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ST ANDREW'S JUNIOR COLLEGE



JC 2 PRELIMINARY EXAMINATIONS

CHEMISTRY

Paper 4 Practical

You must answer on the question paper.

You will need: The materials and apparatus listed in the Confidential Instructions Insert

9476/04

13 Aug 2026

2 hours 30 minutes

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 and class 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.
- 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		14
2		23
3		13
Total		50

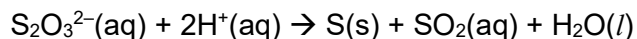
This document consists of **24** printed pages. Any blank pages are indicated.

1 Investigating the kinetics of the reaction between thiosulfate ions and acid

FA 1 is $0.100 \text{ mol dm}^{-3}$ sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$.

FA 2 is 1.00 mol dm^{-3} sulfuric acid, H_2SO_4 .

The thiosulfate ion, $\text{S}_2\text{O}_3^{2-}$, decomposes when an acid is added according to the equation shown.



In this experiment, the rate of the reaction is studied by measuring the rate of formation of sulfur using a 'clock' method. You will vary the concentration of thiosulfate ions and measure the time taken for a fixed amount of sulfur to be produced. This will be indicated by how long it takes for the solid sulfur forming to obscure the print on the insert.

You will perform a series of five experiments. For each experiment you will need to ensure that the same total volume of reaction mixture is used, by adding deionised water as required. For each experiment, you will measure the time, t , for the sulfur to obscure the print on the insert.

Note: A small amount of sulfur dioxide gas may be formed in the experiment. It is very important that you avoid inhaling any fumes. As soon as each experiment is complete, add the reaction mixture to the waste container of sodium carbonate solution and rinse the beaker thoroughly.

(a) Prepare a table in the space provided on page 4 in which to record, to an appropriate degree of precision:

- the volumes of **FA 1** ($V_{\text{FA 1}}$) and deionised water used
- all values of t
- rate

The rate of reaction can be calculated using the following formula.

$$\text{rate} = \frac{1000}{t}$$

Experiment 1

- 1) Use the 50 cm^3 measuring cylinder to measure 40.0 cm^3 of **FA 1** into the 100 cm^3 beaker.
- 2) Use the 25 cm^3 measuring cylinder to measure 10.0 cm^3 of **FA 2**.
- 3) Pour the **FA 2** into the same beaker, starting the stopwatch during this addition.
- 4) Stir the mixture once and place the beaker on the printed insert.
- 5) Stop the stopwatch when the print on the insert becomes obscured.

- 6) Record the time taken, to the nearest second, in your table.
- 7) Discard the reaction mixture immediately into the waste container of sodium carbonate solution.
- 8) Wash out the beaker thoroughly with tap water and then with deionised water. Stand the beaker upside down on a paper towel to drain.

Experiment 2

- 9) Use the 50 cm³ measuring cylinder to measure 20.0 cm³ of **FA 1** into another 100 cm³ beaker.
- 10) Use the same 50 cm³ measuring cylinder to measure 20.0 cm³ of deionised water into the same beaker.
- 11) Use the 25 cm³ measuring cylinder to measure 10.0 cm³ of **FA 2**.
- 12) Pour the **FA 2** into the same beaker, starting the stopwatch during this addition.
- 13) Stir the mixture once and place the beaker on the printed insert.
- 14) Stop the stopwatch when the print on the insert becomes obscured.
- 15) Record the time taken, to the nearest second, in your table.
- 16) Discard the reaction mixture immediately into the waste container of sodium carbonate solution.
- 17) Wash out the beaker thoroughly with tap water and then with deionised water. Stand the beaker upside down on a paper towel to drain.

Experiments 3 - 5

Carry out three further experiments to investigate how using different volumes of **FA 1** affects the reaction time.

Do not use a volume of **FA 1** that is less than 15.0 cm³.

In each experiment, you should adjust the volume of deionised water in step 10 to ensure the **same total volume** of reaction mixture is used.

You should alternate the use of the two 100 cm³ beakers.

Record all your results in a table. You should include all volumes, the time taken and the reaction rate for each of your five experiments in your table.

Keep FA 1 for use in Question 2.

Keep FA 2 for use in Questions 2 and 3.

