AQA Chemistry Unit 1

Atomic Structure & The Periodic Table

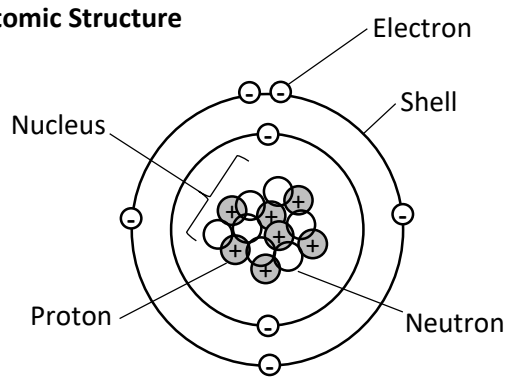
S.L.O.P *Shed Loads of Practice!*

Element
Made from only one type of atom.

Symbols
One or two letters, first letter always capital, second letter always lower case e.g.
Na Mg N Cl Fe Al

Atom
The smallest part of an element.

Atomic Structure



14 ← Mass number
= Protons + Neutrons in the nucleus

N

7 ← Atomic number
= Protons = Electrons

Atoms have **no overall charge** as the number of positive protons is equal to the number of negative electrons, their opposite charges cancel.

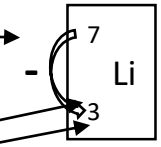
Subatomic particle	Location	Relative mass	Relative charge
Proton	Nucleus	1	+1
Neutron	Nucleus	1	0
Electron	Shells	1/2000th	-1

The **radius of the whole atom** is about 0.1nm which is 1×10^{-10} m

The **radius of the nucleus** is 1/10,000th that of the whole atom (1×10^{-14} m) , however it contains almost all of the atom's mass. This means the atom is mostly empty space, except for its tiny nucleus.

How to work out the number of protons, neutrons and electrons in an atom:

- **Neutrons** = atomic mass – atomic number
  7 - 3 = 4
- **Protons** = atomic number = 3
- **Electrons** = protons = 3



Isotopes – *Versions of an element with a different number of neutrons.*

Protons = 6
Neutrons = 6
Electrons = 6

12 C 6 vs. 13 C 6

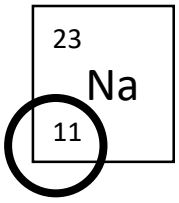
Protons = 6
Neutrons = 7
Electrons = 6

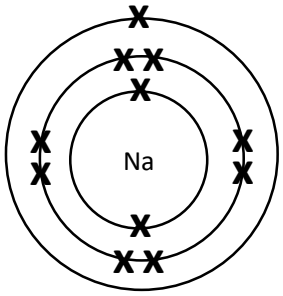
- Both are carbon as they both have 6 protons.
- Therefore they have the same number of electrons (6).
- They are isotopes of carbon as they contain a different number of neutrons 6 vs. 7.
- This means they also have different atomic masses.

You must state the numbers of each particle to gain the marks!

Electronic Structure

- The negative electrons (x) occupy shells (energy levels) orbiting the nucleus of the atom.
- The shells are filled from the lowest energy level (innermost/first shell) outwards.
- The first (innermost) shell is full when it contains **2** electrons.
- All other shells are full when they contain **8** electrons.





2,8,1

- Sodium (Na) has 11 electrons.
- The first shell takes 2.
- The next shell takes 8.
- This leaves 1 for the outer shell.
- Sodium is in group 1 of the periodic table, because it has 1 electron in its outermost shell.

