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9701/31

October/November 2008

2 hours

Additional Materials: As listed in the Confidential Instructions

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.
Give details of the practical session and laboratory where appropriate, in the boxes provided.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
DO NOT WRITE IN ANY BARCODES.

Answer **all** questions.
You are advised to show all working in calculations.
Use of a Data Booklet is unnecessary.

Qualitative Analysis Notes are printed on pages 11 and 12.

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.

Session
Laboratory

For Examiner's Use	
1	
2	
3	
Total	

This document consists of **11** printed pages and **1** blank page.

- 1 **FA 1** contains the monoprotic (monobasic) acid RCO_2H . You are to determine the relative molecular mass, M_r , of the acid and deduce its molecular formula.

For
Examiner's
Use

You are provided with the following.

FA 1, the aqueous acid, containing $38.68 \text{ g dm}^{-3} \text{ RCO}_2\text{H}$

FA 2, aqueous sodium hydroxide containing $3.40 \text{ g dm}^{-3} \text{ NaOH}$

Phenolphthalein indicator.

(a) Dilution of FA 1

By using a burette measure between 38.00 cm^3 and 39.00 cm^3 of **FA 1** into the 250 cm^3 graduated (volumetric) flask labelled **FA 3**.

Record your burette readings and the volume of **FA 1** added to the flask in the space below.

Make up the contents of the flask to the 250 cm^3 mark with distilled water. Place the stopper in the flask and mix the contents thoroughly by slowly inverting the flask a number of times.

Titration

Fill a second burette with **FA 3**, the diluted solution containing RCO_2H .

Pipette 25.0 cm^3 of **FA 2** into the conical flask and add 2–3 drops of phenolphthalein indicator.

Titrate the sodium hydroxide in the flask with **FA 3** until the solution just turns colourless.

Perform a rough (trial) titration and sufficient further titrations to obtain accurate results.

Record your titration results in the space below. Make certain that your recorded results show the precision of your working.

i	
ii	
iii	
iv	
v	
vi	

[6]

- (b) From your titration results obtain a volume of **FA 3** to be used in your calculations. Show clearly how you obtained this volume.

For
Examiner's
Use

[1]

Calculations

Show your working and appropriate significant figures in all of your calculations.

- (c) Calculate how many moles of NaOH have been pipetted into the conical flask.
[A_r : H, 1.0; O, 16.0; Na, 23.0]

..... mol of NaOH were pipetted into the conical flask.

Use your titre volume in (b) and the answer above to calculate how many moles of RCO_2H are contained in 250 cm^3 of the diluted acid **FA 3**.

250 cm^3 of **FA 3** contains mol of RCO_2H .

Use this answer to calculate the concentration, in mol dm^{-3} , of the undiluted acid in **FA 1**.

The concentration of RCO_2H in **FA 1** is mol dm^{-3} .

Use this answer to calculate, correct to **3 significant figures**, the relative molecular mass, M_r , of RCO_2H .

The relative molecular mass, M_r , of RCO_2H is

Use this answer to deduce the formula of the acid RCO_2H .

The formula of RCO_2H is

[5]

[Total: 12]

i	
ii	
iii	
iv	
v	

- 2 You are required to find the percentage by mass of water of crystallisation in **FA 4**, hydrated magnesium sulphate, $\text{MgSO}_4 \cdot x\text{H}_2\text{O}$.

For
Examiner's
Use

The water contained in the crystals can be removed by heating the crystals.

Method

- (a) Follow the instructions below to determine the mass of water driven off when heating magnesium sulphate crystals.

- Weigh the empty hard glass boiling-tube.
- Tip the contents of the tube labelled **FA 4** into the boiling-tube.
- Reweigh the boiling-tube and **FA 4**.
- Hold the boiling-tube in the holder provided and heat gently at first, then strongly for several minutes.
- Leave the boiling-tube to cool on a heat-proof mat.
- **Carry on with other parts of the paper, e.g. question 3, while the boiling-tube cools.**
- When cool weigh the boiling-tube and its contents.
- Continue the heating, cooling and weighing until you are satisfied that all of the water of crystallisation has been driven from the crystals.

In an appropriate form record below

- all measurements of mass,
- the final mass of the residue and the mass of water driven off.

Results

i	
ii	
iii	
iv	
v	
vi	
vii	

[7]

CalculationsFor
Examiner's
Use

- (b) Calculate the percentage by mass of water of crystallisation in the crystals.

