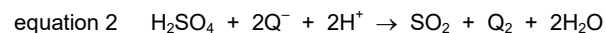
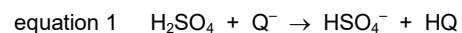


**21** Equation 1 and equation 2 show two different reactions of halide ion  $Q^-$  with concentrated sulfuric acid.



What is Q?

- A**  $Cl^-$  or  $Br^-$       **B**  $Br^-$  or  $I^-$       **C**  $Cl^-$  only      **D**  $I^-$  only

**22** X and Y are sodium salts of Group 17 elements.

When X reacts with concentrated sulfuric acid, hydrogen sulfide,  $H_2S$ , is produced.

When Y reacts with concentrated sulfuric acid, there is no change in the oxidation number of the sulfur.

Which statement is correct?

- A** Aqueous X reduces aqueous bromine.  
**B** Aqueous Y reacts with aqueous silver nitrate to give a precipitate which is insoluble in concentrated aqueous ammonia.  
**C** X and Y react separately with concentrated sulfuric acid to produce halogens.  
**D** When X reacts with concentrated sulfuric acid, six halide ions are needed to reduce one sulfur atom to  $H_2S$ .

**21** X, Y and Z are three aqueous solutions. Equal volumes of pairs of the solutions are mixed and observations noted.

X mixed with Y shows no reaction.

X mixed with Z shows an immediate reaction.

Z mixed with Y shows no reaction.

What are X, Y and Z?

|          | X          | Y          | Z          |
|----------|------------|------------|------------|
| <b>A</b> | $Br_2(aq)$ | $I_2(aq)$  | $HBr(aq)$  |
| <b>B</b> | $Cl_2(aq)$ | $I_2(aq)$  | $HBr(aq)$  |
| <b>C</b> | $HCl(aq)$  | $HI(aq)$   | $Br_2(aq)$ |
| <b>D</b> | $HCl(aq)$  | $Br_2(aq)$ | $HBr(aq)$  |

**3 (a)** A bottle labelled **FA 5** is thought to contain hydrated zinc sulfate. It would therefore contain zinc ions and sulfate ions as well as water of crystallisation.

- (i)** Devise and carry out tests to investigate whether zinc ions, sulfate ions and water of crystallisation are present.

Record the tests you carry out and the observations you see in the space provided.

- (ii) Use your observations in (a)(i) to complete Table 3.1 to show whether each species is present in FA 5.

Use a tick (✓) if the species is present.

Use a cross (X) if the species is **not** present.

Table 3.1

|                               |  |
|-------------------------------|--|
| Zn <sup>2+</sup>              |  |
| SO <sub>4</sub> <sup>2-</sup> |  |
| H <sub>2</sub> O              |  |

[1]

- (b) You are provided with solid FA 6.

- (i) Heat a few crystals of FA 6 in a hard-glass test-tube until no further gas is evolved. Record all your observations.

Leave the test-tube until it is cool.

Keep the cooled residue for use in (b)(ii).

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

- (ii) To the cooled residue from (b)(i), add approximately 3 cm depth of distilled water and stir. Filter the solution formed into a test-tube.

The colour of the solution is .....

[1]

- (c) You are provided with aqueous solutions FA 7 and FA 8 and with solid FA 9.

FA 7 is an aqueous solution of FA 6.

FA 7, FA 8 and FA 9 contain compounds which all have one metal that is the same but which may be in different oxidation states.

- (i) Carry out the following tests on FA 7, FA 8 and FA 9 and record your observations in Table 3.2. For each test use a 1 cm depth of a solution or a spatula measure of solid.