Questions: Atomic Structure, Isotopes & Electronic Structure

1. Define the keyword **atom**.
2. Define the keyword **element**.
3. Draw a labelled diagram of a lithium atom, showing the protons, neutrons and electrons.
4. Explain what the **mass number** and **atomic number** tell us.
5. What is the mass of a proton?
6. What is the charge of a proton?
7. What is the mass of a neutron?
8. What is the charge of a neutron?
9. What is the mass of an electron?
10. What is the charge of an electron?
11. What fraction of the atomic radius, is the radius of the nucleus of an atom?
12. Give the number of protons (P^+), neutrons (N) and electrons (e^-) for the following atoms:
    a) Na b) S c) Br d) Ca e) K f) F g) He

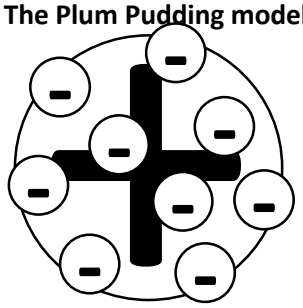
    h) O i) H j) Fe k) Zn l) Pb m) Li n) Al
13. Define the keyword **isotope**
14. Compare the similarities and differences between these two isotopes of oxygen (READ THE GUIDE!). $_{8}^{18}O$ vs $_{8}^{16}O$
15. Compare the similarities and differences between these two isotopes of chlorine (READ THE GUIDE!). $_{17}^{37}Cl$ vs $_{17}^{35}Cl$
16. What is the maximum number of electrons that can fill the first shell?
17. What is the maximum number of electrons that can fill the second shell?
18. Draw electronic structures for the following elements:
    a) H b) He c) Li d) C e) O f) S g) Ca

    h) Na i) Al j) S k) Ne
19. What group of the periodic table is oxygen in and why?
20. What group of the periodic table is magnesium in and why?
21. What group of the periodic table is chlorine in and why?
22. Why are the noble gases all in group 0?

Development of the atomic model.

New evidence has led to the atomic model changing over time.

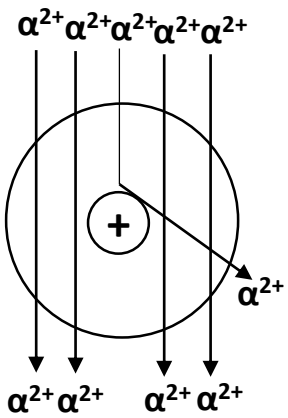
The Plum Pudding model of the atom:



When the electron was discovered, J.J Thomson suggested the atom was a positively charged sphere with negatively charged electrons embedded in it.

Protons and neutrons were not included in the plum pudding as they had yet to be discovered.

The Rutherford alpha particle experiment:



Ernest Rutherford tested the plum pudding model by firing positively charged alpha particles at gold atoms.

Most of the alpha particles passed straight through, which suggested the atom was mostly empty space.

A tiny proportion positive alpha particles scattered off in different directions, this suggests they collided with, and were repelled by, a tiny nucleus of positive charge.

This new evidence proved that the plum pudding model was wrong.

Niels Bohr:

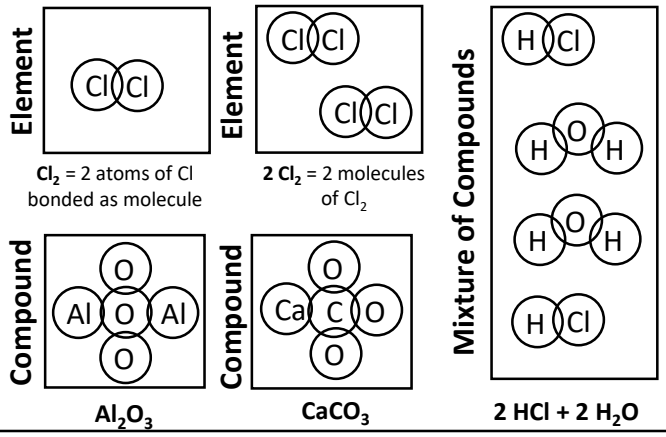
Niels Bohr suggested that the electrons occupied energy levels (shells surrounding the atom).

James Chadwick:

James Chadwick discovered that the nucleus also contains neutrons.

Chemical Formulae

Tell us how many atoms of each element a molecule or compound contains.



Compound

Two or more different elements bonded together.

Reaction equations

When different elements and/or compounds react with each other we write word and symbol equations.

