**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.

[5]

**(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 (✗) if the species is **not** present.

**Table 3.1**

| | |
|---|---|
| $Zn^{2+}$ | |
| $SO_4^{2-}$ | |
| $H_2O$ | |

[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** |
| **Test 1**<br>Add hydrogen peroxide. | | | |
| **Test 2**<br>Add aqueous sodium hydroxide, then | | | |
| leave to stand. | | | |
| **Test 3**<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)** | **$NH_3$(aq)** |
| aluminium, $Al^{3+}$(aq) | white ppt. soluble in excess | white ppt. insoluble in excess |
| ammonium, $NH_4^+$(aq) | no ppt.<br>ammonia produced on warming | – |
| barium, $Ba^{2+}$(aq) | faint white ppt. is observed unless [$Ba^{2+}$(aq)] is very low | no ppt. |
| calcium, $Ca^{2+}$(aq) | white ppt. unless [$Ca^{2+}$(aq)] is very low | 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 | pale blue ppt. soluble in excess giving dark blue solution |
| iron(II), $Fe^{2+}$(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), $Fe^{3+}$(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<br>insoluble in excess | off-white ppt. rapidly turning brown on contact with air<br>insoluble in excess |
| zinc, $Zn^{2+}$(aq) | white ppt. soluble in excess | white ppt. soluble in excess |

### 2 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 cream / off-white ppt. with $Ag^+$(aq) (partially soluble in $NH_3$(aq)) |
| iodide, $I^-$(aq) | gives pale 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;<br>decolourises acidified aqueous $KMnO_4$ |
| sulfate, $SO_4^{2-}$(aq) | gives white ppt. with $Ba^{2+}$(aq) (insoluble in excess dilute strong acids);<br>gives white ppt. with high [$Ca^{2+}$(aq)] |
| sulfite, $SO_3^{2-}$(aq) | gives white ppt. with $Ba^{2+}$(aq) (soluble in excess dilute strong acids);<br>decolourises acidified aqueous $KMnO_4$ |
| thiosulfate, $S_2O_3^{2-}$(aq) | gives off-white / pale yellow ppt. slowly with $H^+$ |

## 3 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 |
| hydrogen, $H_2$ | 'pops' with a lighted splint |
| oxygen, $O_2$ | relights a glowing splint |



**3** Half-fill the 250 $cm^3$ beaker with water and place it on a tripod and gauze. Heat the water until boiling then switch off your Bunsen burner. This will be your hot water bath for use in **(b)(i)**. Start **(a)(i)** while the water is heating.

**(a)** **FA 4** is an aqueous solution containing three ions. One ion is **not** listed in the Qualitative analysis notes. **FA 5** is an aqueous solution containing two ions. The cation in **FA 5** is listed in the Qualitative analysis notes. The anions in both **FA 4** and **FA 5** contain sulfur.

**(i)** Carry out the following tests using a 1 cm depth of either **FA 4** or **FA 5** in a test-tube. Record your observations in Table 3.1.

**Table 3.1**

| *test* | *observations* | |
|---|---|---|
| | **FA 4** | **FA 5** |
| **Test 1**<br>Add aqueous<br>sodium hydroxide. | | |
| **Test 2**<br>Add aqueous ammonia. | | |
| **Test 3**<br>Add aqueous<br>sodium carbonate. | | |
| **Test 4**<br>Add aqueous barium chloride<br>or aqueous barium nitrate. | | |
| **Test 5**<br>Add acidified aqueous<br>potassium manganate(VII). | | |

[5]

**(ii)** From your observations in **(a)(i)**, deduce the identities of the ions present in **FA 4** and **FA 5**. Give the formula of each ion in Table 3.2. If you are unable to identify an ion write 'unknown'.

**Table 3.2**

| *ions present* | **FA 4** | **FA 5** |
|---|---|---|
| cations | | |
| anions | | |

[3]

**(b) (i)** Both **FA 6** and **FA 7** are one of propan-1-ol, propan-2-ol, methanoic acid or ethanoic acid. You will carry out tests to investigate the identities of **FA 6** and **FA 7**. For each test use a 1 cm depth of **FA 6** or **FA 7** in a test-tube. Record your observations in Table 3.3.

