..... [1]

(g) IR spectroscopy distinguishes ketones from carboxylic acids.

.....  
..... [1]

(h) 1.323 g of  $\text{N}_2\text{O(g)}$  has a volume of  $1.00 \text{ dm}^3$  at 100 kPa and 400 K.

.....  
..... [1]

(i) 4.25 g of  $\text{C}_6\text{H}_5\text{COOCH}_3$  contains  $1.88 \times 10^{22}$  molecules.

.....  
..... [1]

(j) The rate of hydrolysis of 1-bromobutane is faster than that of 1-chlorobutane.

.....  
..... [1]

2 This question looks at ions and complexes.

(a)\* You are provided with two boiling tubes containing solutions of the same ionic compound. The compound contains one cation and one anion from the lists below.

- cations:  $\text{Fe}^{2+}$ ,  $\text{Mn}^{2+}$ ,  $\text{NH}_4^+$
- anions:  $\text{Cl}^-$ ,  $\text{CO}_3^{2-}$ ,  $\text{SO}_4^{2-}$

Solutions of common laboratory reagents are available.

Plan a series of tests that you could carry out on the samples to identify the ionic compound. Your tests should produce at least one positive result for each ion.

For each test,

- include details of reagents, relevant observations and equations
- explain how your observations allow the ions to be identified.

You may include flowcharts or tables in your answer.

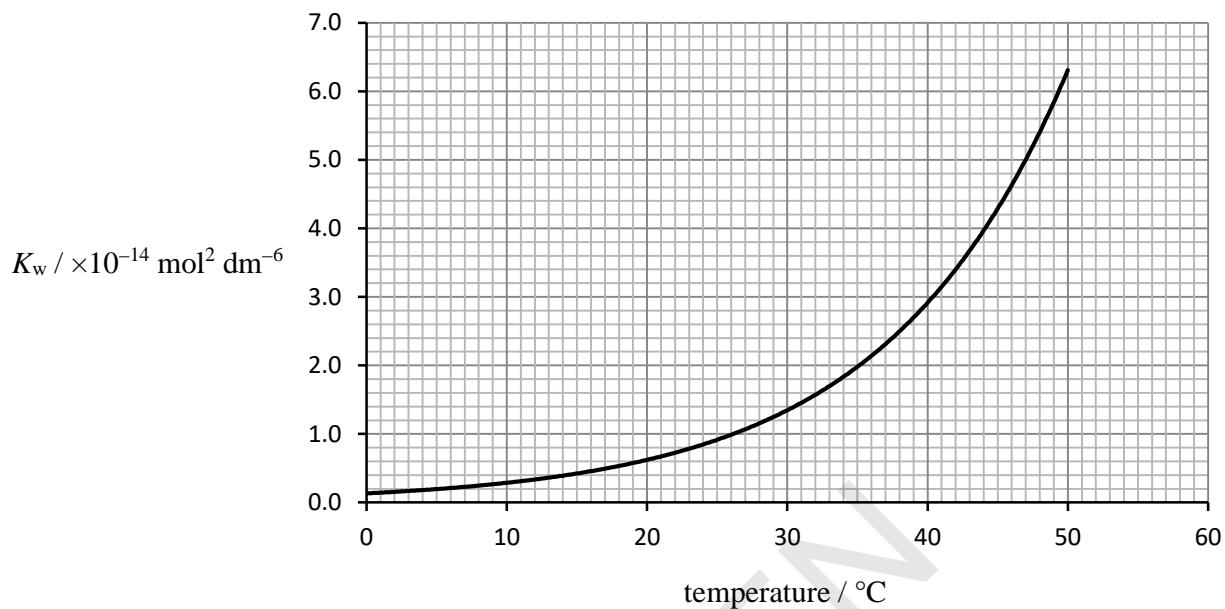
[6]

SPECIMEN

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Additional answer space if required.

(b) The dissociation of water is measured by the ionic product of water,  $K_w$ . The value of  $K_w$  varies with temperature as shown in the graph below.



Calculate the pH of water at body temperature, 37 °C.

pH = ..... [3]

(c) A complex of cobalt has the following composition by mass:

Co, 21.98%; N, 31.35%; H, 6.72%; Cl, 39.75%

(i) Calculate the empirical formula of this complex.

empirical formula = ..... [2]

(ii) The formula of this cobalt complex can be expressed in form  $[\text{Co}(\text{L})_m]^{x+}(\text{Cl}^-)_n$

Suggest the chemical formula of  $[\text{Co}(\text{L})_m]^{x+}$ .

..... [1]

SPECIMEN

3 This question looks at properties of iron compounds and iron ions in different oxidation states.

(a)  $\text{Fe}^{2+}$  and  $\text{Fe}^{3+}$  are the most common ions of iron.

(i) Write the electron configuration, in terms of sub-shells, for the  $\text{Fe}^{2+}$  ion.

..... [1]

(ii) How many orbitals contain an unpaired electron in an ion of  $\text{Fe}^{2+}$ ?

..... [1]

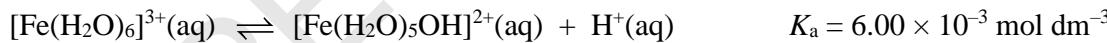
(b)  $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$  ions take part in ligand substitution reactions.

