ECTON HILL

From Minerals…

to Chemistry…

Field Studies Association

From minerals…

Minerals: chemical compounds - and the occasional free element - occurring naturally in the Earth's crust.

Over 3000 minerals are known - not including the components of oil. Of these, some 300 are common enough, or of sufficient economic value, to be considered as important.

An **ore** is any mass of minerals that can be worked profitably.

Rocks are simply mixtures of minerals formed in various ways.

to Chemistry…

Minerals are almost all **ionic compounds**. That is, they are formed of atoms, or groups of atoms, carrying electrical charges.

Cations have one, two or three **positive** charges.

Most cations are single atoms of a metallic element, e.g. Na^+, Mg^{2+}, Al^{3+}. The charge is often the same as the number of the group in the Periodic Table where the element is found:

Group 1 (alkali metals): M^+.

Group 2 (alkaline earth metals): M^{2+}.

Group 3: M^{3+}

In addition the hydrogen ion is often given as H^+.

If a metal can form more than one cation, then its **oxidation number** is included in its name; this gives the number of charges:

e.g. Fe^{2+} is iron(II), while Fe^{3+} is iron(III);

and Cu^+ is copper(I), while Cu^{2+} is copper (II).

Anions have one, two, three or four **negative** charges.

Some anions are atoms of one non-metallic element; their names end in -ide (e.g. sulphide, S^{2-}). The charge is again often related to the group number in the Periodic Table, but this time as (8 - group number):

Group 6 (chalcogens): oxide, O^{2-}, sulphide, S^{2-}.

Group 7 (halogens): F^-, Cl^-, Br^-, I^-.

Other anions are groups of atoms of more than one element; their names often end in –ate:

e.g. carbonate, CO_2^{2-} nitrate, NO_3^{2-} sulphate, SO_4^{2-}

The Periodic Table in the Ground!

What compounds are likely to occur as minerals?

You need a good knowledge of the Periodic Table to recognise which chemical elements and compounds you are likely to find occurring naturally as minerals in the rocks.

Some guiding principles:

1. Most elements are too reactive to occur naturally, and the unreactive ones are too rare, so you are unlikely to find free elements.
2. Almost all minerals are insoluble in water. You are unlikely to find minerals that are soluble in water **unless** they have been formed by evaporation of solutions in a hot dry climate, and then buried under more sediment to keep them away from later weathering.

So it is useful to have general rules of which compounds are soluble, and which are insoluble. Refer to the following as you need them - **no need to read them in detail now**.

Group 1: **alkali metal compounds** with simple anions: all **soluble** with rare exceptions.

Group 2: alkaline earth metal ions form:

soluble compounds with anions of charge 1^-, including OH^-

insoluble compounds with anions of higher charge (2^- and 3^-)

important exceptions:

fluorides (F^-) are insoluble

$MgSO_4$ is very soluble, $CaSO_4$ is sparingly soluble

the oxides and sulphides are too reactive with water to be stable

Group 3: **aluminium** (the only common metal in this group) forms compounds which are mainly soluble, Others, such as carbonate, are not stable and easily convert to aluminium oxide or to complex silicates which are insoluble, which is how it occurs naturally.

Group 4: **carbon** is sometimes found as the element (graphite and diamond), but usually as compounds. Metal carbonates are very common (why?), as are hydrocarbons from the remains of living organisms - oil!

silicon is the second most common element, and it is all combined with oxygen: Quartz (crystalline SiO_2), chert and flint (amorphous/ non-crystalline - SiO_2), and silicates in great variety. Amorphous silica is in effect dried-out silica gel.

tin is uncommon though important; like aluminium it readily converts to the oxide, so this is the usual mineral, though it is so insoluble that is not widely distributed.

lead is quite common, but forms mostly **insoluble** compounds (lead nitrate is the only common soluble one), so there is a great variety of different lead minerals.

Group 5: **nitrogen** is a very unreactive gas; very few compounds are found as minerals.

All nitrates and all ammonium compounds are **soluble**.

Phosphates of Group 1 metals are **soluble**, but the rest are generally **insoluble**.

Group 6: **oxides** are generally **insoluble** and unreactive except for those of Group 1 and 2 metals, so they are quite common as minerals.

sulphides are similar to oxides, except somewhat more reactive, so are generally **insoluble**. They also form more complex ions, giving a wide range of minerals.

Group 7: **halides** are all generally **soluble**; only significant exceptions are some **fluorides**.

