H2

MINISTRY OF EDUCATION, SINGAPORE
in collaboration with
CAMBRIDGE INTERNATIONAL EDUCATION
General Certificate of Education Advanced Level

CANDIDATE NAME									
CENTRE NUMBER	S					INDEX NUMBER			

0123456789

CHEMISTRY **9476/04**

Paper 4 Practical **For examination from 2026**

SPECIMEN PAPER **2 hours 30 minutes**

You must answer on the question paper.

You will need: The materials and apparatus listed in the confidential instructions

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and index number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen. Do **not** use correction fluid or tape.
- Do **not** write on any bar codes.
- You may use an approved calculator.
- Qualitative analysis notes are printed in the question paper.
- Write the details of the shift and laboratory in the boxes provided.

INFORMATION

- The total mark for this paper is 50.
- The number of marks for each question or part question is shown in brackets [ ].

Shift
Laboratory

For Examiner's Use	
1	
2	
3	
Total	

This document has **20** pages. Any blank pages are indicated.

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Answer **all** the questions in the spaces provided.

1 Determination of the enthalpy change of solution, ΔH_{sol}, of potassium chloride.

FA 1 is potassium chloride, KC*l*, provided in a capped bottle.

In this experiment, you will measure the temperature of the contents of a polystyrene cup at timed intervals, both before and after solid **FA 1** is added. You will analyse your results graphically in order to determine an accurate value for the temperature change of the mixture, caused by solid **FA 1** dissolving.

You will use this temperature change value to calculate the heat change, q, for the experiment, and hence determine a value for the enthalpy change of solution, ΔH_{sol}, for solid **FA 1**.

(a) In the space provided on page 4, prepare tables in which to record results for your experiment:

- all weighings, to an appropriate level of precision
- all values of temperature, T, to an appropriate level of precision
- all values of time, t, recorded to the nearest 0.5 min.

It is important that you measure each temperature at the specified time.

Procedure

step 1 Weigh the capped bottle containing solid **FA 1**. Record the mass in your results table on page 4.

step 2 Place one polystyrene cup inside the other polystyrene cup. Place these in a glass beaker to prevent them from tipping over.

step 3 Use the 50 cm^3 measuring cylinder to transfer 50 cm^3 of deionised water into the first polystyrene cup.

step 4 Stir the water in the polystyrene cup with the **thermometer with 0.2 °C graduation. It is important that you use the correct thermometer**. Start the stopwatch (t = 0.0 min) and immediately read and record the temperature, T. The stopwatch must be left to run for the rest of the experiment.

step 5 Continue to stir the water. Read and record T every minute for two minutes.

step 6 At **exactly** three minutes, tip all the solid **FA 1** into the polystyrene cup. Stir the mixture but do **not** read T.

step 7 Continue to stir the mixture. Read and record T at t = 3.5 min.

step 8 Continue to stir the mixture. Read and record T at t = 4.0 min and every minute until t = 9.0 min.

step 9 Reweigh the empty bottle and its cap. Record this mass in your results table.

Results

[5]

(b) Plot a graph of temperature, T, on the y-axis, against time, t, on the x-axis on the grid in Figure 1.1.

Draw a best-fit straight line taking into account all of the points before t = 3.0 min.

Draw another best-fit straight line taking into account all of the points after the temperature of the mixture has started to rise steadily.

Extrapolate (extend) both lines to t = 3.0 min.