An excess of aqueous potassium cyanide,  $\text{KCN}$ (aq), is added to an aqueous solution containing  $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$  ions. A ligand substitution reaction takes place forming a complex ion that has a molar mass of  $211.8 \text{ g mol}^{-1}$ .

Write an equation for this ligand substitution reaction.

..... [2]

(c) The complex ion,  $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$ , behaves as a weak Brønsted–Lowry acid in aqueous solution. The equation below represents the dissociation of aqueous  $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$  ions, together with the  $K_a$  value.



(i) Write the expression for the acid dissociation constant,  $K_a$ , for  $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$ .

[1]

(ii) Calculate the pH of a  $0.100 \text{ mol dm}^{-3}$  solution of  $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$  to **two** decimal places.

pH = ..... [2]

(d)  $\text{Fe}_2\text{O}_3$  can be oxidised by  $\text{ClO}^-$  ions under alkaline conditions in a redox reaction.

Unbalanced half-equations for this reaction are shown below.

Balance the half-equations and construct an overall equation for the reaction.



overall equation: .....

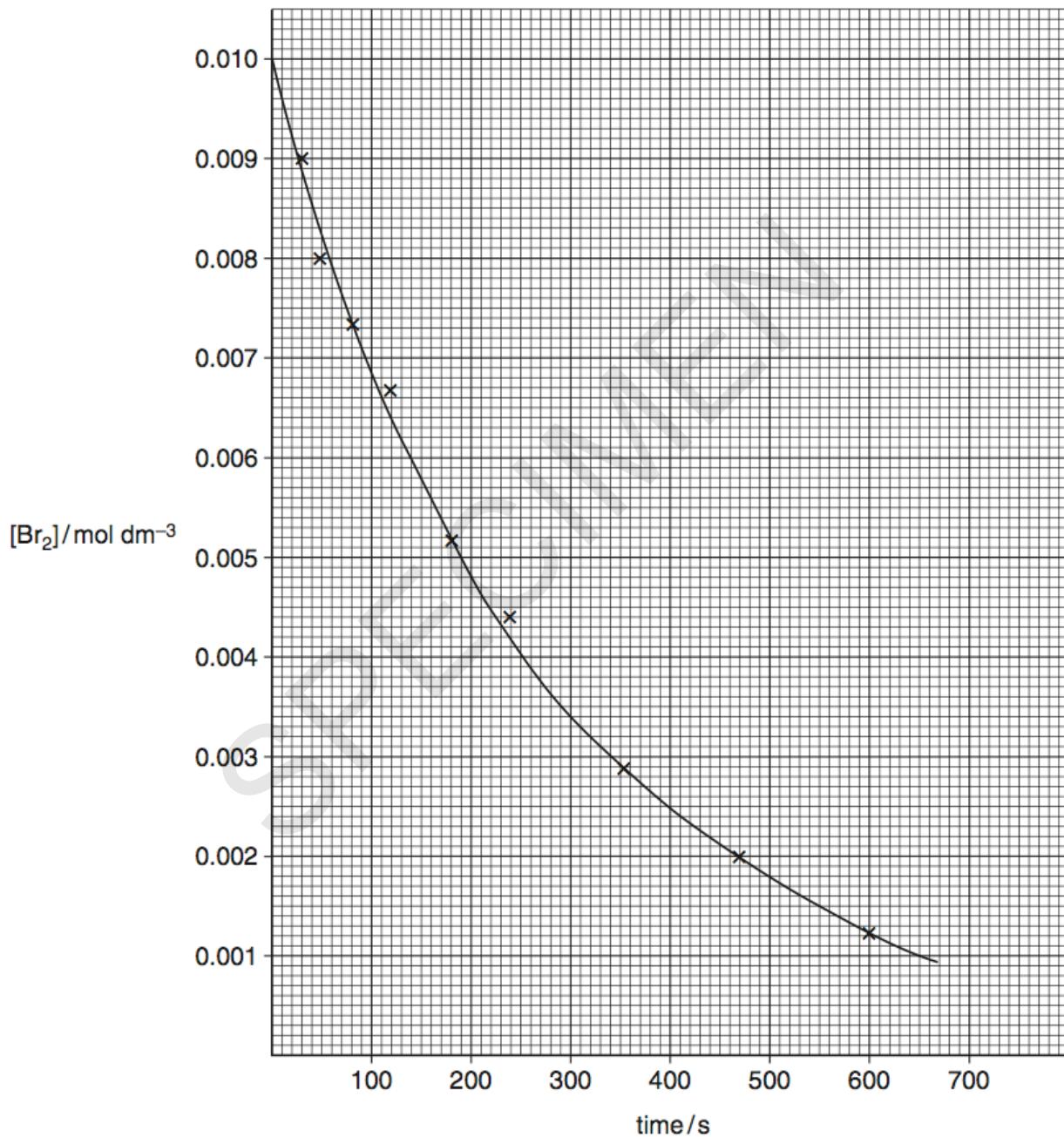
[3]

4 Methanoic acid and bromine react as in the equation below.



A student investigates the rate of this reaction by monitoring the concentration of bromine over time. The student uses a large excess of HCOOH to ensure that the order with respect to HCOOH will be effectively zero.

