Group 7 - Halogens
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- Introducing the halogens
  - Physical properties
  - Reactions and reactivity
  - Displacement reactions
  - Summary activities
In the periodic table, the elements are arranged by their properties and the number of protons they contain. The vertical columns in the table are called groups.
Where are the halogens?

Elements in the same group in the periodic table have very similar properties.

This is because all elements in a single group have the same number of electrons in their outer shell, causing them to react in a similar manner.

The elements in group 7, on the right of the periodic table, are called the halogens.

- fluorine
- chlorine
- bromine
- iodine
- astatine
What are the halogens?

Introducing the halogens

To find out some interesting facts about the halogens and their compounds, and why they are so useful, click on the elements below:
Why are they called the ‘halogens’?

Halogens are very reactive non-metals. As a result, they all have the potential to be toxic or harmful.

Before antiseptics, iodine was used to clean wounds. This is because it is able to destroy harmful organisms, such as bacteria.

Due to their reactivity, halogens are never found in nature in their pure form. Instead they are found in metal compounds.

These halogen-metal compounds are called salts. This gives halogens their name – ‘halo-gen’ means ‘salt-former’.
All halogens have seven electrons in their outer shell.

This means that:

- They can easily obtain a full outer shell by gaining one electron.
- They can gain an electron in reactions to form negative ions with a -1 charge.
- They have similar chemical properties.
How do halogen molecules exist?

To become stable, halogen atoms require one additional electron to obtain a full outer shell.

Each atom can achieve this by sharing one electron with another atom to form a single **covalent bond**.

This means that all halogens exist as **diatomic** molecules: $F_2$, $Cl_2$, $Br_2$ and $I_2$. 
 Testing for chlorine

We can test for chlorine gas using damp blue litmus paper. The chlorine dissolves in the water on the paper, and then reacts with the litmus dye.

First the litmus paper will turn red. This is because chlorine is acidic.

The paper will then be bleached white.

Chlorine will also turn universal indicator paper red then white, and will turn starch-iodide paper from white to blue-black.
Halide ions are negative ions formed from the halogens. These can be detected using silver nitrate solution.

The substance to be tested is first acidified with a small amount of nitric acid. Silver nitrate solution is then added. If a halide ion is present, a precipitate will form.

The precipitates formed are silver halides.

\[
\begin{align*}
\text{sodium chloride} & + \quad \text{silver nitrate} & \rightarrow & \text{silver chloride} & + & \text{sodium nitrate} \\
\text{NaCl}(aq) & + & \text{AgNO}_3(aq) & \rightarrow & \text{AgCl}(s) & + & \text{NaNO}_3(aq) \\
\text{Cl}^- (aq) & + & \text{Ag}^+ (aq) & \rightarrow & \text{AgCl}(s)
\end{align*}
\]
Silver halides

The different types of silver halide precipitates can be distinguished by their colour.

- **chloride**: white AgCl precipitate
- **bromide**: cream AgBr precipitate
- **iodide**: yellow AgI precipitate
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What are the properties of the halogens?

All the halogens are:

- non-metals and so do not conduct electricity
- brittle and crumbly when solid
- poisonous and smelly.

They become darker in colour down the group:

**fluorine** is a pale yellow gas at room temperature.

**chlorine** is a green-yellow gas at room temperature.

**bromine** is a dark orange liquid at room temperature.
    It becomes an orange-brown gas when heated.

**iodine** is a dark grey solid at room temperature.
    It sublimes to a purple gas when heated.

**astatine** is a dark coloured solid at room temperature.
Going down group 7, the size, density and relative molecular mass of halogens all increase.

<table>
<thead>
<tr>
<th>Element</th>
<th>Relative size</th>
<th>Relative molecular mass</th>
<th>Density (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>fluorine</td>
<td>38</td>
<td></td>
<td>0.0017</td>
</tr>
<tr>
<td>chlorine</td>
<td>71</td>
<td></td>
<td>0.0032</td>
</tr>
<tr>
<td>bromine</td>
<td>160</td>
<td></td>
<td>3.1</td>
</tr>
<tr>
<td>iodine</td>
<td>254</td>
<td></td>
<td>4.9</td>
</tr>
<tr>
<td>astatine</td>
<td>420</td>
<td></td>
<td>approx 6.4*</td>
</tr>
</tbody>
</table>
## Melting and boiling points

The melting and boiling points of the halogens increase down the group. Predict the states and values to fill in the table.

