HALOGENS

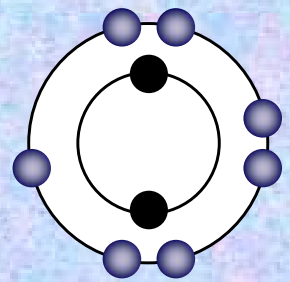
Electron structure and reactivity

Group 7 – the halogens

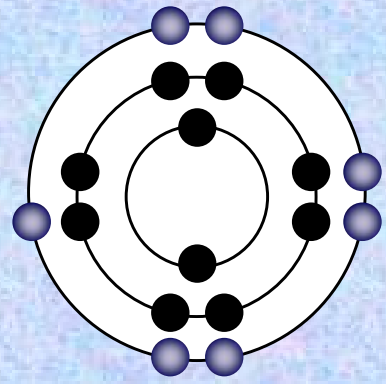
- **Halogens** are in group 7 of the periodic table, on the right.

Electron structure

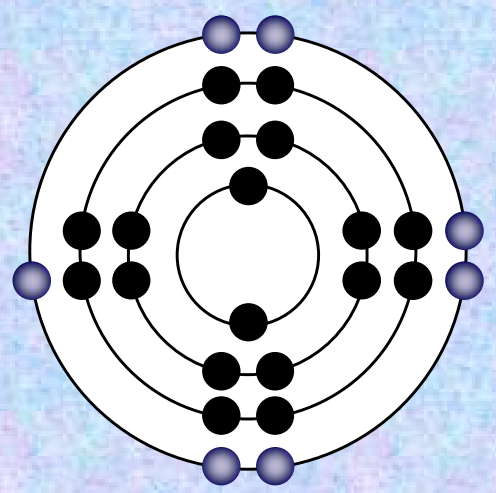
- All halogens have 7 electrons in their outer shell.
  This means that:



fluorine
2,7



chlorine
2,8,7

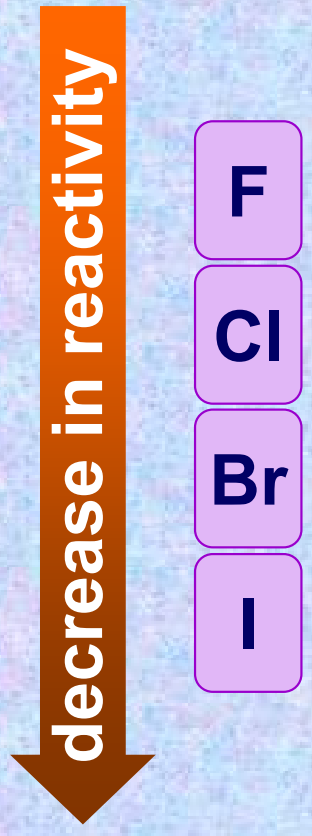


bromine
2,8,8,7

- They can easily obtain a full outer shell by gaining 1 electron.
- They all gain an electron in reactions to form **negative ions** with a -1 charge.
- They have similar chemical properties.

Electron structure and reactivity

- All halogens are reactive, and the reactivity decreases down the group. What is the reason for this?