Table 3.2

| test                                                                       | observations |      |      |
|----------------------------------------------------------------------------|--------------|------|------|
|                                                                            | FA 7         | FA 8 | FA 9 |
| <b>Test 1</b><br>Add hydrogen peroxide.                                    |              |      |      |
| <b>Test 2</b><br>Add aqueous sodium hydroxide, then<br><br>leave to stand. |              |      |      |
| <b>Test 3</b><br>Add aqueous iron(II) sulfate.                             |              |      |      |

[4]

- (ii) Suggest the identity of the metal in FA 6/FA 7, FA 8 and FA 9.

The metal is .....

[1]

- (iii) Complete Table 3.3 to suggest the oxidation state of the metal in FA 6/FA 7 and FA 8.

Table 3.3

|                 | FA 6/FA 7 | FA 8 |
|-----------------|-----------|------|
| oxidation state |           |      |

[1]

[Total: 15]

**Qualitative analysis notes****1 Reactions of 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) | no ppt.<br>ammonia produced on warming                                       | –                                                                            |
| barium, Ba <sup>2+</sup> (aq)               | faint white ppt. is observed unless [Ba <sup>2+</sup> (aq)] is very low      | no ppt.                                                                      |
| calcium, Ca <sup>2+</sup> (aq)              | white ppt. unless [Ca <sup>2+</sup> (aq)] is very low                        | 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                                           | pale 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                                                 |

**2 Reactions of anions**

| anion                                                         | reaction                                                                                                                                     |
|---------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| carbonate, CO <sub>3</sub> <sup>2-</sup>                      | CO <sub>2</sub> liberated by dilute acids                                                                                                    |
| chloride, Cl <sup>-</sup> (aq)                                | gives white ppt. with Ag <sup>+</sup> (aq) (soluble in NH <sub>3</sub> (aq))                                                                 |
| bromide, Br <sup>-</sup> (aq)                                 | gives cream/off-white ppt. with Ag <sup>+</sup> (aq) (partially soluble in NH <sub>3</sub> (aq))                                             |
| iodide, I <sup>-</sup> (aq)                                   | gives pale yellow ppt. with Ag <sup>+</sup> (aq) (insoluble in NH <sub>3</sub> (aq))                                                         |
| nitrate, NO <sub>3</sub> <sup>-</sup> (aq)                    | NH <sub>3</sub> liberated on heating with OH <sup>-</sup> (aq) and Al foil                                                                   |
| nitrite, NO <sub>2</sub> <sup>-</sup> (aq)                    | NH <sub>3</sub> liberated on heating with OH <sup>-</sup> (aq) and Al foil;<br>decolourises acidified aqueous KMnO <sub>4</sub>              |
| sulfate, SO <sub>4</sub> <sup>2-</sup> (aq)                   | gives white ppt. with Ba <sup>2+</sup> (aq) (insoluble in excess dilute strong acids);<br>gives white ppt. with high [Ca <sup>2+</sup> (aq)] |
| sulfite, SO <sub>3</sub> <sup>2-</sup> (aq)                   | gives white ppt. with Ba <sup>2+</sup> (aq) (soluble in excess dilute strong acids);<br>decolourises acidified aqueous KMnO <sub>4</sub>     |
| thiosulfate, S <sub>2</sub> O <sub>3</sub> <sup>2-</sup> (aq) | gives off-white/pale yellow ppt. slowly with H <sup>+</sup>                                                                                  |

**3 Tests for gases**

| gas                             | test and test result              |
|---------------------------------|-----------------------------------|
| ammonia, NH <sub>3</sub>        | turns damp red litmus paper blue  |
| carbon dioxide, CO <sub>2</sub> | gives a white ppt. with limewater |
| hydrogen, H <sub>2</sub>        | 'pops' with a lighted splint      |
| oxygen, O <sub>2</sub>          | relights a glowing splint         |

- 3 (a) (i)** To a 1 cm depth of **FB 4** in a boiling tube, slowly add a 1 cm depth of dilute nitric acid. Stir gently until the reaction is complete. Use this solution for your tests. Select reagents to identify which sodium halide is present. Record details of the reagents used and your observations. Identify the sodium halide that is present as an impurity in **FB 4**.

