Chemical Tests for Positive Ions (CATIONS)
Flame Tests

All compounds of a particular element give the same flame colour, but the chlorides are the best to use because they vaporise relatively easily in a Bunsen flame. This experiment will allow you to determine the characteristic flame colours of certain elements in Groups 1 and 2 of the periodic table.

**Apparatus:**
- Nichrome wire
- Lithium chloride
- Calcium chloride
- Potassium chloride
- Sodium chloride

**Safety:**
- Wear goggles
- Concentrated hydrochloric acid - corrosive
- Calcium & copper chloride - harmful
- Barium chloride - poisonous

**What to do**

1. Clean a nichrome wire by heating it in a Bunsen flame, dipping it in a beaker of concentrated acid and then heating it again; continue with this until the wire produces little or no colour in the flame.

2. Dip the clean wire into the acid and then into the powdered compound.

3. Hold the wire so that the solid is in the edge of the flame and note any colour in the flame that results. Write your observations in the table below.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Flame Colour</th>
<th>Cation Present</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium chloride</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lithium chloride</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium chloride</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potassium chloride</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barium chloride</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copper chloride</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

After checking with your answers in class or with your teacher, list the characteristic colours shown by the metal cations in your notes.
Precipitation Reactions

Precipitation – Definition

A precipitate is the formation of an insoluble solid from the reaction between two solutions.

e.g. word equation

silver nitrate  +  sodium chloride  →  silver chloride  +  sodium nitrate

Balanced equation with state symbols:

\[
\text{AgNO}_3 (aq) + \text{NaCl (aq)} \rightarrow \text{AgCl (s)} + \text{NaNO}_3 (aq)
\]

The equation shows that all the reactants and products are ‘aq’, meaning dissolved in water, except for the silver chloride which is an insoluble solid. This is the precipitate.

Using Precipitation in Analysis

Some cations produce a specific colour when they undergo a precipitation reaction. This principle can be used in chemical analysis to identify the cation present.

**Apparatus:**
- Test tubes
- Test tube rack
- Pipettes

**Access to:**
- Copper(II)sulphate solution
- Iron(II)sulphate solution
- Iron(III)chloride solution
- Sodium hydroxide solution
- Ammonia solution

**Safety:**
- Wear goggles
- Sodium hydroxide & ammonia - corrosive
- Iron and copper salts - harmful

**What to do**

1. Put 2cm\(^3\) of copper (II) sulphate solution into a test tube.

2. Add a few drops of sodium hydroxide solution and note what happens. Now add more sodium hydroxide solution, until present in excess. Record any further observations.

3. Put another 2cm\(^3\) of copper (II) sulphate solution into another test tube
4. Add a few drops of ammonia solution (ammonium hydroxide), and note what happens. Again, add more ammonia solution, until present in excess, and note what happens.

5. Repeat steps 1 – 4 again but using (a) Iron (II) sulphate and (B) Iron (III) chloride.

6. Record all results in the table on the next page.

Results table

<table>
<thead>
<tr>
<th>Solution Under Test</th>
<th>Sodium hydroxide</th>
<th>Ammonia solution</th>
<th>Cation present</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper (II) sulphate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iron (II) Sulphate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iron (III) chloride</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Write both word and balanced symbol equations for all the reactions in experiment 4. You must also include symbols of state for the balanced symbol equations.
Ammonium Ions

Most cations i.e. positively charged ions are made from metals. However, there are a few that are made up from non-metals. One example that is important to learn is the ammonium ion, $\text{NH}_4^+$. Both hydrogen and nitrogen are non-metals, yet they can still form a positive charge.

The ammonium ion is basically an ammonia molecule that bonds covalently to a hydrogen ion.

$$\text{NH}_3 \quad + \quad \text{H}^+ \quad \rightarrow \quad \text{NH}_4^+$$

The nitrogen of the ammonia forms a special kind of covalent bond with the hydrogen ion. It is called a dative covalent bond. Instead of both elements donating one electron to form the electron, both electrons actually come from one atom, in this case the nitrogen atom.

Draw a dot and cross diagram to show the bonding in an ammonium ion.

A dative covalent bond is indistinguishable from an ordinary covalent bond. An arrow is also used to show that a dative covalent bond has been formed.

Testing for Ammonium Ions

Sodium hydroxide solution is used to test form ammonium ions. Sodium hydroxide solution reacts with ammonium salts to produce ammonia gas. In the cold, there is just enough ammonia gas produced for you to be able to smell it. If you warm the reaction mixture, you can test the gas coming off with a piece of damp red litmus paper. Ammonia is alkaline and turns the litmus paper blue.

E.g. testing for ammonium chloride

$$\text{NH}_4\text{Cl}_{(aq)} \quad + \quad \text{NaOH}_{(aq)} \quad \rightarrow \quad \text{NaCl}_{(aq)} \quad + \quad \text{H}_2\text{O}_{(l)} \quad + \quad \text{NH}_3(g)$$

Ionic equation:

$$\text{NH}_4^+_{(aq)} \quad + \quad \text{OH}^-_{(aq)} \quad \rightarrow \quad \text{H}_2\text{O}_{(l)} \quad + \quad \text{NH}_3(g)$$
Experiment

What to do

1. Put 2cm³ of ammonium chloride solution into a test tube.

2. Add a few drops of sodium hydroxide solution and note what happens.

3. Heat the reacting mixture gentle in a Bunsen burner and test any gas produced using damp blue litmus paper.

4. Record all observations below

<table>
<thead>
<tr>
<th>Ammonium Salt</th>
<th>Sodium hydroxide</th>
<th>Cation present</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonium chloride (NH₄Cl)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Access to:
- Ammonium chloride solution
- Sodium hydroxide solution
- Blue litmus paper

Apparatus:
- Test tubes
- Test tube rack
- Pipettes
- Bunsen burner
- Test tube holders

Safety:
- Wear goggles
- Sodium hydroxide is corrosive
**Summary of Tests for Cations**

Write down a summary of all the positive results for the tests for cations. Give a brief account of the chemicals used and the results if the test is positive.

**Flame Tests**

<table>
<thead>
<tr>
<th>Cation name</th>
<th>Cation Formula</th>
<th>Flame Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lithium</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potassium</td>
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<td></td>
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<tr>
<td>Barium</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copper</td>
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</tbody>
</table>

**Precipitation Reactions**

<table>
<thead>
<tr>
<th>Cation name</th>
<th>Cation Formula</th>
<th>Test</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper (II)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iron (II)</td>
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<td></td>
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<tr>
<td>Iron (III)</td>
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</tbody>
</table>

**Test for Ammonium Ions**

<table>
<thead>
<tr>
<th>Ammonium Ion Formula</th>
<th>Test</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

Ionic Equation for the reaction: