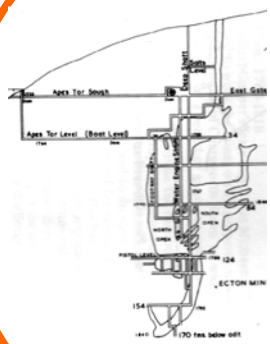
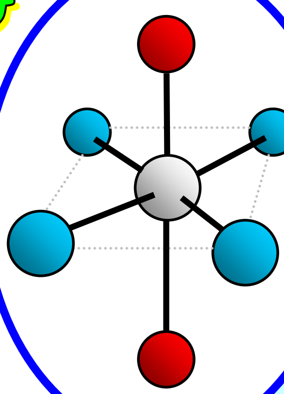
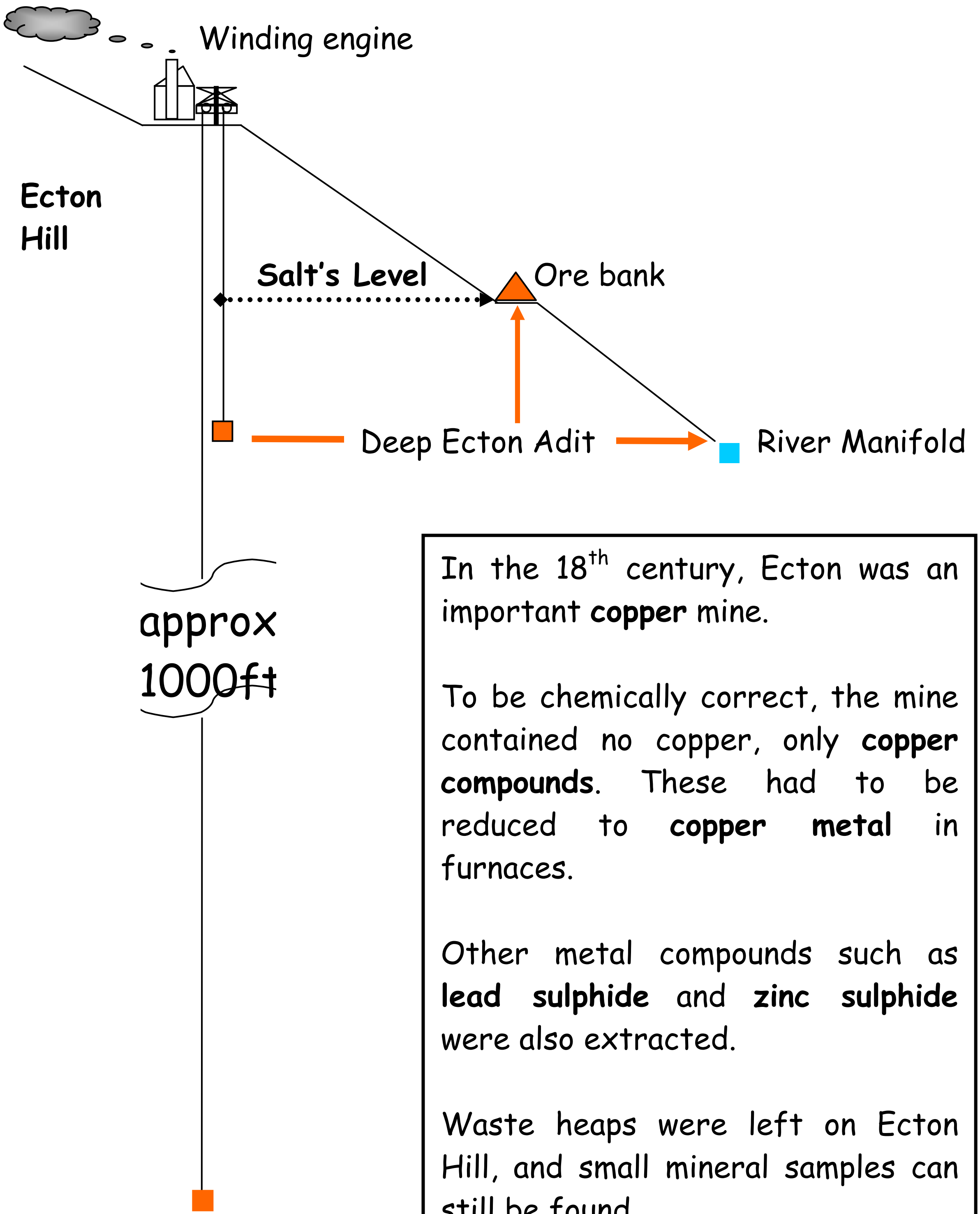
# G A Cox Educational Centre




# Minerals and Chemistry



# Introduction Ecton Mine




In the 18th century, Ecton was an important **copper** mine.

To be chemically correct, the mine contained no copper, only **copper compounds**. These had to be reduced to **copper metal** in furnaces.

Other metal compounds such as **lead sulphide** and **zinc sulphide** were also extracted.

Waste heaps were left on Ecton Hill, and small mineral samples can still be found.

The main ore is

**$CuS.FeS$**

**copper(II) iron(II) sulphide,**

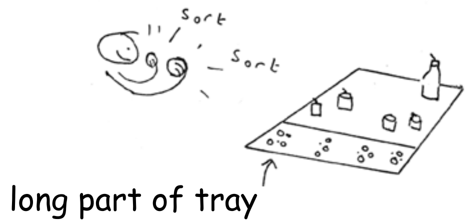
The ore was taken out of the mine via **Deep Ecton**.
Later, **Salt's Level** was used instead.

| Other | Ecton | Minerals |
|---|---|---|
| white | calcium carbonate | $CaCO_3$ |
| green | 'copper(II) carbonate' | $CuCO_3.Cu(OH)_2$ |
| blue | 'copper(II) carbonate' | $(CuCO_3)_2.Cu(OH)_2$ |
| brown | iron(III) oxide | $Fe_2O_3$ |
| silver | lead(II) sulphide | $PbS$ |

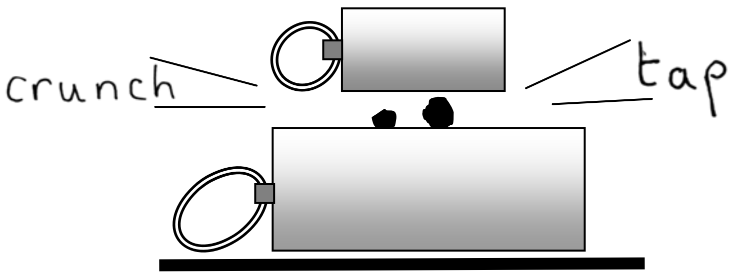
Minerals are also described by names such as
calcite, **chalcopyrite**, **malachite**, **azurite** and galena

The aim of the following experiments is to confirm the presence of the metal ions $Ca^{2+}$, $Cu^{2+}$, $Fe^{3+}$ and $Pb^{2+}$ in Ecton minerals.

# Sorting and crushing



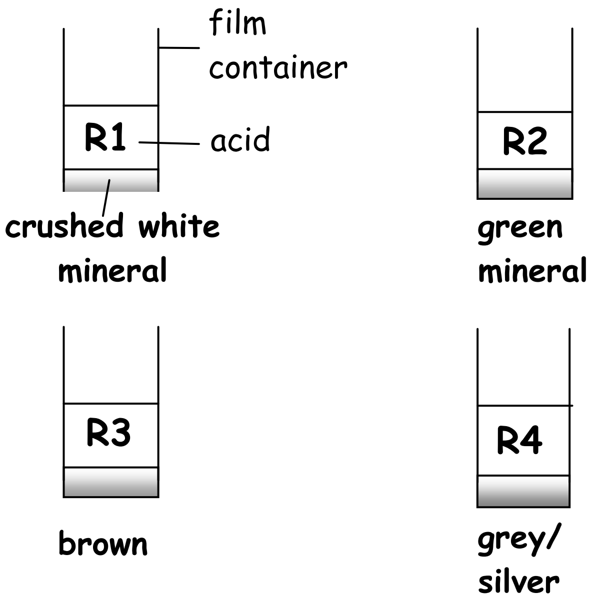

Put the minerals you have collected, into the long section of a plastic tray. Sort into white, green, brown and grey/silver pieces. Crush using the **sides** of two weights.




Wash four film containers with water. Half fill with **dilute nitric acid**, $HNO_3$.