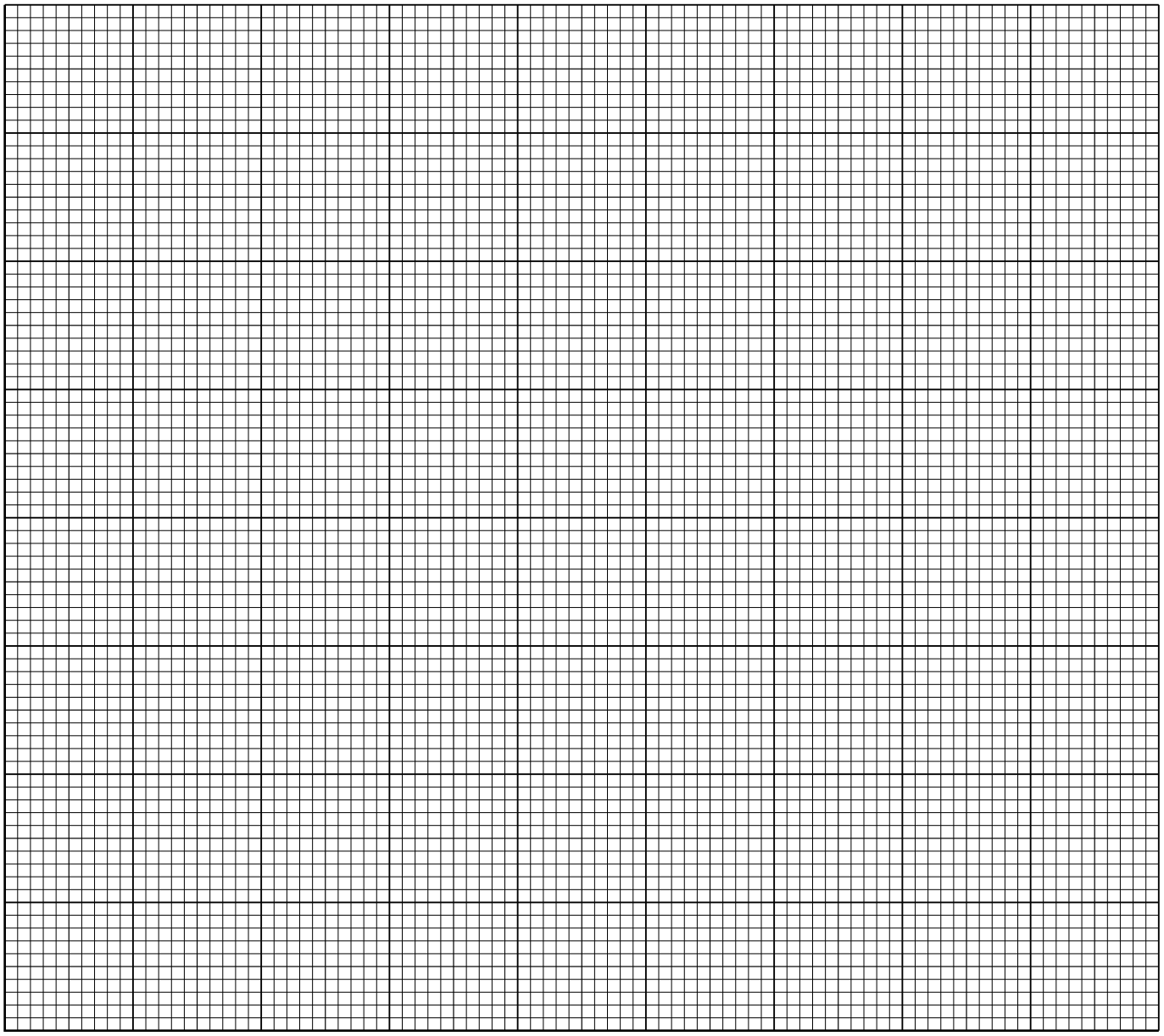

Figure 1.1

[3]

(c) From your graph, read the minimum temperature, T_{min}, and the maximum temperature, T_{max}, at t = 3.0 min. Record these values in the spaces provided.

Deduce the temperature change, ΔT, at t = 3.0 min.

T_{min} = ...

T_{max} = ...

ΔT = ...

[1]

(d) Calculate the heat change, q, for your experiment using the ΔT value you deduced in **1(c)**.