From the experimental results, the student plots the graph below.



(a) Suggest how the concentration of the bromine could have been monitored.

.....

.....

[1]

(b) Suggest a different experimental method that would allow the rate of this reaction to be followed over time.

..... [1] .....

(c) Why would use of excess HCOOH ensure that the order with respect to HCOOH is effectively zero?

..... [1]

**(d)\*** Using the graph, determine

- the initial rate of reaction
- the rate constant.

Your answer must show full working using the graph and the lines below as appropriate. [6]

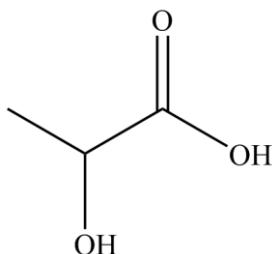
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**SPECIMEN**

5 This question is about organic acids.

(a) Lactic acid, shown below, has two functional groups.



Lactic acid reacts with bases and with many metals.

- An aqueous solution containing 1.125 g of lactic acid is reacted with an excess of magnesium producing hydrogen gas.
- The excess magnesium is removed.  
The water is evaporated, leaving a white solid, A.

(i) Name the type of reaction of lactic acid with bases and with metals.

reaction with bases: .....

reaction with metals: .....

[1]

(ii) Calculate the volume of  $\text{H}_2(\text{g})$  produced, measured at room temperature and pressure.

volume of  $\text{H}_2$  = ..... [2]

(iii) What is the empirical formula of the white solid A?

..... [1]

(iv) Predict **two** reactions of lactic acid, each involving a different functional group.

Do **not** include reactions with bases or metals.

For each reaction,

- state the type of reaction, the reagents and conditions
- draw the structures of any organic products formed.

SPECIMEN

[4]

(b) In basic conditions,  $\alpha$ -amino acids form anions with the general formula,  $\text{RCH}(\text{NH}_2)\text{COO}^-$ . These anions can act as bidentate ligands.

Copper(II) ions can form a square planar complex with anions of the amino acid glycine ( $\text{R} = \text{H}$ ). There are two stereoisomers of this complex, **B** and **C**.

(i) Draw the **skeletal** formula of the anion of glycine.

[1]

(ii) Draw diagrams of stereoisomers **B** and **C**.

In your structures, show the ligands as skeletal formulae.

[2]

(iii) Anion ligands of the amino acid alanine ( $\text{R} = \text{CH}_3$ ) would be expected to form more than two square planar stereoisomers with copper(II) ions.

Explain this statement.

.....  
.....

[1]

(c) Methanoic acid is added to water. An acid–base equilibrium is set up containing two acid–base pairs.

Suggest a mechanism for the forward reaction in this equilibrium.

Your mechanism should use displayed formulae and curly arrows, and show all species present at equilibrium.

SPECIMEN

[2]

(d) Information about a monobasic organic acid **D** is shown below.

- **D** reacts by both electrophilic substitution and electrophilic addition.
- The molecular formula of **D** is  $C_xH_yO_2$ .
- The mass spectrum of **D** has a molecular ion peak at  $m/z = 148$ .
- The  $^{13}C$  NMR spectrum of **D** contains seven peaks.

Determine and draw a possible structure for **D**.

Explain your reasoning from the evidence provided.

[5]

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**SPECIMEN**

6 Hydroxylamine,  $\text{NH}_2\text{OH}$ , is a strong reducing agent.

When heated in aqueous solution,  $\text{NH}_2\text{OH}$  reduces  $\text{Fe}^{3+}$  ions to  $\text{Fe}^{2+}$  ions.

A student suggests the three possible equations for the reaction, shown below.



The student plans to carry out an investigation to determine which equation is correct.

The method is outlined below.

**Stage 1** Using a pipette, add  $25.0 \text{ cm}^3$  of  $4.32 \times 10^{-2} \text{ mol dm}^{-3} \text{ NH}_2\text{OH}$  to a conical flask. Add  $10 \text{ cm}^3$  of  $1 \text{ mol dm}^{-3} \text{ H}_2\text{SO}_4$  to the conical flask followed by an excess of a solution containing  $0.0400 \text{ mol dm}^{-3} \text{ Fe}^{3+}(\text{aq})$ .

**Stage 2** Boil the mixture for 5 minutes and allow to cool.

**Stage 3** Titrate the cooled mixture with  $2.00 \times 10^{-2} \text{ mol dm}^{-3} \text{ KMnO}_4(\text{aq})$ .

(a) Determine the minimum volume of  $0.0400 \text{ mol dm}^{-3} \text{ Fe}^{3+}(\text{aq})$  that the student should plan to use in **Stage 1**.

Explain your reasoning.

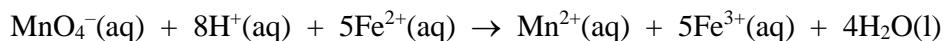
volume = .....  $\text{cm}^3$

explanation: .....  
.....  
.....

