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# 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 | |
| Last name | |
| Centre number | |
| Candidate number | |



**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.

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…… **[1]**

**(b)** A carton of milk expands on freezing.

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…… **[1]**

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

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…… **[1]**

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

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…… **[1]**

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

……

…… **[1]**

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

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…… **[1]**

**(g)** IR spectroscopy distinguishes ketones from carboxylic acids.

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…… **[1]**

**(h)** 1.323 g of $N_2O(g)$ has a volume of 1.00 $dm^3$ at 100 kPa and 400 K.

……

…… **[1]**

**(i)** 4.25 g of $C_6H_5COOCH_3$ 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: $Fe^{2+}$, $Mn^{2+}$, $NH_4^+$
- anions: $Cl^-$, $CO_3^{2-}$, $SO_4^{2-}$

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]**



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Additional answer space if required.

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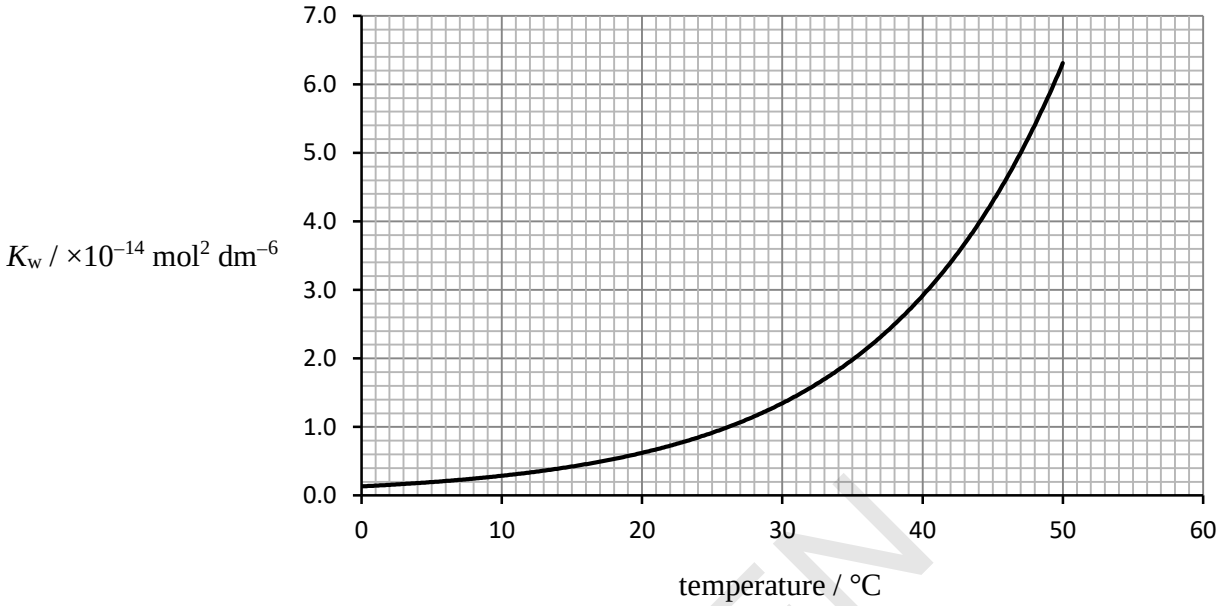
**(b)** The dissociation of water is measured by the ionic product of water, $K_w$. The value of $K_w$ varies with temperature as shown in the graph below.




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 $[Co(L)_m]^{x+}(Cl^-)_n$

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

…… **[1]**

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

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

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

…… **[1]**

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

…… **[1]**

**(b)** $[Fe(H_2O)_6]^{3+}$ ions take part in ligand substitution reactions.

An excess of aqueous potassium cyanide, KCN(aq), is added to an aqueous solution containing $[Fe(H_2O)_6]^{3+}$ ions. A ligand substitution reaction takes place forming a complex ion that has a molar mass of 211.8 g $mol^{-1}$.

Write an equation for this ligand substitution reaction.