You should assume that the specific heat capacity of the solution is 4.18 J g^{-1} K^{-1} and the density of the solution is 1.00 g cm^{-3}.

q = ... [1]

(e) Determine the enthalpy change of solution, ΔH_{sol}, for solid **FA 1**.

Include the sign of ΔH_{sol} in your answer.

[A_r: C*l*, 35.5; K, 39.1]

ΔH_{sol} = ... [5]

(f) Suggest the effect that using 100 cm^3, rather than 50 cm^3, of water would have on your value for ΔT. Hence, deduce and explain the effect this will have on the value for ΔH_{sol}.

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..... [1]

[Total: 16]

2 Determination of the M_r of a hydrated ethanedioate salt

Ethanedioic acid, $H_2C_2O_4$, forms salts with metals. One of these salts can be represented by the formula $\mathbf{X}_2C_2O_4 \cdot H_2O$, where **X** is a Group 1 metal.

Solution **Q** contains 64.5 g dm^{-3} of $\mathbf{X}_2C_2O_4 \cdot H_2O$ in deionised water. You are **not** provided with **Q**.

FA 2 is a diluted sample of solution **Q**. To prepare **FA 2**, 35.70 cm^3 of **Q** was made up to 250 cm^3 with deionised water in a volumetric flask.
FA 3 is 0.0200 mol dm^{-3} potassium manganate(VII), $KMnO_4$.
FA 4 is 1.00 mol dm^{-3} sulfuric acid, H_2SO_4.

Ethanedioate ions, $C_2O_4^{2-}$, react with acidified manganate(VII) ions as shown by the following equation.

$$5C_2O_4^{2-} + 2MnO_4^- + 16H^+ \rightarrow 10CO_2 + 2Mn^{2+} + 8H_2O$$

In this question, you will perform a titration. The data from this titration will be used to determine:

- the concentration of $C_2O_4^{2-}$ ions in **Q**
- the M_r of $\mathbf{X}_2C_2O_4 \cdot H_2O$ and hence the identity of the metal **X**.

(a) Titration of FA 2 against FA 3

In this titration, you will run **FA 3** from the burette into a conical flask containing **FA 2** and **FA 4**. Initially, the colour of the **FA 3** will take some time to disappear. After some **FA 3** has been added, sufficient $Mn^{2+}(aq)$ ions will be present to allow the reaction to occur faster. $Mn^{2+}(aq)$ ions catalyse the reaction.

The end-point is reached when a **permanent** pale pink colour is obtained.

(i) step 1 Fill the burette with **FA 3**.

step 2 Use the pipette to transfer 25.0 cm^3 of **FA 2** into a 250 cm^3 conical flask.

step 3 Use the 50 cm^3 measuring cylinder to transfer 50.0 cm^3 of **FA 4** to the same conical flask.

step 4 Heat the mixture in the conical flask to approximately 65 °C, monitored with the **thermometer with 1 °C graduation**. **It is important that you use the correct thermometer.** Take care when removing the conical flask from the heat.

step 5 Run **FA 3** from the burette into this flask until a **permanent** pale pink colour is obtained. If a brown precipitate appears during your titration, add another 50.0 cm^3 of **FA 4** and reheat the solution until the precipitate disappears. Then continue with the titration.

step 6 Record your titration results in Table 2.1 on page 8. Make certain that your recorded results show the precision of your working.

step 7 Repeat steps 1 to 6 as necessary until consistent results are obtained.

step 8 **Turn off your Bunsen burner.**

Keep FA 3 and FA 4 for use in Question 3

Results

Table 2.1

final burette reading / cm^3					
initial burette reading / cm^3					
volume of FA 3 added / cm^3					

[4]

(ii) From your titrations, obtain a suitable volume of **FA 3** to be used in your calculations. Show clearly how you obtained this volume.

volume of **FA 3** = ... cm^3 [1]

(b) (i) The equation for the reaction between ethanedioate ions and manganate(VII) ions is shown.

