

**NATIONAL JUNIOR COLLEGE**  
**SH 2 Year – End Practical Examination**  
Higher 2

CANDIDATE  
NAME

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SUBJECT  
CLASS

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REGISTRATION  
NUMBER

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**CHEMISTRY**

**9729/04**

Paper 4 Practical

**Wednesday 28 August 2024**

Candidate answer on the Question paper.

**2 hours 30 minutes**

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**READ THESE INSTRUCTIONS FIRST**

Write your identification number and name.

Give details of the practical shift and laboratory where appropriate, in the boxes provided.

Write in 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 21 and 22.

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

<b>Shift</b>
<b>Laboratory</b>

For Examiner's use	
1	/ 14
2	/ 20
3	/ 12
4	/ 9
Total	/ 55

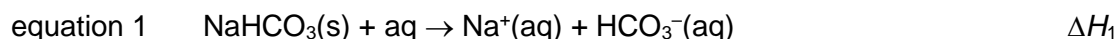
This paper consists of **22** printed pages including this cover page.

# 1 Determination of a value for an enthalpy change of solution Via Hess's Law.

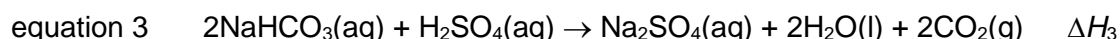
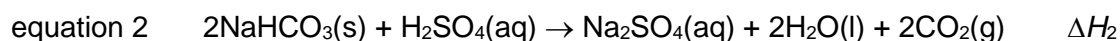
**FA 1** is solid sodium hydrogencarbonate,  $\text{NaHCO}_3$ .

**FA 2** is  $1.00 \text{ mol dm}^{-3}$  sulfuric acid,  $\text{H}_2\text{SO}_4$ .

Sodium hydrogencarbonate dissolves in water according to equation 1.



Both solid and aqueous sodium hydrogencarbonate react with sulfuric acid.



In this question, you will perform an experiment to determine a value for  $\Delta H_2$ . You will use data provided to calculate  $\Delta H_3$  and hence a value for  $\Delta H_1$ .

## (a) Determination of the molar enthalpy change of reaction, $\Delta H_2$

In this experiment, you will determine the maximum temperature change when a known mass of solid sodium hydrogencarbonate, **FA 1**, reacts with excess dilute sulfuric acid, **FA 2**.

In an appropriate format in the space provided on page 3, 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.

### Procedure

1. Weigh the capped bottle containing **FA 1**. Record this mass.
2. Place one polystyrene cup inside another polystyrene cup and place both in a glass beaker.
3. Use a  $50 \text{ cm}^3$  measuring cylinder to transfer  $30.0 \text{ cm}^3$  of **FA 2** into the polystyrene cup.
4. Stir the **FA 2** in the polystyrene cup with the thermometer. Read and record its initial temperature,  $T_i$ .
5. Slip the thermometer through the lid. Carefully transfer all the solid **FA 1** in the bottle to the **FA 2** in the polystyrene cup, in small portions, to avoid too much frothing. Secure the lid onto the cup.
6. Use the thermometer to stir the mixture. Observe the temperature until it shows the maximum change from the initial temperature. Record this temperature,  $T_m$ .
7. Reweigh the empty capped bottle. Record this mass.

Determine the maximum temperature change,  $\Delta T$ , and the mass of **FA 1** used.

**Results**

[5]

- (b) In the following calculations, you should assume that the specific heat capacity of the solution is  $4.18 \text{ J g}^{-1} \text{ K}^{-1}$ , and the density of the solution is  $1.00 \text{ g cm}^{-3}$ .

- (i) Use your results from **1(a)** to calculate the heat change for your experiment.

heat change = ..... [1]

- (ii) Hence, determine a value for  $\Delta H_2$ .

Include the sign of  $\Delta H_2$  in your answer.

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

$\Delta H_2 =$  ..... [1]

The results of an experiment where a solution of  $0.690 \text{ mol dm}^{-3}$  aqueous sodium hydrogencarbonate,  $\text{NaHCO}_3(\text{aq})$  was reacted completely with an excess of dilute sulfuric acid, **FA 2**, are shown in Table 1.1.