Results

- (b) (i) Plot a graph of rate on the y-axis against volume of **FA 1** on the x-axis on the grid in Fig 1.1.

Start each axis at the origin (0,0).

Draw the best-fit line.

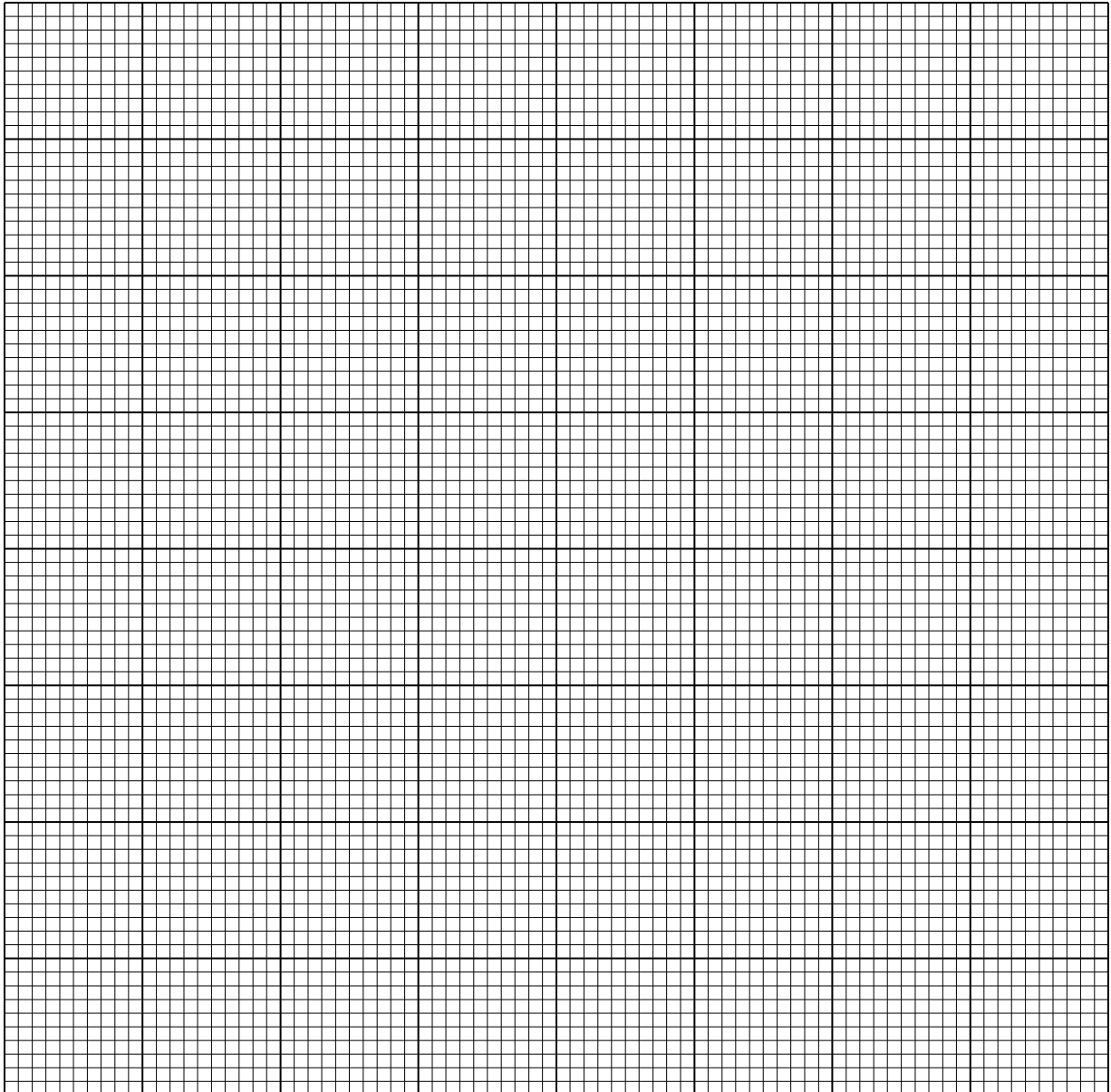


Fig 1.1

[3]

- (ii) From your graph, what conclusion can be drawn about the relationship between the rate of reaction and the volume of **FA 1** used?

