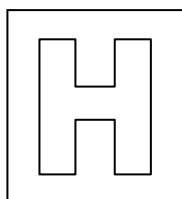


Candidate Name: _____

Class Adm No

--	--



Shift
Laboratory

2019 Preliminary Exams Pre-University 3

H2 CHEMISTRY

Paper 4 Practical

9729/04

4th Sept 2019

2 hour 30 mins

Candidates answer on the Question paper.

READ THESE INSTRUCTIONS FIRST

Do not turn over this question paper until you are told to do so

Write your name, class and admission number on all the work you hand in.

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 at the back of the Question Paper.

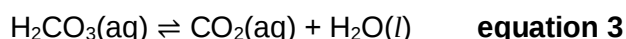
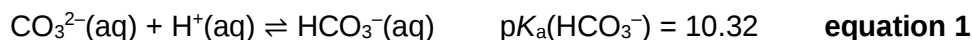
At the end of the examination, fasten all your work securely together.

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

Question	1	2	3	4	Total
Marks	18	22	9	6	55

1 Determination of titration value at equivalence point

The reaction between acid and carbonates is well known. In the presence of excess acid, the following reaction occurs:

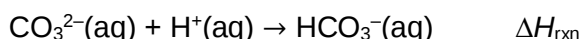


$\text{CO}_2(\text{aq})$ is then released from the solution as $\text{CO}_2(\text{g})$, which is observed as effervescence. The entire reaction is known to release heat.

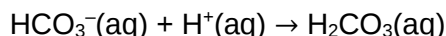
FA 1 is 1.8 mol dm^{-3} of aqueous potassium carbonate, K_2CO_3 .

FA 2 is nitric acid, HNO_3 , of concentration between $1.9\text{--}2.1 \text{ mol dm}^{-3}$.

Assuming that the first equivalent of H^+ fully reacts with CO_3^{2-} before reacting with the HCO_3^- produced, the reaction between **FA 1** and the first equivalent of **FA 2** can be simplified as:



And the reaction between **FA 1** and the second equivalent of **FA 2** can be simplified as:



As the precise concentration of **FA 2** is unknown, determination of ΔH_{rxn} can be done using a thermometric titration to simultaneously determine both the concentration of **FA 2** as well as ΔH_{rxn} . Thermometric titration is a technique whereby equivalence points of a reaction can be located by observing temperature changes, hence eliminating the need for an indicator.

In **1(a)**, you will perform an acid-carbonate thermometric titration. The data from this titration will be used to determine:

- the titration value at the first equivalence point, V_{eq1} ,
- the precise concentration of **FA 2**, $[\text{HNO}_3]$,
- the maximum temperature change, ΔT_{max} ,
- the enthalpy change of reaction, ΔH_{rxn} .

(a) (i) 25.0 cm^3 of **FA 1** is reacted with **FA 2**.

Calculate the **theoretical volume of FA 2** needed for the first equivalence point, V_{eq1}' , and the second equivalence point, V_{eq2}' , of the reaction between **FA 1** and **FA 2**. Assume $[\text{HNO}_3]$ to be 2.0 mol dm^{-3} .

$$V_{\text{eq1}}' = \dots\dots\dots \text{cm}^3 \quad \text{M1}$$

$$V_{\text{eq2}}' = \dots\dots\dots \text{cm}^3 \quad \text{M2}$$

[2]

Determination of V_{eq1} and ΔH_{rxn} using thermometric titration

For this experiment, you will need to measure the **maximum temperature** of the reaction mixture when specified volumes of **FA 2** have been added to **FA 1**.

In an appropriate format in the space provided below, prepare a table to record your results. Record all values of temperature, T , to 0.1°C , and each total volume of **FA 2** added.

Note: You should aim to perform each subsequent addition of **FA 2** quickly.

1. Fill a burette with **FA 2**.
2. Using a pipette, transfer 25.0 cm^3 of **FA 1** into a Styrofoam cup. Place this cup inside a second Styrofoam cup, which is placed in a 250 cm^3 glass beaker.
3. Stir and measure the temperature of this **FA 1**. Record this temperature.
4. Add 4.00 cm^3 of **FA 2** from the burette to the **FA 1** in the Styrofoam cup.
5. Using the thermometer, stir the mixture thoroughly and record the maximum temperature reached and the volume of **FA 2** added.
6. Repeat steps **4** and **5** until a total volume of 48.00 cm^3 of **FA 2** has been added.

Results

[2]

- (ii) Plot a graph of temperature, T , on the y -axis, against volume of **FA 2** added, on the x -axis on the grid in **Fig. 1.1**.

