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ST ANDREW'S JUNIOR COLLEGE



JC2 PRELIMINARY EXAMINATION

Chemistry (9729)

17 August 2020

Paper 4 Practical

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 on all the work you hand in.
 Give details of the practical shift and laboratory 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** the 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 **21** and **22**.

Shift
Laboratory

The number of marks is given in the brackets [] at the end of each question or part question.

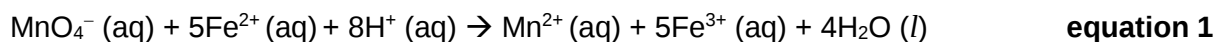
For Examiners' Use	1	2	3	4	Total

This document consists of **22** printed pages.

[Turn Over

1 Investigation of the concentration of potassium manganate(VII)

Potassium manganate(VII) is a very useful oxidising agent. It oxidises iron(II) ions in acidic medium according to **equation 1**.



In solution, ammonium iron(II) sulfate, $(\text{NH}_4)_2\text{SO}_4 \bullet \text{FeSO}_4 \bullet 6\text{H}_2\text{O}$, dissociates into iron(II), sulfate and ammonium ions according to **equation 2**.



You are provided with

- FA 1**, ammonium iron(II) sulfate crystals,
- FA 2**, potassium manganate(VII) solution,
- 1.0 mol dm⁻³ sulfuric acid.

(a) (i) Preparation of standard solution of FA 3 and titration of FA 3 against FA 2

In an appropriate format in the space provided on page 3, prepare tables in which to record results for your experiment in **(a)**:

- All weighings to an appropriate level of precision
 - All burette readings and the volume of **FA 2** added
1. Weigh the capped bottle containing **FA 1**.
 2. Dissolve this in about 50 cm³ of 1.0 mol dm⁻³ sulfuric acid in a 100 cm³ beaker.
 3. Transfer the solution and washings into a 250 cm³ standard flask.
Make up to the mark with deionised water and shake well to obtain a homogeneous solution, **FA 3**.
 4. Reweigh the emptied bottle and its cap.
 5. Fill a burette with **FA 2**.
 6. Pipette 25.0 cm³ of **FA 3** prepared into a conical flask.
 7. Add about 10 cm³ of aqueous sulfuric acid into the conical flask.
 8. Run **FA 2** from the burette into the flask. The end-point is reached when the solutions changes from pale green to orange.
 9. Repeat steps 6 to 8 until consistent titres are obtained.

Results

[4]

- (ii) From your titrations, obtain a suitable volume of **FA 2** to be used in your calculations. Show clearly how you obtained this volume.

Volume of **FA 2** =

[1]

[Turn Over

(b) [A_r of K: 39.1; Mn: 54.9; O: 16.0; N: 14.0; H: 1.0; Fe: 55.8; S:32.1]

- (i) Calculate the number of moles of **FA 1** in the weighed sample and hence calculate the number of moles of Fe^{2+} ions used during the titration.

number of moles of **FA 1** =

number of moles of Fe^{2+} ions used =

[2]

- (ii) Calculate the number of moles of MnO_4^- reacted during titration and hence the mass of potassium manganate (VII), KMnO_4 , in 1 dm^3 of **FA 2**.

number of moles of MnO_4^- reacted =

mass of KMnO_4 in **FA 2** =

[3]

- (c) A student performed the same experiment, using the quantities described earlier, and obtained a mean titre volume of 25.45 cm^3 .

The errors (uncertainties) associated with each reading is shown below:

Apparatus	Uncertainties
volumetric flask	$\pm 0.15 \text{ cm}^3$
pipette	$\pm 0.1 \text{ cm}^3$
burette	$\pm 0.05 \text{ cm}^3$

Calculate the maximum percentage error (uncertainty) of this mean titre volume.

maximum percentage error =%

[2]

- (d) The teacher informed the student who performed the experiment in (c) that the titre volume should have been 26.00 cm^3 instead.

- (i) Calculate the percentage error in the student's result.

percentage error =%

[1]

[Turn Over

- (ii) Using your answers in (c) and (d)(i), comment on the accuracy of the student's result.