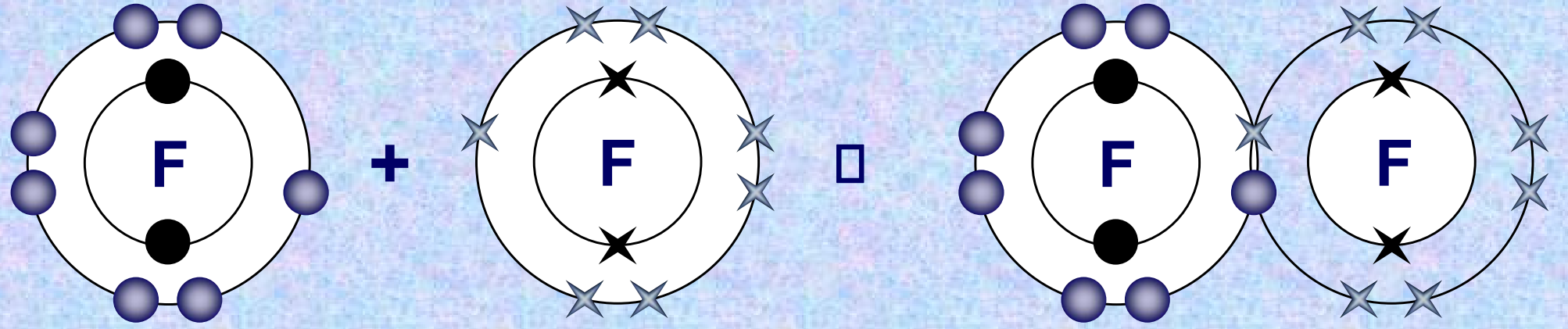


- The size of each element's atoms, and the number of full electron shells, increases down the group.
- This means that, down the group, the outer shell gets further away from the nucleus and is shielded by more electron shells.
- The further the outer shell is from the positive attraction of the nucleus, the harder it is to attract another electron.
- This means that reactivity decreases with the size of the atom.

Halogen molecules

- All halogen atoms require one more electron to obtain a full outer shell and become stable.

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**.

Physical properties

General properties

- All 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 pale yellow

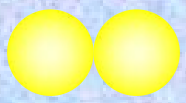
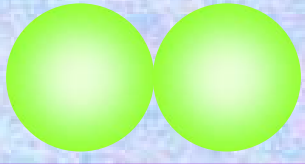
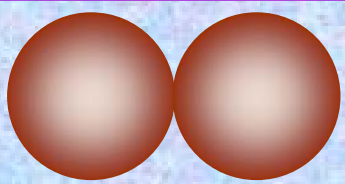
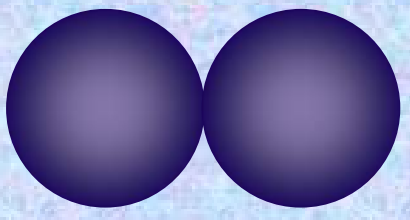
chlorine is green-yellow