**Table 1.1**

volume of $\text{NaHCO}_3(\text{aq})$ used / $\text{cm}^3$	50.0
initial temperature of $\text{NaHCO}_3(\text{aq})$ / $^{\circ}\text{C}$	27.6
volume of <b>FA 2</b> used / $\text{cm}^3$	25.0
initial temperature of <b>FA 2</b> / $^{\circ}\text{C}$	31.2
minimum temperature / $^{\circ}\text{C}$	28.4

- (iii) Use the results given in Table 1.1 and the formula below to calculate the weighted average initial temperature,  $T_{\text{av}}$ , of the reaction mixture.

The formula for  $T_{\text{av}}$  is given as

$$T_{\text{av}} = \frac{(\text{vol. of FA 2} \times \text{initial temp. of FA 2}) + (\text{vol. of NaHCO}_3 \times \text{initial temp. of NaHCO}_3)}{\text{total volume of reaction mixture}}$$

$$T_{\text{av}} = \dots\dots\dots [1]$$

- (iv) Hence, calculate a value for  $\Delta H_3$ .

$$\Delta H_3 = \dots\dots\dots [4]$$

- (c) Use your answers from **1(b)(ii)** and **1(b)(iv)** to calculate a value for  $\Delta H_1$  for the reaction shown in equation 1.

If you are not able to determine a value for **1(b)(ii)** and/or **1(b)(iv)**, you may use  $x$  and  $y$  to represent the respective enthalpy changes and proceed with this part of the question.

$\Delta H_1 = \dots\dots\dots$  [2]

[Total: 14]

## 2 To determine the order of reaction with respect to the concentration of iodine in the iodination of propanone reaction

**FA 2** is 1.00 mol dm<sup>-3</sup> sulfuric acid, H<sub>2</sub>SO<sub>4</sub>.

**FA 3** is 1.00 mol dm<sup>-3</sup> propanone, CH<sub>3</sub>COCH<sub>3</sub>.

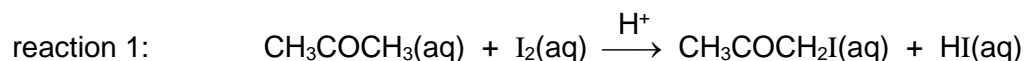
**FA 4** is an aqueous solution of iodine, I<sub>2</sub>.

**FA 5** is 0.0100 mol dm<sup>-3</sup> sodium thiosulfate, Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub>.

**FA 6** is 0.50 mol dm<sup>-3</sup> sodium hydrogencarbonate, NaHCO<sub>3</sub>.

You are also provided with a starch indicator.

The equation in reaction 1 represents the reaction between CH<sub>3</sub>COCH<sub>3</sub> and I<sub>2</sub>.



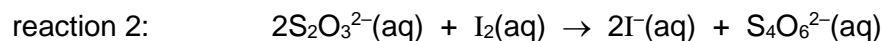
This reaction is first order with respect to both CH<sub>3</sub>COCH<sub>3</sub> and H<sup>+</sup> ions.

You are to investigate the order of reaction with respect to I<sub>2</sub>.

A reaction mixture containing an acidified solution of CH<sub>3</sub>COCH<sub>3</sub> and I<sub>2</sub> is first prepared. At timed intervals, aliquots (portions) of this reaction mixture will be removed and quenched using excess NaHCO<sub>3</sub>.

It is **not** essential that you complete the titration of one aliquot before extracting the next one from the reaction mixture.

The remaining amount of I<sub>2</sub> at different times can then be determined by titration against Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub>. Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub> reacts with I<sub>2</sub> as shown in the equation in reaction 2.



The required order of reaction can be obtained by graphical analysis of your results.

### (a) Preparing and titration of the reaction mixture

#### Notes:

You will perform each titration **once** only. Great care must be taken that you do not exceed the end-point.

