YISHUN INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME	SAMPLE DATA IN RED		
CG		INDEX NO	

CHEMISTRY **9729/04**

Paper 4 Practical **25 August 2025**

2 hours 30 minutes

Candidates answer on the Question Paper.

Additional Materials: As listed in the Confidential Instructions

READ THESE INSTRUCTIONS FIRST

Write your name and class in the spaces at the top of this page.
Give details of the practical shift and laboratory where appropriate, in the boxes provided.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions in the spaces provided on the Question Paper.

The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.
Qualitative Analysis Notes are printed on pages 19 and 20.

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.

Shift
Laboratory

For Examiner's Use	
1	**/ 16**
2	**/ 17**
3	**/ 6**
4	**/ 16**
Total	**/ 55**

This document consists of **18** printed pages and **2** blank pages.

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

1 Determination of concentrations of sodium hydroxide and of sodium carbonate in a mixture

Sodium hydroxide reacts with hydrochloric acid according to the equation below:

reaction 1 $NaOH + HCl \rightarrow NaCl + H_2O$

Sodium carbonate reacts with hydrochloric acid in two separate stages. The reactions that occur are:

reaction 2 $Na_2CO_3 + HCl \rightarrow NaCl + NaHCO_3$

reaction 3 $NaHCO_3 + HCl \rightarrow NaCl + CO_2 + H_2O$

You are required to find the concentrations of sodium hydroxide and of sodium carbonate in **FA 1** by means of a *double-indicator* titration.

In a *double-indicator* titration, **two different indicators** are used, separately, in the **same titration**.

For this experiment, you will be using thymolphthalein indicator followed by methyl orange indicator. Thymolphthalein indicates the end-point when reactions 1 and 2 are complete, while methyl orange indicates the end-point when reaction 3 is complete.

FA 1 is a solution containing sodium hydroxide, NaOH, and sodium carbonate, Na_2CO_3.
FA 2 is an aqueous solution containing 1.50 mol dm^{-3} hydrochloric acid, HC*l*.
Solution T is thymolphthalein indicator.
Solution M is methyl orange indicator.

(a) Dilution of FA2

Use a burette to transfer 20.00 cm^3 of **FA 2** into a 250 cm^3 volumetric flask.

Make the solution up to the mark with deionised water and shake well to mix. Label this solution **FA 3**. This is a solution of hydrochloric acid of a concentration that is suitable for the titration.

(b) (i) Titration of FA 1 against FA 3

You are to titrate **FA 1** with **FA 3** using **Solution T**, thymolphthalein indicator, and **Solution M**, methyl orange indicator.

Record your titration results to an appropriate level of precision in the table provided on page 3.

1. Fill a second burette with **FA 3**. Record the initial burette reading.
2. Pipette 25.0 cm^3 of **FA 1** into a 250 cm^3 conical flask.

   Place the cap back over the **FA 1** bottle to prevent absorption of carbon dioxide from the atmosphere.
3. Add 4 to 5 drops of **Solution T**.

4. Titrate the solution in the conical flask with **FA 3** from the burette. The first end-point is reached when the solution turns from blue to colourless.

   Record the burette reading. **Keep the contents in the flask for step 5**.

5. **To the solution from step 4**, add 4 to 5 drops of **Solution M.** Continue to titrate with **FA 3** from the burette. The second end-point is reached when the solution turns from yellow to orange.

   Record the burette reading.

6. Repeat steps 2 to 5 until consistent results for the **total volume of FA 3 used** for the titration are obtained.

   The volume of FA 3 used to reach the first end-point in step 4 may not be consistent across titrations.

Titration results

Initial burette reading / cm^3	4.10	2.20	
Burette reading at first end-point / cm^3	26.10	24.20	
Burette reading at second end-point / cm^3	37.20	35.20	
Volume of **FA 3** used to complete reactions 1 and 2 / cm^3	22.00	22.00	
Volume of **FA 3** used to complete reaction 3 / cm^3	11.10	11.00	
Total volume of **FA 3** used for titration / cm^3	33.10	33.00	

[4]

(ii) You should consider **only** the total volume of **FA 3** used for the titration when deciding which sets of titration results to use.

From your titrations, obtain

- a suitable volume of **FA 3** used to complete reactions 1 and 2, and
- a suitable total volume of **FA 3** used for the titration

to be used in your calculations.

