CANDIDATE NAME	( )	CLASS	22S0		

RAFFLES INSTITUTION
2022 YEAR 6 PRELIMINARY EXAMINATION

Higher 2

CHEMISTRY 9729/04

Paper 4 Practical

24 August 2022

2 hours 30 minutes

Do NOT turn over the Question Booklet until you are told to do so.

READ THESE INSTRUCTIONS FIRST.

Write your name and class on the space provided when instructed to do so.
Give details of the practical shift and laboratory where appropriate, in the space provided.
Write in dark blue or black pen.
You may use a 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 number of marks is given in brackets [ ] at the end of each question or part question.

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 22 and 23.

Shift	
Laboratory	
Bench Number	

For Examiner's Use	
Question	**Marks**
1	**/ 14**
2	**/ 14**
3	**/ 16**
4	**/ 11**
Total	**/ 55**

This document consists of **22** printed pages and **2** blank pages.

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

1 Investigation of the effect of temperature on the rate of a reaction

D-glucose, $C_6H_{12}O_6$, is a sugar that can act as a reducing agent.

In this question, you will investigate the effect of temperature on the rate of the redox reaction between acidified potassium manganate(VII) and D-glucose.

FA 1 is 0.010 mol dm^{-3} potassium manganate(VII), $KMnO_4$.
FA 2 is 1.0 mol dm^{-3} sulfuric acid, H_2SO_4.
FA 3 is 0.20 mol dm^{-3} D-glucose, $C_6H_{12}O_6$.

Initially, the reaction mixture is intensely purple. As the reaction proceeds, the intensity of the purple colour will decrease until the reaction mixture becomes colourless when the reaction is completed. The rate of the reaction is studied by measuring the time taken for the purple colour to disappear.

You will perform a series of four experiments. Graphical analysis of your results will enable you to determine how temperature affects the rate of the reaction.

For each experiment, you will measure and record the
- time taken, t, in seconds for the reaction mixture to turn colourless,
- initial temperature, $T_{initial}$, and final temperature, T_{final}, in degree Celsius of the reaction mixture.

You will then calculate values for
- $1/t$,
- lg $(1/t)$,
- T_{ave}, which is the average temperature of $T_{initial}$ and T_{final} in degree Celsius,
- T_K, which is the average temperature in kelvin (0 °C = 273 K),
- $1/T_K$.

(a) In Table 1.1 on page 4, record:
- all values of t to the nearest second,
- all values of $T_{initial}$ and T_{final} to an appropriate level of precision,
- all calculated values of $1/t$, lg $(1/t)$, T_{ave}, T_K and $1/T_K$ to three significant figures.

Experiment 1

1. Fill the burette labelled **FA 1**, with **FA 1**.

2. Transfer 10.00 cm^3 of **FA 1** into a 100 cm^3 conical flask.

3. Use a 50 cm^3 measuring cylinder to transfer 25.0 cm^3 of **FA 2** into the conical flask containing **FA 1**.

4. Using a 25 cm^3 measuring cylinder, measure 25.0 cm^3 of **FA 3**.

5. Record the initial temperature, $T_{initial}$, of the solution in the conical flask.

6. Add the **FA 3** from the measuring cylinder into the conical flask. Start the stopwatch during this addition.

7. Mix the contents thoroughly by swirling the flask. Then place the flask on a white tile.

8. Stop the stopwatch as soon as the solution turns colourless. Record the final temperature, T_{final}, of the solution.

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

10. Discard the reaction mixture. Wash out the conical flask and stand it upside down on a paper towel to drain.

Experiment 2

11. Use the burette to transfer 10.00 cm^3 of **FA 1** into a 100 cm^3 conical flask.

12. Use a 50 cm^3 measuring cylinder to transfer 25.0 cm^3 of **FA 2** into the conical flask containing **FA 1**.

13. Place the conical flask on the tripod and heat its contents to between 55 ^oC and 65 ^oC.

14. When the temperature of the solution in the conical flask has reached between 55 ^oC and 65 ^oC, use a paper towel and **carefully** remove the conical flask from the Bunsen burner.

15. Repeat points 4 to 10 of **Experiment 1**.

Experiments 3 and 4

Repeat points 11 to 15 of **Experiment 2** two times, keeping the temperature of the contents of the conical flask between that of **Experiment 1** and **Experiment 2**. You should ensure that there is a difference of at least 5 ^oC between each of the initial temperatures in all your experiments.

You should alternate the use of the two 100 cm^3 conical flasks.

Record all temperatures, time taken and calculated values in Table 1.1.