Transition metals: **insoluble** oxides, sulphides, carbonates and silicates. Most other compounds are **soluble**.

What have you collected?

A very large number of minerals have been found in the past at Ecton. You should have collected a good range of minerals which might include these:

azurite	deep to mid-blue
barite	grey/pink - and dense
calcite	white
chalcopyrite	gold/brassy
fluorite	purple or yellow

galena	dark grey and shiny
limonite	yellow to rusty brown
malachite	green
pyrite	gold/brassy
sphalerite	dark brown/black

How shall we start?

You will need to sort samples of **calcite, galena, malachite, limonite and chalcopyrite** for these tests. Try to obtain pieces as free as possible from impurities such as limestone.

We can identify minerals by their **physical properties** - colour, hardness, density and so on. But this only tells us the name of the mineral. They do not reveal its chemical composition.

We have to carry out **chemical tests** to find the chemical composition. Such tests must identify the cation and the anion present in each mineral.

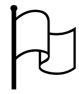
As you sort, think about which cations and which anions might be worth testing for in each of these five minerals - **calcite, galena, malachite, limonite and chalcopyrite.**

To test, **cations** must be in solution in water. So in order to test, we must first get the ions in the minerals into solution. Remember that almost all minerals are very insoluble in water

Some tests for **anions** also require a solution. But others depend on the solid reacting with an acid. For our tests today, we will only be using anion tests on the solid mineral, using **dilute nitric acid**. This will test for **carbonate** and **sulphide** anions, which are decomposed by hydrogen ions in the acid. **Oxide** anions will also react, but there is no visible evidence of that reaction. Reaction with acid also brings the **cations** into solution at the same time; refer to page 2 to find out why this will happen.

The reaction of many minerals with dilute nitric acid is slow. How can we speed up the reaction? Concentrated nitric acid is too hazardous to use, and we have no Bunsen burners available!

Preparing the minerals for testing

Throughout these experiments you must wear EYESHIELDS	

- Wash all the small plastic containers with purified water.
- Obtain as pure a sample of each mineral as you can obtain by gentle crushing and hand sorting. Now carefully crush the separated sample into a fine powder
- Place each mineral sample into a separate small plastic container - you should now have a row of five such containers with five different minerals. **Use the five labelled squares to place your tubes so that you know which is which!**
- Half-fill each of the five containers with **dilute nitric acid**, swirl carefully to mix and leave to react for five minutes. Note any gas evolution; test carefully for the faint smell of hydrogen sulphide (bad eggs) or sulphur dioxide (pungent).

X

Now, before you test… think!... ask! Make sure you know what you are trying to do!

Which anions are present?

Warning: all the minerals at Ecton are likely to be mixed with limestone. What chemical is limestone made of? Be careful in drawing conclusions about the anions present!

Mineral name	**Did it 'fizz'? (i.e. CO_2)**	**Was there any smell of H_2S or SO_2?**	**Conclusion (if any) about anion in mineral**
calcite			
galena			
malachite			
limonite			
chalcopyrite			

Testing the mineral solutions for metal cations

- Test the solutions one at a time, in order. After each test, keep the result of the test to show later - don't throw it away by mistake! Clean out the other tubes you have used for that mineral. Leave the rest of the mineral solutions alone until you are ready to test each one.
- You are now ready to test the solution for cations… but which ones? Look at the Periodic Table. Remember that the minerals you have found are insoluble compounds, and are only likely to contain common elements.
- Consider the possibilities, using your own chemical knowledge and referring to page 2 again as needed.

s-block elements: Group 1 (Li → Cs) and Group 2 (Be → Ra)

What colour are most of their compounds? ____________________

Which of these groups has insoluble compounds? ____________________

So which group is more likely to be represented in minerals at Ecton? ____________________

Which element(s) in particular in this group is/are most likely? ____________________

p-block elements: Groups 3-7

Which common metallic elements occur in this block? Again, there are not many of them. ______________

Which *p*-block elements may be worth testing for? ______________

d-block (or transition) elements:

What characteristic of compounds of the *d*-block elements makes them easy to recognise? ______________

Which transition elements are reasonably common, and might be worth testing for? Again, not many! ______________

Before you test for anything…

Before testing each solution, decant (pour off carefully) into a clean tube, leaving the solid sludge behind. Split this clear solution into two or more portions in more clean tubes, so that you do not use up all the solution in one go. That could be a silly mistake if your test 'goes wrong' for any reason. Make sure you use clean tubes each time.