*For
Examiners'
Use*

The temperature axis should allow you to include a point at least $1.0\text{ }^{\circ}\text{C}$ greater than the maximum temperature recorded.

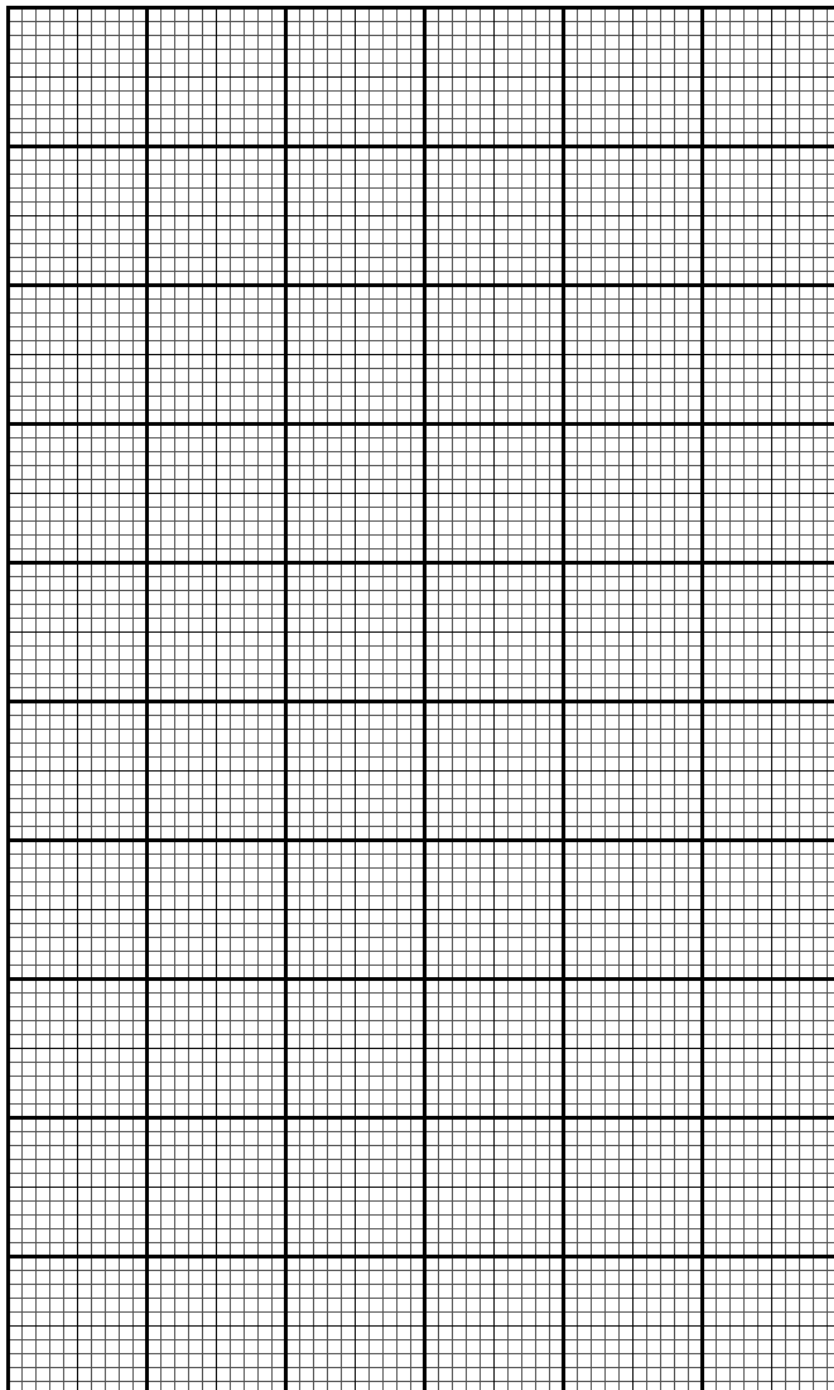


Fig. 1.1

Draw **two** most appropriate best-fit lines in **Fig. 1.1**, taking into account all of your plotted points. Extrapolate (extend) these two best-fit lines until they cross each other.

[3]

(iii) From your graph in **Fig. 1.1**, determine:

- the titre at equivalence point, V_{eq} ,
- the maximum temperature reached, T_{max} ,
- the maximum temperature change, ΔT_{max} .