[4]

(b) In the student's titration, 21.6 cm<sup>3</sup> of KMnO<sub>4</sub>(aq) is required to reach the end point.

The equation that takes place during the titration is shown below.



Analyse the student's results to determine which of the three equations is correct.

[3]

(c) The student intends to repeat the procedure to check their results.

There is insufficient time for the student to repeat all three stages and the student decides to omit **Stage 2**, the boiling stage. Unfortunately the resulting titre is much less than the original titre.

The student rejects the results from the repeated procedure.

(i) Suggest the purpose of the boiling in **Stage 2** and reasons for the second titre being much less than the original titre.

.....

.....

.....

.....

[2]

(ii) The main reason for insufficient time is the need to boil and cool the mixture for each titration.

Suggest how the procedure could be modified so that **Stage 2** does not need to be carried out repeatedly.

Give your reasoning.

.....  
.....  
.....

[1]

**END OF QUESTION PAPER**

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Oxford Cambridge and RSA

...day June 20XX – Morning/Afternoon

A Level Chemistry A

H432/03 Unified chemistry

**SAMPLE MARK SCHEME**

**Duration:** 1 hour 30 minutes

**MAXIMUM MARK** 70

This document consists of 20 pages

**MARKING INSTRUCTIONS****PREPARATION FOR MARKING****SCORIS**

1. Make sure that you have accessed and completed the relevant training packages for on-screen marking: *scoris 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 scoris and mark the **required number** of practice responses (“scripts”) and the **required number** of standardisation responses.

YOU MUST MARK 10 PRACTICE AND 10 STANDARDISATION RESPONSES BEFORE YOU CAN BE APPROVED TO MARK LIVE SCRIPTS.

**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 scoris 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 scoris messaging system.

5. Work crossed out:
  - a. where a candidate crosses out an answer and provides an alternative response, the crossed out response is not marked and gains no marks
  - b. if a candidate crosses out an answer to a whole question and makes no second attempt, and if the inclusion of the answer does not cause a rubric infringement, the assessor should attempt to mark the crossed out answer and award marks appropriately.
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).

8. The scoris **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 scoris 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, concentrating on features that make it a stronger or weaker answer using the indicative scientific content as guidance. The indicative scientific content 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 science content of the answer, first decide which set of level descriptors, Level 1, Level 2 or Level 3, **best** describes the overall quality of the answer using the guidelines described in the level descriptors in the mark scheme.

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 science content determines the level.**
- **The communication statement determines the mark within a level.**

Level of response questions on this paper are **2(a)** and **4(d)**.

## 11. Annotations

Annotation	Meaning
<b>DO NOT ALLOW</b>	Answers which are not worthy of credit
<b>IGNORE</b>	Statements which are irrelevant
<b>ALLOW</b>	Answers that can be accepted
( )	Words which are not essential to gain credit
—	Underlined words must be present in answer to score a mark
<b>ECF</b>	Error carried forward
<b>AW</b>	Alternative wording
<b>ORA</b>	Or reverse argument

## 12. 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
1	(a)	Bromine has stronger/more induced dipole interactions <b>OR</b> temporary dipole interactions <b>OR</b> London forces ✓	1	<b>ALLOW</b> van der Waals' forces <b>OR</b> intermolecular forces
	(b)	Hydrogen bonds in ice hold H <sub>2</sub> O molecules further apart (than in water) ✓	1	
	(c)	Potassium (atoms) have one more proton (than argon) ✓	1	
	(d)	Further substitution occurs ✓	1	<b>ALLOW</b> multiple substitution occurs <b>ALLOW</b> examples of further substitution products
	(e)	1 dm <sup>3</sup> water has a mass of 1000 g $n(\text{H}_2\text{O}) \text{ in } 1 \text{ dm}^3 = \frac{1000}{18} \approx 56 \text{ mol}$ ✓	1	
	(f)	π bonds in benzene are delocalised ✓	1	
	(g)	Carboxylic acids have a broad O–H absorption at 2500–3300 (cm <sup>-1</sup> ) (which ketones do not) ✓	1	<b>ORA</b>
	(h)	$n = \frac{pV}{RT} = \frac{(100 \times 10^3) \times (1.00 \times 10^{-3})}{8.314 \times 400} = 0.0301 \text{ mol}$ <b>AND</b> mass of N <sub>2</sub> O = $0.0301 \times 44.0 = 1.323 \text{ g}$ ✓	1	<b>AW</b> $n(\text{N}_2\text{O}) = 1.323 / 44.0 = 0.0301 \text{ mol}$ $V = \frac{0.0301 \times 8.314 \times 400}{100 \times 10^3} = 1.00 \times 10^{-3} \text{ m}^{-3}$ (= 1.00 dm <sup>-3</sup> ) ✓  Requires evidence of use of ideal gas equation <b>AND</b> $M(\text{N}_2\text{O}) = 44.0$
	(i)	$M(\text{C}_6\text{H}_5\text{COOCH}_3) = 136 \text{ g mol}^{-1}$	1	Answer needs evidence of the 4.25, 136 and