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[1]

[Total: 14]

2 Investigation of the effect of temperature on chemical reactions

Potassium manganate(VII) is widely used as a strong oxidising agent. It can oxidise both organic and inorganic compounds. Besides oxidising iron(II) ions, it can also oxidise ethanedioate ions.



In this experiment, the effect of temperature on the rate of this reaction is studied by measuring the time taken for the purple solution to turn colourless.

You will perform a series of four experiments. Then, you will graphically analyse your results to determine the effect of temperature on the rate of the reaction between potassium manganate(VII) and ethanedioate ions.

For each experiment, you will note the time taken, t , for the reaction mixture to become colourless.

You will use the same potassium manganate(VII) solution, **FA 2**, and 1.0 mol dm^{-3} sulfuric acid, H_2SO_4 , in **Question 1**.

You are also provided with

FA 4, 0.1 mol dm^{-3} sodium ethanedioate, $\text{Na}_2\text{C}_2\text{O}_4$.

(a) Prepare a table in the space provided on **page 9** in which to record for each experiment, with the appropriate level of precision:

- temperature of the solution inside the boiling tube,
- time taken for solution to turn colourless, t , *to the nearest second*,
- calculated values of $1/t$ and $\lg (1/t)$.

It is recommended for you to draw this table after step 6 of experiment 1 on page 8.

Safety notes

Hot water to be collected from the metal dispenser is heated to 90°C . **Use a Styrofoam cup placed in a 250 cm^3 beaker to collect the hot water (according to step 4 of experiment 1 on the next page) to prevent your hands from being scalded.**

Gently pull/push the tap of the dispenser to prevent the hot water from spurting/splashing out.

Experiment 1

1. Using a measuring cylinder, add 5.0 cm³ of **FA 2** to a boiling tube.
2. Using the same measuring cylinder, add 10.0 cm³ of 1.0 mol dm⁻³ H₂SO₄(aq) to the boiling tube.
3. Using another measuring cylinder, measure 5.0 cm³ of **FA 4**. Do not add it to the boiling tube yet.
4. Place a Styrofoam cup inside a 250 cm³ beaker. Dispense hot water from the metal dispenser into the Styrofoam cup until it is half-filled.
5. **This hot water is reused for subsequent experiments. Do not discard it.**
6. Place the thermometer inside the boiling tube containing **FA 2** and place the boiling tube inside the Styrofoam cup containing hot water.
7. **While waiting for the temperature of the solution inside the boiling tube to increase to around 70 °C, you should prepare the table to record your measurements.**
8. It should take about two to three minutes for the temperature to stabilise. Once the temperature reading hardly increases or stays almost constant, note the temperature and remove the boiling tube from the Styrofoam cup and place it in a test tube rack.
9. Pour **FA 4** from step 3 **rapidly** into the boiling tube. Start the stopwatch during this addition.
10. Mix the contents thoroughly by stirring gently with the thermometer but do not read the temperature. Then hold the boiling tube over a white tile.
11. Stop the stopwatch when the solution turns colourless.
12. Record the time taken, *t*, to the nearest second.
13. Discard the reaction mixture. Wash out the boiling tube and stand it upside down in the test tube rack to drain.
14. Wash the thermometer and dry it on a paper towel.

Experiments 2 to 4

Using the same Styrofoam cup of hot water, repeat experiment 1 until a total of **four** experiments at different temperatures are conducted between 40 °C and 70 °C, and their results recorded. You should alternate the use of the two boiling tubes.

(i) Results

[4]

[Turn Over

- (b) (i)** Plot a graph of $\lg(1/t)$ on the y-axis against temperature on the x-axis on the grid in Fig. 2.1.

Draw the best-fit curve taking into account all of your plotted points.