Explain your answer.

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[2]

- (iii) Using your graph, determine the time it would take for the print to be obscured if 7.5 cm³ of **FA 1**, 32.5 cm³ of water and 10.0 cm³ of **FA 2** had been used.

Show clearly on the graph how you worked out your answer.

time for print to be obscured = s [2]

- (c) (i) A student found that the reaction was first order with respect to [H⁺].

Predict and explain how the value of t in Experiment 1 would be affected if hydrochloric acid of the same concentration and volume had been used instead of **FA 2**.

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[1]

- (ii) Predict and explain how the value of t in Experiment 1 would be affected if a 250 cm^3 beaker with a larger base area was used instead of the 100 cm^3 beaker.

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[1]

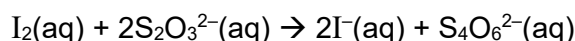
[Total: 14]

2 Determination of the value x of an iodate ion, IO_x^-

Iodate ions contain iodine and oxygen. They have the formula IO_x^- where x is an integer.

- (a) In this experiment you will determine the value of x in an iodate. You will first react IO_x^- with an excess of iodide ions, I^- , to form iodine, I_2 .

The amount of iodine produced is then determined by titration with thiosulfate ions, $\text{S}_2\text{O}_3^{2-}$.



FA 1 is $0.100 \text{ mol dm}^{-3}$ sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$.

FA 2 is 1.00 mol dm^{-3} sulfuric acid, H_2SO_4 .

FA 3 is a solution containing $0.0140 \text{ mol dm}^{-3}$ IO_x^- ions.

FA 4 is $0.500 \text{ mol dm}^{-3}$ potassium iodide, KI .

Solution S is starch solution.

(i) Titration

- 1) Fill the burette with **FA 1**.
- 2) Use the pipette to transfer 25.0 cm^3 of **FA 3** into a 250 cm^3 conical flask.
- 3) Use the 25 cm^3 measuring cylinder to transfer 10.0 cm^3 of **FA 2** to the same conical flask.
- 4) Use the same measuring cylinder to transfer 10.0 cm^3 of **FA 4** to the same conical flask.
- 5) Run **FA 1** from the burette into this flask until the solution turns yellow.
- 6) Add 10–15 drops of **Solution S** to the solution in the conical flask.
- 7) Continue to add more **FA 1** from the burette until the blue-black colour just disappears.
- 8) Record your titration results in Table 2.1 on page 9. Make certain that your recorded results show the precision of your working.
- 9) Repeat steps 1 to 8 as necessary until consistent results are obtained.

Keep FA 3 for use in Question 3.

Table 2.1

final burette reading / cm ³					
initial burette reading / cm ³					
volume of FA 1 added / cm ³					

[4]

- (ii) From your titrations, obtain a suitable volume of **FA 1** to be used in your calculations. Show clearly how you obtained this volume.

Volume of **FA 1** = cm³ [1]

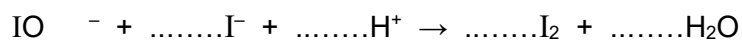
- (b) (i) Calculate the amount of iodine formed when 25.0 cm³ of **FA 3** reacts with 10.0 cm³ of **FA 4**.

amount of iodine formed = mol [1]

- (ii) Calculate the amount of IO_x⁻ ions in 25.0 cm³ of **FA 3**.

amount of IO_x⁻ ions in 25.0 cm³ of **FA 3** = mol [1]

- (iii) An unbalanced equation for the reaction of IO_x^- ions with iodide ions, I^- , and hydrogen ions, H^+ , is shown.



Use the ratio of your answers to **(b)(i)** and **(b)(ii)** to balance this equation and determine the value of x .

Show your working.

[2]

- (iv) Suggest how the titration would be affected if potassium iodide solution was not added in excess. Explain your answer.

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[2]

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

The teacher calculated that the mean titre volume of **FA 1** 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 reaction between iodate and iodide in acidic solution is highly exothermic. Other than the direct titration method in **2(a)**, it is possible to determine the equivalence point and subsequently the concentration of iodate through thermometric titration.

A solution of $8.00 \text{ g dm}^{-3} \text{ IO}_x^-$ was prepared from solid KIO_x . 2.00 cm^3 of iodate solution is progressively added to 25.0 cm^3 of acidified iodide solution until equivalence point is reached and passed. The temperature is monitored throughout the experiment.