Hydrated magnesium sulphate crystals contain % of water by mass.
[1]

- (c) Use the relative molecular mass information provided to complete the table below.
[M_r : MgSO_4 , 120.4; H_2O , 18.0]

possible value of x in $\text{MgSO}_4 \cdot x\text{H}_2\text{O}$	% water by mass
1	13.0
2	23.0
3	
4	37.4
5	42.8
6	47.3
7	51.1
8	54.5
9	
10	59.9

Use your answer in (b) and the information in the table to find the experimental value of x in the formula $\text{MgSO}_4 \cdot x\text{H}_2\text{O}$.

..... is the value of x in $\text{MgSO}_4 \cdot x\text{H}_2\text{O}$.
[2]

- (d) A student is instructed to repeat the whole experiment to ensure **reliability** of results. Explain how repeating the experiment would lead to greater **reliability** in the experimental results.

.....

[1]

- (e) On a balance weighing to 1 decimal place assume the maximum error is ± 0.1 g. What mass would have to be weighed out on this balance to result in an error of 0.04%?

For
Examiner's
Use

The mass is g.
[1]

[Total: 12]

3 FA 5 is a solid metal oxide. FA 6 and FA 7 are aqueous solutions.

You will carry out specified tests to deduce

- the chemical properties of **FA 5** and **FA 7**,
- the identities of the anion and cation present in **FA 6**.

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added.

Where gases are released they should be identified by a test, **described in the appropriate place in your observations.**

You should indicate clearly at what stage in a test a change occurs.

Marks are **not** given for chemical equations.

No additional tests for ions present should be attempted.

- (a) Pour 1 cm depth of **FA 7** into a boiling-tube, stand the tube in a test-tube rack and, using a spatula, add a **very small** amount of the solid **FA 5**.
A vigorous reaction will be observed.

The gas evolved is one of carbon dioxide, hydrogen or oxygen.

By considering the density of each gas compared to that of air, you are to decide which of these three gases you should test for first. Explain your answer.

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

[1 mol of any gas occupies approximately 24 dm^3 at room temperature and pressure.]

[24 dm^3 of air at room temperature and pressure has a mass of approximately 25.6 g.]

.....
.....
.....

Add a further 1 cm depth of **FA 7** to the boiling-tube. Test and identify the gas given off. Record in a suitable form the test or tests performed and the observation made for any test carried out.

*For
Examiner's
Use*

Deduce the identity of the gas evolved.

The gas evolved is
[4]

i	
ii	
iii	
iv	

- (b) Place 1 cm depth of 10% potassium iodide solution, KI, in a test-tube and add a **very small** amount of **FA 5**. Observe, then add a few drops of starch solution.

Record the tests used and all of your observations in an appropriate form below.

[2]

(c) Conclusions about the chemical properties of FA 5

In test **(a)** **FA 5** remained unchanged at the end of the reaction.

FA 5 was acting as in this reaction.

In test **(b)** **FA 5** was acting as

Where in the Periodic Table might you find the metallic element contained in **FA 5**?

..... [2]

- (d)** To 1 cm depth of **FA 6** in a boiling-tube add an equal volume of **FA 7**. Mix thoroughly by gently shaking the tube.
Using aqueous sodium hydroxide and aqueous ammonia you are to identify the cation present in **FA 6**, and the cation present in the mixture of **FA 6** and **FA 7**.

Record all of your observations in the table below.

<i>test</i>	<i>observations</i>	
	FA 6	mixture of FA 6 and FA 7
To 1 cm depth of solution in a test-tube add, drop by drop, 1 cm depth of aqueous sodium hydroxide. Stir the mixture, then add a further 1 cm depth of aqueous sodium hydroxide.		
To 1 cm depth of solution in a test-tube add, drop by drop, 1 cm depth of aqueous ammonia. Stir the mixture, then add a further 1 cm depth of aqueous ammonia.		

Conclusions

The cation present in **FA 6** is

The cation present in the mixture of **FA 6** and **FA 7** is

When **FA 6** and **FA 7** reacted together, **FA 7** was acting as

[5]

i	
ii	
iii	
iv	
v	

- (e) Solution **FA 6** was prepared using a bottle of solid whose label was partly missing. The solid is believed to contain the sulphate ion, SO_4^{2-} , but may contain the sulphite ion, SO_3^{2-} .

For
Examiner's
Use

By selecting appropriate reagents from those listed on page 12 of the qualitative analysis notes show that sulphate ions, SO_4^{2-} , are present.

Record your tests, observations and conclusions in an appropriate form below.