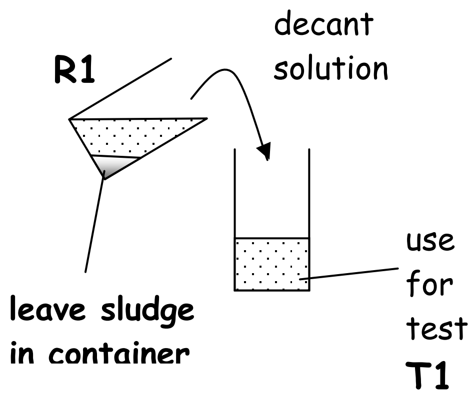
Add a crushed **mineral** to each as shown.

Each mineral reacts to give a solution containing a **metal nitrate**.

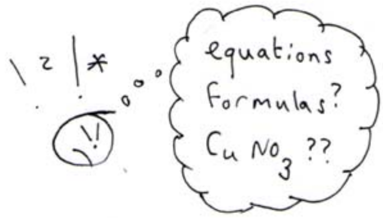



While you are waiting for the reactions to end, work out equations for **R1 to R4** (see the next page).

Pour the solution from R1 carefully into an empty film container.
Pour the solution from R2 into another empty film container.
Repeat for R3 and R4



# Equations for minerals + acid




**R1** $CaCO_3$ —dilute nitric acid→ $Ca(NO_3)_2$ colourless

**R2** $CuCO_3$ —$HNO_3$→ $Cu(NO_3)_2$

$CaCO_3$ + ………… → ………… + ………… + ……………

$CuCO_3$ + ………… → ………… + ………… + ……………

**R3** $Fe_2O_3$ —$HNO_3$→ $Fe(NO_3)_3$ almost colourless

$Fe_2O_3$ + ………… → ………… + ……………

Write an equation for the reaction between PbO and $HNO_3$
(This will be similar to the one for R3).

PbO + ………… → …. $Pb(NO_3)_2$ + ….……………

O and S are in group 6 of the Periodic Table,
so you can remove the O in PbO and replace with S.

**R4** PbS + ……………… → $Pb(NO_3)_2$ + ………………

# Testing for $Ca^{2+}(aq)$

Only test the liquid from R1 (i.e. acid + crushed white mineral).

## Test 1(a)

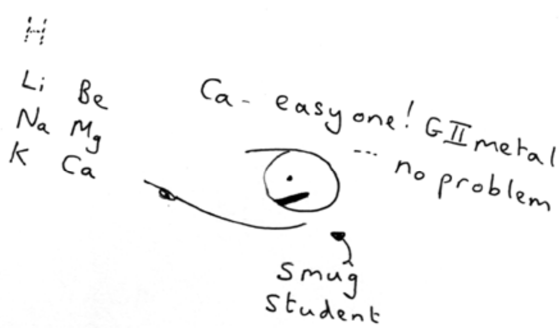
Put some of the solution from **R1** in a film container. Add **dilute sulphuric acid.** The reaction (if any) is slow.
Pouring from the film container to another and back again may help.
The reaction is not specific for calcium.
Lead ions will also give a reaction.

Result ........................................

## Test 1(b)

Put some of the solution from **R1** in a film container. Add **potassium ethanedioate** solution **(TOXIC)**. Stir to help the chemicals to mix. Pouring from the film container into another and back again is the easiest way to mix the solutions.

Result ........................................



# Equations for T1 $Ca^{2+}(aq)$

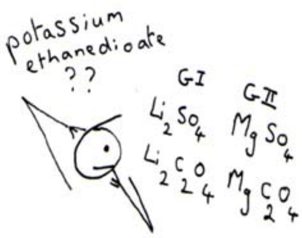
## T1(a) This is a simple precipitation reaction.

calcium nitrate + sulphuric acid ⟶ .................... + calcium sulphate

$Ca(NO_3)_2$ + $H_2SO_4$ ⟶ .................... + $CaSO_4$ (s)

$Ca^{2+}$ (aq) + $SO_4^{2-}$ (aq) ⟶ .................... (s)

## T1(b)




This is also a precipitation reaction. The equation is similar to **T1(a)**. Change sulphate, $SO_4^{2-}$

to ethanedioate, $C_2O_4^{2-}$ .

calcium nitrate + potassium ethanedioate ⟶ .................... + ....................