Once you have started the stopwatch, it must continue running for the duration of the experiment. You must **not** stop the stopwatch until you have finished this experiment.

You should aim to transfer your first aliquot approximately four minutes after starting the reaction.

You should aim **not** to exceed a maximum reaction time of 20 minutes for this experiment.

In an appropriate format in the space provided on page 8, prepare a table in which to record for each aliquot

- the time of transfer,  $t$ , in minutes and seconds,
- the decimal time,  $t_d$ , in minutes, to 0.1 min, for example, if  $t = 4 \text{ min } 33 \text{ s}$  then  $t_d = 4 \text{ min} + 33/60 \text{ min} = 4.6 \text{ min}$ ,
- the burette readings and the volume of **FA 5** added.

**Question 2 continues on the next page.**

**Safety:**

Propanone is flammable. Transfer your titrated solutions into the **waste** bottle for later disposal. Keep this bottle stoppered when not in use.

Keep the conical flask labelled **reaction mixture** stoppered except when removing aliquots.

1. Fill a burette with **FA 5**.
2. Using a 25 cm<sup>3</sup> measuring cylinder, add the following to a 100 cm<sup>3</sup> beaker.
  - 25.0 cm<sup>3</sup> of **FA 2**
  - 25.0 cm<sup>3</sup> of **FA 3**
3. Using a 100 cm<sup>3</sup> measuring cylinder, transfer 50.0 cm<sup>3</sup> of **FA 4** into the 250 cm<sup>3</sup> conical flask, labelled **reaction mixture**.
4. Pour the contents of the 100 cm<sup>3</sup> beaker into this 250 cm<sup>3</sup> conical flask. Start the stopwatch, **insert the stopper** and swirl the mixture thoroughly to mix its contents.
5. Using a 10 cm<sup>3</sup> measuring cylinder, measure 10.0 cm<sup>3</sup> of **FA 6** into a second conical flask.
6. At approximately 4 minutes, using a 10.0 cm<sup>3</sup> pipette, remove a 10.0 cm<sup>3</sup> aliquot of the reaction mixture. **Immediately** transfer this aliquot into the second conical flask containing **FA 6** and swirl the mixture thoroughly.

Note the time of transfer,  $t$ , to the nearest second, when half of the reaction mixture has been dispensed from the pipette. Replace the stopper in the reaction flask.

7. Titrate the iodine in the second conical flask with **FA 5**. When the colour of the solution turns pale yellow, add about 1 cm<sup>3</sup> of starch indicator. The solution will turn blue–black. The end–point is reached when the blue–black colour just disappears. Record your results.
8. Empty the contents of this conical flask into the waste bottle. Wash this conical flask thoroughly with water.
9. Repeat steps 5 to 8 until a total of **five** aliquots have been titrated and their results recorded.

**Results**



- (b) (i) On the grid in Fig. 2.1, plot a graph of the volume of **FA 5** added, on the  $y$ -axis, against decimal time,  $t_d$ , on the  $x$ -axis.

Draw the best-fit line taking into account all of your plotted points. Extrapolate (extend) this line to  $t_d = 0.0$  min.