**Table 3.3**

| *test* | *observations* | |
|---|---|---|
| | **FA 6** | **FA 7** |
| **Test 1**<br>Add a few drops of acidified aqueous potassium manganate(VII), then | | |
| place the test-tube in the hot water bath. | | |
| **Test 2**<br>Add a 2 cm depth of aqueous iodine followed by drops of aqueous sodium hydroxide until the colour just disappears. | | |
| If no reaction is visible, place the test-tube in the hot water bath. | | |
| **Test 3**<br>Add aqueous sodium carbonate. | | |

[3]

**(ii)** From your observations in **(b)(i)** deduce the identities of **FA 6** and **FA 7**. Give reasons for your answers.

**FA 6** is .....

reasons .....

.....

**FA 7** is .....

reasons .....

.....

[2]

**(c)** A student carrying out a similar set of tests identifies two unknown compounds to be ethanol and propanoic acid.

Write an equation for the reaction between these two compounds.

..... [1]

[Total: 14]

## Qualitative analysis notes

### 1 Reactions of 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) | no ppt.<br>ammonia produced on warming | – |
| barium, $Ba^{2+}$(aq) | faint white ppt. is observed unless [$Ba^{2+}$(aq)] is very low | no ppt. |
| calcium, $Ca^{2+}$(aq) | white ppt. unless [$Ca^{2+}$(aq)] is very low | 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 | pale blue ppt. soluble in excess giving dark blue solution |
| iron(II), $Fe^{2+}$(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), $Fe^{3+}$(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<br>insoluble in excess | off-white ppt. rapidly turning brown on contact with air<br>insoluble in excess |
| zinc, $Zn^{2+}$(aq) | white ppt. soluble in excess | white ppt. soluble in excess |

### 2 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 cream / off-white ppt. with $Ag^+$(aq) (partially soluble in $NH_3$(aq)) |
| iodide, $I^-$(aq) | gives pale 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;<br>decolourises acidified aqueous $KMnO_4$ |
| sulfate, $SO_4^{2-}$(aq) | gives white ppt. with $Ba^{2+}$(aq) (insoluble in excess dilute strong acids);<br>gives white ppt. with high [$Ca^{2+}$(aq)] |
| sulfite, $SO_3^{2-}$(aq) | gives white ppt. with $Ba^{2+}$(aq) (soluble in excess dilute strong acids);<br>decolourises acidified aqueous $KMnO_4$ |
| thiosulfate, $S_2O_3^{2-}$(aq) | gives off-white/pale yellow ppt. slowly with $H^+$ |

## 3 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 |
| hydrogen, $H_2$ | 'pops' with a lighted splint |
| oxygen, $O_2$ | 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 $cm^3$ measuring cylinder to measure 20 $cm^3$ 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* |
|---|---|
| **Test 1**<br>Add aqueous sodium hydroxide. | |
| **Test 2**<br>Add aqueous ammonia. | |
| **Test 3**<br>Add a piece of aluminium foil. | |

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

[4]

**(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* |
|---|---|
| **Test 1**<br>Add aqueous sodium hydroxide. | |
| **Test 2**<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)** | **$NH_3$(aq)** |
| aluminium, $Al^{3+}$(aq) | white ppt. soluble in excess | white ppt. insoluble in excess |
| ammonium, $NH_4^+$(aq) | no ppt.<br>ammonia produced on warming | – |
| barium, $Ba^{2+}$(aq) | faint white ppt. is observed unless [$Ba^{2+}$(aq)] is very low | no ppt. |
| calcium, $Ca^{2+}$(aq) | white ppt. unless [$Ca^{2+}$(aq)] is very low | 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 | pale blue ppt. soluble in excess giving dark blue solution |
| iron(II), $Fe^{2+}$(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), $Fe^{3+}$(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<br>insoluble in excess | off-white ppt. rapidly turning brown on contact with air<br>insoluble in excess |
| zinc, $Zn^{2+}$(aq) | white ppt. soluble in excess | white ppt. soluble in excess |

### 2 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 cream / off-white ppt. with $Ag^+$(aq) (partially soluble in $NH_3$(aq)) |
| iodide, $I^-$(aq) | gives pale 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;<br>decolourises acidified aqueous $KMnO_4$ |
| sulfate, $SO_4^{2-}$(aq) | gives white ppt. with $Ba^{2+}$(aq) (insoluble in excess dilute strong acids);<br>gives white ppt. with high [$Ca^{2+}$(aq)] |
| sulfite, $SO_3^{2-}$(aq) | gives white ppt. with $Ba^{2+}$(aq) (soluble in excess dilute strong acids);<br>decolourises acidified aqueous $KMnO_4$ |
| thiosulfate, $S_2O_3^{2-}$(aq) | gives off-white / pale yellow ppt. slowly with $H^+$ |

## 3 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 |
| hydrogen, $H_2$ | 'pops' with a lighted splint |
| oxygen, $O_2$ | relights a glowing splint |



**5** **(a)** Copper shows typical properties of transition elements, including its behaviour as a catalyst.

Complete Table 5.1 to show the total number of **unpaired** electrons in the 3d and 4s orbitals of an isolated gaseous Cu atom and a $Cu^{2+}$ ion.