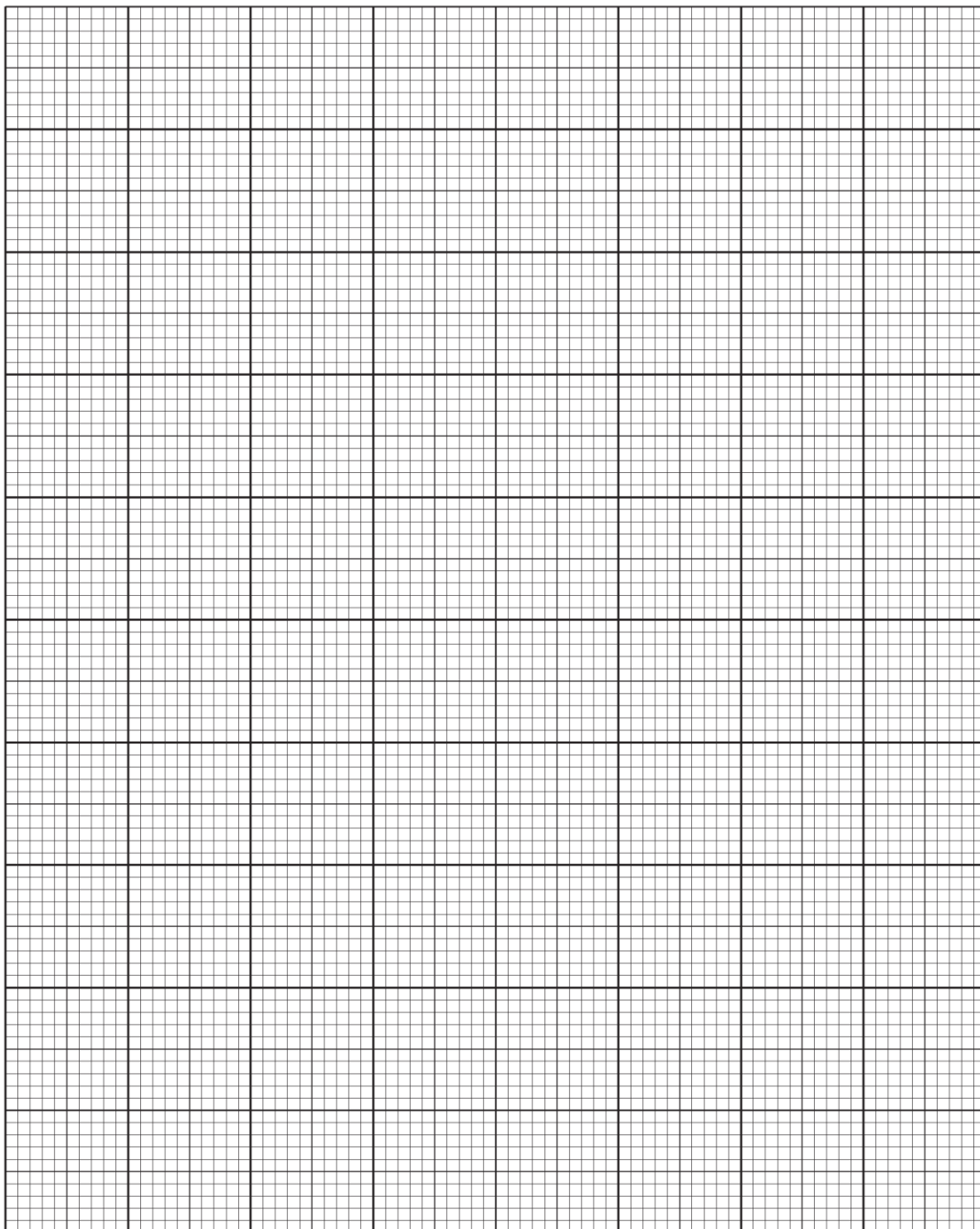


Fig 2.1

- (ii) Suggest the significance of $1/t$ in this series of experiments.

.....

[1]

- (iii) With reference to the Arrhenius equation shown below, explain why a curve should be obtained in (b)(i).

$$k = Ae^{-\frac{E_a}{RT}}$$

where:

k = rate constant, A = Arrhenius constant, E_a = activation energy, R = molar gas constant, T = temperature.

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.....

.....

[1]

- (c) Suggest why it is important to alternate the use of the two boiling tubes and the effect on the measurements collected if this was not carried out.