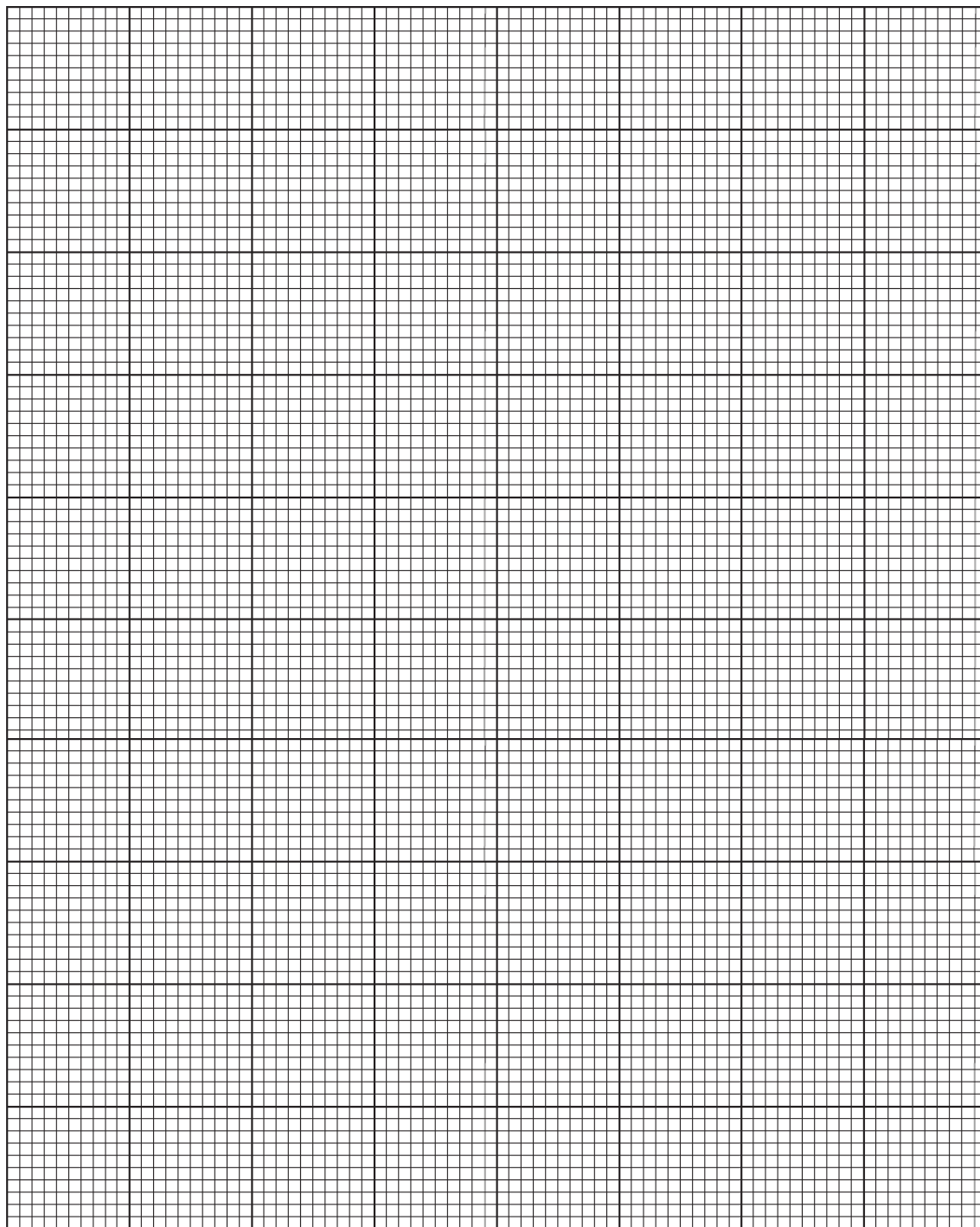


Fig. 2.1

[4]

- (ii) Deduce the order of reaction with respect to the  $[I_2]$  in reaction 1. Explain your answer.

order.....

explanation.....

.....

..... [1]

- (iii) Calculate the gradient of the line, showing your working clearly on the graph.

gradient = ..... $\text{cm}^3 \text{ min}^{-1}$  [2]

- (iv) The y-intercept of your line gives the volume of sodium thiosulfate required to completely react with the iodine present if an aliquot is taken at  $t_d = 0.0 \text{ min}$ .

Read from your graph and record this volume of **FA 5**,  $V_{\text{max}}$ . Use this value to calculate the concentration of iodine in **FA 4**.

volume of **FA 5**,  $V_{\text{max}} = \text{.....cm}^3$

concentration of iodine in **FA 4** = ..... $\text{mol dm}^{-3}$  [3]

- (c) Use the information provided on page 6 and your answer to **2(b)(ii)**, write an expression for the rate equation for reaction 1. Include the units for rate in your answer.