…… **[2]**

**(c)** The complex ion, $[Fe(H_2O)_6]^{3+}$, behaves as a weak Brønsted–Lowry acid in aqueous solution. The equation below represents the dissociation of aqueous $[Fe(H_2O)_6]^{3+}$ ions, together with the $K_a$ value.

$$[Fe(H_2O)_6]^{3+}(aq) \rightleftharpoons [Fe(H_2O)_5OH]^{2+}(aq) + H^+(aq) \qquad K_a = 6.00 \times 10^{-3} \text{ mol dm}^{-3}$$

**(i)** Write the expression for the acid dissociation constant, $K_a$, for $[Fe(H_2O)_6]^{3+}$.

**[1]**

**(ii)** Calculate the pH of a 0.100 mol $dm^{-3}$ solution of $[Fe(H_2O)_6]^{3+}$ to **two** decimal places.

pH = …… **[2]**

**(d)** $Fe_2O_3$ can be oxidised by $ClO^-$ 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.

**……** $ClO^-$ + **……** $H_2O$ + **……** $e^-$ → **……** $Cl^-$ + **……** $OH^-$

**……** $Fe_2O_3$ + **……** $OH^-$ → **……** $FeO_4^{2-}$ + **……** $H_2O$ + **……** $e^-$

overall equation: **……**

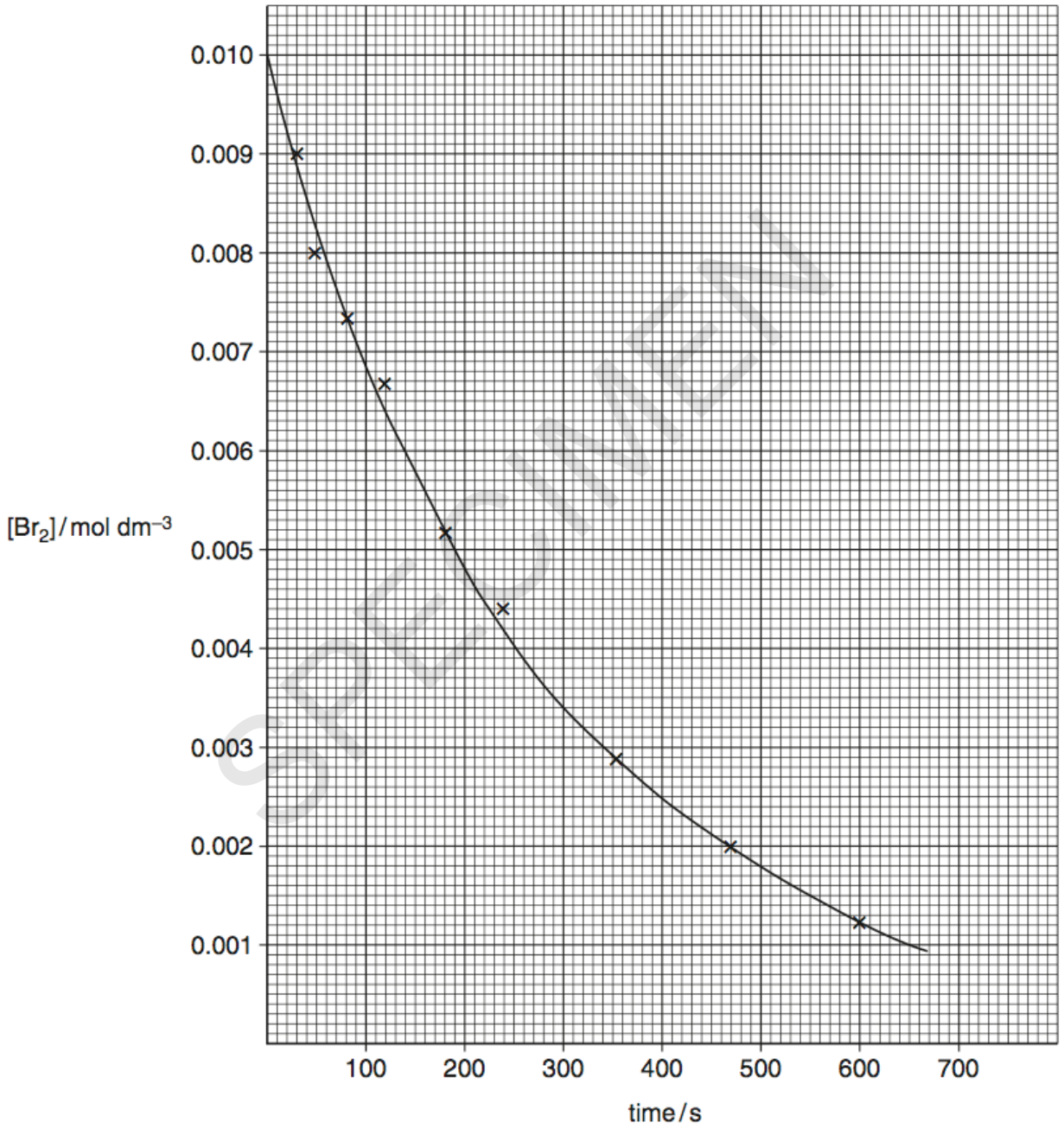
**[3]**

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

$$Br_2(aq) + HCOOH(aq) \rightarrow 2H^+(aq) + 2Br^-(aq) + CO_2(g)$$

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.

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..... **[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?

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…… **[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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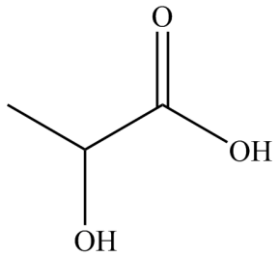
**5** This question is about organic acids.

**(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 $H_2(g)$ produced, measured at room temperature and pressure.

volume of $H_2$ = **……** **[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.

**[4]**

**(b)** In basic conditions, α-amino acids form anions with the general formula, $RCH(NH_2)COO^-$. These anions can act as bidentate ligands.

Copper(II) ions can form a square planar complex with anions of the amino acid glycine (R = 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 ($R = CH_3$) 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.