On your graph, show clearly how you obtained these values.

$$V_{\text{eq1}} = \dots\dots\dots \text{cm}^3$$

$$T_{\text{max}} = \dots\dots\dots ^\circ\text{C}$$

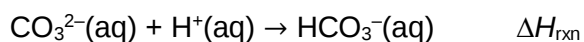
$$\Delta T_{\text{max}} = \dots\dots\dots ^\circ\text{C}$$

[3]

(iv) Determine the concentration of HNO_3 , $[\text{HNO}_3]$, in **FA 2**.

$$[\text{HNO}_3] \text{ in FA 2} = \dots\dots\dots [1]$$

(v) Determine the enthalpy change of reaction, ΔH_{rxn} .



Assume that the reaction mixture has a density of 1.00 g cm^{-3} and a specific heat capacity, c , of $4.18 \text{ J g}^{-1} \text{ K}^{-1}$.

$$\Delta H_{\text{rxn}} = \dots\dots\dots [3]$$

[Turn over

- (b) (i) With reference to your graph in **Fig. 1.1**, explain why the titre at second equivalence point, V_{eq2} , cannot be determined from this experiment.

.....

.....

.....

[1]

- (ii) Suggest, using chemistry concepts, a possible explanation for the observation in **(b)(i)**.

.....

.....

.....

[1]

- (iii) The value of V_{eq1} could also have been determined via a regular acid-base titration with a suitable indicator.

Suggest which titration method is likely to give a more accurate value of V_{eq1} and give two reasons for why this is so.

Method:

I.

.....

II.

.....

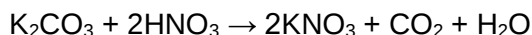
[2]

[Total: 18]

2 Investigation of the kinetics of an acid-carbonate reaction via gravimetric analysis

FA 1 is 1.8 mol dm^{-3} of K_2CO_3 .

FA 3 is dilute nitric acid, HNO_3 , of concentration 1.0 mol dm^{-3} .



The rate equation of the reaction between **FA 1** and **FA 3** is expressed as such:

$$\text{Rate} = k[\text{K}_2\text{CO}_3]^a[\text{H}^+]$$

where a represents the order of reaction with respect to K_2CO_3 , and is an integer value of either 0, 1, or 2.

The acid-carbonate reaction results in the release of $\text{CO}_2(\text{g})$, which escapes the reaction vessel as effervescence. To determine the kinetics of a reaction involving the loss of a gas, gravimetric analysis can be used, where the change in mass of the reaction vessel is monitored over time.

In this experiment, you will use gravimetric analysis to determine the value of a .

(a) Determination of orders of reaction via the 'continuous method'

The orders of reaction can be determined via either the 'continuous method' or the 'initial rates method'. In the 'continuous method', a single reaction is carried out and a measurement (e.g. concentration; mass) is monitored over time.

You will be using the 'continuous method' in this part of the experiment, monitoring the change in mass over time.

1. Weigh and record the mass of an empty 100 cm^3 measuring cylinder.
2. Measure out 80 cm^3 of **FA 3** into this measuring cylinder and record the mass of the measuring cylinder with **FA 3**.
3. Measure out 20 cm^3 of **FA 1** using a 25 cm^3 measuring cylinder into an empty 250 cm^3 conical flask. Weigh and record the mass of the conical flask with **FA 1**.
4. Place the conical flask with **FA 1** on the mass balance provided individually.
5. Start the stopwatch and **simultaneously** pour the **FA 3** in the measuring cylinder into the conical flask. **Do not swirl the flask.**
6. Record the mass readings at 10s intervals until 90s has elapsed, then at 30s intervals. Continue taking readings **until it is appropriate to stop.**

Given that:

initial mass of conical flask with **FA 1** and **FA 3**

= initial mass of **FA 3** + initial mass of conical flask with **FA 1**

In an appropriate form in the space on the next page, record all your time values, balance readings, and mass of $\text{CO}_2(\text{g})$ evolved.

Results

- (i) Plot a graph of mass of $\text{CO}_2(\text{g})$ evolved, m , on the y -axis, against time of reaction, t , on the x -axis on the grid in **Fig. 2.1**.