After testing, keep a container with the result of each successful test to display at the end.

Testing for Group 2 cations

Barium is not a common element, but barium sulphate is so insoluble that it is commonly found in mineral deposits. However this also makes it difficult to test for chemically.

Magnesium and **calcium** compounds are very common. In this investigation we will test for calcium ions.

Tests for Group 2 cations are based on precipitating insoluble compounds from solution.

Identifying the ions in Calcite in Tube 1

Which **anion** did you identify in calcite? Write its name in the box below.

Throughout these experiments you must wear EYESHIELDS

Now test for the **cation** in the solution from Tube 1, which came from the mineral **calcite**.

- Carefully, and a little at a time, add just enough dilute ammonia solution to neutralise the remaining acid; swirl and make sure the solution smells faintly of ammonia. **CAUTION:** the smell is very pungent.
- Add a few drops of potassium ethanedioate solution, $K_2C_2O_4$.

What do you observe? ____________________

This is the test for calcium ions, **Ca^{2+}**

Calcium ethanedioate is insoluble; what colour should it be? ____________________

Complete the word equation:

Calcium nitrate (aq)	+	Potassium ethanedioate (aq)	→		+	

Which <u>cation</u> is present in calcite?

Which <u>anion</u> is present in calcite?

So what is the chemical name and formula for <u>calcite</u>?

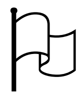
Chemical name	Formula

Testing the solution from galena in Tube 2

Before you start, make sure you have divided the clear solution into three equal portions, two for the tests that follow, and one spare.

The only *p*-block (Groups 3-7) cation likely to be present in common minerals around Ecton is lead. There are two simple tests for lead cations, and it is worthwhile trying both. Use a fresh sample of solution for each test. These tests are based on precipitating insoluble compounds, this time compounds of lead.

Testing for lead cations (Lead ions, Pb^{2}+)

Throughout these experiments you must wear EYESHIELDS	

CAUTION: The smell of ammonia is very pungent.

You require two tubes with separate samples of the solution to be tested, one for each of the following tests. These are both tests for lead cations.

Sample 1: Carefully add ammonia solution as before to neutralise any remaining acid.

Then add a few drops of potassium chromate(VI) solution, K_2CrO_4.

What do you observe? ______________________

What new compound has been formed? ______________________

Sample 2: Add a few drops of potassium iodide solution, KI.

What do you observe? ______________________

What new compound has been formed? ______________________

Complete the word equations:

lead nitrate (aq)	+	potassium chromate (aq)	→		+	
lead nitrate	+	potassium iodide (aq)	→		+	

Which cation is present in galena? ______________________

Which anion is present in galena? ______________________

(Refer to your previous results on page 4.)

So what is the chemical name and formula for galena?

Chemical name	Formula

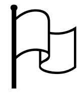
Testing for d-block (transition metal) cations in Tubes 3, 4, 5

Tests for *d*-block cations can also be based on precipitation of insoluble compounds, but another type of reaction is often more useful. These cations form **complex compounds** with a variety of molecules and anions. These often have characteristic colours.

Testing the solution from malachite in Tube 3

CAUTION: The smell of ammonia is very pungent.

Throughout these experiments you must wear EYESHIELDS



This test is carried out in two steps on a single sample of the solution from Tube 3.

Step 1: Add ammonia solution with careful swirling. At first this neutralises excess acid, but eventually a precipitate may be seen.

What colour is it? ____________________

Step 2: Add more ammonia with swirling until this precipitate dissolves again to form a clear solution.

What colour is it? ____________________

This solution contains a copper(II)-ammonia complex.

The intense colour of this complex is a sensitive test for copper ions, Cu^{2+}

What is the compound precipitated in Step 1? ____________________

Which <u>cation</u> is present in malachite?

Which <u>anion</u> is present in malachite?

(Refer to your previous results on page 4.)

So what is the chemical name and formula for malachite?

Chemical name	Formula

Testing the solution from limonite in Tube 4

You need two separate samples of the solution to be tested, one for each of the following tests. These are both tests for iron(III) cations.

TEST 1

To the first sample add a few drops of potassium thiocyanate solution, KCNS.

What do you observe? ______________________

This is a very sensitive test; even trace impurities of iron(III) can give a positive result.

