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

1 Identification of two cations and two anions

FA 1 and **FA 2** each contain one cation and one anion.
Neither of the anions contains sulfur.

You will carry out tests to identify the ions in **FA 1** and in **FA 2**.

Unless otherwise stated, the volumes given in Table 1.1 are approximate and should be estimated rather than measured.

Test any gases evolved during the tests.

If there is no observable change, write **no observable change**.

(a) Carry out the tests in Table 1.1 on both **FA 1** and **FA 2**.
Carefully record your observations in Table 1.1 on page 3.

Table 1.1

tests		observations with **FA 1**	observations with **FA 2**
1	Add 2 cm depth of the **FA** solution to a test-tube. Add aqueous sodium hydroxide until there is no further change. Keep the reaction mixture for test 2.	White ppt formed Soluble in excess NaOH(aq) to give a colourless solution **Cation test**	White ppt Soluble in excess NaOH(aq) to give a colourless solution
2	Pour the reaction mixture from test 1 into a boiling tube. Add 1 cm depth of aqueous sodium hydroxide to the reaction mixture. Add a piece of aluminium foil to the reaction mixture. Warm the mixture.	Effervescence observed Damp red litmus remains red **NO_3^- test**	Effervescence observed Damp red litmus turns blue
3	Add 2 cm depth of the **FA** solution to a test-tube. Add aqueous ammonia until there is no further change.	White ppt formed Insoluble in excess NH_3(aq). **Cation test**	White ppt formed Soluble in excess NH_3(aq) to give a colourless solution.
4	Add 2 cm depth of the **FA** solution to a test-tube. Add a 1 cm depth of dilute hydrochloric acid.	**CO_3^{2-} test** No effervescence observed Solution remains clear and colorless.	No effervescence observed Solution remains clear and colorless.
5	Add 2 cm depth of the **FA** solution to a test-tube. Add a 1 cm depth of aqueous silver nitrate.	**halide test** White ppt formed	No ppt
	Add aqueous ammonia to the mixture, with shaking, until the aqueous ammonia is in excess. **solubility of AgX and cation test**	White ppt partially dissolves to give colorless solution. when NH_3(aq) is in excess, white ppt remain insoluble.	White ppt soluble in excess NH_3(aq) to give a colourless solution

[8]

(b) Complete Table 1.2 to identify the ions present in **FA 1** and in **FA 2**.

Table 1.2

	FA 1	**FA 2**
cation present	Al^{3+}	Zn^{2+}
anion present	Cl^-	NO_3^-

[4]

[Total: 12]

2 Investigating the kinetics of the reaction between iodate(V) ions and hydrogensulfite ions

FA 3 is 0.100 mol dm^{-3} potassium iodate(V), KIO_3.

FA 4 is 0.0500 mol dm^{-3} sodium hydrogensulfite, $NaHSO_3$.

You are also provided with:

- **Solution S**, 1% starch solution
- deionised water
- a waste beaker containing sodium carbonate solution.

Iodate(V) ions react with hydrogensulfite ions according to the equation shown.

$$2IO_3^- + 5HSO_3^- \rightarrow I_2 + 5SO_4^{2-} + 3H^+ + H_2O$$

In this experiment, the rate of the reaction is studied by measuring the rate of formation of iodine using a 'clock' method. You will vary the concentration of iodate(V) ions and measure the time taken for a fixed amount of iodine to be produced. This will be indicated by the formation of a blue-black/purple colour in the presence of starch.

The reaction takes place in a series of steps. As a result, the blue-black/purple colour does not appear immediately.

You will perform a series of six experiments. For each experiment you will need to ensure that the same total volume of reaction mixture is used, by adding deionised water as required. For each experiment, you will measure the time, t, for the blue-black/purple colour to appear. You should avoid inhaling any gases produced.

(a) Prepare a table in the space provided on page 6 in which to record, to an appropriate degree of precision:

- the volumes of **FA 3** ($V_{FA\,3}$), **FA 4** ($V_{FA\,4}$) and deionised water (V_{water}) used
- all values of t
- calculated values of $\log(1/t)$
- calculated values of $\log(V_{FA\,3})$.

Experiment 1

1. Use a teat pipette to add 10 drops of **Solution S** to a 100 cm^3 conical flask.
2. Use a 10 cm^3 measuring cylinder to measure 2.0 cm^3 of **FA 3** into the conical flask.
3. Use a 25 cm^3 measuring cylinder to measure 16.0 cm^3 of deionised water into the same conical flask.
4. Use a second 10 cm^3 measuring cylinder to measure 2.0 cm^3 of **FA 4**.
5. Pour the **FA 4** into the same conical flask, starting the stopwatch during this addition.
6. Mix the contents thoroughly by swirling the flask several times. Then place the flask on a white tile.
7. Stop the stopwatch at the first appearance of a blue-black/purple colour.
8. Record the time taken, to the nearest second, in your table.
9. Discard the reaction mixture immediately into the waste beaker containing sodium carbonate solution.
10. Wash out the flask thoroughly with tap water and then with deionised water. Stand the flask upside down on a paper towel to drain.