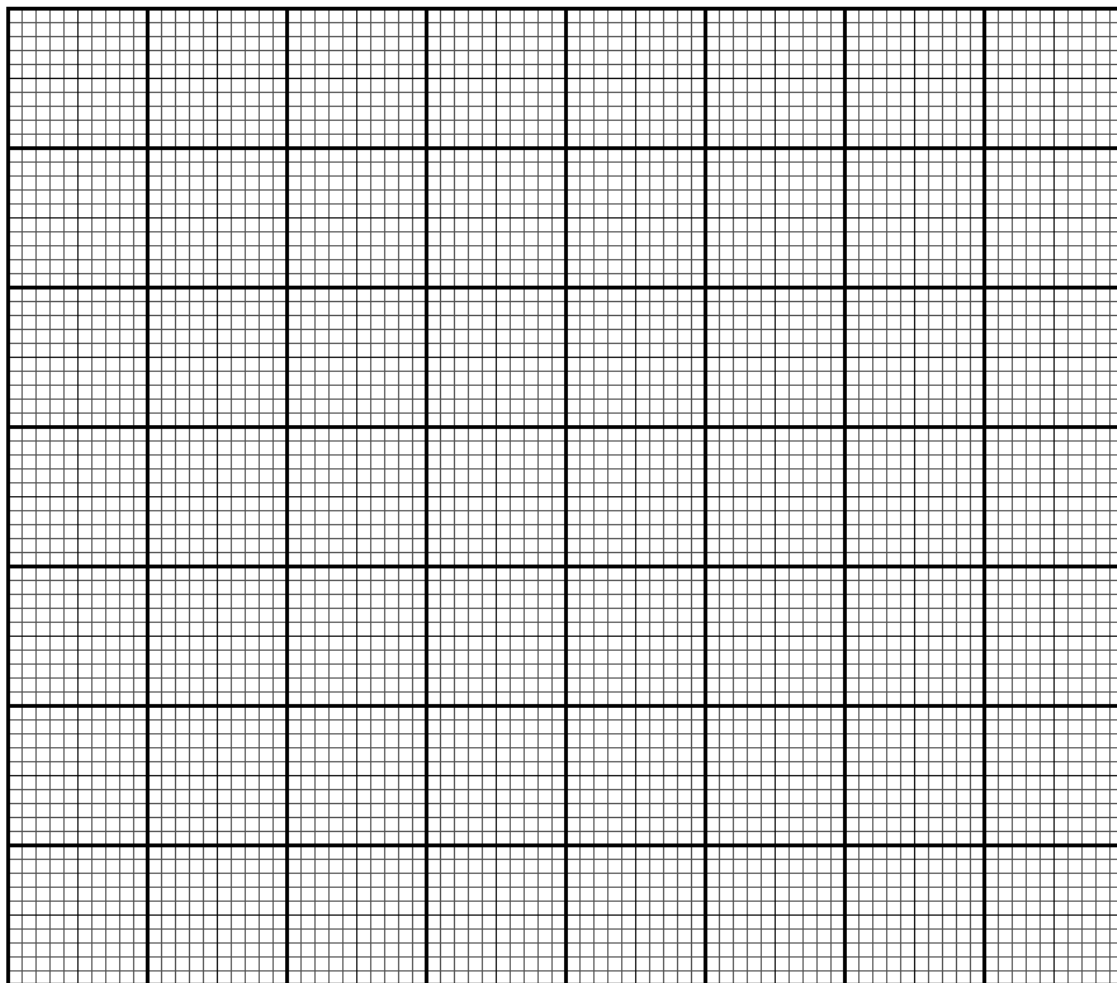


Fig. 2.1

[3]

- (ii) By means of a suitable extrapolation drawn on your graph in **Fig. 2.1**, determine a value for the mass of $\text{CO}_2(\text{g})$ evolved when the reaction is complete.

mass of $\text{CO}_2(\text{g})$ evolved = g [1]

- (iii) The observed half-life ($t_{1/2}$) of a reaction would be constant if the reaction proceeds with an overall order of 1. The table below shows the percentage of reactants and products in the reaction vessel at different instances of time elapsed:

time elapsed	% of reactants	% of products
0	100	0
$t_{1/2} \times 1$	50	50
$t_{1/2} \times 2$	25	75
$t_{1/2} \times 3$	12.5	87.5
⋮		
$t_{1/2} \times \infty$	0	100

Assume that the reaction proceeds with an overall order of 1.

Using your answer from **(a)(ii)**, calculate the theoretical total mass of $\text{CO}_2(\text{g})$ evolved after the first half-life has elapsed, and then after the second half-life has elapsed.

total mass of $\text{CO}_2(\text{g})$ evolved after first half-life = g

total mass of $\text{CO}_2(\text{g})$ evolved after second half-life = g [1]

- (iv) Hence, determine from your experiment whether the acid-carbonate reaction has a consistent half-life, and state if the reaction has an overall order of 1.

Show your working clearly on your graph in **Fig. 2.1** and in the space below.

[2]

- (v) Rate = $k[\text{K}_2\text{CO}_3]^a[\text{H}^+]$, where a is an integer value of either 0, 1, or 2.