[3]

[Total: 16]

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Qualitative Analysis Notes

Key: [ppt. = precipitate]

1 Reactions of aqueous cations

ion	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
lead(II), Pb ²⁺ (aq)	white ppt. soluble in excess	white 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

[Lead(II) ions can be distinguished from aluminium ions by the insolubility of lead(II) chloride.]

2 Reactions of anions

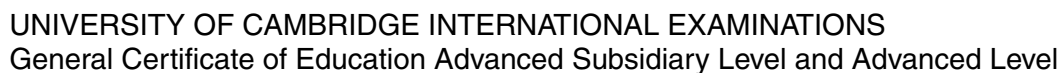
<i>ion</i>	<i>reaction</i>
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chromate(VI), CrO_4^{2-} (aq)	yellow solution turns orange with H^+ (aq); gives yellow ppt. with Ba^{2+} (aq); gives bright yellow ppt. with Pb^{2+} (aq)
chloride, Cl^- (aq)	gives white ppt. with Ag^+ (aq) (soluble in NH_3 (aq)); gives white ppt. with Pb^{2+} (aq)
bromide, Br^- (aq)	gives pale cream ppt. with Ag^+ (aq) (partially soluble in NH_3 (aq)); gives white ppt. with Pb^{2+} (aq)
iodide, I^- (aq)	gives yellow ppt. with Ag^+ (aq) (insoluble in NH_3 (aq)); gives yellow ppt. with Pb^{2+} (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 $\text{NO} \rightarrow$ (pale) brown NO_2 in air)
sulphate, SO_4^{2-} (aq)	gives white ppt. with Ba^{2+} (aq) or with Pb^{2+} (aq) (insoluble in excess dilute strong acids)
sulphite, SO_3^{2-} (aq)	SO_2 liberated with dilute acids; gives white ppt. with Ba^{2+} (aq) (soluble in excess dilute strong acids)

3 Tests for gases

<i>gas</i>	<i>test and test result</i>
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
sulphur dioxide, SO_2	turns aqueous potassium dichromate(VI) (aq) from orange to green

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Session
Laboratory

For Examiner's Use	
1	
2	
3	
Total	

This document consists of **12** printed pages.

- 1 You are required to find the concentration in mol dm^{-3} of sodium thiosulphate, $\text{Na}_2\text{S}_2\text{O}_3$, in solution **FB 1**.

FB 1 contains sodium thiosulphate.

FB 2 is potassium manganate(VII) containing $28.44 \text{ g dm}^{-3} \text{ KMnO}_4$.

FB 3 is 1.0 mol dm^{-3} sulphuric acid, H_2SO_4 .

FB 4 is 10% potassium iodide containing $100 \text{ g dm}^{-3} \text{ KI}$.

You are also provided with starch indicator.

Dilution of **FB 2**

- (a) By using a burette measure between 41.00 cm^3 and 42.00 cm^3 of **FB 2** into the 250 cm^3 graduated (volumetric) flask labelled **FB 5**.

Record your burette readings and the volume of **FB 2** added to the flask in the space below.

Make up the contents of the flask to the 250 cm^3 mark with distilled water. Place the stopper in the flask and mix the contents thoroughly by slowly inverting the flask a number of times.

Titration

Fill a second burette with **FB 1**, the solution containing sodium thiosulphate.

Use a measuring cylinder to transfer 10 cm^3 of **FB 3** and 10 cm^3 of **FB 4** into a conical flask. Pipette 25.0 cm^3 of **FB 5** into the conical flask containing the mixture of **FB 3** and **FB 4**. The potassium manganate(VII) oxidises potassium iodide to iodine, I_2 .

Titrate the liberated iodine with **FB 1** as follows. Run the solution from the burette into the conical flask until the initial red/brown colour of the iodine becomes pale yellow. Then add 1 cm^3 of the starch indicator and continue to add **FB 1** drop by drop until the blue/black colour of the starch/iodine complex disappears, leaving a colourless solution. This is the end-point of the titration.

Perform a rough (trial) titration and sufficient further titrations to obtain accurate results.

Record your titration results in the space below. Make certain that your recorded results show the precision of your working.

i	
ii	
iii	
iv	
v	
vi	

[6]

- (b) From your titration results obtain a volume of **FB 1** to be used in your calculations. Show clearly how you obtained this volume.

The volume of **FB 1** is cm³. [1]

Calculations

Show your working and appropriate significant figures in all of your calculations.

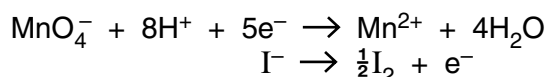
- (c) Calculate how many moles of KMnO_4 are contained in the **FB 2** run into the graduated flask. [A_r: K, 39.1; O, 16.0; Mn, 54.9]

..... mol of KMnO_4 are run into the graduated flask.