Question		Answer	Marks	Guidance
		$\frac{4.25}{136} \times 6.02 \times 10^{23} = 1.88 \times 10^{22} \checkmark$		6.02 $\times 10^{23}$ being used correctly
(j)		The C–Br bond is weaker (than the C–Cl bond) $\checkmark$	1	ORA
		<b>Total</b>	<b>10</b>	

Question	Answer	Marks	Guidance
2 (a)*	<p><i>Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.</i></p> <p><b>Level 3 (5–6 marks)</b>  <b>Develops a plan that allows identification of all six ions</b>  <b>AND</b>  <b>includes essential detail and equations for all test procedures and observations, with three anion tests in the correct sequence, <math>\text{CO}_3^{2-}</math>, <math>\text{SO}_4^{2-}</math> then <math>\text{Cl}^-</math></b>  <b>AND</b>  <b>includes cation test with essential detail and all equations</b></p> <p><i>There is a well-developed, detailed plan which is clear and logically structured. The plan is substantiated with relevant information, e.g. justification of the sequence of anion tests. There is a clear explanation of how the observations allow the ions to be identified.</i></p> <p><b>Level 2 (3–4 marks)</b>  <b>Develops a plan that allows identification of at least three ions</b>  <b>AND</b>  <b>includes detail of at least three test procedures and observations, and three equations</b></p> <p><i>There is an appropriate plan presented with some structure. Parts of the fine detail, correct sequence, or reference to use of both samples may be missing. There is some attempt to explain how the observations allow the ions to be identified.</i></p>	6	<p><b>Indicative scientific points may include:</b></p> <p>Use one sample for cation test, other sample for anion tests</p> <p><b>Details of tests</b></p> <p><b>Cation test</b>  add Aqueous sodium hydroxide</p> <p>Positive observations</p> <ul style="list-style-type: none"> <li>• for <math>\text{Mn}^{2+}</math> : pink/buff precipitate</li> <li>• for <math>\text{Fe}^{2+}</math> : green precipitate</li> <li>• for <math>\text{NH}_4^+</math> : litmus paper held over the opening of the tube turns blue</li> </ul> <p>Fine detail:</p> <ul style="list-style-type: none"> <li>• (gentle) heating for <math>\text{NH}_4^+</math> test</li> </ul> <p>Equations:</p> $\text{Mn}^{2+} + 2\text{OH}^- \rightarrow \text{Mn}(\text{OH})_2$ $\text{Fe}^{2+} + 2\text{OH}^- \rightarrow \text{Fe}(\text{OH})_2$ $\text{NH}_4^+ + \text{OH}^- \rightarrow \text{NH}_3 + \text{H}_2\text{O}$ <p><b>Anion tests</b></p> <p><math>\text{CO}_3^{2-}</math>:</p> <ul style="list-style-type: none"> <li>• add nitric acid;  positive observation: effervescence</li> </ul> <p><math>\text{SO}_4^{2-}</math>:</p> <ul style="list-style-type: none"> <li>• add aqueous barium nitrate;  positive observation: white precipitate</li> </ul> <p><math>\text{Cl}^-</math>:</p> <ul style="list-style-type: none"> <li>• add silver nitrate solution;  positive observation: white precipitate</li> </ul> <p>Fine detail for <math>\text{Cl}^-</math>:</p>

Question		Answer	Marks	Guidance
		<p><b>Level 1 (1–2 marks)</b>  <b>Develops a plan that allows identification of at least two ions</b>  <b>AND</b>  <b>includes detail of at least two test procedures and observations, and one equation</b></p> <p><i>The plan is basic and communicated in an unstructured way. The response lacks fine detail and no reference to correct sequence of anion tests. There is little or no attempt to explain how the observations allow the ions to be identified.</i></p> <p><i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i></p> <p><b>0 marks</b>  No response or no response worthy of credit.</p>		<ul style="list-style-type: none"> <li>subsequent addition of dilute ammonia solution</li> <li>positive observation: precipitate dissolves.</li> </ul> <p>Fine detail: correct sequence of all three anion tests</p> <ul style="list-style-type: none"> <li>carbonate test followed by sulfate test followed by halide test</li> <li>justification of sequence</li> <li><b>ALLOW</b> splitting of solution over three boiling tubes/test tubes and performing each test on a different sample.</li> </ul> <p>Equations:</p> $\text{CO}_3^{2-} + \text{H}^+ \rightarrow \text{CO}_2 + \text{H}_2\text{O}$ $\text{Ba}^{2+} + \text{SO}_4^{2-} \rightarrow \text{BaSO}_4$ $\text{Ag}^+ + \text{Cl}^- \rightarrow \text{AgCl}$
	(b)	<p><math>K_w</math> value from graph from <math>2.2</math> to <math>2.4 \times 10^{-14}</math> (<math>\text{mol}^2 \text{ dm}^{-6}</math>) ✓</p> <p>Using <math>2.4 \times 10^{-14}</math>,  <math>[\text{H}^+] = \sqrt{2.4 \times 10^{-14}}</math> OR <math>1.55 \times 10^{-7}</math> ✓</p> <p><math>\text{pH} = -\log (1.55 \times 10^{-7}) = 6.81</math> (using <math>K_w = 2.4 \times 10^{-14}</math>) ✓</p>	3	<p>Actual <math>K_w = 2.38 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}</math></p> <p><b>ALLOW ECF</b> only if candidate uses a value between <math>2.0</math> and <math>2.6 \times 10^{-14}</math> (<math>\text{mol}^2 \text{ dm}^{-6}</math>), i.e. from the approximately correct region of the graph</p> <p><b>ALLOW</b> <math>6.8</math> (1DP) up to calculator value</p> <p><b>ALLOW ECF</b> only if candidate has generated a value of <math>[\text{H}^+]</math> by attempting to take a square root of a value between <math>2.0</math> and <math>3.0 \times 10^{-14}</math></p>
	(c) (i)	$\text{Co : N : H : Cl} = \frac{21.98}{58.9} : \frac{31.35}{14.0} : \frac{6.72}{1.0} : \frac{39.75}{35.5}$	2	