Show clearly how you obtained these volumes.

volume of **FA 3** required to reach first end-point = ... cm^3

total volume of **FA 3** required for the titration = ... cm^3

[1]

(c) **(i)** Calculate the concentration of HC*l* in **FA 3**.

concentration of HC*l* in **FA 3** = ... [1]

(ii) Calculate the amount of sodium carbonate, Na_2CO_3, present in 25.0 cm^3 of **FA 1**.

amount of Na_2CO_3 in 25.0 cm^3 of **FA 1** = ... [2]

(iii) Calculate the amount of sodium hydroxide, NaOH, present in 25.0 cm^3 of **FA 1**.

amount of NaOH in 25.0 cm^3 of **FA 1** = ... [2]

(iv) Using your answers from **(c)(ii)** and **(c)(iii)**, calculate the concentrations, in mol dm^{-3}, of Na_2CO_3 and NaOH in **FA 1**. If you were unable to obtain an answer in **(c)(ii)** or in **(c)(iii)**, use the values 0.00120 mol and 0.00100 mol respectively. These are **not** the correct answers.

concentration of Na_2CO_3 in **FA 1** = ... [1]

concentration of NaOH in **FA 1** = ... [1]

(d) (i) Both thymol blue and thymolphthalein change colour over a similar pH range. Thymolphthalein changes from blue to colourless, while thymol blue changes from blue to yellow.

Suggest **one** reason why thymolphthalein is a more suitable indicator than thymol blue for the titration.

....

.... [1]

(ii) Common indicators used in titrations can be weak organic acids or bases. Methyl orange is an example of an indicator that can behave as a weak base.

Deduce the effect on the volume of **FA 3** required to reach the second end-point when too much **Solution M** is added after the first end-point.

....

.... [1]

(e) In step 2 of **(b)(i)**, you were instructed to place the cap back over the **FA 1** bottle immediately after use. This is to prevent the absorption of carbon dioxide, CO_2, from the atmosphere which reacts with sodium hydroxide.

$$2NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$$

A student performed the experiment in **(b)(i)** and forgot to replace the cap on the **FA 1** bottle.

Suggest what effect, if any, using the uncapped **FA 1** would have on the **total** volume of **FA 3** required for the titration. Explain your answer.

effect ....

explanation ....

....

....

[1]

(f) The discontinuous method can also be used to investigate the composition of NaOH and Na_2CO_3 by conducting two separate titrations on two separate samples, each with a different indicator.

Suggest how the accuracy of the calculated composition of NaOH and Na_2CO_3 may be affected.

....

.... [1]

[Total: 16]

2 To determine the enthalpy change of a reaction between sodium carbonate, water and carbon dioxide

It is difficult to directly determine the enthalpy change of the reaction between sodium carbonate, water and carbon dioxide, as shown in equation 1.

equation 1 $Na_2CO_3(s) + H_2O(l) + CO_2(g) \rightarrow 2NaHCO_3(s)$ ΔH_1

Sodium carbonate and sodium hydrogencarbonate each react with hydrochloric acid.

equation 2 $NaHCO_3(s) + HCl(aq) \rightarrow NaCl(aq) + CO_2(g) + H_2O(l)$ ΔH_2

equation 3 $Na_2CO_3(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + CO_2(g) + H_2O(l)$ ΔH_3

In this question, you will perform an experiment to determine a value for ΔH_2. You will then use this value and the given value of ΔH_3 to calculate a value for ΔH_1.

FA 4 is solid sodium hydrogencarbonate, $NaHCO_3$.

You are also provided with **FA 2**, 1.50 mol dm^{-3} hydrochloric acid, HC*l*, which you used in Question 1.

1.50 mol dm^{-3} hydrochloric acid is an irritant. Very rapid effervescence occurs when **FA 4** is added to **FA 2**. For safe working, and to minimise the risk of 'acid spray', the solid must be added carefully to the acid. See further instructions in the procedure on page 7.

(a) (i) Determination of the molar enthalpy change for the reaction in equation 2, ΔH_2

In this experiment, you will measure the temperature of hydrochloric acid in a Styrofoam cup at regular time intervals, before and after sodium hydrogencarbonate is added. You will analyse your results graphically to obtain an accurate value for the temperature change caused by the reaction.