Table 1.1

expt	$T_{initial}$ / ^{o}C	T_{final} / ^{o}C	t / s	$1/t$ / s^{-1}	lg ($1/t$)	T_{ave} / ^{o}C	T_K / K	$1/T_K$ / K^{-1}
1								
2								
3								
4								

[3]

(b) (i) Plot a graph of lg (1/t), on the y-axis, against $1/T_K$, on the x-axis, on the grid in Fig. 1.1.

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

Extrapolate (extend) your line to $1/T_K = 0.00340\ K^{-1}$. [3]

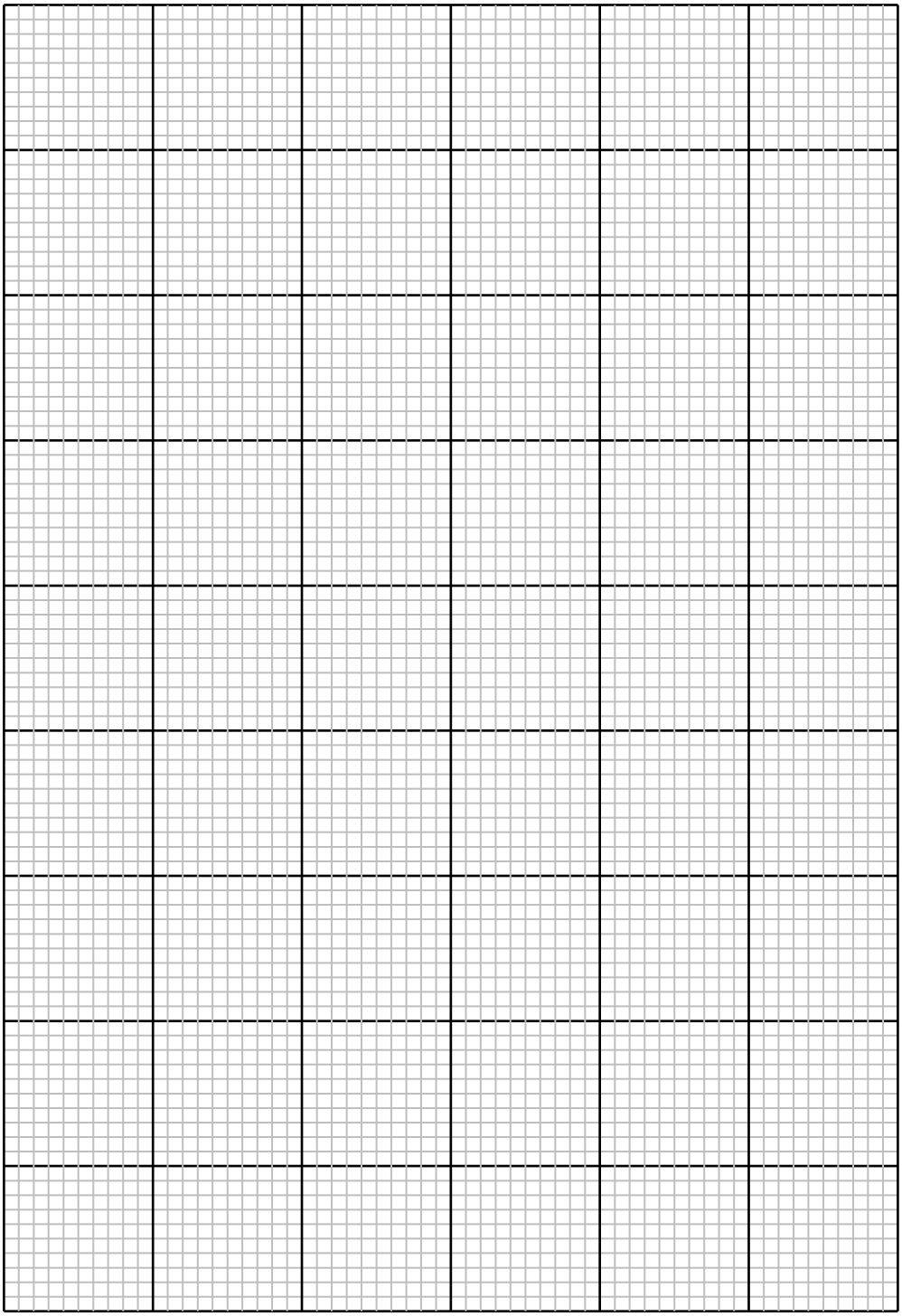

Fig. 1.1

(ii) The clock reaction can be used as a timer, such that the time taken for the reaction mixture to turn colourless is 3 minutes.

Use your graph to calculate the average temperature, T_{ave}, at which this reaction should be carried out. Give your answer to one decimal place.