bromine is red-brown

iodine is blue-black

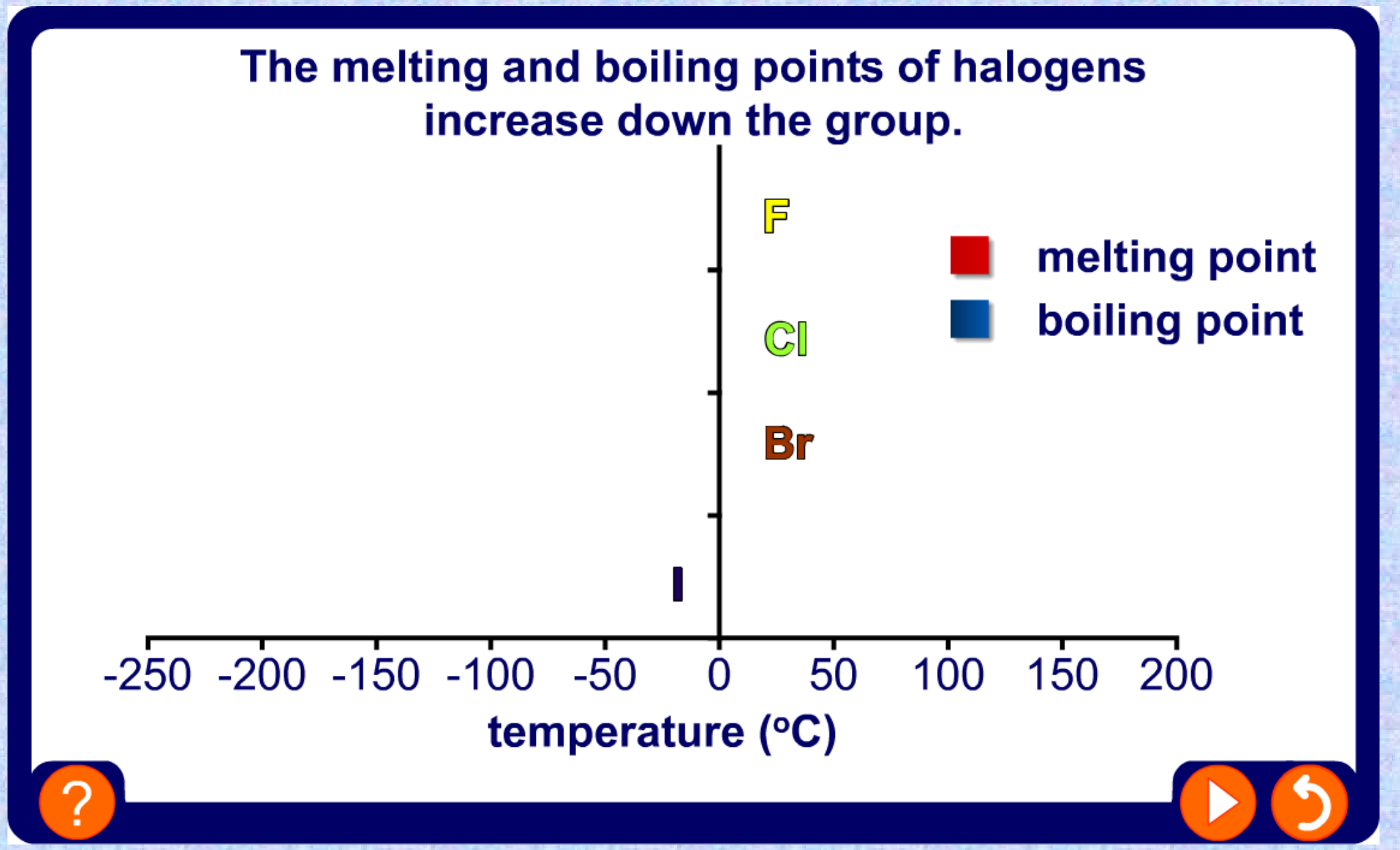
Physical state of halogens

- The melting and boiling points of halogens increase down the group, as the molecules become bigger.

Halogen	Relative size	Melting point (°C)	Boiling point (°C)	State
fluorine		-220	-118	gas
chlorine		-101	-34	gas
bromine		-7	59	liquid
iodine		114	184	solid

What is the state of each halogen at room temperature?

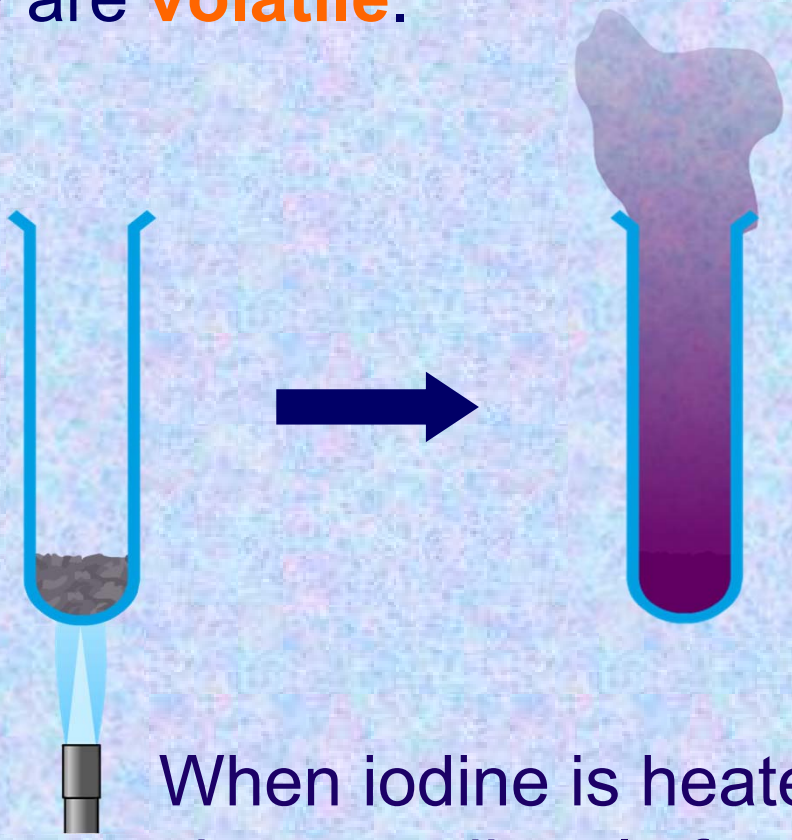
Melting and boiling points of halogens



Halogen vapours

- Bromine and iodine are not gaseous, but have low boiling points. This means that they produce vapour at relatively low temperature. They are **volatile**.

Bromine produces a red-brown vapour.



When iodine is heated gently, it changes directly from a solid to a gas without first becoming a liquid. This is called **sublimation**.

True or false?

Are these statements about halogens true or false?

1. In their elemental state, halogens exist as monoatomic molecules.	
2. The reactivity of halogens increases down the group.	
3. Halogens form negative ions.	
4. All halogens are gases.	
5. Halogens become darker in colour down the group.	
6. Halogens have 6 electrons in their outer shell.	

true false

?