<table>
<thead>
<tr>
<th>Element</th>
<th>State at room temperature</th>
<th>Melting point (°C)</th>
<th>Boiling point (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>fluorine</strong></td>
<td>gas</td>
<td>-220</td>
<td>-188</td>
</tr>
<tr>
<td><strong>chlorine</strong></td>
<td>gas</td>
<td>-101</td>
<td>-34</td>
</tr>
<tr>
<td><strong>bromine</strong></td>
<td>liquid</td>
<td>-7</td>
<td>59</td>
</tr>
<tr>
<td><strong>iodine</strong></td>
<td>solid</td>
<td>114</td>
<td>184</td>
</tr>
<tr>
<td><strong>astatine</strong></td>
<td>solid</td>
<td>302*</td>
<td>337*</td>
</tr>
</tbody>
</table>
Melting and boiling points of halogens

What are the melting and boiling points of halogens?

The graph shows the melting and boiling points of halogens on a temperature scale. The points for each halogen are marked, indicating their specific melting and boiling temperatures.
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Reactions with metals and non-metals

Halogens have 7 electrons in their outer shell. By gaining one more electron they can obtain a full shell and become stable.

Metals need to lose electrons to gain a full outer shell. Metals can react with halogens to form ionic compounds called metal halides.

Non-metals need to gain electrons to become stable.

When non-metals react with halogens, they can share electrons and form covalent bonds.

sodium chloride

hydrogen chloride
What are halides?

Halogen atoms can form negative ions by gaining an electron.

When this happens, they are called **halides**.

The name of each of the halogens changes once it has reacted. Instead of ending with ‘–ine’, it ends with ‘–ide’.

<table>
<thead>
<tr>
<th>Halogen</th>
<th>Halide</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>fluorine</strong> (F)</td>
<td><strong>fluoride</strong> (F⁻)</td>
</tr>
<tr>
<td><strong>chlorine</strong> (Cl)</td>
<td><strong>chloride</strong> (Cl⁻)</td>
</tr>
<tr>
<td><strong>bromine</strong> (Br)</td>
<td><strong>bromide</strong> (Br⁻)</td>
</tr>
<tr>
<td><strong>iodine</strong> (I)</td>
<td><strong>iodide</strong> (I⁻)</td>
</tr>
</tbody>
</table>
How do alkali metals react with halogens?

The electron structure of halogens means that they react vigorously with group 1 alkali metals.

An alkali metal has 1 electron in its outer shell. By losing this electron, it has a filled outer shell and forms a positive ion.

A halogen has 7 electrons in its outer shell. By gaining an electron from the alkali metal, it obtains a filled outer shell and forms a negative ion.
How are ionic bonds formed?

The positive alkali metal ions and the negative halide ions are strongly attracted to each other.

It is this electrostatic attraction that forms ionic bonds in metal halides and other ionic compounds.
When a halogen reacts with a metal it forms a metal halide:

\[ \text{halogen} + \text{metal} \rightarrow \text{metal halide} \]

Write a balanced symbol equation for the reaction between chlorine and sodium.

\[ \text{Cl}_2 + 2\text{Na} \rightarrow 2\text{NaCl} \]

Write a word equation and a balanced symbol equation for the reaction between bromine and potassium.

\[ \text{Br}_2 + 2\text{K} \rightarrow 2\text{KBr} \]
The reactivity of halogens decreases going down the group. What is the reason for this?

- The atoms of each element get larger going down the group.

- This means that the outer shell gets further away from the nucleus and is shielded by more electron shells.

- The further the outer shell is from the positive attraction of the nucleus, the harder it is to attract another electron to complete the outer shell.
Halogen reaction with iron wool

How do the halogens react with iron wool?

By seeing how each halogen reacts with iron wool, you can see how reactive the halogens are compared to each other.

Click on each of the halogens below to see the experiments:

- Chlorine
- Bromine
- Iodine
The iron wool experiment shows that the reactivity of halogens decreases down the group.

<table>
<thead>
<tr>
<th>Halogen</th>
<th>Reaction with iron wool</th>
</tr>
</thead>
<tbody>
<tr>
<td>chlorine</td>
<td>Iron wool burns and glows brightly.</td>
</tr>
<tr>
<td>bromine</td>
<td>Iron wool glows, but less brightly than with chlorine.</td>
</tr>
<tr>
<td>iodine</td>
<td>Iron wool has a very slight glow.</td>
</tr>
</tbody>
</table>

Astatine appears directly below iodine in group 7. Fluorine appears directly above chlorine.