Word equation:

Sodium + Chlorine → Sodium Chloride

Symbol equation:

$2\ Na_{(s)} + Cl_{2\ (g)} \rightarrow 2\ NaCl_{\ (g)}$

State symbols:

Written in symbol equations to tell you the state of matter for each substance.

(s) – Solid (l) – Liquid

(g) – Gas (aq) – aqueous

Balancing equations:

The number of atoms of each element either side of the equation must be the same.

1. Count the number of atoms of each element on both sides.

$\_\_\ Al + \_\_\ O_2 \rightarrow \_\_\ Al_2O_3$

Al = 1	Al = 2
O = 2	O = 3

2. Find common denominators between the numbers and multiply so they match.

$\_\_\ Al + \_\_\ O_2 \rightarrow \_\_\ Al_2O_3$

Al = 1 x 4	= 4	Al = 4	= 4
O = 2 x 3	= **6**	O = 3 x 2	= **6**

3. Put the numbers you multiplied by in the equation's gaps.

$\underline{\mathbf{4}}\ Al + \underline{\mathbf{3}}\ O_2 \rightarrow \underline{\mathbf{2}}\ Al_2O_3$

Al = 1 **x 4**	= 4	Al = 2 **x 2**	= 4
O = 2 **x 3**	= 6	O = 3 **x 2**	= 6

Conservation of mass

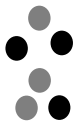
Mass is conserved, so it will be equal on both sides of a chemical equation.

$4\ Al + 3\ O_2 \rightarrow 2\ Al_2O_3$

So five grams of aluminium and 3 grams of oxygen will give 8 grams of aluminium oxide!

Mixture

Two or more elements or compounds not chemically combined. The chemical properties of each substance in a mixture remain unchanged.

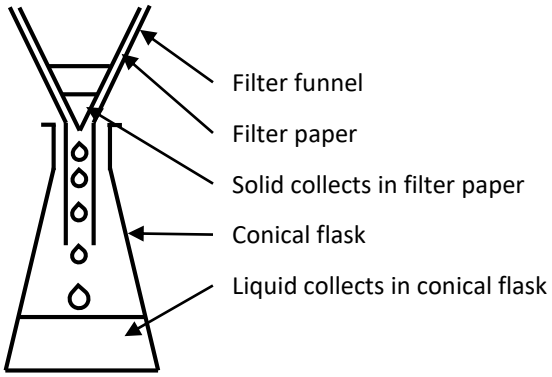


Physical processes

Physical processes can be used to separate mixtures. They do not result in a chemical reaction.

Filtration

Filtration is used to separate a mixture of a <u>liquid and solid</u> for example, sand and water.



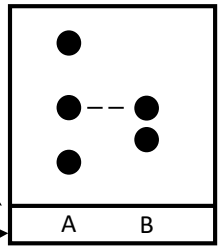
Chromatography

Chromatography is used to separate mixtures containing colours, such as pen inks or food colourings.

- A contains 3 colours, B contains 2.
- A and B share 1 colour.
- A has 2 colours B does not.
- B has 1 colour A does not.

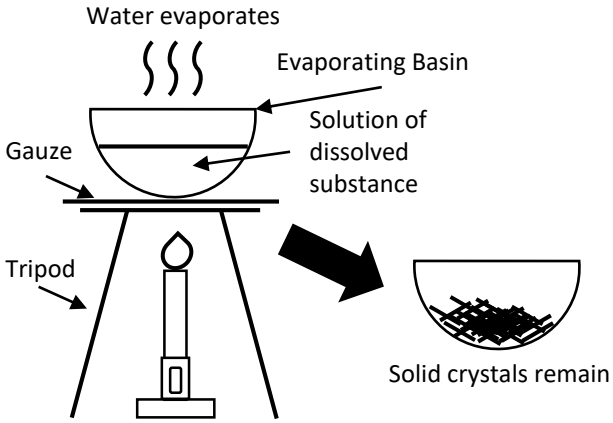
The <u>baseline</u> is drawn in pencil so it doesn't smudge!

The solvent (liquid) level must not submerge the baseline!