Experiments 2 to 6

Repeat experiment 1 five times, adding 3.0 cm^3, 4.0 cm^3, 6.0 cm^3, 8.0 cm^3 and 10.0 cm^3 of **FA 3** respectively in step 2.

In each experiment, you should adjust the volume of deionised water in step 3 to ensure the **same total volume** of reaction mixture is used.

You should alternate the use of the two 100 cm^3 conical flasks. You should keep **FA 3** and **Solution S** for use in Question 3.

Record all volumes, the time taken and the calculated values of log(1/*t*) and log($V_{FA\,3}$) in your table.

Results

expt	V_{water}/ cm^3	$V_{FA\,3}$/ cm^3	$V_{FA\,4}$/ cm^3	t/s	log (1/t)	log ($V_{FA\,3}$)
1	16.0	2.0	2.0	39	−1.59	0.301
2	15.0	3.0	2.0	27	−1.43	0.477
3	14.0	4.0	2.0	24	−1.38	0.602
4	12.0	6.0	2.0	13	−1.11	0.778
5	10.0	8.0	2.0	11	−1.04	0.903
6	8.0	10.0	2.0	10	−1.00	1.00

[5]

(b) (i) Plot a graph of log(1/t) on the y-axis against log(V_{FA3}) on the x-axis on the grid in Fig. 2.1. Draw the best-fit straight line.