Question		Answer	Marks	Guidance
		= 0.373 : 2.24 : 6.72 : 1.12 ✓ = 1 : 6 : 18 : 3 Formula = $\text{CoN}_6\text{H}_{18}\text{Cl}_3$ ✓		
	(ii)	$[\text{Co}(\text{NH}_3)_6]^{3+}$ ✓	1	
		<b>Total</b>	<b>12</b>	

Question		Answer	Marks	Guidance
3	(a) (i)	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$ ✓	1	
	(ii)	4	1	
	(b)	<p><math>[\text{Fe}(\text{CN})_6]^{3-}</math> shown as product in equation ✓</p> <p>Remaining species and balancing correct balanced equation:  <math>[\text{Fe}(\text{H}_2\text{O})_6]^{3+} + 6\text{CN}^- \rightarrow [\text{Fe}(\text{CN})_6]^{3-} + 6\text{H}_2\text{O}</math> ✓</p>	2	<p>Notice different charges on complex ions:  LHS 3+, RHS 3-</p> <p><b>ALLOW</b> equations with KCN, i.e.:</p> $[\text{Fe}(\text{H}_2\text{O})_6]^{3+} + 6\text{KCN}$ $\rightarrow [\text{Fe}(\text{CN})_6]^{3-} + 6\text{K}^+ + 6\text{H}_2\text{O}$ $[\text{Fe}(\text{H}_2\text{O})_6]^{3+} + 6\text{K}^+ + 6\text{CN}^-$ $\rightarrow [\text{Fe}(\text{CN})_6]^{3-} + 6\text{K}^+ + 6\text{H}_2\text{O}$ <p>state symbols <b>not</b> required</p>
	(c) (i)	$K_a = \frac{[[\text{Fe}(\text{H}_2\text{O})_5\text{OH}]^{2+}(\text{aq})][\text{H}^+(\text{aq})]}{[[\text{Fe}(\text{H}_2\text{O})_6]^{3+}(\text{aq})]}$ ✓	1	state symbols <b>not</b> required
	(ii)	$[\text{H}^+] = \sqrt{6.00 \times 10^{-3} \times 0.100}$ OR $0.0245 \text{ (mol dm}^{-3})$ ✓ $\text{pH} = -\log 0.0245 = 1.61$ ✓	2	<p><b>ALLOW ECF</b> from calculated <math>[\text{H}^+]</math> provided that <b>BOTH</b> <math>6.0 \times 10^{-3}</math> <b>AND</b> 0.100 only have been used</p> <p><b>ALLOW</b> calculation via quadratic equation → pH 1.66</p>
	(d)	$\dots\text{ClO}^- + \dots\text{H}_2\text{O} + 2\text{..e}^- \rightarrow \dots\text{Cl}^- + 2\text{..OH}^-$ ✓ $\text{Fe}_2\text{O}_3 + 10\text{..OH}^- \rightarrow 2\text{..FeO}_4^{2-} + 5\text{..H}_2\text{O} + 6\text{..e}^-$ ✓	3	<b>ALLOW</b> multiples throughout

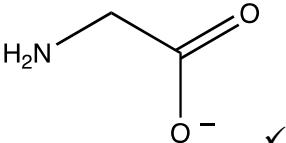
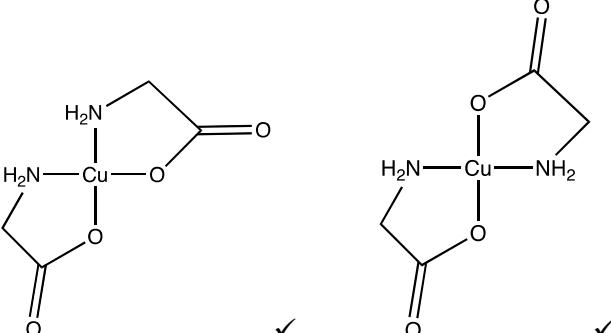
Question		Answer	Marks	Guidance
		$\text{Fe}_2\text{O}_3 + 3\text{..ClO}^- + 4\text{..OH}^- \rightarrow 2\text{..FeO}_4^{2-} + 3\text{..Cl}^- + 2\text{..H}_2\text{O}$ ✓		
		Total	10	