Crystallisation

Crystallisation is used to obtain a solid form of a dissolved substance, for example getting solid salt from salty water.

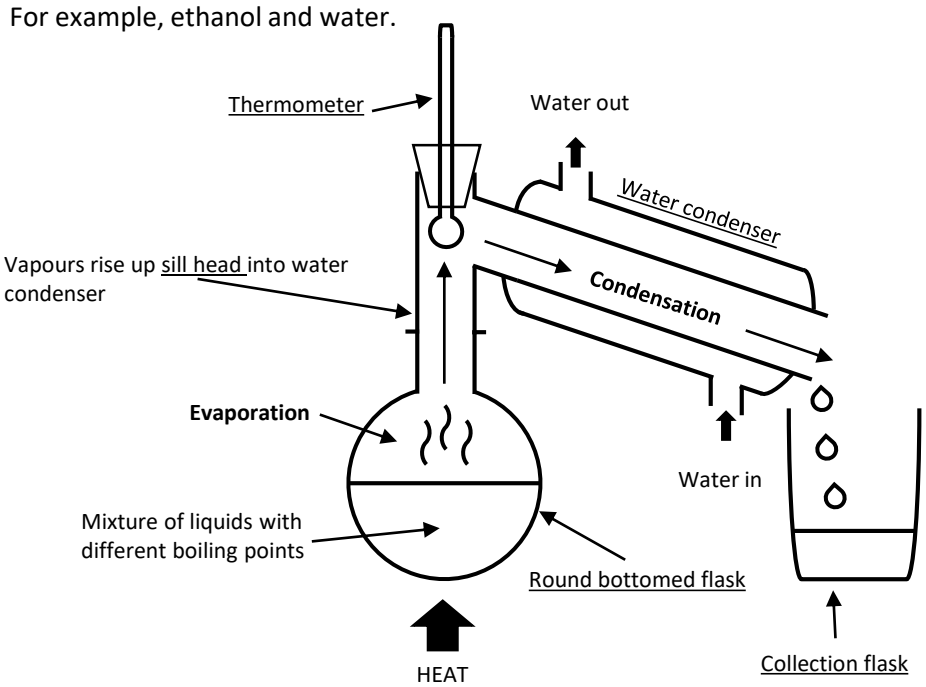


1. The solution is **heated** inside an **evaporating basin**.
2. The water **evaporates**.
3. This leaves behind **solid crystals** of what was a dissolved substance.

TIP: Crystallisation is used for preparing crystals of blue copper sulfate. The copper sulfate is made by reacting copper oxide (an insoluble base) with sulfuric acid.

Distillation

Distillation is used to separate mixtures of liquids with different boiling points. For example, ethanol and water.

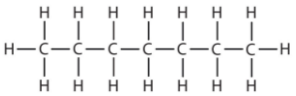
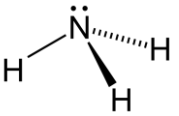
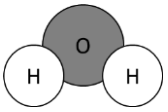
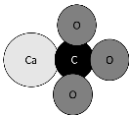
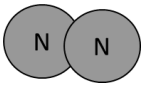


1. The mixture of liquids is **heated.**
2. The substance with the lowest boiling point **evaporates** first.
3. Its vapours rise up the sill head and are **cooled** in the water condenser.
4. The vapours **condense** into a liquid and **collect** in the collection flask.
5. The substance with the higher boiling point remains in the round bottomed flask.

TIP: The water condenser has a water jacket. This cools the vapours down <u>faster</u> so none of them escape.

