READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.
Give details of the practical session and laboratory where appropriate, in the boxes provided.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
DO NOT WRITE IN ANY BARCODES.

Answer all questions.
Electronic calculators may be used.
You may lose marks if you do not show your working or if you do not use appropriate units.
Use of a Data Booklet is unnecessary.

Qualitative Analysis Notes are printed on pages 10 and 11.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

This document consists of 11 printed pages and 1 blank page.
You are provided with a solution of an organic acid which is known to be one of the following.

methanoic acid, HCOOH
propanoic acid, C₂H₅COOH
pent-2-enoic acid, CH₃CH₂CH=CHCOOH

The solution was made by dissolving 1.85 g of acid in 250 cm³ of solution.

You are to suggest the identity of the acid by finding its relative molecular mass, \( M_r \), using a titration method.

FA 1 is the solution of the unknown organic acid.
FA 2 is 0.100 mol dm⁻³ sodium hydroxide, NaOH.
phenolphthalein indicator

(a) Method

- Fill the burette with FA 2.
- Pipette 25.0 cm³ of FA 1 into a conical flask.
- Titrate FA 1 with FA 2 using phenolphthalein as indicator.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is ......................... cm³.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make certain any recorded results show the precision of your practical work.
- Record, in a suitable form below, all of your burette readings and the volume of FA 2 added in each accurate titration.
(b) From your accurate titration results, obtain a suitable value to be used in your calculations. Show clearly how you obtained this value.

25.0 cm$^3$ of FA 1 required ............... cm$^3$ of FA 2 [1]

(c) Calculations

Show your working and appropriate significant figures in the final answer to each step of your calculations.

(i) Calculate the number of moles of sodium hydroxide in the volume of FA 2 you have calculated in (b).

\[\text{moles of NaOH} = \ldots \ldots \ldots \ldots \text{mol}\]

(ii) One mole of any of the organic acids reacts with one mole of sodium hydroxide. Calculate the concentration, in mol dm$^{-3}$, of the acid in FA 1.

\[\text{concentration of the acid in FA 1} = \ldots \ldots \ldots \ldots \text{mol dm}^{-3}\]

(iii) Calculate the concentration, in g dm$^{-3}$, of the acid used to make solution FA 1.

\[\text{concentration of the acid in FA 1} = \ldots \ldots \ldots \ldots \text{g dm}^{-3}\]

(iv) Using your answers to (ii) and (iii), calculate the relative molecular mass, $M_r$, of the acid in FA 1.

\[M_r, \text{ of the acid} = \ldots \ldots \ldots \ldots\]
(v) Suggest which of the acids, methanoic, propanoic or pent-2-enoic acid, is present in FA 1.

Acid present is .................................................

(vi) Suggest a test that could be carried out to distinguish pent-2-enoic acid from methanoic acid and propanoic acid.

Give the expected result of your test.

test .....................................................................................

expected result .....................................................................................
The formula of hydrated iron(II) sulfate is $\text{FeSO}_4 \cdot x\text{H}_2\text{O}$ where $x$ shows the number of moles of water of crystallisation.

The value of $x$ can be found by heating solid hydrated iron(II) sulfate to remove the water of crystallisation.

$\text{FA 3}$ is hydrated iron(II) sulfate, $\text{FeSO}_4 \cdot x\text{H}_2\text{O}$.

(a) Method

Record all weighings, in an appropriate form, in the space below.

- Weigh and record the mass of the empty crucible.
- Tip the contents of the tube labelled $\text{FA 3}$ into the weighed crucible. Reweigh and record the mass of the crucible and $\text{FA 3}$.
- Use a pipe-clay triangle to support the crucible and contents on a tripod.
- Heat gently for about three minutes.
- Leave the crucible to cool for approximately five minutes.

While you are waiting for the crucible to cool, start work on Question 3.

- When cool, reweigh the crucible with the residue.
- Reheat gently for three minutes, cool and reweigh the crucible until you are satisfied that all the water of crystallisation has been lost. It should not be necessary to reheat the crucible more than three times.
(b) (i) Calculate the mass of water lost and the mass of anhydrous iron(II) sulfate that remains after the heating process.

mass of water lost = ................. g

mass of anhydrous iron(II) sulfate = ................. g

(ii) Determine the value of \( x \) in the formula of hydrated iron(II) sulfate, \( \text{FeSO}_4 \cdot x\text{H}_2\text{O} \).

\( (A, : H, 1.0; O, 16.0; S, 32.1; \text{Fe}, 55.8) \)

value of \( x \) = .................

[3]

(c) A group of students carried out this practical and made their measurements correctly. The students calculated a value of 9 for \( x \). The textbook value of \( x \) is less than 9.

(i) Suggest an error in the practical procedure of the experiment that could account for this result and explain why this gives a value of \( x \) that is too high.