The formula of the impurity is .....

[2]

- (ii)** Suggest why it is necessary to add the nitric acid to **FB 4** before carrying out your tests in **(a)(i)**.

.....

..... [1]

(b) **FB 7** contains a metal cation which is listed in the Qualitative analysis notes.

- (i) Place half the sample of **FB 7** in a hard-glass test-tube. Heat gently at first and then more strongly.  
Record your observations.

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

- (ii) Use the 25 cm<sup>3</sup> measuring cylinder to measure 20 cm<sup>3</sup> of **FB 1**.  
Place the remaining sample of **FB 7** in a boiling tube and add portions of **FB 1** from the measuring cylinder until all the **FB 7** has reacted. Stir until the reaction is complete.  
Record your observations.

Keep this solution for use in (b)(iii).

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

- (iii) Carry out the following tests. For each test use a 1 cm depth of the solution from (b)(ii) in a test-tube.  
Record your observations in Table 3.1.  
Identify the metal ion present in **FB 7**.

Table 3.1

| test                                            | observations |
|-------------------------------------------------|--------------|
| <b>Test 1</b><br>Add aqueous sodium hydroxide.  |              |
| <b>Test 2</b><br>Add aqueous ammonia.           |              |
| <b>Test 3</b><br>Add a piece of aluminium foil. |              |

The formula of the metal ion in **FB 7** is .....

(c) **FB 8** is an acidified aqueous solution containing a metal cation which is listed in the Qualitative analysis notes.

- (i) Carry out the following tests. For each test use a 1 cm depth of **FB 8** in a test-tube.  
Record your observations in Table 3.2.  
Identify the metal ion present in **FB 8**.

Table 3.2

| test                                                                             | observations |
|----------------------------------------------------------------------------------|--------------|
| <b>Test 1</b><br>Add aqueous sodium hydroxide.                                   |              |
| <b>Test 2</b><br>Add a 1 cm depth of acidified aqueous potassium manganate(VII). |              |

The formula of the metal ion in **FB 8** is .....

[3]

- (ii) State the type of reaction between the metal ion in **FB 8** and acidified aqueous potassium manganate(VII).  
Explain how your observations support your answer.

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

[Total: 15]

## Qualitative analysis notes

## 1 Reactions of 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) | no ppt.<br>ammonia produced on warming                                          | –                                                                               |
| barium, Ba <sup>2+</sup> (aq)               | faint white ppt. is observed unless [Ba <sup>2+</sup> (aq)] is very low         | no ppt.                                                                         |
| calcium, Ca <sup>2+</sup> (aq)              | white ppt. unless [Ca <sup>2+</sup> (aq)] is very low                           | 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                                              | pale blue ppt. soluble in excess giving dark blue solution                      |
| iron(II), Fe <sup>2+</sup> (aq)             | green ppt. turning brown on contact with air<br>insoluble in excess             | green ppt. turning brown on contact with air<br>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<br>insoluble in excess | off-white ppt. rapidly turning brown on contact with air<br>insoluble in excess |
| zinc, Zn <sup>2+</sup> (aq)                 | white ppt. soluble in excess                                                    | white ppt. soluble in excess                                                    |