Questions: Development of the Atomic Model, Compounds, Formulae & Equations, Separating Mixtures

1. Describe the plum pudding model suggested by J.J. Thomson.
2. In the Rutherford experiment, most of the alpha particles passed straight through. What did this prove?
3. In the Rutherford experiment, a small proportion of particles were deflected/scattered by large angles, what did this prove?
4. Who suggested that electrons occupy energy levels (shells)?
5. Who discovered that the nucleus of an atom contains neutrons?
6. Write chemical formula for the following elements & compounds:

a) 	**b)** 	**c)** 
d) 	**e)** 	**f)** 

7. Define the keyword **compound**.
8. Define the state symbols (s), (l), (g), (aq).
9. Describe simply what is meant by the state symbol (aq).
10. Balance the following equations:
    a) __ Na + Cl_2 → __ NaCl
    b) __ Mg + O_2 → __ MgO
    c) __ Al + __ Cl_2 → __ $AlCl_3$
    d) __ Na + O_2 → __ Na_2O
11. If 12 tonnes of iron reacts with 4 tonnes of oxygen, what mass of iron oxide is produced?

12. Define the keyword **mixture**.
13. Why is separating a mixture a **physical process**?
14. Name four methods of separating mixtures.
15. Which separating technique is used to separate a solid from a liquid?
16. Which separating technique is used to obtain a pure dry solid crystal of a dissolved substance?
17. Which separating technique is used to separate a mixture of colours or food additives?
18. Which separating technique is used to separate mixtures of liquids with different boiling points?
19. What is the first stage of distillation?
20. What is the second stage of distillation?
21. What do the warm vapours in distillation rise up into?
22. Why is the condenser cooled with water?

Development of the Periodic Table

For hundreds of years, scientists have tried to order the known elements into a periodic table. Over time, each version was tested, and whenever new evidence suggested another order was better, the periodic table was changed.

John Dalton's Early Periodic Table.

John Dalton arranged the known elements in order of atomic mass and he gave each element a unique symbol:

Hydrogen	1	Strontian	46
Azote	5	Barytes	68
Carbon	5	Iron	50
Oxygen	7	Zinc	56
Phosphorus	9	Copper	56
Sulphur	13	Lead	90
Magnesia	20	Silver	190
Lime	24	Gold	190
Soda	28	Platina	190
Potash	42	Mercury	167

John Newlands' Law of Octaves

John Newlands also arranged the known elements in order of atomic mass. He also placed elements in vertical groups with other elements that had similar properties.

	No.		No.		No.		No.		No.		No.		No.		No.
H	1	F	8	Cl	15	Co & Ni	22	Br	29	Pd	36	I	42	Pt &Ir	50
Li	2	Na	9	K	16	Cu	23	Rb	30	Ag	37	Cs	44	Os	51
Be	3	Mg	10	Ca	17	Zn	24	Sr	31	Cd	38	Ba & V	45	Hg	52
B	4	Al	11	Cr	19	Y	25	Ce & La	33	U	40	Ta	46	Tl	53
C	5	Si	12	Ti	18	In	26	Zr	32	Sn	39	W	47	Pb	54
N	6	P	13	Mn	20	As	27	Bi & Mo	34	Sb	41	Nb	48	Bi	55
O	7	S	14	Fe	21	Se	28	Rh & Ru	35	Te	43	Au	49	Th	56

There were some key issues with Newlands periodic table:

- He did not account for undiscovered elements so the order broke down each time a new element was discovered.
- Some metals were placed with non-metals despite having very different physical and chemical properties.
- Therefore, it was not widely accepted by other scientists.

Mendeleev's Periodic Table

	I	II	III	IV	V	VI	VII	VIII
1	H							
2	Li	Be	B	C	N	O	F	
3	Na	Mg	Al	Si	P	S	Cl	
4	K Cu	Ca Zn	? ?	Ti ?	V As	Cr Se	Mn Br	Fe Co Ni
5	Rb Ag	Sr Cd	Y In	Zr Sn	Nb Sb	Mo Te	? I	Ru Rh Pd

Mendeleev's periodic table was the most revolutionary:

Mendeleev placed elements in vertical groups with other elements of similar properties.

Mendeleev placed elements in order of atomic mass but he did not follow this order strictly if it meant disrupting the vertical groups.

He left gaps for undiscovered elements. This meant that he could predict the properties of this new element to aid in its discovery.

Mendeleev's periodic table did not include a group 0 (Noble gases).