Calculate how many moles of KMnO_4 are then pipetted from the 250 cm³ graduated flask into the titration flask.

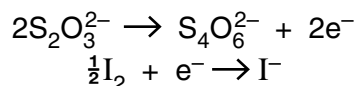
..... mol of KMnO_4 are pipetted into the titration flask.

Use this answer to calculate how many moles of **iodine molecules, I_2** , are formed when the manganate(VII) ions react with an excess of iodide ions in the titration flask.



..... mol of **iodine molecules, I_2** , are formed in the reaction.

Use this answer to calculate how many moles of sodium thiosulphate will react with the **iodine molecules** formed.



..... mol of thiosulphate ions react with the **iodine molecules** formed in the reaction.

i	
ii	
iii	
iv	
v	

Calculate, to **3 significant figures**, the concentration in mol dm^{-3} of the sodium thiosulphate, $\text{Na}_2\text{S}_2\text{O}_3$, in **FB 1**.

The concentration of sodium thiosulphate in **FB 1** is mol dm^{-3} .

[5]

[Total: 12]

2 Read through the instructions before starting the experiment.

The relative molecular mass, M_r , of a metal carbonate can be estimated by adding a weighed sample of the carbonate to a weighed excess of hydrochloric acid and measuring the mass of carbon dioxide evolved.

The tubes labelled **FB 6** and **FB 7** each contain the solid carbonate X_2CO_3 .
FB 8 is 2.0 mol dm^{-3} hydrochloric acid.

Method

(a) Follow the instructions below to determine the mass of carbon dioxide given off when X_2CO_3 reacts with an excess of hydrochloric acid.

- Use a measuring cylinder to transfer 75 cm^3 of **FB 8** into a 250 cm^3 conical flask.
- Weigh the flask and acid **FB 8**.
- Weigh the tube labelled **FB 6** which contains the carbonate X_2CO_3 .
- Tip the contents of the tube **FB 6** into the acid in the flask, a little at a time. This prevents loss of acid as spray from the vigorous reaction.
- When the reaction appears to be complete, swirl the flask and leave to stand for 2–3 minutes, then reweigh the flask and its contents.
- Reweigh the tube **FB 6** and any residual carbonate not added to the acid.
- Rinse out and drain the flask.
- Repeat the whole experiment using tube **FB 7**.

In an appropriate form below record the following.

- all measurements of mass made
- the mass of the carbonate, X_2CO_3 , added
- the mass of carbon dioxide given off

[mass of CO_2 = (initial mass of flask + acid) + (mass of carbonate) – (final mass of flask + contents)]

Results

i	
ii	
iii	
iv	

[4]

Calculations

- (b) From your results for each experiment calculate the mass of X_2CO_3 that would produce 1.0 g of CO_2 .

With **FB 6** g of CO_2 are given off from g X_2CO_3 .

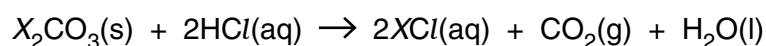
1.0 g of CO_2 is given off from g X_2CO_3 .

With **FB 7** g of CO_2 are given off from g X_2CO_3 .

1.0 g of CO_2 is given off from g X_2CO_3 .

[3]

- (c) For each experiment calculate the relative molecular mass, M_r , of X_2CO_3 .



[A_r : C, 12.0; O, 16.0]

M_r of X_2CO_3 from the experiment with **FB 6** is

M_r of X_2CO_3 from the experiment with **FB 7** is

[1]

- (d) Carbon dioxide is soluble in aqueous solutions and this can lead to an error in the molecular mass calculated.

From your observations on carrying out the experiments suggest another significant source of error. Explain the effect this will have on the measurements made and the molecular mass calculated.

.....

[1]

- (e) Some of the carbon dioxide given off in the reaction remains dissolved in the acid solution.

Suggest how you might modify the experimental method described to reduce or eliminate this error.

.....

[1]

- (f) Carry out the following instructions.

- Half fill each of two test-tubes with distilled water and place the tubes in a test-tube rack.
- To one test-tube add 1 spatula measure of powdered barium carbonate, BaCO_3 .
- To the second test-tube add 1 spatula measure of X_2CO_3 .
- Stopper each test-tube and shake vigorously.
- Half fill each of two boiling-tubes with **FB 3**, dilute sulphuric acid.
- To one boiling-tube add 1 spatula measure of powdered barium carbonate, BaCO_3 .
- To the second boiling-tube add 1 spatula measure of X_2CO_3 .
- **Do not attempt to stopper or shake either of these boiling-tubes.**

Record your observations in the table below.