$Ca(NO_3)_2$ + .................... ⟶ .................... + ....................

$Ca^{2+}$ (aq) + .................... (aq) ⟶ .................... (s)

| | |
|---|---|
| Testing for $Cu^{2+}(aq)$ | Only test the liquid from **R2** (i.e. acid + crushed green mineral). |

## Test 2(a)

Put some of the solution from **R2** in a film container. Add **ammonia** solution. Remember that there will be nitric acid to neutralise before any other reaction can take place.

As ammonia solution is added, look for a colour change. Continue adding ammonia till the new colour is seen throughout the mixture.

You should now have a solution with a few bits of solid left. If the mixture still has a lot of solid in it – add more ammonia solution

**Result** ........................................

## Test 2(b)

Put some of the rest of the solution from **R2** in a film container. Add dilute sulphuric acid slowly until just acidic (pale blue). Add a piece of scrap metal. This should displace copper from solution.

How can you tell if this works? ........................................

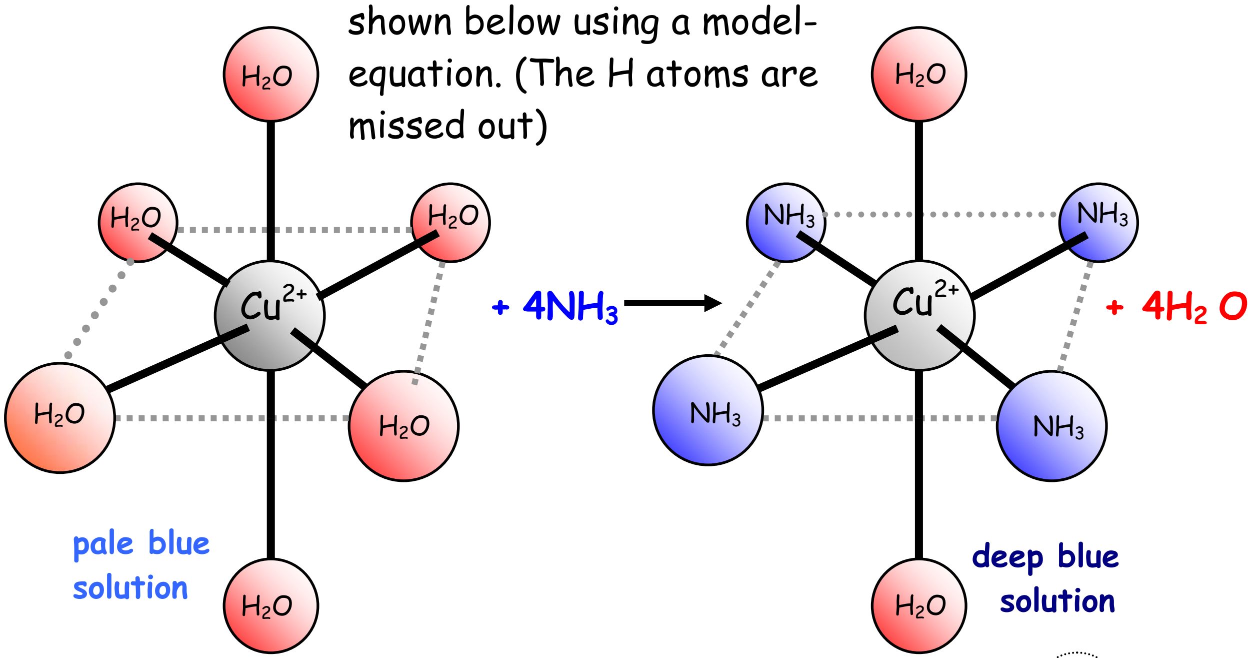
Can you recall the order of metals in the activity series?

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

# Equations for T2 $Cu^{2+}(aq)$

## T2(a)

The **replacement*** reaction is shown below using a model-equation. (The H atoms are missed out)




[ $Cu(H_2O\ )$ ] ◌ + $4NH_3$ ⟶ [ $Cu(H_2O)\ \ (NH_3)$ ] ◌ + $4H_2O$

Put the total + charge on the **outside** of each [ ] and no charges inside.