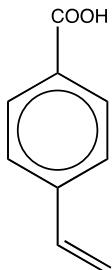
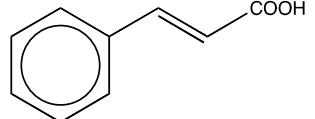
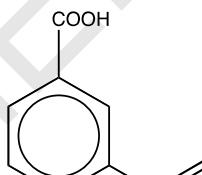
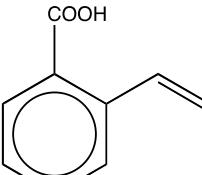
SPECIMEN

Question		Answer	Marks	Guidance
4	(a)	Measure reduction of colour of bromine ✓	1	
	(b)	Measure volume of $\text{CO}_2$ (produced) ✓	1	
	(c)	Concentration of $\text{HCOOH}$ would be constant ✓	1	
	(d)*	<p><i>Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.</i></p> <p><b>Level 3 (5–6 marks)</b> A comprehensive conclusion which uses quantitative data from the graph to correctly identify and calculate initial rate <b>AND</b> half lives and reasoned order of <math>\text{Br}_2</math> <b>AND</b> determination of <math>k</math> with units</p> <p><i>There is a well-developed conclusion showing a line of reasoning which is clear and logically structured. The working for initial rate, half life and order are clearly shown. Determination of <math>k</math> is clear and correct.</i></p> <p><b>Level 2 (3–4 marks)</b> Reaches a sound, but not comprehensive, conclusion based on quantitative data from the graph. Correctly identifies and calculates initial rate <b>AND</b> half lives and reasoned order of <math>\text{Br}_2</math></p> <p><i>The conclusion has a line of reasoning presented with some structure. The initial rate and order is relevant and supported by correct evidence from the graph. There may be errors in the calculations which prevent the correct determination of <math>k</math>.</i></p>	6	<p><b>Indicative scientific points may include:</b></p> <p><b>Initial rate</b></p> <ul style="list-style-type: none"> <li>Evidence of tangent on graph drawn to line at <math>t = 0 \text{ s}</math> <b>AND</b> gradient determined in range <math>4 \pm 1 \times 10^{-5}</math></li> <li><i>initial rate</i> expressed as gradient value with units of <math>\text{mol dm}^{-3} \text{ s}^{-1}</math>, e.g. <i>initial rate</i> = <math>4 \times 10^{-5} \text{ mol dm}^{-3} \text{ s}^{-1}</math></li> </ul> <p><b>Half lives and reasoned order of <math>\text{Br}_2</math></b></p> <ul style="list-style-type: none"> <li>Half life measured on graph <b>OR</b> within text <b>OR</b> stated in range 180–200 s</li> <li>Constant half life <b>OR</b> two stated half lives within <math>\pm 20 \text{ s}</math> <b>AND</b> conclusion that <math>\text{Br}_2</math> is 1st order</li> </ul> <p><b>Determination of <math>k</math> with units</b></p> <ul style="list-style-type: none"> <li>Rate constant <math>k</math> clearly linked to initial rate <b>OR</b> half-life: <math display="block">k = \frac{\text{rate}}{[\text{Br}_2]} \quad \text{OR} \quad k = \frac{\ln 2}{t_{1/2}}</math> </li> <li><math>k</math> determined correctly from measured initial rate or measured half life with units of <math>\text{s}^{-1}</math>, e.g. <math>k = 4 \times 10^{-3} \text{ s}^{-1}</math> from initial rate of <math>4 \times 10^{-5} \text{ mol dm}^{-3} \text{ s}^{-1}</math> <b>OR</b> <math>t_{1/2}</math> of 175 s</li> </ul>

Question		Answer	Marks	Guidance
		<p><b>Level 1 (1–2 marks)</b> Reaches a simple conclusion using at least one piece of quantitative data from the graph. Attempts calculation of initial rate <b>OR</b> half lives and reasoned order of <math>\text{Br}_2</math>.</p> <p><i>The information selected from the graph is basic and communicated in an unstructured way. The calculations may not be clear and the evidence used from the graph may not be clearly shown.</i></p> <p><i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i></p> <p><b>0 marks</b> No response or no response worthy of credit.</p>		
		<b>Total</b>	<b>9</b>	