$$5C_2O_4^{2-}(aq) + 2MnO_4^-(aq) + 16H^+(aq) \rightarrow 10CO_2(g) + 2Mn^{2+}(aq) + 8H_2O(l)$$

Calculate the amount of ethanedioate ions, $C_2O_4^{2-}$, in 25.0 cm^3 of **FA 2**.

amount of $C_2O_4^{2-}$ in 25.0 cm^3 of **FA 2** = ... mol [1]

(ii) Determine the concentration in mol dm^{-3} of $C_2O_4^{2-}$ in **Q**.

concentration of $C_2O_4^{2-}$ in **Q** = ... mol dm^{-3} [2]

(iii) Use your answer to **2(b)(ii)** to calculate the M_r of the ethanedioate salt, $\mathbf{X}_2C_2O_4 \cdot H_2O$.

M_r of the ethanedioate salt = ... [1]

(iv) Hence, deduce the identity of **X**. Show your working.

[A_r: H, 1.0; C, 12.0; O, 16.0; Li, 6.9; Na, 23.0; K, 39.1; Rb, 85.5; Cs, 132.9; Fr, 223.0]

X is ..... [2]

(c) A student performed the experiment in **2(a)(i)** using a sample of another ethanedioate salt. The student obtained a mean titre value of 22.20 cm^3.

The teacher calculated that the mean titre volume of **FA 3** required should have been 22.40 cm^3. The teacher told the student that the total percentage error from the burette in the experiment was 0.4%.

Calculate the percentage error in the student's result, based on these data. State and explain whether or not the student's result is accurate.

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..... [2]

(d) The volume of carbon dioxide produced from the reaction between ethanedioate ions and manganate(VII) ions can be used to confirm the identity of **X** in the hydrated ethanedioate salt, $\mathbf{X}_2C_2O_4 \cdot H_2O$.

$$5C_2O_4^{2-}(aq) + 2MnO_4^-(aq) + 16H^+(aq) \rightarrow 10CO_2(g) + 2Mn^{2+}(aq) + 8H_2O(l)$$

You may assume you are provided with:

- 10 g of hydrated ethanedioate salt, $\mathbf{X}_2C_2O_4 \cdot H_2O$, where **X** is a Group 1 metal
- 150 cm^3 of **FA 3**
- 150 cm^3 of **FA 4**
- the equipment normally found in a school or college laboratory.

(i) Calculate the mass of $\mathbf{X}_2C_2O_4 \cdot H_2O$ to make 250.0 cm^3 of 0.05 mol dm^{-3} $\mathbf{X}_2C_2O_4$ solution, using your answer to **2(b)(iv)**. If you did not deduce the identity of **X** in **2(b)(iv)**, then assume **X** is Na.

mass of $\mathbf{X}_2C_2O_4 \cdot H_2O$ = ... g [1]

(ii) Plan an experiment to collect the carbon dioxide gas produced in the reaction between ethanedioate ions and manganate(VII) ions by displacement of water. You may draw a labelled diagram of the set-up that could be used to carry out this experiment.

In your plan, you should include brief details of:

- the preparation of 250.0 cm^3 of 0.05 mol dm^{-3} $\mathbf{X}_2C_2O_2$ solution
- the volumes of **FA 3**, **FA 4** and the 0.05 mol dm^{-3} $\mathbf{X}_2C_2O_4$ solution to use in the experiment
- a calculation of the expected volume of gas collected using your specified volume of 0.05 mol dm^{-3} $\mathbf{X}_2C_2O_4$ solution
- the apparatus you would use
- the procedure you would follow
- the measurements you would make
- how your experimental results could be used to confirm the identity of **X**.

You may assume that the experiment is carried out at room temperature.

The molar volume of a gas = 24 dm^3 mol^{-1}.

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..... [8]

(iii) A gas syringe can be used to measure the volume of gas produced, instead of collection over water.