The data obtained is plotted and two best-fit graph lines are drawn. One line is drawn using data before equivalence-point and the second line using the remaining data. These lines are then extrapolated (extended) until they cross.

You may assume you are provided with

- 10 g of KIO_x solid
- 100 cm^3 of $0.500 \text{ mol dm}^{-3}$ acidified potassium iodide, KI
- the equipment normally found in a school or college laboratory.

- (i) Describe how you would make 250.0 cm^3 of $8.00 \text{ g dm}^{-3} \text{ KIO}_x$ solution for your experiment.

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- (ii) Plan a thermometric titration in which iodate solution prepared in (d)(i) is added to acidified iodide solution. You should assume the equivalence volume is between 10.00 cm³ to 40.00 cm³.

In your plan, you should include brief details of:

- the apparatus you would use
- the procedure you would follow
- the measurements you would make.

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

This image shows a full page of a handwriting practice worksheet. It consists of multiple sets of three horizontal dotted lines spaced evenly down the page, providing a guide for letter height and placement. The background is plain white, and there are no other markings or text present.

[4]

- (iii) On Fig 2.1, label the axes and sketch the graph you would obtain. Indicate the equivalence volume, V_{eq} , on the graph.

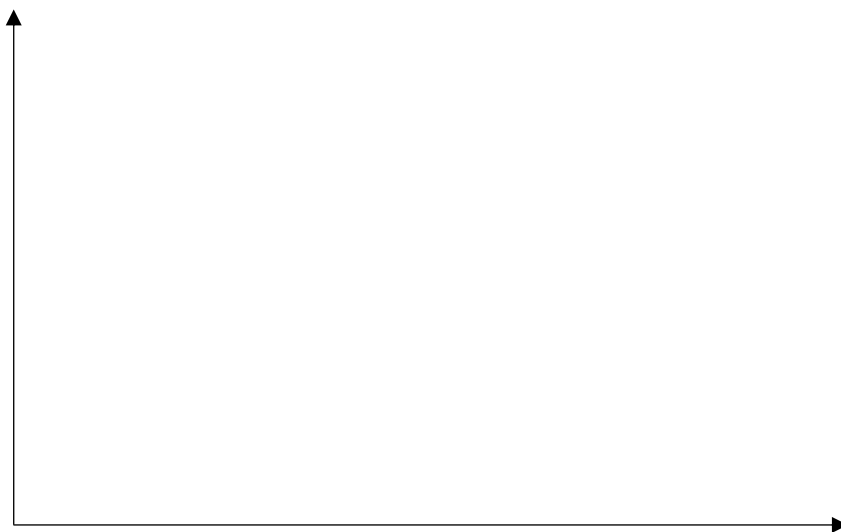


Fig 2.1

[2]

- (iv) Explain the shape of the graph after V_{eq} .

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[1]

[Total: 23]

3 Investigation of an inorganic compound and an organic compound.

FA 5 contains two cations and one anion.

Compound **Y** is an organic compound with two functional groups.

(a) (i) You will carry out tests to identify the ions present in **FA 5**.

You are provided with **FA 5** and other necessary bench reagents. You will also need access to the **FA 3** solution you used in **Questions 2 and 3**.

Carry out the tests described in Table 3.1 on page 16.

Carefully record your observations **at each stage** of the tests in Table 3.1.

The volumes given in Table 3.1 are approximate and should be estimated rather than measured.

Test and identify any gases evolved.

If there is no observable change, write **no observable change**.

Table 3.1

Tests		observations
1	Add 1 cm depth of FA 5 to a boiling tube. Add aqueous sodium hydroxide slowly, with shaking, until the aqueous sodium hydroxide is in excess. Warm the mixture.	
2	Add 1 cm depth of FA 5 to a boiling tube. Add 2 cm depth of FA 3. Warm the mixture. Keep the reaction mixture for test 3.	
3	To the reaction mixture from test 2, add aqueous sodium hydroxide slowly, with shaking, until the aqueous sodium hydroxide is in excess.	
4	Add 1 cm depth of FA 5 to a test-tube. Add 1 cm depth of aqueous barium nitrate. Add dilute nitric acid until the nitric acid is in excess.	