Show on Fig. 1.1 how you obtained your answer.

average temperature, T_{ave} = ... ^{o}C [2]

(c) In an experiment, it was found that 1 mol of acidified potassium manganate(VII), $KMnO_4$, oxidised 2.5 mol of D-glucose.

The half-equation for the reduction of MnO_4^- under acidic conditions is given below.

$$MnO_4^- + 8H^+ + 5e^- \longrightarrow Mn^{2+} + 4H_2O$$

(i) Calculate the amount of electrons lost per mole of D-glucose.

amount of electrons lost per mole of D-glucose = ... mol [1]

(ii) The structure of D-glucose is shown in Fig. 1.2.

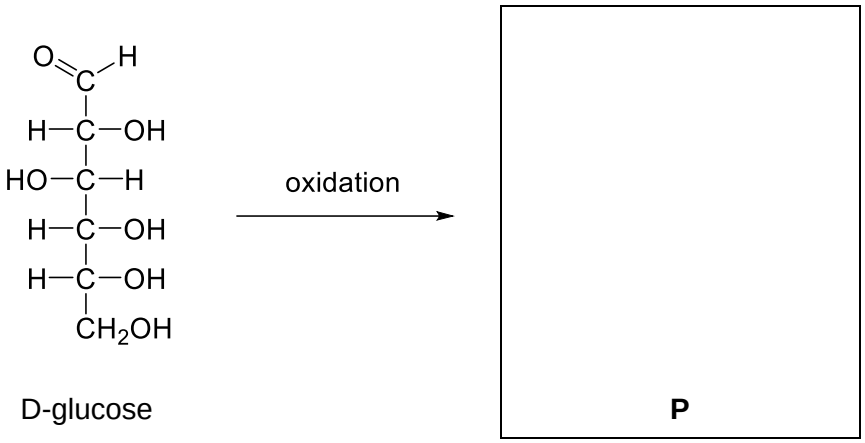

Fig. 1.2

Given that only one carbon atom in D-glucose is oxidised, suggest a structure of the organic product **P** formed from the oxidation of D-glucose. Draw your structure of **P** on Fig. 1.2.

Explain your answer by describing the change in oxidation state of the carbon atom which has undergone oxidation.

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…… [2]

(d) **(i)** The uncertainty (error) associated with each reading using either a 25 cm^3 or 50 cm^3 measuring cylinder is ± 0.5 cm^3.

Calculate the maximum total percentage uncertainty (error) in the total volume of the reaction mixture for **Experiment 1**.

maximum total percentage uncertainty = …… [1]

(ii) Identify a source of error in the experimental procedure. Do not include any errors involving the precision of apparatus.

Hence, suggest a modification that could be used to reduce this error.

source of error: ...……..….....

……..……..….....

……..……..….....

……..……..….....

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modification: ...……..….....

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……..……..….....

……..... [2]

[Total: 14]

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2 Determination of the formula of a hydrated salt

FA 4 is a hydrated salt of ammonium iron(II) sulfate and has the formula $(NH_4)_aFe(SO_4)_b \cdot 6H_2O$.

In this question, you will prepare **FA 5**, a solution containing **FA 4**, and perform a titration. The data from the titration will be used to calculate:

- the concentration of Fe^{2+} in **FA 5**
- the M_r of **FA 4** and hence the values of *a* and *b*.

FA 1 is 0.010 mol dm^{-3} potassium manganate(VII), $KMnO_4$.

FA 2 is 1.0 mol dm^{-3} sulfuric acid, H_2SO_4.

In the space provided on page 11, prepare tables in which to record for your experiment:

- all weighings to an appropriate level of precision
- titration results to an appropriate level of precision.

(a) (i) Preparation of FA 5 and titration of FA 5 against FA 1

1. Weigh the capped container containing solid **FA 4**. Record the mass in your table.
2. Empty the solid **FA 4** into a 100 cm^3 glass beaker. Reweigh the capped container after emptying the solid. Record this mass in your table.
3. Use a 50 cm^3 measuring cylinder to transfer 50.0 cm^3 of **FA 2** into the beaker. Stir to dissolve the solid.
4. Transfer the solution from the beaker quantitatively to a 250 cm^3 graduated flask. Rinse the beaker with deionised water a few times, adding all the washings to the graduated flask.
5. Make up to the mark with deionised water. Stopper and shake well to obtain a homogeneous solution, **FA 5**.
6. Fill the burette labelled **FA 1**, with **FA 1**.
7. Use the pipette to transfer 25.0 cm^3 of **FA 5** into a 250 cm^3 conical flask.
8. Titrate the solution in the conical flask until the end-point is reached.
9. Record your titration results in your table.
10. Repeat points 7 to 9 until consistent results are obtained.