You will use this value to calculate the heat change, q_2, for the experiment and hence determine a value for the molar enthalpy change of the reaction, ΔH_2.

In the space provided on page 8, prepare tables in which to record 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 0.5 min.

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

Procedure

1. Weigh the capped weighing bottle labelled **FA 4** containing solid sodium hydrogencarbonate. Record the mass in your table on page 8.

2. Place one Styrofoam cup inside another Styrofoam cup and place both in a 250 cm^3 glass beaker.

3. Use a measuring cylinder to transfer 30 cm^3 of **FA 2** (an excess) into the Styrofoam cup.

4. Insert a thermometer through the lid and place the lid with thermometer onto the Styrofoam cup, ensuring the thermometer's bulb is totally immersed. Carefully stir the **FA 2** in the Styrofoam cup with the thermometer. Read and record the temperature, *T*. Start the stopwatch (*t* = 0.0 min). The stopwatch must be left to run for the rest of the experiment.

5. Continue to stir **FA 2**. Read and record *T* every 0.5 minute.

6. At **exactly** 2.5 minutes, open the lid and carefully transfer all the solid **FA 4** to the Styrofoam cup. **Place the lid with thermometer back onto the cup immediately.**
   Stir the mixture but do not read *T*.

7. Continue to stir the mixture. Read and record *T* at *t* = 3.0 min, and every 0.5 min until *t* = 8.0 min.

8. Reweigh the empty capped weighing bottle labelled **FA 4**. Record this mass in your table on page 8. Calculate the mass of **FA 4** used and record this mass in the same table.

Results

mass of capped weighing bottle & **FA 4** / g	7.960
mass of emptied capped weighing bottle / g	5.596
mass of **FA 4** / g	2.094

time, *t* /min	temperature, *T* / °C
0.0	32.0
0.5	32.0
1.0	32.0
1.5	32.0
2.0	32.0
2.5	-
3.0	26.8
3.5	26.3
4.0	26.4
4.5	26.4
5.0	26.5
5.5	26.6
6.0	26.6
6.5	26.8
7.0	26.8
7.5	27.0
8.0	27.0

[4]

(ii) Plot a graph of temperature, *T*, on the *y*-axis, against time, *t*, on the *x*-axis, on the grid in Fig. 2.1.

Draw a best-fit straight line taking into account all of the points before *t* = 2.5 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 both lines to *t* = 2.5 min. [3]