	BaCO_3	X_2CO_3
water		
FB 3 dilute sulphuric acid		

It is suggested that sulphuric acid could be used in place of hydrochloric acid in experiments to determine the M_r of metal carbonates.

Make use of your observations and your knowledge of the chemistry of barium, to explain why the use of sulphuric acid would not be appropriate if the carbonate is barium carbonate.

.....

[2]

[Total: 12]

- 3 **FB 9, FB 10 and FB 11** are aqueous solutions, each containing one of the cations listed on page 11 of the qualitative analysis notes.

You will react **FB 9, FB 10 and FB 11** with aqueous sodium hydroxide, NaOH, and aqueous ammonia, NH_3 , to identify the cations present in each of these solutions. You will also perform tests to identify the anions present in **FB 9** and **FB 10**.

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Note that three of the cations listed on page 11 may give **no** precipitate with aqueous NaOH.

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.

Marks are **not** given for chemical equations.

- (a) Pour 1 cm depth of **FB 9, FB 10 and FB 11** into separate test-tubes. Stand the tubes in a test-tube rack and add aqueous sodium hydroxide, NaOH, a little at a time until the reagent is in excess. Repeat the test with aqueous ammonia, NH_3 , as the reagent.

Record your observations in an appropriate form below.

i	
ii	
iii	
iv	

[4]

- (b) Using the observations above it is not possible to identify a single cation for any of the solutions. Use your observations and the qualitative analysis notes on page 11 to identify, for each solution, two **or** three cations which could be present.

FB 9 could contain the cations

FB 10 could contain the cations

FB 11 could contain the cations

[2]

- (c) Use the qualitative analysis notes on page 11 to select further reagents or tests to identify precisely which cation is present in each of **FB 9**, **FB 10** and **FB 11**.

Record in an appropriate form below,

- details of the reagents to be used,
- the tests to be carried out,
- your observations when the additional tests are carried out.

A boiling-tube **must** be used if any solution is to be heated.

i	
ii	
iii	
iv	

Conclusion

FB 9 contains the cation

FB 10 contains the cation

FB 11 contains the cation

[4]

(d) **FB 9** and **FB 10** each contain one anion which is either a sulphate or a halide.

Use the qualitative analysis notes on page 12 to select appropriate reagents and tests to determine which anion is present in each solution.

Record in an appropriate form below,

- details of the reagents to be used,
- the tests to be carried out,
- your observations when the tests are carried out.

i	
ii	
iii	
iv	
v	
vi	

Conclusion

FB 9 contains the anion

FB 10 contains the anion

[6]

[Total: 16]

Qualitative Analysis Notes

Key: [ppt. = precipitate]

1 Reactions of aqueous cations

ion	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
lead(II), Pb ²⁺ (aq)	white ppt. soluble in excess	white 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

[Lead(II) ions can be distinguished from aluminium ions by the insolubility of lead(II) chloride.]

2 Reactions of anions

<i>ion</i>	<i>reaction</i>
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chromate(VI), CrO_4^{2-} (aq)	yellow solution turns orange with H^+ (aq); gives yellow ppt. with Ba^{2+} (aq); gives bright yellow ppt. with Pb^{2+} (aq)
chloride, Cl^- (aq)	gives white ppt. with Ag^+ (aq) (soluble in NH_3 (aq)); gives white ppt. with Pb^{2+} (aq)
bromide, Br^- (aq)	gives pale cream ppt. with Ag^+ (aq) (partially soluble in NH_3 (aq)); gives white ppt. with Pb^{2+} (aq)
iodide, I^- (aq)	gives yellow ppt. with Ag^+ (aq) (insoluble in NH_3 (aq)); gives yellow ppt. with Pb^{2+} (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 $\text{NO} \rightarrow$ (pale) brown NO_2 in air)
sulphate, SO_4^{2-} (aq)	gives white ppt. with Ba^{2+} (aq) or with Pb^{2+} (aq) (insoluble in excess dilute strong acids)
sulphite, SO_3^{2-} (aq)	SO_2 liberated with dilute acids; gives white ppt. with Ba^{2+} (aq) (soluble in excess dilute strong acids)

3 Tests for gases

<i>gas</i>	<i>test and test result</i>
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
sulphur dioxide, SO_2	turns potassium dichromate(VI) (aq) from orange to green

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