Results

[5]

(ii) From your titrations, obtain a suitable volume of **FA 1** to be used in your calculations. Show clearly how you obtained this volume.

volume of **FA 1** = …… cm^3 [1]

(b) **(i)** The equation for the reaction in the titration is as shown.

$$5Fe^{2+} + MnO_4^- + 8H^+ \longrightarrow 5Fe^{3+} + Mn^{2+} + 4H_2O$$

Calculate the concentration of Fe^{2+} in **FA 5**.

concentration of Fe^{2+} = …… mol dm^{-3} [2]

(ii) Determine the M_r of **FA 4**.

M_r of **FA 4** = …… [1]

(iii) The formula of the hydrated salt in **FA 4** is $(NH_4)_aFe(SO_4)_b \cdot 6H_2O$.

By considering that the salt is electrically neutral, express *a* in terms of *b*.

[1]

(iv) Using your answers from **2(b)(ii)** and **2(b)(iii)**, determine the values of *a* and *b*.
[A_r: H, 1.0 N, 14.0 O, 16.0 S, 32.1 Fe, 55.8]

a = ……

b = ……
[2]

(c) A student performs the same experiment but mistakenly uses 5.0 cm^3 instead of 50.0 cm^3 of **FA 2** in the preparation of **FA 5**.

The student observes that a brown-black precipitate is formed during the titration.

Besides making the end-point more difficult to be determined, state the effect this mistake has on the student's titration results. Explain your answer.

effect on titration results ……..……

……..……..

explanation ……..……..……

……..……..

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……..……..

……..... [2]

[Total: 14]

3 Investigation of some organic and inorganic reactions

Safety Precautions

Wear safety goggles and gloves to avoid any direct contact with these chemicals. Wash with plenty of water immediately if there is any accidental skin contact with these chemicals.

FA 3 is 0.20 mol dm^{-3} D-glucose, $C_6H_{12}O_6$.

FA 6 and **FA 7** each contains an organic compound comprising C, H and O atoms only. Both do not decolourise $Br_2(aq)$.

FA 8 is a solution containing one cation and one anion listed in the Qualitative Analysis Notes on pages 22 and 23.

Carry out the following tests. Carefully record your observations in Tables 3.1, 3.2 and 3.4. Unless otherwise stated, the volumes given are approximate and should be estimated rather than measured. Test and identify any gases evolved. If there is no observable change, write **no observable change**.

Preparation of hot water bath

Fill a 250 cm^3 glass beaker with about 150 cm^3 of water. Using a Bunsen burner, heat this beaker of water until the water starts to boil.

While you are waiting for the water to boil, continue with Question 4.

Table 3.1

	test	observations
(a)	**Once the water in the beaker starts to boil, turn off the Bunsen burner.** Using a 10 cm^3 measuring cylinder, add 5.0 cm^3 of **FA 3** to a boiling tube. To this boiling tube, add 5.0 cm^3 of **FA 8** using the same 10 cm^3 measuring cylinder. Leave this boiling tube in the hot water bath for about 3 minutes. Filter the reaction mixture into another boiling tube. Wash the residue with some deionised water. The residue is **FA 9**. Retain the filter funnel containing **FA 9** for **3(c)(iii)**.	
While you are waiting for the mixture to filter, continue with 3(b).		

[1]

Table 3.2

		test	observations with **FA 6**	observations with **FA 7**
(b)	**(i)**	Add about 2 cm depth of **FA 6** to a test-tube. To this test-tube, add 2 cm depth of dilute sulfuric acid, followed by 1 drop of potassium manganate(VII) solution and shake well. Leave the test-tube to stand in a beaker of hot water for about 5 minutes.		no observable change
	(ii)	Add 1 cm depth of aqueous silver nitrate to a test-tube. Then slowly add 1 cm depth of aqueous sodium hydroxide. Add aqueous ammonia slowly, with shaking, until the precipitate just dissolves. You may use a clean glass rod to stir the mixture and help dissolve the precipitate. Add 1 cm depth of **FA 6** to this mixture, shake the tube and place it in the test-tube rack to stand.		no observable change
	(iii)	Add about 1 cm depth of **FA 7** to a test-tube. To this test-tube, add 4 drops of sodium hydroxide solution followed by iodine solution, dropwise, until a permanent orange/red colour is present. Warm the mixture in a beaker of hot water for about 2 minutes.	solution **FA 6** turns orange	
		Add sodium hydroxide solution using a teat pipette until no further change is seen. **Dispose the contents into the beaker labelled "waste".**	solution **FA 6** turns colourless	

[4]

(iv) Complete Table 3.3 with the functional groups present in **FA 6** and **FA 7**. Give evidence from the observations in Table 3.2 to support your conclusions.

