Cambridge (CIE) IGCSE Chemistry

Your notes

Group Properties & Trends

Contents

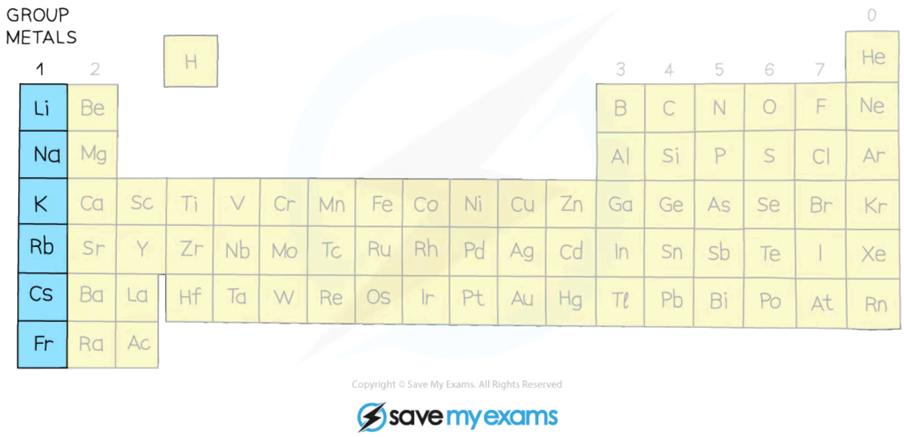
Your notes

Group I properties & trends: basics

- The Group 1 metals are also called the alkali metals as they form **alkaline solutions** with high pH values when reacted with water
- Group 1 metals are lithium, sodium, potassium, rubidium, caesium and francium
- They all contain just **one electron** in their outer shell

Physical properties of the Group 1 metals

- The Group 1 metals:
  - Are soft and easy to cut, getting even **softer** and generally denser as you move down the Group (sodium and potassium do not follow the trend in density)
  - Have **shiny** silvery surfaces when freshly cut
  - Conduct **heat** and **electricity**
  - They all have **low** melting points and **low** densities compared to other metals, and the melting point generally **decreases** as you move down the Group; some would melt on a hot day



The alkali metals lie on the far left-hand side of the Periodic Table

Chemical properties of the Group I metals

- They react readily with oxygen and water vapour in air so they are stored under **oil** to stop them from reacting
- Group 1 metals will react similarly with water, reacting vigorously to produce an **alkaline** metal hydroxide solution and **hydrogen** gas

- The Group 1 metals get more reactive as you look down the group, so only the first three metals are allowed in schools for demonstrations

Reactions of the Group 1 metals and water

Element	Reaction	Observations
Li	lithium + water → lithium hydroxide + hydrogen $2Li (s) + 2H_2O (l) \rightarrow 2LiOH (aq) + H_2 (g)$	▪ Relatively slow reaction ▪ Fizzing ▪ Lithium moves on the surface of the water
Na	sodium + water → sodium hydroxide + hydrogen $2Na (s) + 2H_2O (l) \rightarrow 2NaOH (aq) + H_2 (g)$	▪ More vigorous fizzing ▪ Moves rapidly on the surface of the water ▪ Dissolves quickly
K	potassium + water → potassium hydroxide + hydrogen $2K (s) + 2H_2O (l) \rightarrow 2KOH (aq) + H_2 (g)$	▪ Reacts more vigorously than sodium ▪ Burns with a lilac flame ▪ Moves very rapidly on the surface ▪ Dissolves very quickly

General trends of the Group I metals

- As you move down the group:
  - Melting point decreases
  - Density increases
  - Reactivity increases

Predicting the Properties of Group I Elements

- Knowing the reactions of elements at the top of the group allows you to predict the properties of other elements further down Group 1

Properties of other Alkali Metals (Rubidium, Caesium and Francium)

- As the reactivity of alkali metals increases down the group, rubidium, caesium and francium will react more vigorously with air and water than lithium, sodium and potassium
- Lithium will be the **least** reactive metal in the group at the top, and francium will be the **most** reactive at the bottom

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- Francium is rare and radioactive so is difficult to confirm predictions
- For example the reactions with water can be predicted:

Predicting the reaction with water

Element	Observations
Rb	- Explodes with sparks
Cs	- Violent explosion due to rapid production of heat and hydrogen
Fr	- Too reactive to predict

- You can also look at other properties such as boiling point, melting point and density of Group 1 elements and use them to predict whether the other properties are likely to be larger or smaller going down the group