State **one** advantage of collecting and measuring the gas in a gas syringe instead of over water.

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..... [1]

[Total: 23]

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3 Organic analysis

Before starting this analysis, ensure your Bunsen burner is turned off.

In this question, you will deduce the identities of the organic compounds **FA 5**, **FA 6**, **FA 7** and **FA 8**.

- Each compound contains only carbon, hydrogen and oxygen.
- Each molecule contains only three carbon atoms and only one oxygen atom.

You will perform a series of test-tube reactions and use the observations to help you identify the compounds. The observations for one of the reactions has already been recorded in Table 3.1.

You are provided with:

- liquid samples **FA 5**, **FA 6**, **FA 7** and **FA 8**
- iodine solution
- Fehling's solution A
- Fehling's solution B
- other necessary bench reagents.

You will also need access to the **FA 3** and **FA 4** solutions you used in **Question 2**.

(a) Perform the tests described in Table 3.1 on pages 14 and 15, and record your observations in Table 3.1. If there is no observable change, write **no observable change**.

Use a fresh sample of each liquid in each test.

Table 3.1

	tests	observations with FA 5	observations with FA 6	observations with FA 7	observations with FA 8
1	Add 1 cm depth of **FA 4** to a clean test-tube. To this test-tube, add 5 drops of **FA 5** followed by 5 drops of **FA 3**. Prepare a hot water bath using the hot water provided. Warm the mixture in the water bath for two minutes. **Repeat using FA 6 and FA 7, in place of FA 5.**				**FA 3** solution decolourises
2	Add 1 cm depth of deionised water to a clean test-tube. To this test-tube, add 5 drops of **FA 5** followed by 6 drops of aqueous sodium hydroxide. Add iodine solution, dropwise, until a permanent yellow / orange colour is present. Warm the mixture in the water bath for two minutes. **Repeat using FA 6, FA 7 and FA 8, in place of FA 5.**				

	tests	observations with FA 5	observations with FA 6	observations with FA 7	observations with FA 8
3	Add 1 cm depth of Fehling's solution A to a clean test-tube. Then add Fehling's solution B, dropwise, until the initial precipitate just dissolves to give a deep blue solution. Add 5 drops of **FA 5**. Warm the mixture in the water bath for five minutes. **Repeat using FA 6, FA 7 and FA 8, in place of FA 5.**				

[6]

(b) When a small amount of solid phosphorus(V) chloride was added to separate samples of each of the organic compounds, white fumes were observed only with **FA 6** and **FA 8**.

Use this information and observations recorded in Table 3.1 to complete Table 3.2 to identify the organic compounds **FA 5**, **FA 6**, **FA 7** and **FA 8**.

For each compound, give evidence to support your conclusion.

Table 3.2

	identity of compound	evidence
FA 5		
FA 6		
FA 7		
FA 8		

[4]

(c) Suggest the structure of a compound with M_r = 74.0 that would give:

- no observable change in tests 1–3 in Table 3.1
- effervescence with a positive test with limewater when reacted with sodium carbonate.

[A_r: H, 1.0; C, 12.0; O, 16.0]

[1]

[Total: 11]

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  [Turn over

Qualitative analysis notes
[ppt. = precipitate]

(a) Reactions of cations

cation	reaction with	
	NaOH(aq)	NH_3(aq)
aluminium, Al^{3+}(aq)	white ppt. soluble in excess	white ppt. insoluble in excess
ammonium, NH_4^+(aq)	ammonia produced on heating	–
barium, Ba^{2+}(aq)	no ppt. (if reagents are pure)	no ppt.
calcium, Ca^{2+}(aq)	white ppt. with high [Ca^{2+}(aq)]	no ppt.
chromium(III), Cr^{3+}(aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess
copper(II), Cu^{2+}(aq)	pale blue ppt. insoluble in excess	blue ppt. soluble in excess giving dark blue solution
iron(II), Fe^{2+}(aq)	green ppt. turning brown on contact with air insoluble in excess	green ppt. turning brown on contact with air insoluble in excess
iron(III), Fe^{3+}(aq)	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess
magnesium, Mg^{2+}(aq)	white ppt. insoluble in excess	white ppt. insoluble in excess
manganese(II), Mn^{2+}(aq)	off-white ppt. rapidly turning brown on contact with air insoluble in excess	off-white ppt. rapidly turning brown on contact with air insoluble in excess
zinc, Zn^{2+}(aq)	white ppt. soluble in excess	white ppt. soluble in excess