How do you think astatine and fluorine would react with iron wool?
How do the halogens react with hydrogen?

Halogens react with hydrogen to create **hydrogen halides**.

![Diagram showing the reaction between hydrogen and chlorine to form hydrogen chloride.](image)

hydrogen + chlorine → hydrogen chloride

When halogens react with non-metals, they can share electrons to form a covalent compound.

All hydrogen halides are gases. They dissolve easily in water and form strong acids.
Reactions with other non-metals

As well as hydrogen, other non-metals can react with halogens to form covalent compounds. These include:

- Halohydrocarbons
e.g. Chloromethane, PVC, PTFE

- Phosgene (COCl₂)
  Used as a chemical weapon in WW1

- Silicon tetrachloride (SiCl₄)
  Used to produce high purity silicon

- Nitrogen tribromide (NBr₃)
  Extremely explosive

- Sulfur dichloride (SCl₂)
  Used in process of making sulfur compounds
<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>In their elemental state, halogens exist as molecular molecules.</td>
<td>False</td>
</tr>
<tr>
<td>2.</td>
<td>The reactivity of halogens increases down the group.</td>
<td>True</td>
</tr>
<tr>
<td>3.</td>
<td>Halogens form negative ions.</td>
<td>False</td>
</tr>
<tr>
<td>4.</td>
<td>All halogens are gases.</td>
<td>True</td>
</tr>
<tr>
<td>5.</td>
<td>Halogens become darker in colour down the group.</td>
<td>True</td>
</tr>
<tr>
<td>6.</td>
<td>Halogens have 6 electrons in their outer shell.</td>
<td>False</td>
</tr>
</tbody>
</table>
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Displacement of halogens

If a halogen is added to a solution of a compound containing a less reactive halogen, it will react with the compound and form a new one.

This is called **displacement**.

\[
\begin{align*}
\text{fluorine} & + \quad \text{sodium chloride} & \rightarrow & \quad \text{sodium fluoride} & + & \quad \text{chlorine} \\
F_2(aq) & + & 2\text{NaCl(aq)} & \rightarrow & 2\text{NaF(aq)} & + & \text{Cl}_2(aq)
\end{align*}
\]

A more reactive halogen will **always** displace a less reactive halide from its compounds in solution.
Displacement of halogens

Why will a more reactive halogen always displace a less reactive halogen?
Displacement theory

Fluorine is more reactive than chlorine.

What happens when fluorine is added to sodium chloride?

The products of the reaction are chlorine and sodium fluoride.

The chlorine has been displaced by the fluorine.
Reduction and oxidation

During a displacement reaction the less reactive halogen is oxidised (loses an election) and the more reactive halogen is reduced (gains an electron).

Oxidation:

\[ 2\text{Cl}^- \rightarrow 2\text{e}^- + \text{Cl}_2 \]

Reduction:

\[ \text{F}_2 + 2\text{e}^- \rightarrow 2\text{F}^- \]

The reaction involves both reduction and oxidation, so it is a redox reaction.

Displacement reactions

In a displacement reaction, a colour change takes place. This tells you whether a halogen is more or less reactive than another halogen.

Click “start” to compare the reactivity of halogens.
What will happen if bromine is added to sodium iodide?

The bromine will displace the iodide ion in the solution to form sodium bromide.

Write a word equation and a balanced symbol equation for this reaction.

\[
\text{bromine} + \text{sodium iodide} \rightarrow \text{sodium bromide} + \text{iodine}
\]

\[
\text{Br}_2 + 2\text{NaI} \rightarrow 2\text{NaBr} + \text{I}_2
\]
Is there a displacement reaction?

<table>
<thead>
<tr>
<th>Halogen</th>
<th>Salt (aq)</th>
<th>Potassium Bromide</th>
<th>Reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorine</td>
<td>?</td>
<td>?</td>
<td>(2KCl + I_2)</td>
</tr>
<tr>
<td>Bromine</td>
<td>?</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td>?</td>
<td>no reaction</td>
<td>?</td>
<td></td>
</tr>
</tbody>
</table>
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Multiple-choice quiz