.............................................................................................................................
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(ii) Suggest a modification that could be made to the experimental procedure to reduce this error. Explain why this modification should give an answer for \( x \) that is closer to the textbook value.

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

[3]

[Total: 12]
3 Qualitative Analysis

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, described in the appropriate place in your observations.

You should indicate clearly at what stage in a test a change occurs. Marks are not given for chemical equations. No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.

Rinse and reuse test-tubes and boiling tubes where possible.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

(a) You are provided with a solid FA 4. FA 4 is a mixture that contains two cations and two anions.

(i) Place a spatula measure of FA 4 in a hard-glass test-tube. Heat the solid and identify the gas given off. Record all your observations.

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

(ii) To a spatula measure of FA 4 in a test-tube, add a 1 cm depth of dilute nitric acid. Record your observations.

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........................................................................................................................................
(iii) To a spatula measure of FA 4 in a test-tube, add approximately a 2 cm depth of distilled water to make a solution. Divide the solution into two portions.

To the first portion, add a 1 cm depth of aqueous sodium hydroxide. Record your observations.

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

To the second portion, add a few drops of aqueous silver nitrate, then add a 1 cm depth of dilute nitric acid. Record your observations.

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

(iv) Use your results from (i) to (iii) to identify two anions and one cation that are present in FA 4.

anions present .................................................. and ..................................................

cation present ..................................................

(v) What further test could be carried out on FA 4 to confirm the presence of the cation you suggested in (iv)? You should state the reagent to be used and the expected result.

Do not carry out this test.

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

(vi) To a spatula measure of FA 4 in a test-tube, add a 1 cm depth of distilled water to make a solution. To this solution, add a few drops of aqueous barium chloride or barium nitrate.

Describe the appearance of the precipitate formed and state its identity.

appearance of precipitate .........................................

identity of precipitate .........................................
(b) **FA 5, FA 6, FA 7 and FA 8** are aqueous solutions each containing one of the ions \( \text{Al}^{3+}, \text{Ca}^{2+}, \text{Zn}^{2+} \) and \( \text{Pb}^{2+} \).

(i) Carry out the following tests. Record your observations in the spaces provided in the table.

<table>
<thead>
<tr>
<th>test</th>
<th>observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>To a 1 cm depth of solution in a test-tube, add a few drops of aqueous sodium hydroxide, then add excess aqueous sodium hydroxide.</td>
<td></td>
</tr>
<tr>
<td>To a 1 cm depth of solution in a test-tube, add a few drops of aqueous ammonia, then add excess aqueous ammonia.</td>
<td></td>
</tr>
<tr>
<td>To a 1 cm depth of solution in a test-tube, add a 1 cm depth of aqueous potassium iodide.</td>
<td></td>
</tr>
</tbody>
</table>

(ii) Use the Qualitative Analysis Notes on page 10 to identify the cation present in each of the solutions.

**FA 5** is ............... , **FA 6** is ............... , **FA 7** is ............... , **FA 8** is ............... 

[6]

[Total: 15]
# Qualitative Analysis Notes

**Key:** \[ppt. = precipitate\]

## 1 Reactions of aqueous cations

<table>
<thead>
<tr>
<th>ion</th>
<th>reaction with</th>
<th>NaOH(aq)</th>
<th>NH₃(aq)</th>
</tr>
</thead>
<tbody>
<tr>
<td>aluminium, (Al^{3+})(aq)</td>
<td>white ppt.</td>
<td>soluble in excess</td>
<td>white ppt.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>insoluble in excess</td>
</tr>
<tr>
<td>ammonium, (NH₄)²⁺(aq)</td>
<td>no ppt.</td>
<td>ammonia produced on heating</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>barium, (Ba^{2+})(aq)</td>
<td>no ppt. (if reagents are pure)</td>
<td>no ppt.</td>
<td></td>
</tr>
<tr>
<td>calcium, (Ca^{2+})(aq)</td>
<td>white ppt.</td>
<td>with high ([Ca^{2+}](aq))</td>
<td>no ppt.</td>
</tr>
<tr>
<td>chromium(III), (Cr^{3+})(aq)</td>
<td>grey-green ppt. soluble in excess</td>
<td>grey-green ppt.</td>
<td>grey-green ppt.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>giving dark green solution</td>
<td>insoluble in excess</td>
</tr>
<tr>
<td>copper(II), (Cu^{2+})(aq)</td>
<td>pale blue ppt.</td>
<td>insoluble in excess</td>
<td>blue ppt. soluble in excess</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>giving dark blue solution</td>
</tr>
<tr>
<td>iron(II), (Fe^{2+})(aq)</td>
<td>green ppt.</td>
<td>turning brown on contact with air</td>
<td>green ppt. turning brown on contact</td>
</tr>
<tr>
<td></td>
<td></td>
<td>insoluble in excess</td>
<td>with air</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>insoluble in excess</td>
</tr>
<tr>
<td>iron(III), (Fe^{3+})(aq)</td>
<td>red-brown ppt.</td>
<td>insoluble in excess</td>
<td>red-brown ppt.</td>
</tr>
<tr>
<td>lead(II), (Pb^{2+})(aq)</td>
<td>white ppt.</td>
<td>soluble in excess</td>
<td>white ppt.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>insoluble in excess</td>
</tr>
<tr>
<td>magnesium, (Mg^{2+})(aq)</td>
<td>white ppt.</td>
<td>insoluble in excess</td>
<td>white ppt.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>insoluble in excess</td>
</tr>
<tr>
<td>manganese(II), (Mn^{2+})(aq)</td>
<td>off-white ppt. rapidly turning brown</td>
<td>off-white ppt. rapidly turning brown</td>
<td>off-white ppt. rapidly turning brown</td>
</tr>
<tr>
<td></td>
<td></td>
<td>on contact with air</td>
<td>on contact with air</td>
</tr>
<tr>
<td></td>
<td></td>
<td>insoluble in excess</td>
<td>insoluble in excess</td>
</tr>
<tr>
<td>zinc, (Zn^{2+})(aq)</td>
<td>white ppt.</td>
<td>soluble in excess</td>
<td>white ppt.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>soluble in excess</td>
</tr>
</tbody>
</table>

