YISHUN INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION

CANDIDATE NAME			
CLASS		DATE	

H2 CHEMISTRY 9729/04

Paper 4 Practical Paper **Thursday**

25 August 2020
2 hours 30 minutes

Candidates answer on question paper.
No Additional Materials are required

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 18 and 19.
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	22
2	19
3	14
Total	55

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

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

1 To determine the relative atomic mass of an unknown Group 1 element and the concentration of sulfuric acid solution using a graphical method

FA 1 is a solution of sulfuric acid
FA 2 is 0.550 moldm^{-3} sodium hydroxide, NaOH
FA 3 is solution of unknown Group 1 carbonate, M_2CO_3
FA 4 is methyl orange indicator

Both the Group 1 carbonate and sodium hydroxide are bases which will neutralise sulfuric acid.

$$M_2CO_3 + H_2SO_4 \rightarrow M_2SO_4 + CO_2 + H_2O$$

$$2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$$

In this experiment, you will add different volumes of **FA 3** to identical samples of dilute sulfuric acid, **FA 1**. In each case, the amount of the Group 1 carbonate solution you add will only partially neutralise the sulfuric acid. You will then complete the neutralisation of each mixture by titration with sodium hydroxide, **FA 2**.

Each titration is to be performed **once** only, so great care should be taken that you do not overshoot the end-points.

Graphical analysis of your results will enable you to determine the relative atomic mass of the Group 1 element, and the concentration of the sulfuric acid solution.

(a) Preparation of titration mixtures

Prepare four different mixtures of **FA 1** and **FA 3** as described below.

Mixture 1

1. Pipette 25.0 cm^3 of **FA 1** into a conical flask.
2. Fill a burette with **FA 3**.
3. Add 6.00 cm^3 of **FA 3** into the same conical flask.
4. Thoroughly stir the mixture and set it aside for later use.

Mixture 2

Repeat the procedure used for **Mixture 1** but this time add 25.0 cm^3 of **FA 1** and 20.00 cm^3 of **FA 3** into a second conical flask.

Mixtures 3 and 4

Select **two** other suitable volumes of **FA 3** for use in two additional experiments. Your selected volumes must be between the volumes used in **Mixture 1** and **2**.

Repeat the procedures used for **Mixture 1** but, in each case, add 25.0 cm^3 of **FA 1** and your chosen volume of **FA 3** into a 100 cm^3 beaker.

You may label the 100 cm^3 beaker with the volume of **FA 3** added using a pencil and the sticker label provided, but do remember to remove them after the experiment.

(b) Titration

*Each titration is to be performed **once** only, so great care should be taken that you do not overshoot the end-points.*

1. Fill the second burette with **FA 2**.

2. Add 4 drops of **FA 4** to the conical flask containing **Mixture 1**.

3. Titrate the mixture in the conical flask with **FA 2** until the solution changes from red to orange.

4. Repeat points 1 to 3 above using your remaining mixtures.

   Mixtures **3** and **4** stored in the 100 cm^3 beakers should be transferred **completely** to a conical flask prior to each titration.

   Rinse the conical flask thoroughly between each titration.

5. Record your titration results, to an appropriate level of precision, in the space provided. In addition, you need to record the volume of **FA 3** added to each mixture in your table.