**[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.

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..... **[5]**

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**6** Hydroxylamine, $NH_2OH$, is a strong reducing agent.

When heated in aqueous solution, $NH_2OH$ reduces $Fe^{3+}$ ions to $Fe^{2+}$ ions.

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

**Equation 1** $NH_2OH + Fe^{3+} \longrightarrow Fe^{2+} + \frac{1}{2}N_2 + H^+ + H_2O$

**Equation 2** $NH_2OH + 2Fe^{3+} \longrightarrow 2Fe^{2+} + \frac{1}{2}N_2O + 2H^+ + \frac{1}{2}H_2O$

**Equation 3** $NH_2OH + 3Fe^{3+} \longrightarrow 3Fe^{2+} + NO + 3H^+$

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 $cm^3$ of $4.32 \times 10^{-2}$ mol $dm^{-3}$ $NH_2OH$ to a conical flask. Add 10 $cm^3$ of 1 mol $dm^{-3}$ $H_2SO_4$ to the conical flask followed by an excess of a solution containing 0.0400 mol $dm^{-3}$ $Fe^{3+}(aq)$.

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

**Stage 3** Titrate the cooled mixture with $2.00 \times 10^{-2}$ mol $dm^{-3}$ $KMnO_4(aq)$.

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

Explain your reasoning.

volume = ..... $cm^3$

explanation: .....

.....

.....

**[4]**

**(b)** In the student's titration, 21.6 $cm^3$ of $KMnO_4(aq)$ is required to reach the end point.

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

$$MnO_4^-(aq) + 8H^+(aq) + 5Fe^{2+}(aq) \rightarrow Mn^{2+}(aq) + 5Fe^{3+}(aq) + 4H_2O(l)$$

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.

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…… **[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.

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…… **[1]**

**END OF QUESTION PAPER**

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