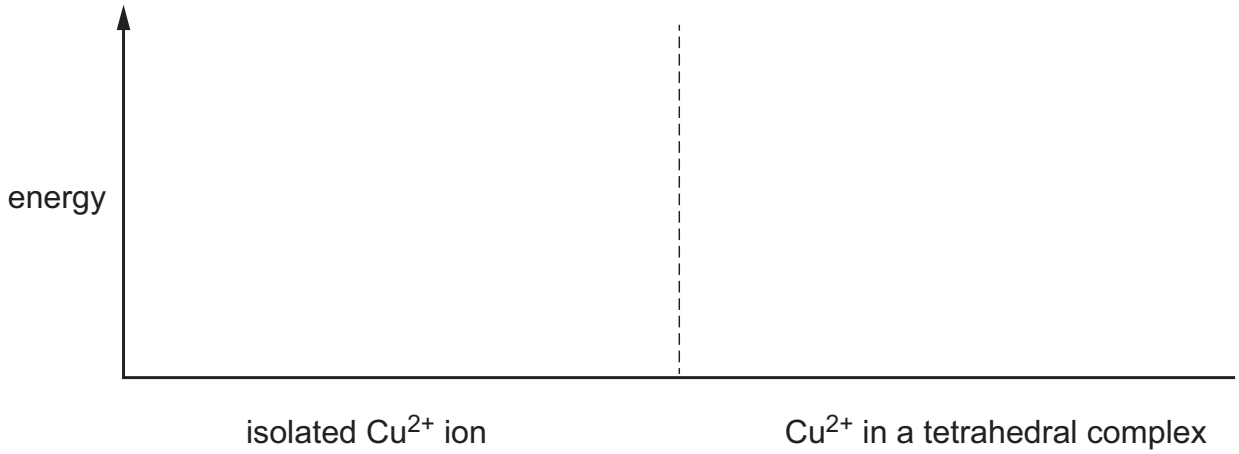
**Table 5.1**

| species | number of **unpaired** electrons | |
|---|---|---|
| | 3d | 4s |
| Cu | | |
| $Cu^{2+}$ | | |

[1]

**(b)** The 3d orbitals in an isolated $Cu^{2+}$ ion are degenerate.

Complete the diagram to show the relative energies of the 3d orbitals in an isolated $Cu^{2+}$ ion and in $Cu^{2+}$ in a tetrahedral complex.




[2]

**(c)** Explain why transition elements behave as catalysts.

.....

.....

..... [2]

**(d)** $CN^-$ is a monodentate ligand.

Table 5.2 shows information about two complex ions that contain only $CN^-$ ions as ligands.

Complete Table 5.2.

**Table 5.2**

| metal ion | coordination number | formula of complex ion | charge of complex ion |
|---|---|---|---|
| $Ag^+$ | 2 | | |
| $Fe^{2+}$ | | | 4– |

[2]

**(e)** The complex ion $[Au(CN)_2Br_2]^-$ displays geometrical (cis / trans) isomerism.

Draw the structure of *trans*-$[Au(CN)_2Br_2]^-$. State its shape and the Br-Au-Br bond angle.

shape .....  Br-Au-Br bond angle = .....

[2]

**(f)** An impure sample of a vanadium(V) compound of mass 0.250 g is dissolved in aqueous acid. This solution contains $VO_3^-$ ions.

An excess of zinc is added to this solution. All the $VO_3^-$ ions are reduced to $V^{2+}$ ions and Zn atoms are oxidised to $Zn^{2+}$ ions.

The unreacted zinc is removed and the resulting solution is titrated with acidified $MnO_4^-$.

The end-point is reached when 22.5 $cm^3$ of 0.0750 mol $dm^{-3}$ $MnO_4^-$ is added.

A redox reaction takes place and all the $V^{2+}$ reacts forming $VO_3^-$.

$$3MnO_4^- + 5V^{2+} + 3H_2O \rightarrow 3Mn^{2+} + 5VO_3^- + 6H^+$$

**(i)** Calculate the percentage by mass of vanadium in the 0.250 g of impure sample.

Assume the impurities do not contain any vanadium ions.