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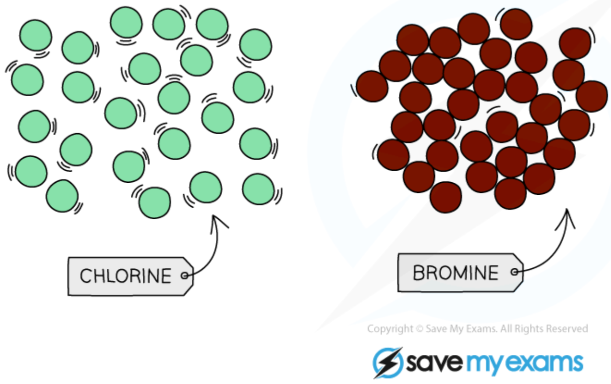
Group VII properties & trends

- These are the Group VII non-metals that are **poisonous** and include fluorine, chlorine, bromine, iodine and astatine
- Halogens are **diatomic**, meaning they form molecules of **two** atoms
  - The formulae of the halogens are:
    - Fluorine = F_2
    - Chlorine = Cl_2
    - Bromine = Br_2
    - Iodine = I_2
    - Astatine = At_2
- All halogens have seven electrons in their outer shell
- They form **halide** ions by gaining one more electron to complete their outer shells
- Fluorine is not allowed in schools so observations and experiments tend to only involve chlorine, bromine and iodine

Properties of the halogens

Physical state and density

- At room temperature (20 °C), the physical state of the halogens changes as you go down the group
  - Chlorine is a **pale yellow-green gas**
  - Bromine is a **red-brown liquid**
  - Iodine is a **grey-black solid**
- This demonstrates that the **density** of the halogens **increases** as you go **down the group:**



The physical state of the halogens at room temperature

Reactivity

- The **reactivity** of Group 7 elements **decreases** as you go down the group
  - This is the opposite trend to Group 1
- When a halogen reacts, it needs to gain one outer electron to achieve a full outer shell of electrons
- As you go down Group 7, the number of electron shells **increases**

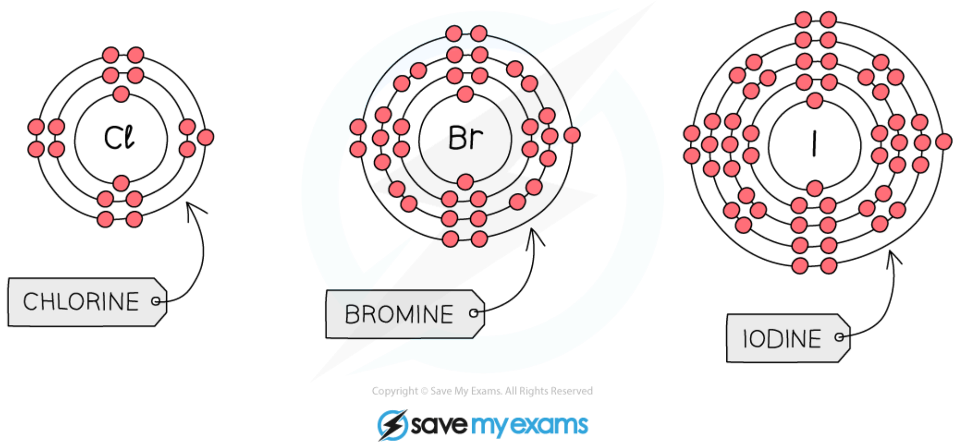


Diagram showing the electronic configuration of the first three elements in Group 7

- The increasing number of electron shells has two main effects:
  - The **atomic radius increases**, so the outer shell is further from the nucleus
  - There is more **electron shielding** from the inner shells
- There factors reduce the force of attraction between the nucleus and an incoming electron
- Therefore, it becomes harder to attract an electron

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- This means that the reactivity of the halogens **decreases** down the group

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Examiner Tips and Tricks

Solid iodine, iodine in solution and iodine vapour are different colours.

- Solid iodine is dark **grey-black**
- Iodine vapour is **purple**
- Aqueous iodine is **brown**.

Predicting group VII properties

- You may be given information about some elements and asked to predict the properties of other elements in the group
- The information you might be given could be in relation to melting/boiling point or physical state/density so it is useful to know the trends in properties going down the group

Predicting melting and boiling point

- The melting and boiling point of the halogens **increases** as you go down the group
- Fluorine is at the top of Group 7 so will have the **lowest** melting and boiling point
- Astatine is at the bottom of Group 7 so will have the **highest** melting and boiling point

Predicting physical states

- The halogens become **denser** as you go down the group
- Fluorine is at the top of Group 7 so will be a **gas**
- Astatine is at the bottom of Group 7 so will be a **solid**

Predicting colour

- The colour of the halogens becomes **darker** as you go down the group
- Fluorine is at the top of Group 7 so the colour will be **lighter**, so fluorine is **yellow**
- Astatine is at the bottom of Group 7 so the colour will be **darker**, so astatine is **black**

Examiner Tips and Tricks

If you are doing the extended course you can be asked to identify trends in chemical or physical properties of the Group 7 elements, given appropriate data.