- (ii) Use your observations in Table 3.1 to identify the cations and the anion in **FA 5**.

cations and

anion

[2]

- (iii) Explain the reaction between **FA 3** and **FA 5** in test 2.

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[1]

(b) In this question, you will deduce the two functional groups in **Y**.

Consider the observations recorded in Table 3.2.

You do not perform the following tests. Observations have been recorded for you.

Table 3.2

tests		observations
5	Add 1 cm depth of Y into a test-tube. To this test-tube, add 8 drops of sodium hydroxide solution followed by iodine solution, dropwise, until a permanent orange colour is present. Warm the mixture in a water bath for two minutes.	yellow precipitate formed
6	Add 1 cm depth of Y into a test-tube. Add a small amount of phosphorus pentachloride solid.	no white fumes evolved
7	Add 1 cm depth of Y into a test-tube. Add a small piece of sodium.	effervescence observed and gas evolved extinguishes lighted splint with a 'pop' sound

- (i) Use the information and observations recorded in Table 3.2 to complete Table 3.3 and identify the two functional groups in **Y**.

For each functional group, give evidence to support your conclusion.

Table 3.3

functional group	evidence

[4]

- (ii) Suggest the structure of a compound with 8 carbons that contain the functional groups identified in Table 3.3.

[1]

[Total: 13]

21
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Qualitative Analysis Notes

[ppt. = precipitate]

(a) Reactions of aqueous cations

cation	<i>reaction with</i>	
	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

anion	reaction
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chloride, $\text{Cl}^-(\text{aq})$	gives white ppt. with $\text{Ag}^+(\text{aq})$ (soluble in $\text{NH}_3(\text{aq})$)
bromide, $\text{Br}^-(\text{aq})$	gives pale cream ppt. with $\text{Ag}^+(\text{aq})$ (partially soluble in $\text{NH}_3(\text{aq})$)
iodide, $\text{I}^-(\text{aq})$	gives yellow ppt. with $\text{Ag}^+(\text{aq})$ (insoluble in $\text{NH}_3(\text{aq})$)
nitrate, $\text{NO}_3^-(\text{aq})$	NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil
nitrite, $\text{NO}_2^-(\text{aq})$	NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil; NO liberated by dilute acids (colourless NO (pale) $\rightarrow$ brown NO_2 in air)
sulfate, $\text{SO}_4^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (insoluble in excess dilute strong acid)
sulfite, $\text{SO}_3^{2-}(\text{aq})$	SO_2 liberated with dilute acids; gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (soluble in dilute strong acid)

(c) Test for gases

gas	tests 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 $\text{Br}_2(\text{aq})$
chloroalkane	heat with $\text{NaOH}(\text{aq})$, white ppt. formed on adding dilute HNO_3 , followed by $\text{Ag}^+(\text{aq})$
bromoalkane	heat with $\text{NaOH}(\text{aq})$, pale cream ppt. formed on adding dilute HNO_3 , followed by $\text{Ag}^+(\text{aq})$
iodoalkane	heat with $\text{NaOH}(\text{aq})$, yellow ppt. formed on adding dilute HNO_3 , followed by $\text{Ag}^+(\text{aq})$
alcohol	• forms white fumes with solid PCl_5 • decolourises purple acidified $\text{KMnO}_4(\text{aq})$ on heating (for primary and secondary alcohols) • gives pale yellow ppt. with alkaline $\text{I}_2(\text{aq})$ on warming (for alcohols with $\text{CH}_3\text{CH}(\text{OH})-$ group)
phenol	decolourises orange $\text{Br}_2(\text{aq})$ and forms a white ppt.
carbonyl compounds (aldehydes and ketones)	• gives orange ppt. with 2,4-dinitrophenylhydrazine • gives pale yellow ppt. with alkaline $\text{I}_2(\text{aq})$ on warming (for carbonyl compounds with $\text{CH}_3\text{CO}-$ 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 $\text{Na}_2\text{CO}_3(\text{aq})$ • gives white fumes with solid PCl_5
phenylamine	decolourises orange $\text{Br}_2(\text{aq})$ and forms a white ppt.
primary amide	NH_3 liberated on heating with $\text{NaOH}(\text{aq})$