Show your working.

percentage of vanadium = ..... [3]

**(ii)** Complete the equation for the reaction between acidified $VO_3^-$ ions and Zn metal.

..... $VO_3^-$ + ..... Zn + ..... → ..... $V^{2+}$ + ..... $Zn^{2+}$ + .....

[2]

[Total: 14]

**5** Cobalt is a transition element which forms compounds containing $Co^{2+}$ and $Co^{3+}$ ions. Cobalt(II) sulfate dissolves in water to form a solution containing the $[Co(H_2O)_6]^{2+}$ complex ion.

**(a) (i)** Complete the electronic configurations of a $Co^{2+}$ ion and a $Co^{3+}$ ion.

$Co^{2+}$ = [Ar] .....

$Co^{3+}$ = [Ar] .....

[1]

**(ii)** Explain why transition elements can form complex ions.

.....

..... [1]

**(iii)** An excess of concentrated HC*l* is added to a solution containing $[Co(H_2O)_6]^{2+}$.

Describe the colour change observed and the state of the cobalt-containing product.

The colour changes from ..... to ..... .

The state of the cobalt-containing product is ..... .

[2]

**(iv)** Write an equation for the reaction occurring in **(a)(iii)**.

..... [1]

**(v)** Name the type of reaction occurring in **(a)(iii)**.

..... [1]

**(vi)** Write an equation for the reaction that occurs when an excess of NaOH(aq) is added to a solution containing $[Co(H_2O)_6]^{2+}$.

..... [1]

**(b)** Cobalt metal can be oxidised by acidified $K_2Cr_2O_7$. The relevant half-equations, and their $E^\ominus$ values, are shown.

$$Co^{2+} + 2e^- \rightleftharpoons Co \qquad E^\ominus = -0.28\,V$$
$$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightleftharpoons 2Cr^{3+} + 7H_2O \qquad E^\ominus = +1.33\,V$$

**(i)** A $Co^{2+}/Co$ electrode is constructed in which $[Co^{2+}]$ is $0.020\,mol\,dm^{-3}$ at 298 K.

Use the Nernst equation to show that the $E$ value for this $Co^{2+}/Co$ electrode is –0.33 V.

[2]

**(ii)** An electrochemical cell is constructed using the $Co^{2+}/Co$ electrode described in **(b)(i)** and a $Cr_2O_7^{2-}/Cr^{3+}$ electrode in which all conditions are standard.

Calculate the value of $E_{cell}$.

$E_{cell}$ = ..... [1]

**(iii)** A current is drawn from the electrochemical cell described in **(b)(ii)**.

Write an equation for the reaction taking place in the cell.

..... [1]

**(iv)** Complete the sentences to identify the negative electrode and the direction of electron flow when a current is drawn from the cell described in **(b)(ii)**.

The ..... electrode is the negative electrode.

Electrons flow from the ..... electrode to the ..... electrode. [1]

**(c)** A molten $Co^{2+}$ salt is electrolysed using a current of 0.500 A.

0.547 g of cobalt metal forms at the cathode. Under the conditions used no other reduction reaction occurs at the cathode.

Calculate the time in minutes for which the current flows to produce this mass of cobalt.

Give your answer to **three** significant figures.

time = ..... min [3]



[Total: 15]

**1** **(a)** Define a transition element.

.....

.....

..... [1]

**(b)** The 3d orbitals in an isolated gaseous $Cu^{2+}$ ion are degenerate.

**(i)** Define the term degenerate.

.....

..... [1]

**(ii)** Complete the electronic configuration of $Cu^{2+}$.

$1s^2$ ..... [1]

**(c)** **(i)** State the colours of the aqueous solutions for the **two** copper(II) complex ions shown.

- $[Cu(NH_3)_4(H_2O)_2]^{2+}(aq)$ .....
- $[CuCl_4]^{2-}(aq)$ .....

[1]

**(ii)** Explain why aqueous complex ions of transition elements are usually coloured.

.....

.....

.....

.....

.....

..... [3]

**(d)** **(i)** When an excess of $NH_3(aq)$ is added to a solution of $[CuCl_4]^{2-}(aq)$, $[Cu(NH_3)_4(H_2O)_2]^{2+}(aq)$ is formed.

State the type of reaction.
Complete the equation for this reaction. State symbols are **not** required.

type of reaction .....

equation

$[CuCl_4]^{2-}$ + ..... ~~19~~ $[Cu(NH_3)_4(H_2O)_2]^{2+}$ + .....