Rate = ..... [2]

- (d) In step 6 of the experimental procedure, the aliquot is transferred into the second conical flask containing **FA 6**.  
Explain why it is necessary to add **FA 6**, and how the titre values will be affected with the omission of **FA 6**.

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

- (e) Suggest how you would carry out a modified experiment of the one that you performed in **2(a)** to verify the order with respect to propanone.

On the axes in Fig. 2.2, sketch the graph you have obtained in **2(b)(i)** and the graph you would expect to obtain from the modified experiment. Label both graphs clearly.

Explain your answer.



**Fig. 2.2**

Modification.....  
 .....  
 explanation .....  
 ..... [3]

[Total: 20]

### 3 Qualitative Analysis

**FA 7** is a solid oxide of an unknown metal cation **Z**. This oxide has an  $M_r$  **not** exceeding 140.

[ $A_r$  of Al: 27.0; Ba: 137.3; Ca: 40.1; Cr: 52.0; Cu: 63.5; Fe: 55.8; Mg: 24.3; Mn: 54.9; O: 16.0; Zn: 65.4]

**FA 8** is solid potassium ethanedioate,  $K_2C_2O_4$ .

**FA 9** is an aqueous organic compound containing one functional group.

You will perform tests to determine:

- the metal cation **Z** in **FA 7**
- the functional group present in **FA 9**

- (a) Perform the tests described in Table 3.1 and record your observations in the table. Test and identify any gases produced.

**Table 3.1**

test	observations
<p><b>(i)</b> Add all of the solid <b>FA 8</b> into a boiling tube. Add 15 cm<sup>3</sup> of <b>FA 2</b> into this boiling tube.</p> <p>Using a hot water bath, gently warm the mixture in the boiling tube until all solid dissolves.</p>	
<p><b>(ii)</b> Add a spatula of <b>FA 7</b> to the mixture.</p> <p>Filter the mixture into another test tube.</p>	
<p><b>(iii)</b> To 1 cm depth of the filtrate in a test tube, add aqueous sodium hydroxide dropwise, until in excess.</p>	

[4]

- (b) Write an equation that explains the observation to the chemical test carried out on the gas evolved in test (a)(ii).

.....  
.....[1]

- (c) What is the chemical role of **FA 7** in the reaction between **FA 7** and **FA 8**? Support your answer using your observations from Table 3.1.

.....  
.....  
..... [1]

- (d) (i) Identify the cation in the filtrate, using your observations from Table 3.1.

.....  
.....  
..... [1]

- (ii) Hence, suggest the formula of the oxide of **Z** in **FA 7** and explain your reasoning by referring to your answer in (c) and the information provided on page 12.

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

- (e) You are provided with an organic solution **FA 9** which contains one functional group.

**Care: FA 9 is flammable. Do not use Bunsen burner for heating.  
Use the hot water provided if heating is required.**

**FA 9** gives a positive test with 2,4–dinitrophenylhydrazine.

Devise one other confirmatory test using the bench reagents provided to identify the functional group present in **FA 9**.

Carry out the test. Record details of the test performed and observations made in Table 3.2.

**Table 3.2**

<i>Confirmatory Test</i>	<i>Observations</i>

Functional group present in **FA 9**: .....

[3]

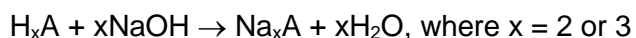
[Total: 12]

**[BLANK]**

#### 4 Planning

The labels for a bottle of carbonic acid and a bottle of citric acid were mixed up. Carbonic acid is dibasic and citric acid is tribasic.

The reaction between the acid and NaOH can be represented by this general equation



A series of experiments can be performed where increasing volumes of acid and decreasing volumes of NaOH(aq) are mixed and the temperature rise,  $\Delta T$ , for each experiment is determined.

In each of the experiments using different volumes of  $\text{H}_x\text{A}(\text{aq})$  and  $\text{NaOH}(\text{aq})$ , the total volume has to be kept constant. Since the total volume of mixture remains the same, the temperature rise,  $\Delta T$ , is a direct measure of the heat liberated by the reaction.