Table of results

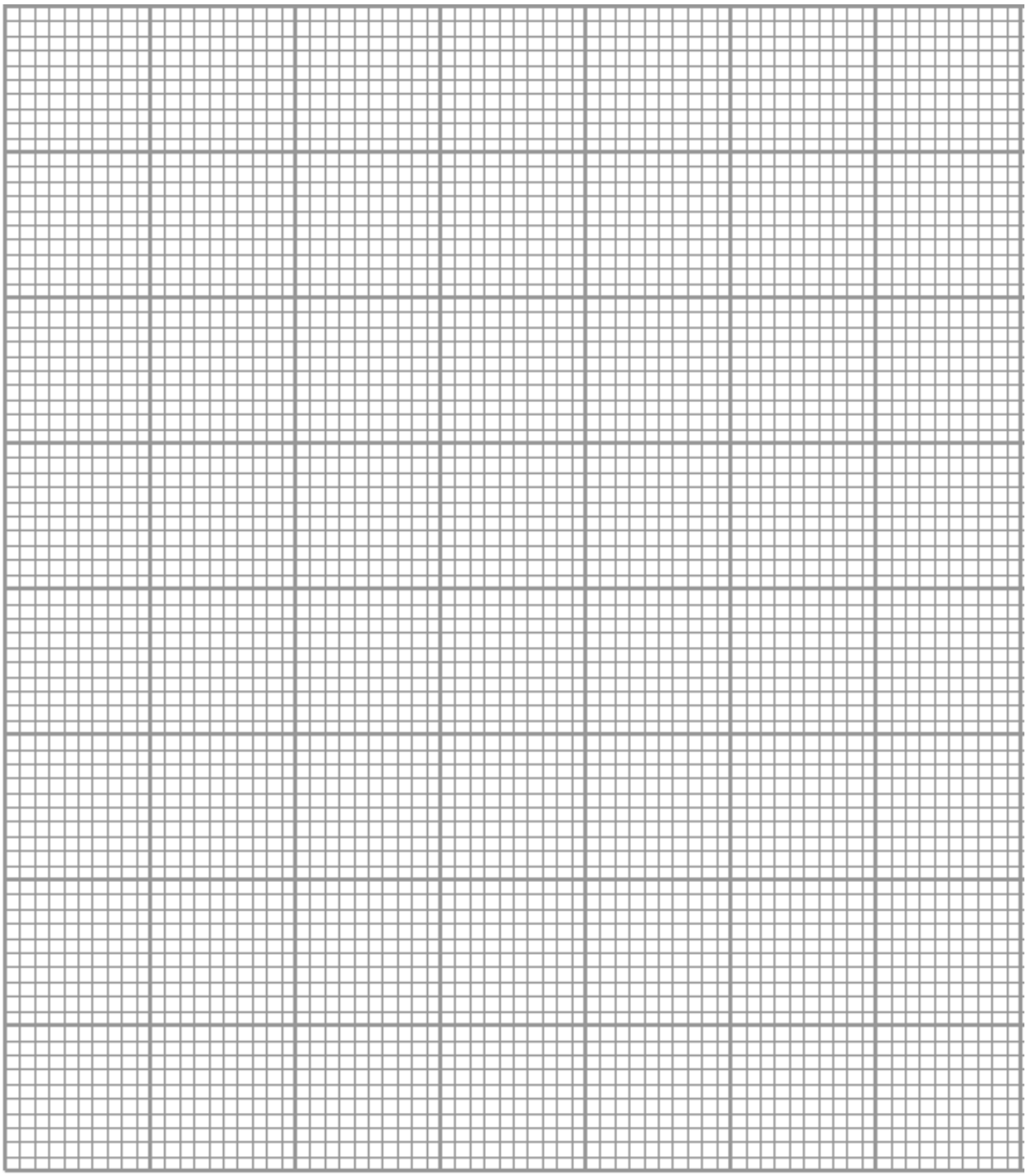
[4]

(c) Plot on the grid below, your values for the **FA 2** titre (*y-axis*) against the volume of **FA 3** added (*x-axis*).

You should choose scales for the axes which allow you to determine by extrapolation

- the volume of **FA 3** required, $\boldsymbol{V_{max}}$**(FA 3)**, to react completely with 25.0 cm^3 of **FA 1** if no **FA 2** is added;
- the volume of **FA 2** required, $\boldsymbol{V_{max}}$**(FA 2)**, to react completely with 25.0 cm^3 of **FA 1** if no **FA 3** is added.

Draw the line of best fit, taking into account all of your plotted points. Hence obtain values for $\boldsymbol{V_{max}}$**(FA 3)** and $\boldsymbol{V_{max}}$**(FA 2)**.