Firstly, make sure that you have placed the elements and associated data in either ascending or descending order according to their position in Group 7. Then look for any general patterns in the data.

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Group VII displacement reactions

- A halogen **displacement reaction** occurs when a more reactive halogen displaces a less reactive halogen from an aqueous solution of its halide
- The reactivity of Group 7 non-metals increases as you move up the group
- Out of the three commonly used halogens, chlorine, bromine and iodine, chlorine is the most reactive and iodine is the least reactive

Colour of halogens in aqueous solutions

Aqueous solution	Colour
Chlorine	Very pale green but usually appears colourless as it is very dilute
Bromine	Orange but will turn yellow when diluted
Iodine	Brown

Halogen displacement reactions

Chlorine and bromine

- If you add chlorine solution to colourless potassium bromide solution, the solution becomes orange as bromine is formed
- Chlorine is **above** bromine in Group 7 so is more reactive
- Chlorine will therefore **displace** bromine from an aqueous solution of the metal bromide
- The least reactive halogen always ends up in the elemental form

potassium bromide + chlorine → potassium chloride + bromine

$$2KBr\,(aq) + Cl_2\,(aq) \rightarrow 2KCl\,(aq) + Br_2\,(aq)$$

Bromine and iodine

- Bromine is above iodine in Group 7 so is **more** reactive
- Bromine will therefore displace iodine from an aqueous solution of metal iodide
- The solution will turn brown as iodine is formed

magnesium iodide + bromine → magnesium bromide + iodine

$$MgI_2\,(aq) + Br_2\,(aq) \rightarrow MgBr_2\,(aq) + I_2\,(aq)$$

Summary table of displacement reactions

	Chlorine (Cl_2)	Bromine (Br_2)	Iodine (I_2)
Potassium chloride (KCl)	x	No reaction	No reaction
Potassium bromide (KBr)	Chlorine displaces the bromide ions Yellow-orange colour of bromine seen	x	No reaction
Potassium Iodide (KI)	Chlorine displaces the iodide ions Brown colour of iodine is seen	Bromine displaces the iodide ions Brown colour of iodine is seen	x

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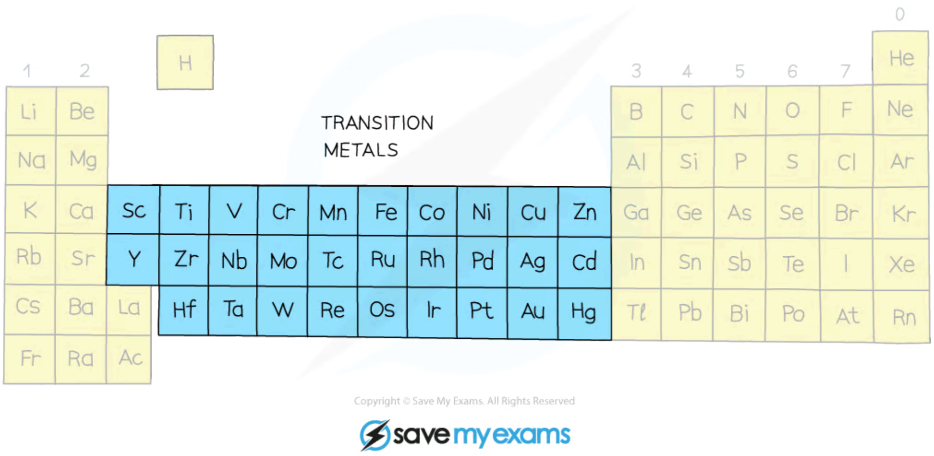
Examiner Tips and Tricks

Iodine solid, solution and vapour are different colours. Solid iodine is dark **grey-black**, iodine vapour is **purple** and aqueous iodine is **brown**.