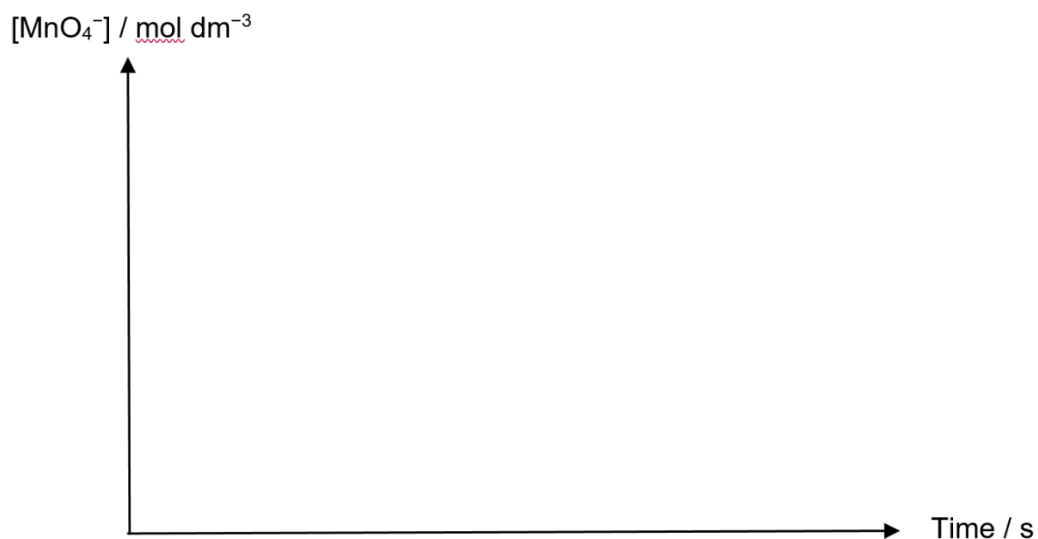
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[1]

- (d) The product, Mn^{2+} ions, can act as a catalyst for the reaction in **equation 3**. This is an example of 'autocatalysis'. On the axes below, sketch and explain the shape of the graph for the reaction between MnO_4^- and $\text{C}_2\text{O}_4^{2-}$ at a fixed temperature.



.....

.....

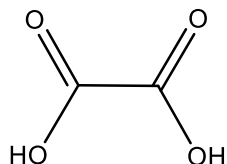
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[2]

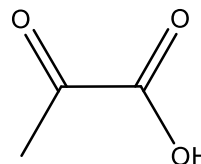
(e) Planning

Potassium manganate(VII) can also oxidise organic compounds.

Plan a simple chemical test, using the reagents provided in **2(a)**, to help you distinguish between the pair of organic compounds below.



Compound A



Compound B

Your plan should include:

- details of the reagents and conditions to be used,
- an outline of the sequence of steps you would follow,
- the expected observation(s) for each compound.

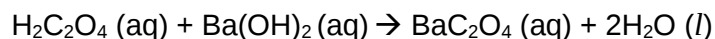
[3]

[Total: 15]

[Turn Over]

3 Planning

A common method to determine the concentration of ethanedioic acid solution is to titrate it with a standard solution of an alkali, such as barium hydroxide. This requires the use of an indicator to determine the equivalence point of the titration.



Neutralisation reactions are exothermic. A *thermometric titration* can also be carried out to determine the equivalence point of the reaction described above, without the use of an indicator. In this method, the temperature is monitored throughout the experiment where small volumes of the solution being analysed are progressively added to the standard solution until the equivalence point is reached and passed.

To determine the concentration of the solution being analysed, data obtained is plotted on a graph. One best-fit line is drawn through the data before the equivalence point is reached, and the second best-fit line is drawn through the remaining data. These two lines are then extrapolated (extended) until they cross.

- (a) Using the information given above, you are required to write a plan for a thermometric titration in which ethanedioic acid is added to aqueous barium hydroxide to determine the concentration of ethanedioic acid.

You may assume that the original solutions are at 25 °C and that the maximum temperature rise obtained in this experiment is between 8 °C and 10 °C.