When new elements were discovered, they matched the properties predicted by Mendeleev, this provided evidence that his periodic table was correct.

The later discovery of isotopes explained why the elements could not strictly be placed in order of atomic mass.

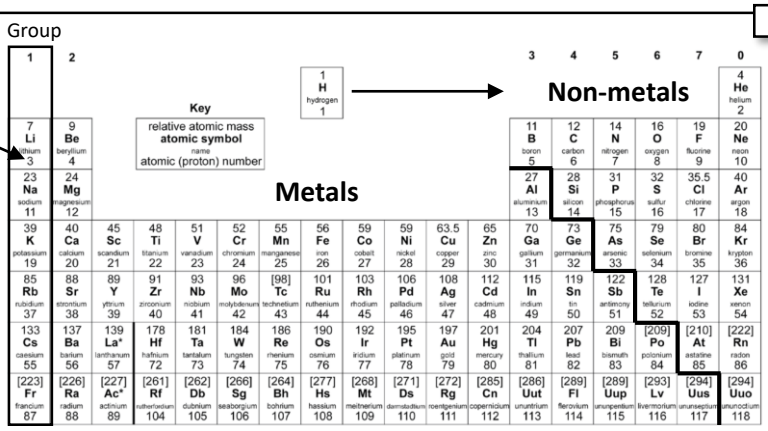
The Modern Periodic Table

Elements on the modern periodic table are organised in order of atomic number (number of protons).

Elements are placed in vertical groups with other elements of similar properties.

The group number corresponds to the number of electrons in the outer shell.

The metals and non-metals are divided.



Metals are to the left of the staircase, non-metals to the right (hydrogen should be treated as a non-metal).
You have to draw the staircase on in the exams, so remember: "Aluminium is under the stairs!"

Group 1: The Alkali Metals

7	Li
lithium	3
23	Na
sodium	11
39	K
potassium	19
85	Rb
rubidium	37
133	Cs
caesium	55
[223]	Fr
francium	87

- The elements of group 1 are called the alkali metals: Lithium (Li), Sodium (Na), Potassium (K) etc.
- They all have one electron in their outer shells, this means they have similar properties.

Key properties:

- Very reactive.
- Float on water due to low density.
- Soft enough to cut with a knife.
- Low melting points.
- Have to be stored in oil (to prevent them reacting with oxygen in the air).
- React with water to form a strongly alkaline solution and hydrogen gas.
- React with non-metals to form white and soluble ionic compounds.
- Upon reacting they lose electrons to form 1+ ions e.g. Na^+, Li^+ and K^+.

Reactions with water:

The alkali metals float on the surface of water (low density) and fizz as they react where hydrogen gas is produced.

Sodium + Water → Sodium hydroxide + Hydrogen

$2\ Na\ (s) + 2\ H_2O\ (l) \rightarrow 2\ NaOH\ (aq) + H_2\ (g)$

Reactivity increases down the group, so Potassium is more reactive. This means it fizzes more and ignites with a purple flame:

Potassium + Water → Potassium hydroxide + Hydrogen

$2\ K\ (s) + 2\ H_2O\ (l) \rightarrow 2\ KOH\ (aq) + H_2\ (g)$

If universal indicator is added to the water, it will turn purple as the "hydroxide (OH^-) ions" produced make the solution strongly alkaline (pH 14).

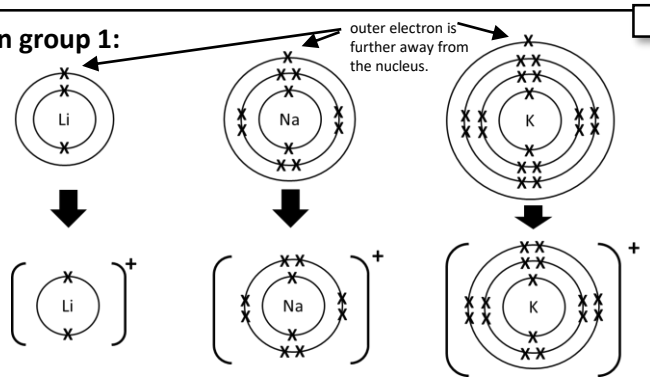
Reactivity increases down group 1:

Metals lose electrons when they react to achieve a full outer shell.