[2]

**(ii)** The $[Cu(NH_3)_4(H_2O)_2]^{2+}$ complex ion shows stereoisomerism.

Complete the three-dimensional diagrams in Fig. 1.1 to show the **two** different stereoisomers of $[Cu(NH_3)_4(H_2O)_2]^{2+}$.

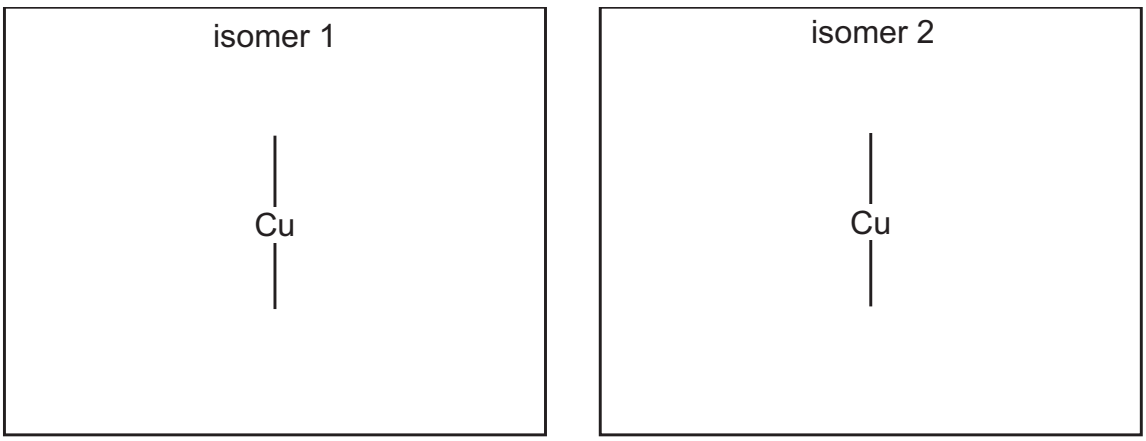



**Fig. 1.1**

[2]

**(iii)** Deduce which stereoisomer in **(d)(ii)** is polar.

Explain your answer.

polar isomer .....

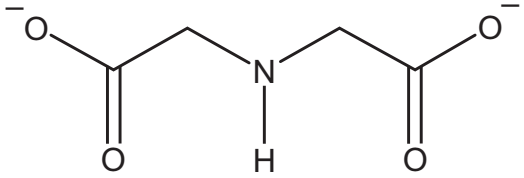
explanation .....

.....

[1]

**(e)** The dianion **P** can act as a tridentate ligand.

**P**




**(i)** Suggest how **P** can form **three** dative covalent bonds.

.....

.....

..... [1]

**(ii)** 2 moles of dianion **P**, $C_4H_5NO_4^{2-}$, react with 1 mole of aqueous cobalt(III) ions, $[Co(H_2O)_6]^{3+}$ to form 1 mole of complex ion **Q**.

Deduce the formula and charge of **Q**.

..... [1]

**(f)** Table 1.1 shows values for the stability constants, $K_{stab}$, of some silver(I) complexes.

**Table 1.1**

| complex | value of $K_{stab}$ |
|---|---|
| $[Ag(CN)_2]^-(aq)$ | $1.1 \times 10^{18}$ |
| $[Ag(NH_3)_2]^+(aq)$ | $1.2 \times 10^{7}$ |
| $[Ag(S_2O_3)_2]^{3-}(aq)$ | $2.9 \times 10^{13}$ |

**(i)** Define the stability constant of a complex.

.....

.....

..... [1]

**(ii)** Use the information in Table 1.1 to identify the most stable silver(I) complex.

Explain your answer.

most stable .....

explanation .....

.....

[1]

**(g)** Sodium sulfite, $Na_2SO_3$, is used as a food preservative.

A 3.75 g sample of impure $Na_2SO_3$ is dissolved in distilled water and made up to 250 $cm^3$ in a volumetric flask.

10.0 $cm^3$ of this solution requires 18.70 $cm^3$ of acidified 0.0150 mol $dm^{-3}$ $MnO_4^-(aq)$ to reach the end-point.

The equation for the reaction is shown.

$$2MnO_4^- + 5SO_3^{2-} + 6H^+ \rightarrow 2Mn^{2+} + 5SO_4^{2-} + 3H_2O$$

Calculate the percentage by mass of $Na_2SO_3$ in the sample.

percentage by mass of $Na_2SO_3$ = ..... [3]

[Total: 19]