## 2 Reactions of anions

| anion                                                         | reaction                                                                                                                                     |
|---------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| carbonate, CO <sub>3</sub> <sup>2-</sup>                      | CO <sub>2</sub> liberated by dilute acids                                                                                                    |
| chloride, Cl <sup>-</sup> (aq)                                | gives white ppt. with Ag <sup>+</sup> (aq) (soluble in NH <sub>3</sub> (aq))                                                                 |
| bromide, Br <sup>-</sup> (aq)                                 | gives cream/off-white ppt. with Ag <sup>+</sup> (aq) (partially soluble in NH <sub>3</sub> (aq))                                             |
| iodide, I <sup>-</sup> (aq)                                   | gives pale yellow ppt. with Ag <sup>+</sup> (aq) (insoluble in NH <sub>3</sub> (aq))                                                         |
| nitrate, NO <sub>3</sub> <sup>-</sup> (aq)                    | NH <sub>3</sub> liberated on heating with OH <sup>-</sup> (aq) and Al foil                                                                   |
| nitrite, NO <sub>2</sub> <sup>-</sup> (aq)                    | NH <sub>3</sub> liberated on heating with OH <sup>-</sup> (aq) and Al foil;<br>decolourises acidified aqueous KMnO <sub>4</sub>              |
| sulfate, SO <sub>4</sub> <sup>2-</sup> (aq)                   | gives white ppt. with Ba <sup>2+</sup> (aq) (insoluble in excess dilute strong acids);<br>gives white ppt. with high [Ca <sup>2+</sup> (aq)] |
| sulfite, SO <sub>3</sub> <sup>2-</sup> (aq)                   | gives white ppt. with Ba <sup>2+</sup> (aq) (soluble in excess dilute strong acids);<br>decolourises acidified aqueous KMnO <sub>4</sub>     |
| thiosulfate, S <sub>2</sub> O <sub>3</sub> <sup>2-</sup> (aq) | gives off-white / pale yellow ppt. slowly with H <sup>+</sup>                                                                                |

## 3 Tests for gases

| gas                             | test and test result              |
|---------------------------------|-----------------------------------|
| ammonia, NH <sub>3</sub>        | turns damp red litmus paper blue  |
| carbon dioxide, CO <sub>2</sub> | gives a white ppt. with limewater |
| hydrogen, H <sub>2</sub>        | 'pops' with a lighted splint      |
| oxygen, O <sub>2</sub>          | relights a glowing splint         |

- 3 (a) (i) **FB 6, FB 7** and **FB 8** are aqueous solutions of different compounds that each contain at least one oxygen atom.

Carry out the following tests and record your observations in Table 3.1. Three of the tests have been done for you. Use a 1 cm depth of solution in a test-tube for each test.

Table 3.1

| test                                                                 | observations |            |            |
|----------------------------------------------------------------------|--------------|------------|------------|
|                                                                      | FB 6         | FB 7       | FB 8       |
| <b>Test 1</b><br>Add a small spatula measure of manganese(IV) oxide. | No change.   | No change. |            |
| <b>Test 2</b><br>Add a 1 cm length of magnesium.                     |              |            | No change. |
| <b>Test 3</b><br>Add a few drops of aqueous iron(II) sulfate.        |              |            |            |

- (ii) Use your observations in Table 3.1 to suggest a possible formula for each of **FB 6**, **FB 7** and **FB 8**.

**FB 6** .....

**FB 7** .....

**FB 8** .....

[2]

- (b) **FB 9** contains two anions and two cations, three of which are listed in the Qualitative analysis notes.

- (i) To a small spatula measure of **FB 9** in a test-tube, add a 2 cm depth of dilute nitric acid. Record your observations.

**Keep the resulting solution for the test in (b)(ii).**

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

- (ii) To the solution from (b)(i), add a few drops of aqueous silver nitrate. Then add excess aqueous ammonia. Record your observations.

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

- (iii) Make an aqueous solution of **FB 9** by adding a 5 cm depth of distilled water to a spatula measure of **FB 9** in a test-tube. Carry out the following tests on the aqueous solution of **FB 9** and record your observations in Table 3.2.

**Table 3.2**

| <i>test</i>                                                                                                                                                                                                       | <i>observations</i> |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|
| <b>Test 1</b><br>To a 1 cm depth in a boiling tube, add aqueous sodium hydroxide, then warm.                                                                                                                      |                     |
| <b>Test 2</b><br>To a 1 cm depth in a test-tube, add a few drops of dilute hydrochloric acid, then add a few drops of aqueous chlorine.<br><b>Empty and rinse the test-tube with water immediately after use.</b> |                     |

[2]

- (iv) Use your observations in (b)(i), (b)(ii) and Table 3.2 to deduce the formulae of the cations and anions in **FB 9**. If you are unable to identify an ion, write 'unknown'.

cations ..... and .....

anions ..... and .....