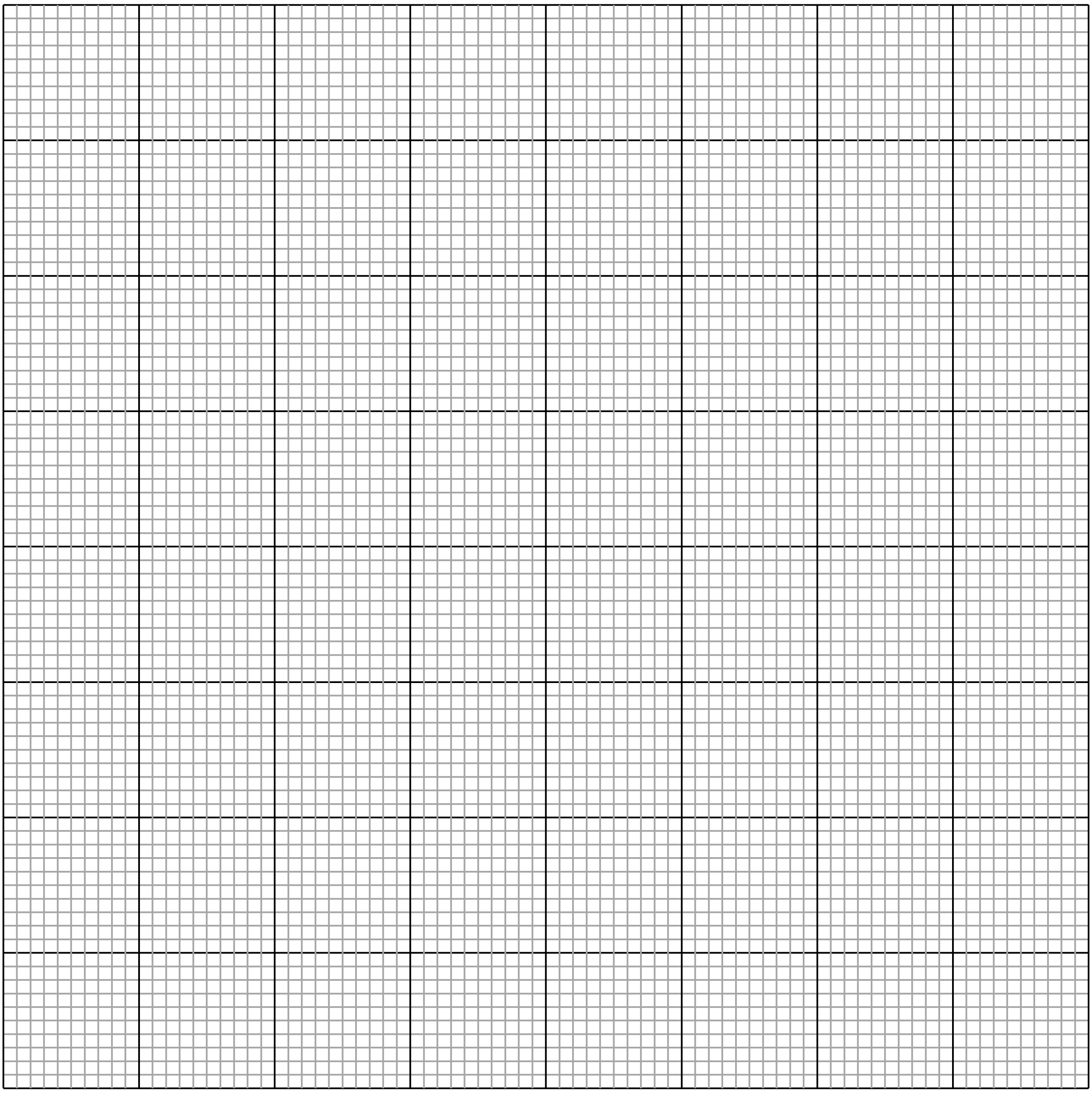

Fig. 2.1

(iii) From your graph, read the minimum temperature, T_{min}, and the maximum temperature, T_{max}, at t = 2.5 min. Record these values in the spaces below.

Calculate the temperature change, ΔT_2, at t = 2.5 min.

T_{min} = ...

T_{max} = ...

ΔT_2 = ...

[1]

(iv) Calculate the heat change, q_2, for your experiment using the value you calculated in **(a)(iii)**.

Assume that the specific heat capacity of the reaction mixture is 4.18 J g^{-1} K^{-1}, and that the density of the reaction mixture is 1.00 g cm^{-3}.

q_2 = ... [1]

(v) Determine the molar enthalpy change, ΔH_2, for the reaction in equation 2. The hydrochloric acid is in excess.

Include the sign of ΔH_2 in your answer.

[A_r: H, 1.0; C, 12.0; O, 16.0; Na, 23.0]

ΔH_2 = ... [2]

(b) The enthalpy change for the reaction in equation 3, ΔH_3, is –24.0 kJ mol^{-1}.

Using your answer to **(a)(v)** and equations 2 and 3, determine the enthalpy change for the reaction in equation 1, ΔH_1.

ΔH_1 = ... [4]

(c) Suggest the effect that using 60 cm^3, rather than 30 cm^3, of **FA 2** would have on your value of ΔT_2. Hence, deduce and explain the effect this will have on the value for ΔH_2.

....

....

.... [1]

(d) The temperature change, ΔT_2, can also be determined by direct measurement of the initial temperature and minimum temperature reached only.

Explain why the graphical method is likely to give a more accurate value for ΔT_2, than the direct measurement method.

....

....

.... [1]

[Total: 17]

3 Planning

Baking powder, a common ingredient in baking, contains sodium hydrogencarbonate, $NaHCO_3$, which helps bread doughs and cake batters rise by releasing carbon dioxide when heated in an oven.

$$2NaHCO_3(s) \rightarrow Na_2CO_3(s) + H_2O(g) + CO_2(g)$$

Interestingly, while $NaHCO_3$ decomposes upon heating, Na_2CO_3 itself remains stable under similar conditions. This difference in thermal stability can be used to determine the proportion of $NaHCO_3$ in a mixture with Na_2CO_3 through careful heating and mass measurements.