What happens in this replacement reaction?

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

## T2(b)

copper(II) ion + iron atom ⟶ copper atom + iron(II) ion

Rewrite in symbols: ........................................................................................................

** ligand substitution, replacement or displacement*

## Testing for $Fe^{3+}(aq)$

Only use the liquid from **R3** (i.e. crushed brown mineral).

## Test 3(a)

Put some of the solution from **R3** in a film container. Add a few drops of **potassium thiocyanate** solution.

The formula for potassium thiocyanate is KCNS or KSCN. It contains the negative ion $CNS^{-}$

Result ..............................................................................................

## Test 3(b)

Put some of the solution from **R3** in a film container. Add a few drops of **potassium hexacyanoferrate(II)** solution.

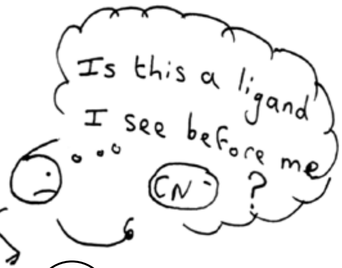
The formula for potassium hexacyanoferrate(II) is $K_4Fe(CN)_6$ It contains the **complex ion** $[Fe(CN)_6]^{4-}$

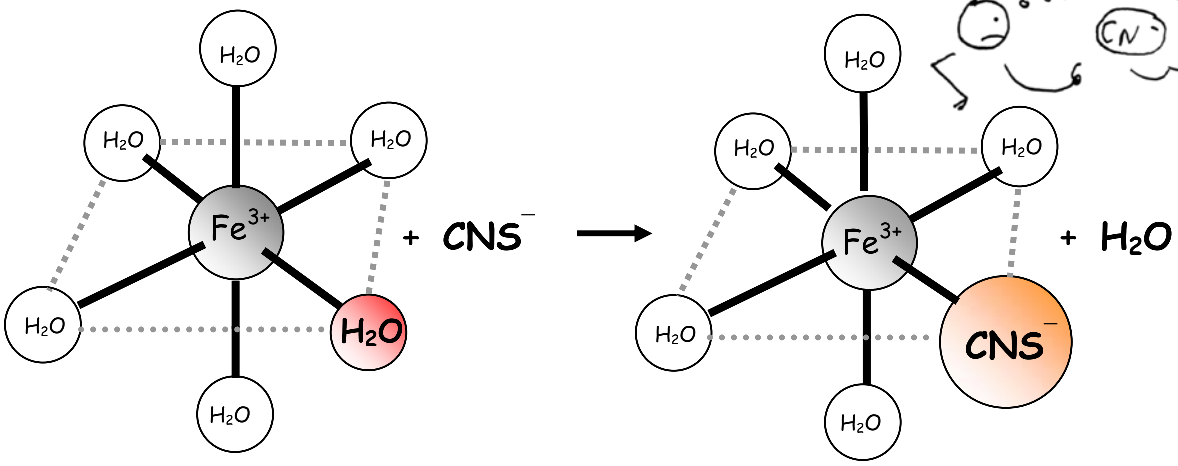
Result ..............................................................................................

# Equations for T3 $Fe^{3+}(aq)$

## T3(a)

The **replacement** reaction is shown below. A **$CNS^-$** ion displaces an **$H_2O$** molecule




**almost colourless complex ion** **deep blood-red**

[ Fe(         )     ] ◌ + CNS$^-$ ⟶ [ Fe(         )     CNS ] ◌ + $H_2O$

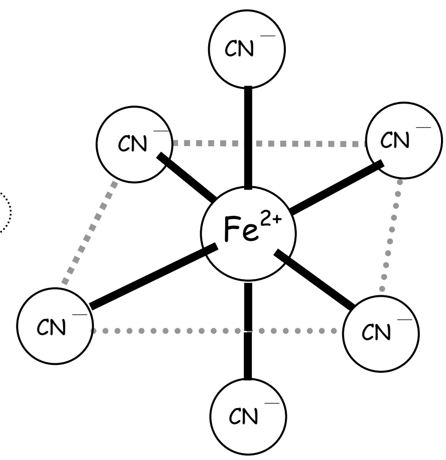
Finish the above ordinary equation.