$\boldsymbol{V_{max}}$**(FA 3)** = …… $\boldsymbol{V_{max}}$**(FA 2)** = ……

[6]

(d) Calculate the gradient of your graph line, showing clearly how you did this.

gradient = …….
[1]

(e) Explain in terms of the chemistry involved, the direction of the slope of your graph.

……

……
[1]

(f) **(i)** Using V_{max}**(FA 2)** from your graph, calculate the concentration of sulfuric acid in **FA 1**.

concentration of H_2SO_4 in **FA 1** = …….
[2]

(ii) Using your answer in **(f)(i)** and V_{max}**(FA 3)** from your graph, calculate the concentration of the Group 1 carbonate in **FA 3**.

concentration of M_2CO_3 in **FA 3** = …….
[1]

(iii) **FA 3** contains 39.75 g dm^{-3} of M_2CO_3 in deionised water.
Using this information as well as your answer from **(f)(ii)**, calculate the relative atomic mass of M.
[A_r: C, 12.0; O, 16.0]

relative atomic mass of M = …….
[1]

(g) A student performs this experiment using a **FA 2** solution that was left uncovered overnight in the laboratory. Suggest what effect this will have on the value of V_{max}**(FA 2)** he obtains and explain your answer.

……

……
[1]

(h) Explain, in terms of the uncertainties associated with the apparatus used, why your **FA 2** titre volume for mixture **1** is likely to be more accurate than that for mixture **2**.

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[2]

(i) Determining the basicity of an unknown acid X

(i) **FA 5** is a solution of 0.75 mol dm^{-3} of an acid **X**.
FA 6 is 1.50 mol dm^{-3} sodium hydroxide, NaOH

You will carry out ***two*** experiments to determine the basicity of acid **X** by mixing different volumes of **FA 5** with **FA 6** as stated in the table provided and measuring the maximum temperature reached.

You may use the following apparatus to carry out the experiments:

- 2 × measuring cylinders
- 1 × thermometer
- 1 × styrofoam cup with cover
- 1 × glass beaker

Record the initial temperature of the **FA 5** solution and the maximum temperature reached in the table. Use your results to determine the maximum change in temperature for each experiment and complete the table. You may assume that the initial temperature of **FA 6** is the same as that of **FA 5**.

experiment	volume of **FA 5** /cm^3	volume of **FA 6** /cm^3	initial temperature of **FA 5** /°C	maximum temperature / °C	maximum change in temperature / °C
1	20.0	40.0			
2	40.0	20.0			

[1]

(ii) Use your data in **(i)(i)** to deduce and explain the basicity of acid **X**.

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……

……

[2]

[Total: 22]

2 To investigate the kinetics of bromate(V)-bromide reaction

In this question, you will investigate the kinetics of the bromate(V)-bromide reaction using the initial rates method.

FA 4 is methyl orange indicator
FA 7 is 0.350 mol dm^{-3} potassium bromate(V), $KBrO_3$
FA 8 is 0.650 mol dm^{-3} potassium bromide, KBr
FA 9 is 0.030 mol dm^{-3} phenol, C_6H_5OH
FA 10 is 0.250 mol dm^{-3} sulfuric acid, H_2SO_4

Bromate(V) and bromide ions react in the presence of acid to form bromine.

$$BrO_3^- + 5Br^- + 6H^+ \rightarrow 3Br_2 + 3H_2O$$

The bromine produced reacts rapidly with phenol to give a monobrominated compound.

$$C_6H_5OH + Br_2 \rightarrow BrC_6H_4OH + H^+ + Br^-$$

The kinetics of the bromate(V)-bromide reaction can be followed by measuring the time taken for bromine to react with a fixed amount of phenol. Methyl orange is used as an indicator. When phenol is used up, the concentration of bromine will increase rapidly, resulting in the decolourisation of methyl orange. The relative rate of reaction, 1/*t*, can then be calculated.

Since one mole of bromate(V) ion supplies sufficient bromine for the monobromination of three moles of phenol, the decrease in concentration of bromate ions up to the time of decolourisation of methyl orange can be calculated.