Question		Answer	Marks	Guidance
5	(a) (i)	reaction with bases: neutralisation <b>AND</b> reaction with metals: redox ✓	1	
	(ii)	correctly calculates $n(A) = \frac{1.125}{90} = 0.0125 \text{ (mol)} \checkmark$  volume of $H_2 = \frac{0.0125}{2} \times 24\,000 = 150 \text{ cm}^3 \checkmark$ <b>units</b> required	2	<b>ALLOW</b> 0.15 dm <sup>3</sup> <b>ALLOW ECF</b> from $n(A)$
	(iii)	$C_6H_{12}O_6Mg \checkmark$	1	<b>DO NOT ALLOW</b> $(C_3H_6O_3)_2Mg$
	(iv)	Type of reaction of COOH: e.g. esterification <b>AND</b> reagents and conditions e.g. $CH_3OH$ <b>AND</b> $H_2SO_4 \checkmark$  Organic product of COOH reaction ✓  Type of reaction of –OH <b>AND</b> reagents and conditions ✓  Organic product of –OH reaction ✓	4	<b>ALLOW</b> esterification with any stated alcohol  e.g. product from $CH_3OH/H_2SO_4$ → $CH_3(CHOH)COOCH_3$  Many possible reactions of secondary alcohol possible, e.g.  oxidation with $K_2Cr_2O_7/H_2SO_4 + \text{heat}$ → $CH_3(CO)COOH$  elimination with $H_2SO_4/H_3PO_4 + \text{heat}$ → $CH_2=CHCOOH$  esterification with $CH_3COOH/H_2SO_4$ <b>OR</b> $CH_3COCl \rightarrow CH_3(CHOOCCH_3)COOH$  bromination with $NaBr/H_2SO_4$ → $CH_3(CHBr)COOH$  <b>ALLOW</b> self-polymerisation as reaction for either

Question		Answer	Marks	Guidance
				group (if another reaction example given) condensation polymerisation with $\text{H}_2\text{SO}_4$ $\rightarrow [\text{OCH}(\text{CH}_3)\text{CO}]_n$
(b) (i)			1	Must be skeletal formula
(ii)			2	<b>IGNORE</b> charges <b>ALLOW</b> Cs and Hs labelled on structures <i>Marks are for correct connectivity</i>
(iii)		Alanine has a chiral C atom/centre	1	
(c)		<p>1 mark for correct reactants <b>AND</b> products <b>AND</b> correct positioning of + and - charges on products</p> <p>1 mark for two correct curly arrows  <b>AND</b> <math>\text{H}_2\text{O}</math> curly arrow starting from O lone pair</p>	2	

Question		Answer	Marks	Guidance
	(d)	<p>Electrophilic substitution means benzene ring ✓</p> <p>Electrophilic addition means alkene / C=C ✓</p> <p>Isomer of <math>C_9H_8O_2</math> containing C=C, benzene ring <b>AND</b> COOH ✓</p> <p>Correct isomer:</p> <p></p> <p>OR</p> <p></p> <p>✓</p> <p>justification in terms of number of carbon environments ✓</p>	5	<p>Concluded using data provided and conclusions from 1<sup>st</sup> two marks.</p> <p><b>ALLOW 1 mark for:</b></p> <p></p> <p>OR</p> <p></p> <p>(does not gain final justification mark)</p>
		Total	19	

Question		Answer	Marks	Guidance
6	(a)	$n(\text{NH}_2\text{OH}) = 4.32 \times 10^{-2} \times 0.0250 = 1.08 \times 10^{-3} \text{ mol} \checkmark$ $n(\text{Fe}^{3+}) = 3 \times 1.08 \times 10^{-3} = 3.24 \times 10^{-3} \text{ mol}$ (assuming Equation 3) $\checkmark$ $\text{volume} = \frac{3.24 \times 10^{-2} \times 1000}{0.0400} = 81.0 \text{ cm}^3 \checkmark$ Explanation: minimum amount of $\text{Fe}^{3+}$ required is maximum amount theoretically required to react with all $\text{NH}_2\text{OH}$ , i.e. if Equation 3 is correct (greatest amount of $\text{Fe}^{3+}$ required) (owtte) $\checkmark$	4	Factor 3 must be included in second mark for ECF on third mark. <b>ALLOW</b> 2 sig figs
	(b)	$n(\text{MnO}_4^-) = 2.00 \times 10^{-2} \times \frac{21.6}{1000} = 4.32 \times 10^{-4} \text{ (mol)} \checkmark$ $n(\text{Fe}^{2+}) = 4.32 \times 10^{-4} \times 5 = 2.16 \times 10^{-3} \text{ (mol)} \checkmark$ Ratio $\text{NH}_2\text{OH}$ : $\text{Fe}^{2+}$ <b>OR</b> $\text{NH}_2\text{OH}$ : $\text{Fe}^{2+}$ $= 1.08 \times 10^{-3} : 2.16 \times 10^{-3} = 1 : 2$ <b>AND</b> Equation 2 is correct $\checkmark$	3	<b>Working must be to at least 3 sig figs throughout until final numerical answer</b> <b>BUT</b> ignore trailing zeroes, e.g. for 0.490 allow 0.49 <b>ECF</b> answer above $\times 5$  This mark is only possible from correct answers above, i.e. <b>no ECF</b>
	(c) (i)	Boiling speeds up the reaction <b>OR</b> Ensures that reaction is complete $\checkmark$ (Titre is less because) there is less $\text{Fe}^{2+}$ $\checkmark$	2	

Question		Answer	Marks	Guidance
	(ii)	In <b>Stage 1</b> , increase quantities so that there is sufficient solution for more than one titration ✓	1	<b>ALLOW</b> increase scale of <b>Stage 1</b>
		<b>Total</b>	<b>10</b>	

## Summary of updates

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Date	Version	Change
January 2019	2.0	Minor accessibility changes to the paper: i) Additional answer lines linked to Level of Response questions ii) One addition to the rubric clarifying the general rule that working should be shown for any calculation questions