The maximum amount of heat is evolved when all the acid present is exactly neutralised by all the alkali present.

Plotting a graph of  $\Delta T$  against the volume of  $\text{H}_x\text{A}(\text{aq})$  used will give 2 straight lines of best-fit.

The total volume for each experiment should be kept constant at  $60.0 \text{ cm}^3$ .

You are to plan a series of **six** experiments so that a graph of  $\Delta T$  against volume of acid can be plotted to determine the basicity of the acid.

You are provided with:

- $1.00 \text{ mol dm}^{-3}$  sodium hydroxide, NaOH
- $1.00 \text{ mol dm}^{-3}$  acid from one of the bottles,  $\text{H}_x\text{A}$
- the equipment normally found in a school or college laboratory.

- (a) (i) Calculate the volumes of acid required for complete reaction if the acid is dibasic and tribasic respectively.

[1]

- (ii) Using your answers in (i), use the space provided below to tabulate the volumes of acid and NaOH in each experiment.

[1]



- [4]

[illegible]



- (c) (i) Sketch on Fig. 4.1 you would expect to obtain from your results if the acid is a dibasic acid. Explain your answer.



Fig 4.1

Explanation .....

.....

.....

.....

.....

.....

[2]

- (ii) Describe how you would make use of the graph to determine the value of enthalpy change of neutralisation,  $\Delta H_{\text{neut}}$ .

[1]

[Total: 9]

**[BLANK]**

## Qualitative Analysis Notes

[ppt. = precipitate]

### (a) Reactions of aqueous cations

cation	reaction with	
	NaOH(aq)	NH <sub>3</sub> (aq)
aluminium, Al <sup>3+</sup> (aq)	white ppt. soluble in excess	white ppt. insoluble in excess
ammonium, NH <sub>4</sub> <sup>+</sup> (aq)	ammonia produced on heating	–
barium, Ba <sup>2+</sup> (aq)	no ppt. (if reagents are pure)	no ppt.
calcium, Ca <sup>2+</sup> (aq)	white ppt. with high [Ca <sup>2+</sup> (aq)]	no ppt.
chromium(III), Cr <sup>3+</sup> (aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess
copper(II), Cu <sup>2+</sup> (aq)	pale blue ppt. insoluble in excess	blue ppt. soluble in excess giving dark blue solution
iron(II), Fe <sup>2+</sup> (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 <sup>3+</sup> (aq)	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess
magnesium, Mg <sup>2+</sup> (aq)	white ppt. insoluble in excess	white ppt. insoluble in excess
manganese(II), Mn <sup>2+</sup> (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 <sup>2+</sup> (aq)	white ppt. soluble in excess	white ppt. soluble in excess

**(b) Reactions of anions**

<i>anion</i>	<i>reaction</i>
carbonate, $\text{CO}_3^{2-}$	$\text{CO}_2$ 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, $\text{NO}_3^-(\text{aq})$	$\text{NH}_3$ liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil
nitrite, $\text{NO}_2^-(\text{aq})$	$\text{NH}_3$ liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil; $\text{NO}$ liberated by dilute acids (colourless $\text{NO} \rightarrow$ (pale) brown $\text{NO}_2$ 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, $\text{SO}_3^{2-}(\text{aq})$	$\text{SO}_2$ liberated 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, $\text{NH}_3$	turns damp red litmus paper blue
carbon dioxide, $\text{CO}_2$	gives a white ppt. with limewater (ppt. dissolves with excess $\text{CO}_2$ )
chlorine, $\text{Cl}_2$	bleaches damp litmus paper
hydrogen, $\text{H}_2$	"pops" with a lighted splint
oxygen, $\text{O}_2$	relights a glowing splint
sulfur dioxide, $\text{SO}_2$	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 aq. solution</i>	<i>colour in hexane</i>
chlorine, $\text{Cl}_2$	greenish yellow gas	pale yellow	pale yellow
bromine, $\text{Br}_2$	reddish brown gas / liquid	orange	orange-red
iodine, $\text{I}_2$	black solid / purple gas	brown	purple