Identify a possible value of a .

[1]

(b) Planning

The 'initial rates method' can also be used to determine the orders of reaction. Unlike the 'continuous method', multiple reactions have to be carried out, each time varying the concentrations of certain solutions.

Although the initial rate of a single reaction can be determined from the gradient of the tangent to a graph plotted at $t = 0$ (such as in **Fig 2.1**), the process is tedious as the graphs for multiple experiments have to be plotted.

A simplified 'initial rates method' experiment would involve determining the time elapsed for a certain *condition* to be met, then simply taking the reciprocal of time elapsed as the initial rate. A common example of such an experiment is iodine-clock reaction, whereby the time taken for the colouration formed to obscure text is measured.

It is important to keep the measured durations of time elapsed for the reactions short (maximum 120s), or the reciprocal becomes a poor approximation of rate.

- (i) Plan an experiment using the simplified "initial rates method" by carrying out multiple reactions to determine the order of reaction with respect to K_2CO_3 , a, for the reaction between K_2CO_3 and HNO_3 .

You may assume that you are provided with

- **FA 1**,
- the same apparatus used in **Experiment 2(a)**,
- 4.0 mol dm^{-3} of nitric acid, $\text{HNO}_3(\text{aq})$,
- the glassware and equipment normally found in a school or college laboratory.

In your plan you should include brief details of

- the quantities you would choose for the experiment and why,
- the procedure for the multiple reactions carried out,
- the measurements you would take,
- an outline of how you would use your results to determine the value of a non-graphically.

You may wish to consider the best mode of presentation for your answers.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

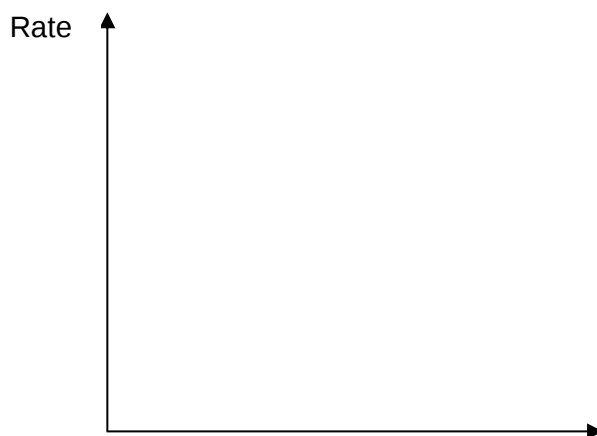
.....

.....

- (ii) The orders of reaction can also be determined graphically.

Assuming that HNO_3 is in large excess, and $a = 2$, label the x-axis and sketch the expected rate-concentration graph that you would expect to obtain from **(b)(i)**.

Explain your answer briefly.



explanation
.....
..... [2]

[Total: 22]

3 Qualitative Analysis of an unknown salt mixture

FA 4 is a salt mixture comprising of an insoluble salt and a soluble salt. It contains **two cations** and **two anions**.

- (a) Transfer 1 spatula of **FA 4** into a test tube and observe its appearance.

State, with explanation, a possible deduction that can be made about the identity of (at least) one of the ions present in **FA 4**.

.....
 [1]

- (b) Perform the tests described in **Table 3.1**, and record your observations in the table. Test and identify any gases evolved.

Table 3.1

tests		observations
1.	To the test tube from (a), add 2 cm depth of HNO_3 , then dropwise until all the FA 4 dissolves. The resulting solution will be known as ' FA 5 solution '.	
2.	Add about 1 cm depth of FA 5 solution to a fresh boiling-tube, followed by NaOH(aq) dropwise, until excess (a further 2 cm depth). Warm the solution gently.	
3.	Add about 1 cm depth of FA 5 solution into a test-tube. To this test-tube, add silver nitrate dropwise.	

[4]

- (c) Based on your observations, deduce the identities of the ions present in **FA 5**.

cation 1: cation 2: anion 1: anion 2:

[2]

(d) Explain in detail, the observations in **(b)(2.)**.

.....

.....

.....

.....

..... [2]

[Total: 9]

[illegible]

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

[Total: 6]

End of Paper 4

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. insoluble in excess	green ppt. 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. insoluble in excess	off-white ppt. insoluble in excess
zinc, Zn ²⁺ (aq)	white ppt. soluble in excess	white ppt. soluble in excess

(b) Reactions of anions

ions	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 $\text{NO} \rightarrow$ (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 with dilute acids; gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (soluble in dilute strong acids)

(c) Test for gases

ions	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