Put +/- charges in a circle, not inside [ ]

## T3(b)

The hexacyano-ferrate(II) ion is shown in the drawing. Rewrite it as a formula for a complex ion.

[Fe (          )      ] ◌




KCN, which contains the $CN^-$ ion is **VERY TOXIC**. So why is it safe to use potassium hexacyanoferrate(II)?

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

**Testing for $Pb^{2+}(aq)$**

Only use the liquid from **R4** (i.e. acid + grey/silver mineral).

## Test 4(a)

Put some of the solution from **R4** in a film container.

Add a few drops of **potassium iodide** solution.


Result ..............................................................................................

## Test 4(b)

Put some of the solution from **R4** in a film container.

Add a few drops of **potassium chromate(VI)** solution.

**CARE!** Keep potassium chromate(VI) solution off your skin. Wash off quickly with water.

Result ..............................................................................................

# Equations for T4 $Pb^{2+}(aq)$

**T4(a)** This is a simple precipitation reaction.

lead nitrate + potassium iodide → .................. + ..................

.................. + KI(aq) → .................. + ..................

$Pb^{2+}(aq) + I^{-}(aq) \longrightarrow$ .................. (s)

**T4(b)** This is also a precipitation reaction.

lead nitrate + potassium chromate(VI) → .................. + ..................

.................. + $K_2CrO_4(aq)$ → .................. + ..................

$Pb^{2+}(aq) + CrO_4^{2-}(aq) \longrightarrow$ .................. (s)

# Complex ions

$Cu^{2+}(aq)$ / $Cl^-(aq)$
$Co^{2+}(aq)$ / $Cl^-(aq)$

**T5(a)** Add solid sodium chloride or **(demonstration)** concentrated hydrochloric acid to copper(II) sulphate solution. Chloride ions replace the water molecules.

$$[Cu(H_2O)_6]^{2+} + 4Cl^- \rightleftharpoons [CuCl_4]^{2-} + 6H_2O$$

**pale blue**
octahedral
complex ion

colour................
shape ................

What happens when water is added?

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

**T5(b)** A similar demonstration uses cobalt(II) chloride solution and concentrated hydrochloric acid.
Again, chloride ions replace the water molecules..

$$[Co(H_2O)_6]^{2+} + 4Cl^- \rightleftharpoons [CoCl_4]^{2-} + 6H_2O$$

**rose/pink**
octahedral
complex ion

colour..............
shape ..............

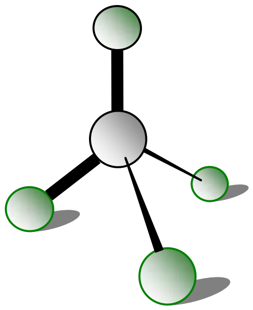
What happens when water is added?

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

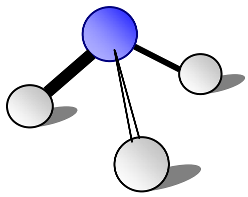
What happens when the mixture is heated?.............................

Explain................................................................................................

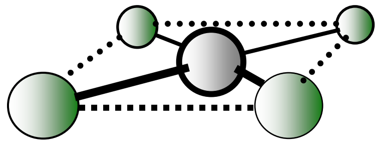
# Complex ions — Ligands and Shapes



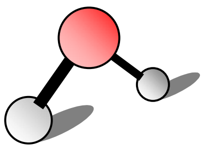
tetrahedral



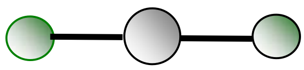
3-sided pyramid



square-planar



non-linear



linear

Try to complete the table of complex ions, shown below. Sometimes, more than one shape may be possible for an ion.

| Metal ion | Ligands | Formula of complex ion | Possible shape of complex ion |
|---|---|---|---|
| Fe(II) | $6CN^-$ | $[Fe(CN)_6]^{4-}$ | octahedral |
| Fe(III) | $6CN^-$ | [ ] | |
| Cu(II) | $4Cl^-$ | | |
| Cu(I) | $2Cl^-$ | | |
| Ce( ) | $6NO_3^-$ | $[Ce(NO_3)_6]^{2-}$ | |
| Pt( ) | $4Cl^-$ | $PtCl_4^{2-}$ | |