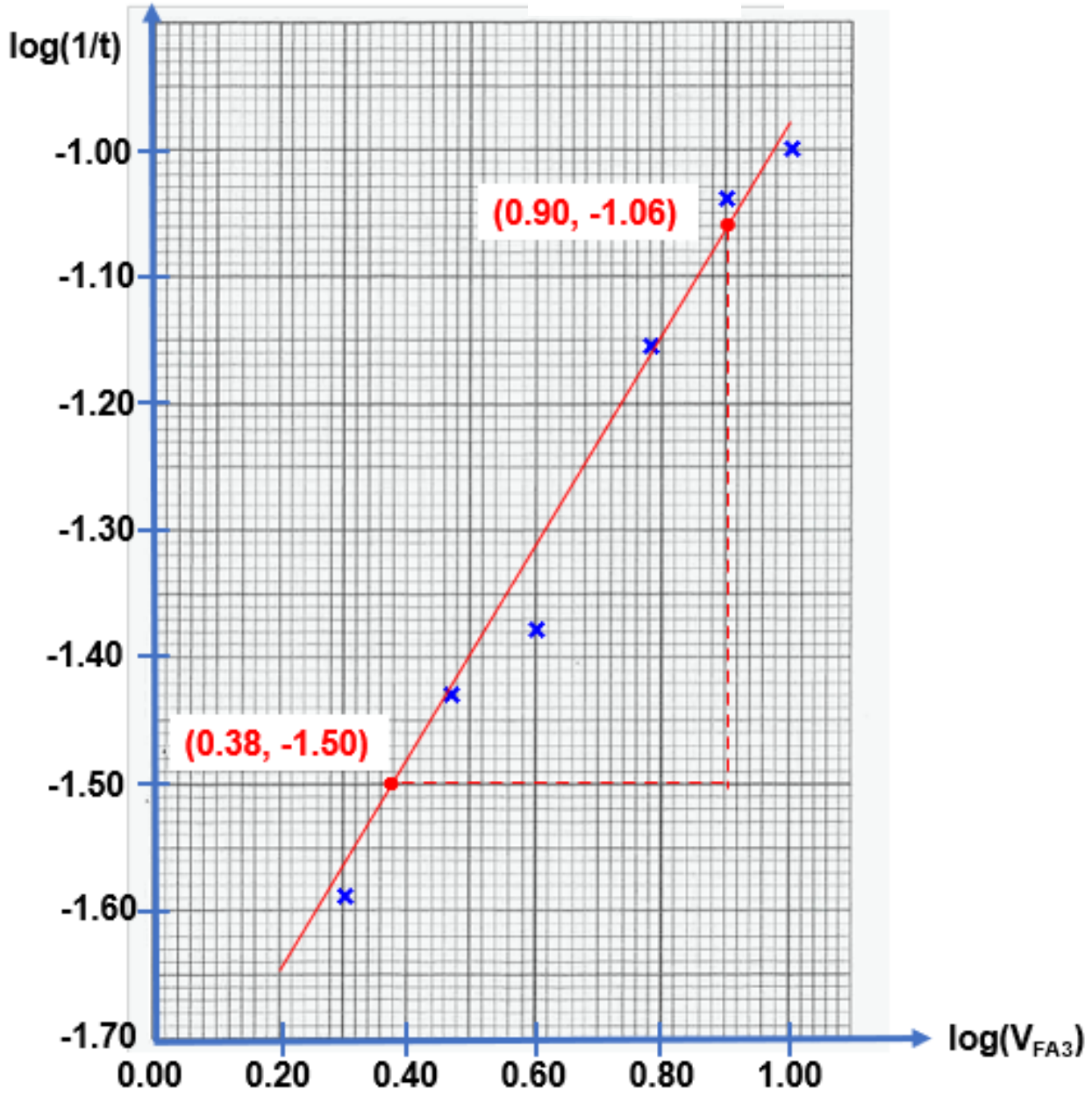


Fig. 2.1

[3]

(ii) Calculate the gradient of the line to three significant figures, showing your working clearly.

(ii) Gradient = $\frac{-1.50-(-1.06)}{0.38-0.9}$

= 0.846 (3s.f.)

gradient = ... [1]

(iii) The gradient of the line gives the order of the reaction with respect to iodate(V) ions. The reaction is first order with respect to iodate(V) ions.
Calculate the percentage error in your value of the gradient.

$$\% \text{ error} = \frac{(0.846 - 1.00)}{1.00} \times 100\%$$

$$= -15.4\%$$

percentage error = ... [1]

(c) Planning

It is suggested that the reaction between iodate(V) and hydrogensulfite ions may be catalysed by transition metal ions.

(i) Suggest why the reaction between iodate(V) and hydrogensulfite ions is slower in the absence of a catalyst.

(i) This reaction involves the collision of two negatively charged HSO_3^- and IO_3^- ions that experiences significant electronic repulsion. Hence the activation energy is very high, and the reaction is slower.

In the presence of transition metal cation catalyst, the reaction proceeds via an alternating reaction pathway of lower activation energy. Both steps of the new reaction mechanism involve the collision of oppositely charge ions (anion and transition metal cation), hence the reaction is faster.]

(ii) Plan an extension to the investigation in **2(a)** to test how well two different transition metal cations, $\mathbf{A^{2+}}$ and $\mathbf{B^{2+}}$, catalyse the reaction between iodate(V) and hydrogensulfite ions. You should **not** carry out your plan.

You may assume you are provided with solutions containing:

- 0.2 mol dm^{-3} $\mathbf{A^{2+}}$(aq)
- 0.1 mol dm^{-3} $\mathbf{B^{2+}}$(aq).

Your plan should include:

- two further experiments
- a table of volumes of solutions used
- how you would know that the transition metal cations are both catalysts for this reaction
- how you would know which transition metal cation is the better catalyst.

You do **not** need to rewrite the method given.

expt	V_{water}/ cm^3	$V_{FA\,3}$/ cm^3	$V_{FA\,4}$/ cm^3	V_{A2+}/ cm^3	V_{B2+}/ cm^3	t/s
1	16.0	2.0	2.0	0.0	0.0	39
7	15.0	2.0	2.0	1.0	0.0	
8	14.0	2.0	2.0	0.0	2.0	

.....

.....

.....

(ii) **Procedure on pg 6 is modified for investigation.**

For expt 7:

Repeat steps 1 to 2.

Step 3: Use 25 cm^3 measuring cylinder to measure 15.0 cm^3 deionised water and top up to 16.0 cm^3 with 1 cm^3 of A^{2+} solution.

Repeat steps 4 to 10.

For expt 8:

Repeat steps 1 to 2.

Step 3: Use 25 cm^3 measuring cylinder to measure 14.0 cm^3 deionised water and top up to 16.0 cm^3 with 2 cm^3 B^{2+} solution.

Repeat steps 4 to 10.

(Note: original B^{2+} has a lower concentration as compared to A^{2+}, hence volume of B^{2+} used should be twice of that of A^{2+}, while keeping total volume constant. This would ensure that we have the same concentration of A^{2+} and B^{2+} in the reaction mixture, thus allowing us to compare which is a better catalyst.

Rate of reaction is inversely proportional to the time taken to attain the blue-black colouration.