You may also assume that you are provided with:

- 1.00 mol dm⁻³ aqueous Ba(OH)₂,
- H₂C₂O₄ of approximate concentration 1.0 mol dm⁻³,
- the equipment normally found in a school or college laboratory.

In your plan you should include brief details of:

- a justification of the quantities you would use,
- the apparatus you would use,
- the procedure you would follow,
- how you would ensure that your results are **accurate** and **reliable**.

- (b) On the axes below, sketch a labelled graph you would expect to obtain from the thermometric titration you planned in **3(a)**. Hence, explain how the data obtained from the graph would be used to determine the concentration of ethanedioic acid.



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.....

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[2]

[Total: 9]

4 Investigation of some inorganic reactions

You are given three different pure solid samples **FA 5**, **FA 6** and **FA 7**.

- (a)** Perform the tests described in Table 4.1 and record your observations in the tables. In all the tests, the reagent should be added gradually until no further change is observed, with shaking after each addition. No additional or confirmatory tests for ions present should be attempted.

Table 4.1 - Tests on FA 5, FA 6 and FA 7

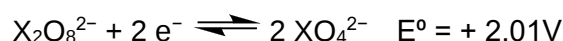
Tests		Observations for FA 5	Observations for FA 6	Observations for FA 7
1.	Add 1 cm ³ of dilute hydrochloric acid to ½ spatula of the solid sample in a test tube and warm. You do not need to test for any gas evolved.			
2.	Add 1 cm ³ of silver nitrate solution to ½ spatula of the solid sample in a test tube.			

3.	Add 1 cm ³ of aqueous iodine to ½ spatula of the solid sample in a test tube.			
4.	Add 1 cm³ of potassium iodide solution to ½ spatula of the solid sample in a test tube. If need be, filter the resultant mixtures. For the test tube involving FA 7 only, add 1 cm³ of barium nitrate solution to the resultant mixture, followed by 1 cm³ of dilute nitric acid.			

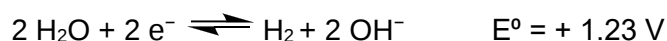
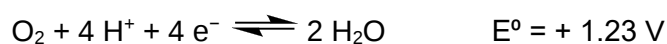
- (b) In test 1 for **FA 6**, sulfur dioxide is also produced. Suggest a chemical test to test for its presence. State the expected observation.

.....
 [2]

- (c) The chemical formula of the salt in **FA 7** is $\text{Na}_2\text{X}_2\text{O}_8$. The half equation and the standard reduction potential for $\text{X}_2\text{O}_8^{2-}$ is as given.



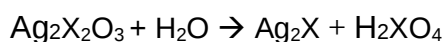
In test 1, $\text{X}_2\text{O}_8^{2-}$ undergoes reduction to produce colourless gas. Given the following data, suggest an equation to explain this observation. Explain your answer with relevant calculations.



.....

 [2]

- (d) In test 2 for **FA 6**, the following equation represents one of the reactions that occurred. $\text{X}_2\text{O}_3^{2-}$ is the anion found in **FA 6**. There is no change to the oxidation state of silver throughout the test.



State the type of reaction. Explain your answer.

.....

 [2]

- (e) From your observations in test 3, suggest the nature of **FA 6**.

..... [1]

- (f) From your observations in test 4, suggest the nature of **FA 7**.

..... [1]

- (g) In test 4 for **FA 7**, a solid is formed after adding barium nitrate solution. Suggest the identity of this solid. State the purpose of adding dilute nitric acid.

.....

.....

..... [2]

[Total: 17]

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

<i>ion</i>	<i>reaction</i>
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 $\text{NO} \rightarrow$ (pale) 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 acids)
sulfite, $\text{SO}_3^{2-}(\text{aq})$	SO_2 liberated on warming with dilute acids; gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (soluble in dilute strong acids)

(c) Tests for gases

<i>gas</i>	<i>test and test result</i>
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

<i>Halogen</i>	<i>colour of element</i>	<i>colour in aqueous solution</i>	<i>colour in hexane</i>
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