[Lead(II) ions can be distinguished from aluminium ions by the insolubility of lead(II) chloride.]
## 2 Reactions of anions

<table>
<thead>
<tr>
<th>ion</th>
<th>reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>carbonate, CO$_3^{2-}$</td>
<td>CO$_2$ liberated by dilute acids</td>
</tr>
<tr>
<td>chromate(VI), CrO$_4^{2-}$(aq)</td>
<td>yellow solution turns orange with H$^+$(aq); gives yellow ppt. with Ba$^{2+}$(aq); gives bright yellow ppt. with Pb$^{2+}$(aq)</td>
</tr>
<tr>
<td>chloride, Cl$^-$ (aq)</td>
<td>gives white ppt. with Ag$^+$(aq) (soluble in NH$_3$(aq)); gives white ppt. with Pb$^{2+}$(aq)</td>
</tr>
<tr>
<td>bromide, Br$^-$ (aq)</td>
<td>gives cream ppt. with Ag$^+$(aq) (partially soluble in NH$_3$(aq)); gives white ppt. with Pb$^{2+}$(aq)</td>
</tr>
<tr>
<td>iodide, I$^-$ (aq)</td>
<td>gives yellow ppt. with Ag$^+$(aq) (insoluble in NH$_3$(aq)); gives yellow ppt. with Pb$^{2+}$(aq)</td>
</tr>
<tr>
<td>nitrate, NO$_3^-$ (aq)</td>
<td>NH$_3$ liberated on heating with OH$^-$ (aq) and Al foil</td>
</tr>
<tr>
<td>nitrite, NO$_2^-$ (aq)</td>
<td>NH$_3$ liberated on heating with OH$^-$ (aq) and Al foil; NO liberated by dilute acids (colourless NO → (pale) brown NO$_2$ in air)</td>
</tr>
<tr>
<td>sulfate, SO$_4^{2-}$(aq)</td>
<td>gives white ppt. with Ba$^{2+}$(aq) or with Pb$^{2+}$(aq) (insoluble in excess dilute strong acids)</td>
</tr>
<tr>
<td>sulfite, SO$_3^{2-}$(aq)</td>
<td>SO$_2$ liberated with dilute acids; gives white ppt. with Ba$^{2+}$(aq) (soluble in excess dilute strong acids)</td>
</tr>
</tbody>
</table>

## 3 Tests for gases

<table>
<thead>
<tr>
<th>gas</th>
<th>test and test result</th>
</tr>
</thead>
<tbody>
<tr>
<td>ammonia, NH$_3$</td>
<td>turns damp red litmus paper blue</td>
</tr>
<tr>
<td>carbon dioxide, CO$_2$</td>
<td>gives a white ppt. with limewater (ppt. dissolves with excess CO$_2$)</td>
</tr>
<tr>
<td>chlorine, Cl$_2$</td>
<td>bleaches damp litmus paper</td>
</tr>
<tr>
<td>hydrogen, H$_2$</td>
<td>“pops” with a lighted splint</td>
</tr>
<tr>
<td>oxygen, O$_2$</td>
<td>relights a glowing splint</td>
</tr>
<tr>
<td>sulfur dioxide, SO$_2$</td>
<td>turns acidified aqueous potassium dichromate(VI) from orange to green</td>
</tr>
</tbody>
</table>