Reactions

Reactivity of halogens

- The reactivity of halogens decreases down the group. This can be demonstrated by comparing how they react with hydrogen.

decrease in reactivity

Halogen	Reactivity with hydrogen
fluorine	Reacts instantly, even at -200 °C.
chlorine	Reacts slowly in the dark. Explodes in the light.
bromine	Needs heating to +200 °C in order to react.
iodine	Does not react completely, even at 500 °C.

Astatine is the halogen that appears directly below iodine in the periodic table. How do you think astatine would react with hydrogen?

Halides

- When halogens react with another substance, they become ions. When this happens, they are called **halides**.

The name of the halogens change slightly once they have reacted – instead of ending with '**–ine**', they end with '**-ide**'.

Halogen	reaction	Halide
fluorine (F)	→	fluoride (F^-)
chlorine (Cl)	→	chloride (Cl^-)
bromine (Br)	→	bromide (Br^-)
iodine (I)	→	iodide (I^-)

Displacement reactions

- 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**.

fluorine	**+**	**sodium chloride**	□	**sodium fluoride**	**+**	**chlorine**
F_2(aq)	**+**	**2NaCl**(aq)	□	**2NaF**(aq)	**+**	**Cl_2**(aq)

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

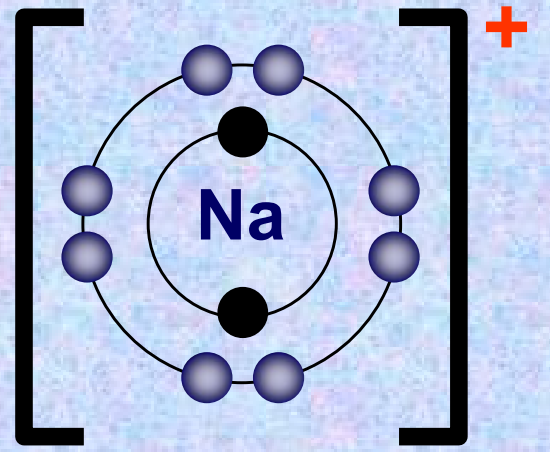
Displacement of halogens

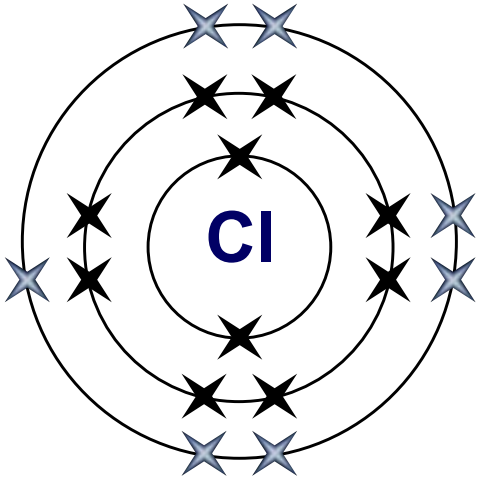
- Why will a halogen always displace a less reactive halogen?

Displacement theory

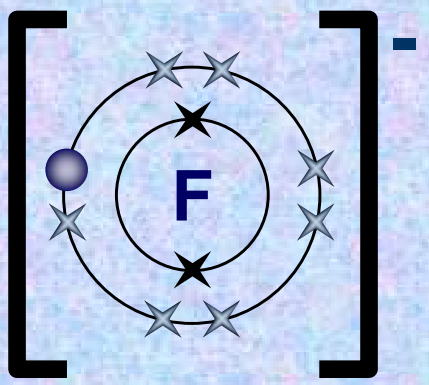
- If a metal halide is mixed with a more reactive halogen, the extra electron will be transferred from the less reactive to the more reactive halogen.

sodium





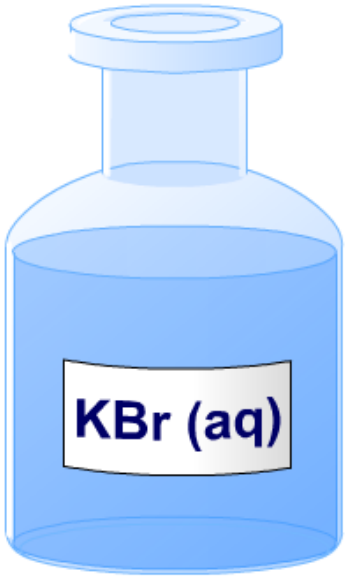
chlorine



fluoride

Displacement reactions of halogens

Displacement reactions of halogens



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.