Expt 1 is the slowest reaction, a significant reduction in time taken to attain the blue-black colouration with total volume, V_{FA3} and V_{FA4} kept constant (rate is **independent** of the concentration of **FA 3** and **FA 4**) proves that A^{2+} and B^{2+} catalyses the reaction.

When the concentration of A^{2+} and B^{2+} in reaction mixture is kept constant (rate is not affected by the concentration of catalyst), the catalyst that reduces the time to reach blue black more significantly is a better catalyst.

3 Analysis of vitamin C tablets

Vitamin C is ascorbic acid, $C_6H_8O_6$. Ascorbic acid can be titrated against potassium iodate(V) in the presence of excess acid and iodide ions.

The iodate(V) ion oxidises acidified iodide ions to iodine according to the equation shown.

$$IO_3^- + 5I^- + 6H^+ \rightarrow 3I_2 + 3H_2O$$

If ascorbic acid is present, the iodine is removed from the solution according to the equation shown.

$$C_6H_8O_6 + I_2 \rightarrow C_6H_6O_6 + 2I^- + 2H^+$$

Once all of the ascorbic acid is used up, iodine remains in the solution and can be seen by the presence of a blue-black/purple colour in the presence of starch.

FA 5 is a solution prepared by dissolving four soluble vitamin C tablets in deionised water and making the solution up to 1 dm^3.

FA 6 is 0.5 mol dm^{-3} potassium iodide.

You are also provided with **FA 3** and **Solution S**, which you used in Question 2, and dilute sulfuric acid.

(a) (i) Dilution of FA 3

FA 3 is 0.100 mol dm^{-3} potassium iodate(V), KIO_3.

Use a pipette to transfer 10.0 cm^3 of **FA 3** into a 250 cm^3 volumetric flask.

Make the solution up to the mark with deionised water. Label this solution **FA 7**. This is a solution of potassium iodate(V) of a concentration suitable for the titration.

Titration of FA 5 against FA 7

1. Fill the burette with **FA 7**.
2. Use a pipette to transfer 25.0 cm^3 of **FA 5** into a 250 cm^3 conical flask.
3. Add to the conical flask:
   - approximately 5 cm^3 of **FA 6** using the 25 cm^3 measuring cylinder
   - approximately 5 cm^3 of dilute sulfuric acid using the same measuring cylinder
   - approximately 1 cm^3 of **Solution S** using a teat pipette.
4. Run **FA 7** from the burette into the conical flask. The end-point is reached when the first permanent blue-black/purple colour (lasting at least 15 seconds) is seen throughout the solution.
5. Record your titration results, to an appropriate level of precision, in the space provided on page 11.
6. Discard the reaction mixture via the sink.
7. Repeat steps 2 to 6 until consistent results are obtained.

Titration results

Final burette reading/ cm^3	28.80	26.90
Initial burette reading/ cm^3	8.00	6.00
Vol of FA 7 used / cm^3	20.80	20.90

[6]

(ii) From your titrations, obtain a suitable volume of **FA 7** to be used in your calculations. Show clearly how you obtained this volume.

$$\text{Vol of FA 7} = \frac{20.80+20.90}{2}$$
$$= 20.85\ cm^3$$

volume of **FA 7** = 20.85 cm^3 ..... [1]

(b) (i) Calculate the concentration of KIO_3 in **FA 7**.

$$[KIO_3]_{FA7} = \frac{10}{250} \times 0.100 = 4.00 \times 10^{-3}\ mol\ dm^{-3}$$

concentration of KIO_3 in **FA 7** = ... [1]

(ii) Calculate the mass of ascorbic acid in one vitamin C tablet.

Show all your working.

[A_r: H, 1.0; C, 12.0; O, 16.0]

(ii) Amount of IO_3^- used = $\frac{20.85}{1000} \times 4.00 \times 10^{-3} = 8.34 \times 10^{-5}$ mol

Amount of I_2 produced = $3 \times 8.34 \times 10^{-5} = 2.502 \times 10^{-4}$ mol

Amount of ascorbic acid that reacted with I_2 = 2.502×10^{-4} mol (in 25 cm^3)

Amount of ascorbic acid in 1 dm^3 of FA 5 = $2.502 \times 10^{-4} \times \frac{1000}{25.0}$

= 0.01001 mol (4 tablets)

Amount of ascorbic acid in each Vitamin C tablet = $0.01001 \div 4 = 2.502 \times 10^{-3}$ mol

Mass of ascorbic acid in one Vitamin C tablet

= $2.502 \times 10^{-3} \times (6 \times 12.0 + 8 \times 1.0 + 6 \times 16.0)$

= 0.440 g

mass of ascorbic acid in one vitamin C tablet = ...