(a) You are required to plan an experiment in which the percentage by mass of $NaHCO_3$ in a mixture of $NaHCO_3$ and Na_2CO_3 can be determined by heating and mass measurements alone.

You are to assume that only a boiling tube and holder, a weighing balance and a Bunsen burner are available.

In your plan, you should include details of:

- the procedure you would follow, including how you would make appropriate weighings and ensure that decomposition was complete,
- the measurements you would take, and
- a brief outline of how the results can be used to determine the percentage by mass of $NaHCO_3$ in the mixture.

[A_r: H, 1.0; C, 12.0; O, 16.0; Na, 23.0]

....

....

....

....

....

....

....

....

....

....

....

....

....

[5]

(b) By considering the products of the decomposition, suggest a reason why a crucible without a lid might be more appropriate than a boiling tube for this experiment.

[1]

[Total: 6]

4 Investigation of an inorganic mixture and an organic compound

FA 5 is a mixture of two salts that each contain one cation and one anion.
FA 6 is an aqueous solution of an organic compound.

You will perform tests to identify:

- the two cations and two anions present in **FA 5**, and
- the organic compound in **FA 6**.

Unless otherwise stated, the volumes given are approximate and should be estimated rather than measured.

Test and identify any gases evolved during the tests.

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

(a) To a 5 cm depth of distilled water in a boiling tube, add a spatula of **FA 5**. Shake the boiling tube to dissolve **FA 5** completely.

(i) Carry out the tests in Table 4.1 on this solution of **FA 5**.
Carefully record your observations in Table 4.1.

Table 4.1

	test	observations
1	Add 1 cm depth of **FA 5** solution to a boiling tube. Add 1 cm depth of aqueous sodium hydroxide. Add a piece of aluminium foil to the reaction mixture. Warm the mixture.	White ppt formed White ppt soluble in excess Moist red litmus paper turn blue Ammonia gas evolved
2	Add 1 cm depth of **FA 5** solution to a test-tube. Add a 1 cm depth of dilute nitric acid, then add a few drops of aqueous silver nitrate. Add aqueous ammonia to the reaction mixture until the aqueous ammonia is in excess.	White ppt formed Soluble in aqueous ammonia
3	Add 1 cm depth of **FA 5** solution to a test-tube. Add a 1 cm depth of aqueous barium nitrate. Add dilute nitric acid.	White ppt formed No observable change

[4]

(ii) Use your observations in Table 4.1 to identify two anions which must be present in **FA 5**.

.... [2]

(iii) Devise and perform further tests to confirm or identify the two cations that are present in **FA 5**.

Your tests should be based on the Qualitative Analysis Notes on pages 19 – 20 and should only use the bench reagents provided. Record your tests and observations in the space below.

[4]

(iv) Use your observations in **(a)(iii)** to deduce the identities of the two cations present in **FA 5**.

.... [2]

(b) **(i)** Fill half a 250 cm^3 beaker with hot water. This will be used as a water bath.

Perform the tests described in Table 4.2. Observations for test 1 have been completed for you. There is no need to carry out test 1. Record your observations in Table 4.2.

Table 4.2

	test	observations
1	To a 1 cm depth of aqueous silver nitrate in a test-tube add a few drops of aqueous sodium hydroxide and then add aqueous ammonia slowly until the grey precipitate that forms just dissolves. To this solution add a 1 cm depth of **FA 6** and leave to stand in the water bath.	Silver mirror formed.
2	To a 1 cm depth of **FA 6** in a test-tube, add a 2 cm depth of dilute sulfuric acid. Place the test-tube in the water bath. Then add two or three drops of aqueous potassium manganate(VII). Leave to stand in the water bath.	Purple solution decolorises
3	To a 1 cm depth of **FA 6** in a test-tube add a small spatula of sodium carbonate.	Effervescence observed. Gas gives white ppt with limewater. Carbon dioxide gas evolved.

[3]

(ii) Use the observations in **(b)(i)** to suggest the structural formula of the organic compound in **FA 6**. The organic compound is made up of **only** elements C, H and O, and it has **only one** carbon atom.

.... [1]

[Total: 16]

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Qualitative Analysis Notes
[ppt. = precipitate]

(a) Reactions of aqueous 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

anion	*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) Test for gases

gas	*reaction*
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