[2]

- (v) Write an ionic equation for the reaction in (b)(ii). Include state symbols.

..... [1]

[Total:14]

**Qualitative analysis notes****1 Reactions of 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) | no ppt.<br>ammonia produced on warming                                          | –                                                                               |
| barium, Ba <sup>2+</sup> (aq)               | faint white ppt. is observed unless [Ba <sup>2+</sup> (aq)] is very low         | no ppt.                                                                         |
| calcium, Ca <sup>2+</sup> (aq)              | white ppt. unless [Ca <sup>2+</sup> (aq)] is very low                           | 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                                              | pale blue ppt. soluble in excess giving dark blue solution                      |
| iron(II), Fe <sup>2+</sup> (aq)             | green ppt. turning brown on contact with air<br>insoluble in excess             | green ppt. turning brown on contact with air<br>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<br>insoluble in excess | off-white ppt. rapidly turning brown on contact with air<br>insoluble in excess |
| zinc, Zn <sup>2+</sup> (aq)                 | white ppt. soluble in excess                                                    | white ppt. soluble in excess                                                    |

**2 Reactions of anions**

| anion                                                         | reaction                                                                                                                                     |
|---------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| carbonate, CO <sub>3</sub> <sup>2-</sup>                      | CO <sub>2</sub> liberated by dilute acids                                                                                                    |
| chloride, Cl <sup>-</sup> (aq)                                | gives white ppt. with Ag <sup>+</sup> (aq) (soluble in NH <sub>3</sub> (aq))                                                                 |
| bromide, Br <sup>-</sup> (aq)                                 | gives cream/off-white ppt. with Ag <sup>+</sup> (aq) (partially soluble in NH <sub>3</sub> (aq))                                             |
| iodide, I <sup>-</sup> (aq)                                   | gives pale yellow ppt. with Ag <sup>+</sup> (aq) (insoluble in NH <sub>3</sub> (aq))                                                         |
| nitrate, NO <sub>3</sub> <sup>-</sup> (aq)                    | NH <sub>3</sub> liberated on heating with OH <sup>-</sup> (aq) and Al foil                                                                   |
| nitrite, NO <sub>2</sub> <sup>-</sup> (aq)                    | NH <sub>3</sub> liberated on heating with OH <sup>-</sup> (aq) and Al foil;<br>decolourises acidified aqueous KMnO <sub>4</sub>              |
| sulfate, SO <sub>4</sub> <sup>2-</sup> (aq)                   | gives white ppt. with Ba <sup>2+</sup> (aq) (insoluble in excess dilute strong acids);<br>gives white ppt. with high [Ca <sup>2+</sup> (aq)] |
| sulfite, SO <sub>3</sub> <sup>2-</sup> (aq)                   | gives white ppt. with Ba <sup>2+</sup> (aq) (soluble in excess dilute strong acids);<br>decolourises acidified aqueous KMnO <sub>4</sub>     |
| thiosulfate, S <sub>2</sub> O <sub>3</sub> <sup>2-</sup> (aq) | gives off-white/pale yellow ppt. slowly with H <sup>+</sup>                                                                                  |

**3 Tests for gases**

| gas                             | test and test result              |
|---------------------------------|-----------------------------------|
| ammonia, NH <sub>3</sub>        | turns damp red litmus paper blue  |
| carbon dioxide, CO <sub>2</sub> | gives a white ppt. with limewater |
| hydrogen, H <sub>2</sub>        | 'pops' with a lighted splint      |
| oxygen, O <sub>2</sub>          | relights a glowing splint         |