Transition elements

- Transition elements are found in the centre of the Periodic Table between Group 2 and Group 3
- Most metals are transition elements and have properties typical of a metal:
  - They are **lustrous**
  - They are **hard** and **strong**
  - They **conduct** heat and electricity
  - They have **high melting points**
    - Except mercury: This has a low melting point which is why it is a liquid at room temperature

The transition elements in the Periodic Table



Transition elements are found in the middle of the Periodic Table

- There are some properties that are only typical of transition elements :
  - They form **ions with different charges**
    - E.g. Iron forms Fe^{2+} and Fe^{3+} ions
  - They are useful as **catalysts**
    - E.g. Iron is used as the catalyst in the Haber process
- They form **coloured compounds**
  - E.g. Copper forms blue copper sulfate, black copper oxide and green copper carbonate

Coloured compounds formed by transition metal ions

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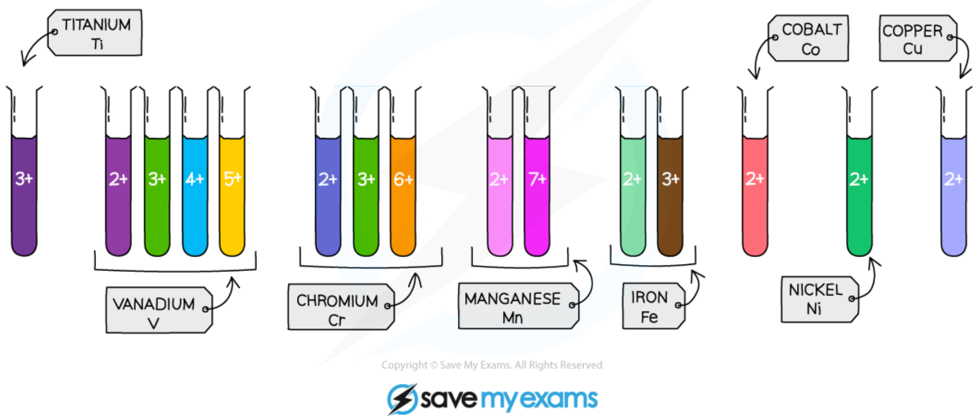

The colours produced by some transition elements ions

Examiner Tips and Tricks

Although scandium and zinc are in the transition element area of the Periodic Table, they are not considered transition elements as they do **not** form coloured compounds and have only **one** oxidation state.

Transition elements oxidation numbers

Extended tier only

- The transition elements have more than one **oxidation number**, as they can lose a different number of electrons
- For example. iron either:
  - Lose **two** electrons to form Fe^{2+} so has an oxidation number of +2
  - Loses **three** electrons to form Fe^{3+} so has an oxidation number of +3
- Compounds containing transition elements in different oxidation states will have different **properties** and colours

Examiner Tips and Tricks

Transition elements also referred to as transition metals.

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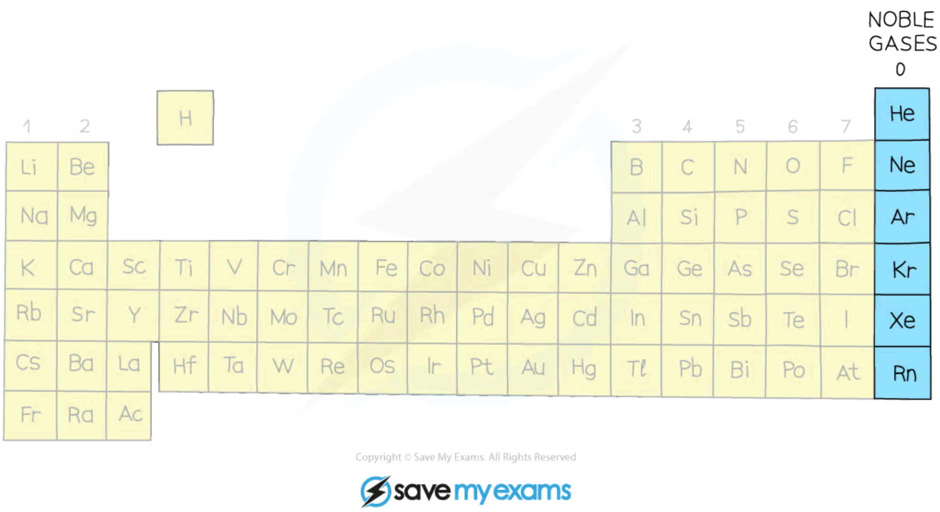
Noble gases properties & electronic configuration

- The noble gases are in Group 8 (or Group 0); they are non-metals and have very **low melting** and **boiling** points
- They are all **monoatomic**, **colourless** gases
- The Group 0 elements all have **full outer shells**
- This electronic configuration is **extremely stable** so these elements are unreactive and are **inert**
- Electronic configurations of the noble gases:
  - He: 2
  - Ne: 2,8
  - Ar: 2,8,8
  - Kr: 2,8,18,8
  - Xe: 2,8,18,18,8

The location of the noble gases



Noble gases are inert (unreactive) as they have a full outer shell of electrons so do not easily lose or gain electrons