[8]

(iii) Suggest how the titration would be affected if potassium iodide solution was **not** added in excess.

If iodide ions (I^-) are not added in excess, the iodine (I_2) produced by IO_3^- will be insufficient to react with the ascorbic acid, endpoint may not be attained as all iodine produced by reaction with IO_3^- is all converted back to colourless I^-, blue-black coloration cannot be observed. .....

..... [2]

[Total: 18]

4 Planning

Consider the following six organic compounds, which are all liquids at room temperature.

C butanal **D** butan-1-ol **E** butan-2-ol

F 2-methylpropan-2-ol **G** pentan-2-one **H** pentan-3-one

Plan an investigation, using test-tube reactions, which would allow you to identify each of these six organic compounds.

Your plan should include:

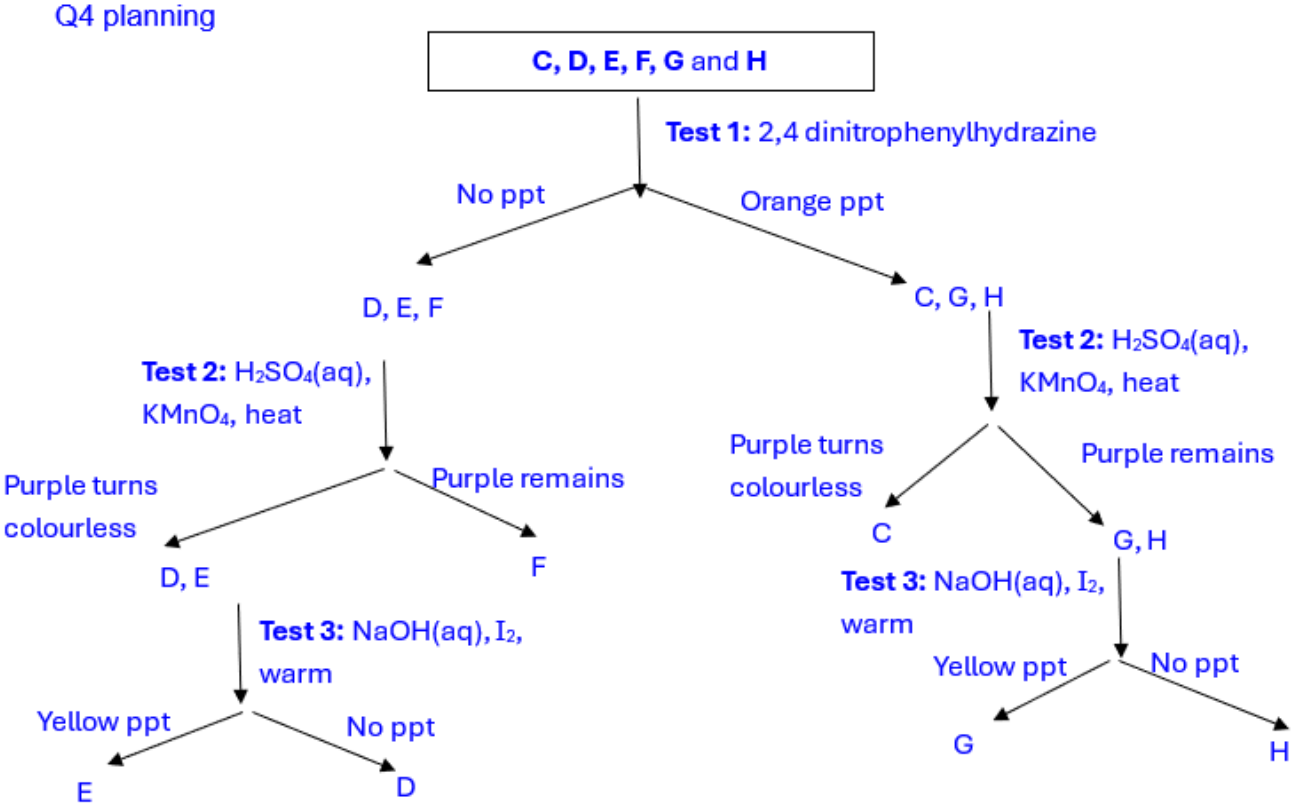
- details of the reagents to be used
- an outline of the sequence of steps you would follow
- how the results of your tests would identify each compound.

Compounds may be identified by positive or negative results in the tests.

You should use as few different tests as possible.

You may present your answer in a flow-chart or table.

Q4 planning



Note:

The sequence of test 1 to 3 maybe swapped to identify the distinguish the different samples.

When warming/ or heat is required, hot water bath is used.

All tests are carried out on fresh samples of **C** to **H**.

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