Table 3.3

	functional group	evidence
FA 6		
FA 7		

[2]

Table 3.4

		test	observations
(c)	**(i)**	Test solution **FA 8** with Universal Indicator paper.	
	(ii)	Add about 1 cm depth of **FA 8** to a test-tube. Then add 1 cm depth of dilute nitric acid. To this test-tube, add about 1 cm depth of aqueous barium nitrate slowly, with shaking, until no further change is seen.	
	(iii)	Place the filter funnel containing **FA 9** into a clean test-tube. Using a 10 cm^3 measuring cylinder, carefully add 2.0 cm^3 of dilute sulfuric acid to the filter funnel. The filtrate will collect in the test-tube. The residue is **FA 10**. The filtrate is **FA 11**.	
	(iv)	Add 1 cm depth of **FA 11** to a test-tube. Add aqueous ammonia slowly, with shaking, until no further change is seen.	

[4]

FA 9, **FA 10** and **FA 11** contain the same element **X** but in three different oxidation states.

FA 10 is the solid metal of the cation present in **FA 11**.

(v) State the identity of the cation present in **FA 11**.

……... [1]

(vi) In **3(c)(iii)**, **FA 10** and **FA 11** are formed in equal amounts.

Identify the oxidation state of element **X** in **FA 9** and state the type of reaction in **3(c)(iii)**.

……..…….…..…..

……... [2]

(vii) Use your observations in Table 3.4 to deduce the identity of the anion in **FA 8**.

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……..…….…..…..

……... [2]

[Total: 16]

4 Planning

Hydrochloric acid, HC*l*, reacts with barium hydroxide, $Ba(OH)_2$, according to equation 1.

equation 1 $$HCl(aq) + \frac{1}{2}Ba(OH)_2(aq) \longrightarrow \frac{1}{2}BaCl_2(aq) + H_2O(l) \qquad \Delta H_{neut}$$

When HC*l* is mixed with $Ba(OH)_2$, the neutralisation reaction releases heat causing a rise in the temperature of the solution.

A series of experiments can be carried out using different volumes of the two solutions, HC*l* and $Ba(OH)_2$. In each experiment, the total volume of the two solutions is to be kept constant at 100 cm^3 and the change in temperature, ΔT, is to be determined.

A suitable graph can then be plotted and used to determine the concentration of the $Ba(OH)_2$ solution and ΔH_{neut}.

(a) (i) In an experiment, 0.200 mol dm^{-3} of HC*l* was reacted with $Ba(OH)_2$ and the total volume of the two solutions used was 100 cm^3.

Assuming that the concentration of $Ba(OH)_2$ is 0.080 mol dm^{-3}, determine the volume of $Ba(OH)_2$ to be used so that stoichiometric amounts of $Ba(OH)_2$ and HC*l* react.

volume of $Ba(OH)_2$ =…… cm^3 [1]

(ii) Plan a procedure to determine the concentration of the $Ba(OH)_2$ solution and ΔH_{neut} using a graphical method.

You may assume that you are provided with:
- 0.200 mol dm^{-3} hydrochloric acid, HC*l*
- approximately 0.080 mol dm^{-3} barium hydroxide, $Ba(OH)_2$
- the equipment normally found in a school or college laboratory.

In your plan you should include brief details of:
- the apparatus you would use
- the quantities you would use
- the procedure you would follow
- the measurements you would make.

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…… [4]

(b) **(i)** Sketch, on Fig. 4.1, the graph you would expect to obtain using the measurements you planned to make in **4(a)(ii)**.

On your graph, label

- V_{neut} for the volume of barium hydroxide used
- ΔT_{max} for the maximum temperature change

when stoichiometric amounts of hydrochloric acid and barium hydroxide react.

Fig. 4.1

[2]

(ii) Describe how you would use your answer in **4(b)(i)** to determine

- the concentration of the $Ba(OH)_2$ solution, in mol dm^{-3},
- ΔH_{neut}, in kJ mol^{-1}.

You may assume the following:

- specific heat capacity of all solutions is 4.18 J g^{-1} $^oC^{-1}$,
- density of all solutions is 1.00 g cm^{-3}.

[2]

(c) Suggest why using a bottle of barium hydroxide solution which has been left standing in the air for some time will result in an inaccurate determination of ΔH_{neut}.

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……[2]

[Total: 11]

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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 → (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) Tests for gases

gas	*test and test result*
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