start

Displacement reactions: summary

- The reactions between solutions of halogens and metal halides (salts) can be summarised in a table:

salt (aq) / halogen	potassium chloride	potassium bromide	potassium iodide
chlorine	X	$2KCl + Br_2$	$2KCl + I_2$
bromine	no reaction	X	$2KBr + I_2$
iodine	no reaction	no reaction	X

What are the missing entries for these displacement reactions?

halogen \ salt (aq)	?	potassium bromide	?
chlorine	X	?	$2KCl + I_2$
bromine	?	X	?
?	no reaction	?	X

$2KBr + I_2$

Reactions of halogens with metals

- The reactivity of halogens means that they readily react with most metals.

Halogens need to gain electrons for a full electron shell and metals need to lose electrons for a full electron shell.

This means that halogens and metals react to form **ionic compounds**. These are **metal halides**, which are a type of salt.

Chlorine reacts vigorously with iron after gentle heating, despite iron's low reactivity.

chlorine	**+**	**iron**	□	**iron (III) chloride**
$3Cl_2$(g)	**+**	**2Fe**(s)	□	**$2FeCl_3$**(s)

More reactions of halogens with metals

- Bromine reacts **steadily** with iron when heated constantly.

bromine	**+**	**iron**	□	**iron (III) bromide**
$3Br_2$(g)	**+**	**2Fe**(s)	□	**$2BrCl_3$**(s)

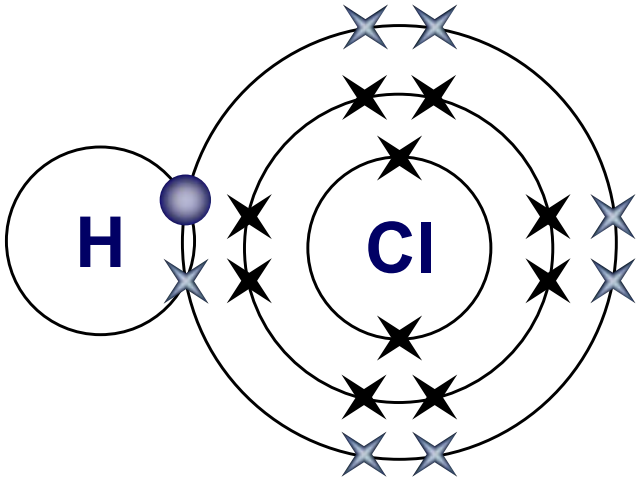
Iodine reacts **slowly** with iron when heated constantly.

iodine	**+**	**iron**	□	**iron (III) iodide**
$3I_2$(g)	**+**	**2Fe**(s)	□	**$2ICl_3$**(s)

Reactions of halogens with non-metals

- Halogens also react with non-metals.

For example, halogens react with hydrogen to create **hydrogen halides**.



hydrogen chloride

Unlike their reactions with metals, halogens share electrons with non-metals, and so react to form **covalent compounds**.

All hydrogen halides are gases. They dissolve easily in water and become strong acids.

Uses

Uses of fluorine

Fluoridation of water, to prevent tooth decay

Toothpaste, to prevent tooth decay

fluorine and its compounds

Polymers, e.g. Teflon for non-stick pans

Processing uranium nuclear fuel

Uses of chlorine

chlorine and its compounds

Pesticides and weed killers

Treatment of drinking water

Antiseptics and disinfectants

Bleach to kill bacteria and to make paper white

Chlorinated carbon compounds, e.g. solvents and plastics (PVC)

Uses of bromine and iodine

bromine and its compounds

- Leaded petrol
- Medicines
- Photography
- Agriculture

iodine and its compounds

- Animal feed supplements
- Antiseptics and water purification tablets

Summary activities

Glossary

- **diatomic –** An element that exists as molecules containing two atoms covalently bonded.
- **displacement –** The reaction when a more reactive halogen reacts with a compound containing a less reactive halogen.
- **halide –** The name of a halogen when it has reacted with another substance and gained a full outer electron shell.
- **halogen –** An element that belongs to group 7 of the periodic table.
- **hydrogen halide –** A compound formed from the reaction between hydrogen and a halogen.
- **metal halide –** A compound formed from the reaction between a metal and a halogen.
- **sublime –** To change from a solid to a gas without first becoming a liquid.
- **volatile –** A substance that evaporates or produces vapour at relatively low temperature.