TEST 2

Add a few drops of potassium hexacyanoferrate(II) solution, $K_4Fe(CN)_6$. This contains the complex ion $[Fe(CN)_6]^{4-}$, which reacts with Fe^{3+}.

What do you observe? ______________________

This intensely coloured compound is known as Prussian Blue.

Which cation is present in limonite?

Which anion is present in limonite?

Do you have any evidence from previous tests?

So what is the chemical name and formula for limonite?

Chemical name	Formula

Testing the solution in Tube 5 from the brassy coloured mineral

This is a more complicated identification. The brassy mineral you reacted in Tube 5 could be either chalcopyrite or pyrite, so we have to test more thoroughly.

Chalcopyrite is a copper iron sulphide, $CuFeS_2$. It is a valuable ore of copper.

Pyrite is an iron sulphide, FeS_2. It is a common mineral of little value.

The tests you have used with Tubes 3 and 4 can be used to find out which cations are present in Tube 5. You will need to divide your clear solution from Tube 5 into at least 3 samples in different tubes.

Now carry out the three tests you used with Tubes 3 and 4. Write down your observations and conclusions.

Result of test with ammonia solution

Result of test with potassium thiocyanate solution

Result of test with potassium hexacyanoferrate(II) solution

Which cation is present in your brassy mineral?

Which anion is present in your brassy mineral? (Refer to your results on page 4.)

So which brassy mineral did you find, and what is its chemical name and formula

Chemical name	Formula

Writing the equations – calcite

Reaction of calcite with dilute acid

Write down the formulae for:

calcium carbonate		Hydrochloric acid	
Calcium chloride		Carbon dioxide	

What is the third product of this reaction?	

Write a balanced symbol equation for the reaction: calcium carbonate with hydrochloric acid:

→

The formula for nitric acid is **HNO_3**	Write down the formula, with charges, for ion:	hydrogen ion:	
		nitrate ion	

Hence work out the formula for calcium nitrate:	

Now write a balanced symbol equation for the reaction of calcite with dilute nitric acid:

→

Write the ionic equation for both reactions:

→

The test for calcium ions

The formula for potassium ethandioate is **$K_2C_2O_4$**	Write down the formula, with charge, for the ethanedioate ion:	**ethanedioate ion:**	
	Now write down the formula for calcium ethanedioate	**calcium ethanedioate**	

Write a balanced symbol equation for the reaction of calcium nitrate with potassium ethanedioate:

→

Write the ionic equation for the reaction:

→

Writing the equations – galena

Reaction of galena with dilute acid

What is the name of the gas produced by this reaction? ______________________

In which group of the periodic table is sulphur		What element is above sulphur in this group?		So what will be the formula of the compound of sulphur with hydrogen?	

Write the word equation for the reaction between lead sulphide and nitric acid:

| →
|---|

What is the charge on the sulphide ion?		So the formula for lead sulphide is:		So the formula for lead nitrate is:	

Write the symbol equation for the reaction:

→

Write the ionic equation:

→

The tests for lead ions

1. The potassium chromate test

The formula for potassium chromate is: K_2CrO_4	Write down the formula, with charge, for the **chromate ion**		Write down the formula of **lead chromate**	

Now write a balanced symbol equation for the reaction of potassium chromate with lead nitrate.

→

Write the ionic equation for the reaction:

→

2. The potassium iodide test

Write down the formula, with charge, for the iodide ion:		Write down the formula for potassium iodide		Write down the formula for lead iodide	

Now write a balanced symbol equation for the reaction of potassium iodide with lead nitrate.

→

Write the ionic equation for the reaction:

→

So galena is:

Chemical name	Formula

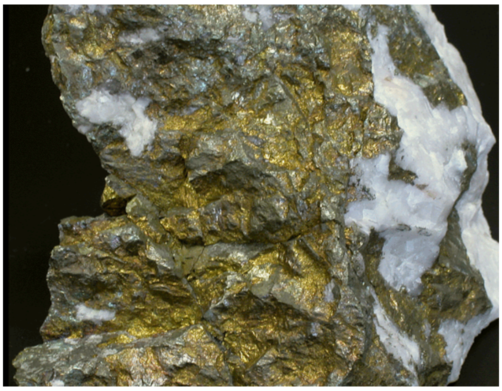
Some Minerals Found at Ecton

Barite

Fluorite

Calcite

Galena



Chalcopyrite

Malachite

Chrysocolla

Pyrite and galena