You will carry out four experiments to determine the order of reaction with respect to concentration of BrO_3^-(**FA 7**), Br^-(**FA 8**) and H^+(**FA 10**). You will prepare two sets of solutions for each experiment: Solution **A** which contains the bromate(V)-bromide mixture, and Solution **B**, which contains the sulfuric acid–phenol–methyl orange mixture.

Experiment 1

Solution A

- Using appropriate measuring cylinders, transfer 5.0 cm^3 of **FA 7**, 5.0 cm^3 of **FA 8** and 10.0 cm^3 of deionised water into a boiling tube.

Solution B

- Using appropriate measuring cylinders, transfer 15.0 cm^3 of **FA 9**, 10.0 cm^3 of **FA 10** and 5.0 cm^3 of **FA 4** into a 250 cm^3 conical flask.
- Mix the contents thoroughly by swirling the flask.

1. Pour the contents of the boiling tube rapidly into the 250 cm^3 conical flask and start the stopwatch. Swirl the conical flask to mix the contents thoroughly.

2. Stop the stopwatch at the point when the reaction mixture decolourises to pale yellow.

3. Record the time taken, *t*, to the nearest second.

4. **Dispose the reaction mixture into the glass waste container immediately after recording the time as a solid gel will form upon standing. Wash the conical flask thoroughly with water and allow to drain.**

Experiment 2–4

Carry out **three** more experiments, varying the volumes of **FA 7**, **FA 8** and **FA 10**, to determine the order of reaction with respect to BrO_3^-, Br^- and H^+. The volumes of **FA 7**, **FA 8** and **FA 10** should **not** be less than those in Experiment 1. Deionised water is added to keep the total volume of the final reaction mixture constant.

Prepare a table in the space provided to record, for each experiment:

- All volumes apart from those of **FA 4 and FA 9**
- The value of *t*, to the nearest second
- Calculated value of the relative rate of reaction, 1/*t*, to 3 significant figures

(a) Results

[4]

(b) Explain why the total volume of the reaction mixture is kept constant in each experiment.

……

……

[1]

(c) Using your results, determine the order of the bromate(V)-bromide reaction with respect to

- $[BrO_3^-]$

order of reaction with respect to $[BrO_3^-]$ = ……
[1]

- $[Br^-]$

order of reaction with respect to $[Br^-]$ = ……
[1]

- $[H^+]$

order of reaction with respect to $[H^+]$ = ……
[1]

(d) Using your answers to **(c)**, write the rate equation for the bromate(V)-bromide reaction.

……...[1]

(e) Determine the concentration, in mol dm^{-3}, of phenol in the reaction mixture at the time of mixing.

concentration of phenol in mixture = ……
[1]

(f) The rate of reaction may be calculated using $-\frac{\text{change in } [BrO_3^-]}{\text{time taken, } t}$

Using your answer to **(e)**, calculate the change in bromate(V) ion concentration up to the time of decolourisation of reaction mixture. Hence, determine the rate of reaction of Experiment 1.

rate of reaction for Experiment 1 = ……
[2]

(g) Using your answers to **(d)** and **(f)**, determine a value for the rate constant, *k*, including units, for the bromate(V)-bromide reaction.

k = ……
[5]

(h) Explain why the volume of **FA 9** is kept constant in each experiment.

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[1]

(i) In these experiments, the bromophenol formed can undergo further reaction to form dibromophenol. However, the second bromination proceeds at a much slower rate. Explain why bromination of bromophenol is slower than that of phenol.

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……

[1]

[Total: 19]

3 Planning

Calcium hydroxide, $Ca(OH)_2$ is a sparingly soluble salt. One method of determining the solubility product, K_{sp}, of a sparingly soluble salt is to first dissolve it in a solution of a known concentration containing a common ion such as, sodium hydroxide, NaOH(aq) to create a saturated solution.

The resultant solution is then titrated with a suitable reagent to determine the concentration of the common ion. The value obtained can then be used to determine the concentration of the counter ion, Ca^{2+} (aq) and the solubility product of the sparingly soluble salt can hence be calculated.

(a) Write an expression for the solubility product of calcium hydroxide.

…….