(b) Reactions of anions

ion	reaction
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chloride, Cl^-(aq)	gives white ppt. with Ag^+(aq) (soluble in NH_3(aq))
bromide, Br^-(aq)	gives pale cream ppt. with Ag^+(aq) (partially soluble in NH_3(aq))
iodide, I^-(aq)	gives yellow ppt. with Ag^+(aq) (insoluble in NH_3(aq))
nitrate, NO_3^-(aq)	NH_3 liberated on heating with OH^-(aq) and Al foil
nitrite, NO_2^-(aq)	NH_3 liberated on heating with OH^-(aq) and Al foil; NO liberated by dilute acids (colourless NO $\rightarrow$ (pale) brown NO_2 in air)
sulfate, SO_4^{2-}(aq)	gives white ppt. with Ba^{2+}(aq) (insoluble in excess dilute strong acids);
sulfite, SO_3^{2-}(aq)	SO_2 liberated with dilute acids; gives white ppt. with Ba^{2+}(aq) (soluble in dilute strong acids)

(c) Tests for gases

gas	test and test result
ammonia, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater (ppt. dissolves with excess CO_2)
chlorine, Cl_2	bleaches damp litmus paper
hydrogen, H_2	'pops' with a lighted splint
oxygen, O_2	relights a glowing splint
sulfur dioxide, SO_2	turns aqueous acidified potassium manganate(VII) from purple to colourless

(d) Colour of halogens

halogen	colour of element	colour in aqueous solution	colour in hexane
chlorine, Cl_2	greenish yellow gas	pale yellow	pale yellow
bromine, Br_2	reddish brown gas / liquid	orange	orange-red
iodine, I_2	black solid / purple gas	brown	purple

(e) Tests for organic compounds

organic compounds	reactions
alkene	decolourises orange $Br_2(aq)$
chloroalkane	heat with NaOH(aq), white ppt. formed on adding dilute HNO_3, followed by $Ag^+(aq)$
bromoalkane	heat with NaOH(aq), pale cream ppt. formed on adding dilute HNO_3, followed by $Ag^+(aq)$
iodoalkane	heat with NaOH(aq), yellow ppt. formed on adding dilute HNO_3, followed by $Ag^+(aq)$
alcohol	• forms white fumes with solid PCl_5 • decolourises purple acidified $KMnO_4(aq)$ on heating (for primary and secondary alcohols) • gives pale yellow ppt. with alkaline $I_2(aq)$ on warming (for alcohols with $CH_3CH(OH)$– group)
phenol	decolourises orange $Br_2(aq)$ and forms a white ppt.
carbonyl compounds (aldehydes and ketones)	• gives orange ppt. with 2,4-dinitrophenylhydrazine • gives pale yellow ppt. with alkaline $I_2(aq)$ on warming (for carbonyl compounds with CH_3CO– group) • gives red-brown ppt. with Fehling's solution on warming (for aliphatic aldehydes) • gives silver mirror with Tollens' reagent on warming (for aldehydes)
carboxylic acid	• CO_2 liberated by $Na_2CO_3(aq)$ • gives white fumes with solid PCl_5
phenylamine	decolourises orange $Br_2(aq)$ and forms a white ppt.
primary amide	NH_3 liberated on heating with NaOH(aq)