[1]

(b) Plan an investigation to prepare a saturated solution of $Ca(OH)_2$ in NaOH(aq) and to determine the total concentration of OH^- in the solution using volumetric analysis.

You may assume that you are provided with:

- 5 g of solid calcium hydroxide, $Ca(OH)_2$ (in excess)
- 250 cm^3 of 0.100 mol dm^{-3} sodium hydroxide, NaOH,
- 0.100 mol dm^{-3} hydrochloric acid, HC*l*
- the equipment normally found in a school or college laboratory.

Your plan should include brief details of:

- the apparatus you would use,
- the quantities that you would use,
- the procedure to prepare a saturated solution of calcium hydroxide,
- the procedures you would follow to carry out a volumetric analysis experiment in order to determine the concentration of the common ion,
- the measurements you would make,
- how you would ensure that accurate and reliable value of your titre values are obtained.

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[6]

(c) Hydrochloric acid undergoes neutralisation reaction with the hydroxide ions in the ratio of 1:1.

In a separate experiment, a student dissolve solid calcium hydroxide in 250 cm^3 of 0.100 mol dm^{-3} of aqueous sodium hydroxide. 25.0 cm^3 of the resultant solution required 26.05 cm^3 of 0.100 mol dm^{-3} of hydrochloric acid for complete neutralisation.

(i) Calculate the total concentration of the hydroxide ions present in the resultant solution.

[2]

(ii) Calculate the concentration of hydroxide ions produced from solid calcium hydroxide, $Ca(OH)_2$.

[1]

(iii) Hence, calculate the concentration of the calcium ions present in the resultant solution.

[1]

(iv) Hence, calculate the solubility product of calcium hydroxide.

[1]

(d) Explain why the solubility of calcium hydroxide will be lower in 250 cm^3 of NaOH than in 250 cm^3 of deionised water.

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[1]

(e) With reference to the experiment described in **3(c)**, sketch, on Fig. 3.1, the shape of the graph of pH against volume of HC*l* added. Suggest a value for the initial pH of the solution.

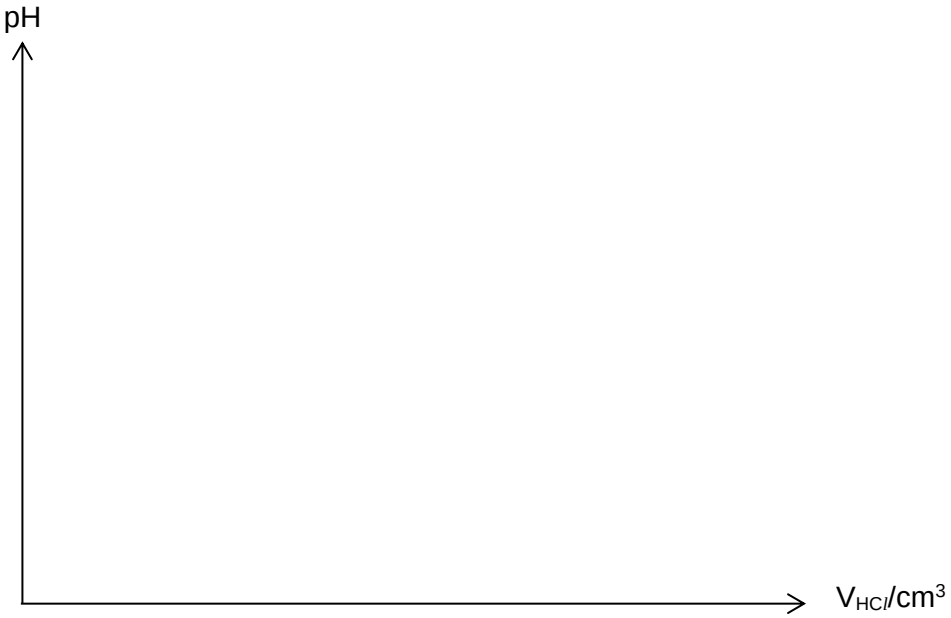

Fig 3.1

[1]

[Total: 14]

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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. 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, 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

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

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