As you go down the group, the outer electron is further away from the nucleus.

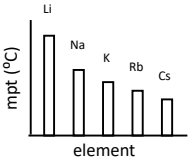
This means it experiences less electrostatic attraction. So is more easily lost.

Therefore reactivity increases.



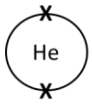
Melting points:

The melting point decreases as you go down group 1, as the metallic bond strength gets weaker.



Group 0: The Noble Gases

- The elements of Group 0 are called the noble gases, Helium (He), Neon (Ne), Argon (Ar) etc.
- They are very unreactive as they have full outer shells of electrons (2 for He, as it's the first shell, 8 for others).
- They exist as single atoms.
- They are gases at room temperature and the boiling point increases down the group proportional to atomic mass.



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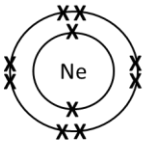

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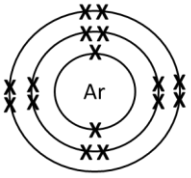

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Full outer shells of electrons make the noble gases very stable and unreactive as they do not need to react to lose or gain electrons.

4	He
helium	2
20	Ne
neon	10
40	Ar
argon	18
84	Kr
krypton	36
131	Xe
xenon	54
[222]	Rn
radon	86

TRIPLE ONLY - Central Block: The Transition Metals

45	48	51	52	55	56	59	59	63.5	65
Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
scandium	titanium	vanadium	chromium	manganese	iron	cobalt	nickel	copper	zinc
21	22	23	24	25	26	27	28	29	30
89	91	93	96	[98]	101	103	106	108	112
Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd
yttrium	zirconium	niobium	molybdenum	technetium	ruthenium	rhodium	palladium	silver	cadmium
39	40	41	42	43	44	45	46	47	48
139	178	181	184	186	190	192	195	197	201
La*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg
lanthanum	hafnium	tantalum	tungsten	rhenium	osmium	iridium	platinum	gold	mercury
57	72	73	74	75	76	77	78	79	80

- The transition metals are found in the central block of the periodic table.
- They have different properties to the alkali metals, for instance, they are stronger, denser and less reactive.
- When they react with non-metals, the ionic compounds formed can be a variety of colours.

Key properties:

- Less reactive than alkali metals.
- Good conductors of heat/electricity.
- High density.
- Strong/Hard
- High melting points
- Good for use as catalysts.
- Form coloured compounds.

- Transition metals have multiple oxidation states. This means they can form ions with different charges e.g:

  - Iron can lose 2 electrons to form green iron (II) Fe^{2+} ions.
  - Or it can lose 3 electrons to form brown iron (III) Fe^{3+} ions.
  - Copper can lose 1 electron to form green copper (I) Cu^+ ions..
  - Or it can lose 2 electrons to form blue copper (II) Cu^{2+} ions.

- The multiple oxidation states make transition metals useful as catalysts, as it enables them to readily take part in redox reactions.

Group 7: The Halogens

19 **F** fluorine 9
35.5 **Cl** chlorine 17
80 **Br** bromine 35
127 **I** iodine 53
[210] **At** astatine 85

- The elements of group 7 are called the <u>halogens</u>. Fluorine (F), Chlorine (Cl), Bromine (Br), Iodine (I) etc.
- They all have <u>seven electrons in their outer shells</u>, this means they have <u>similar properties</u>.

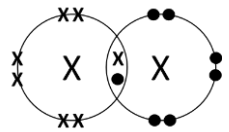
Key properties:

- Low melting and boiling points due to the weak intermolecular forces between their simple molecules.
- Poor conductors of heat/electricity.
- Covalently bond with themselves to form diatomic molecules F_2, Cl_2, Br_2 and I_2.
- Form coloured vapours.
- React with metals to form white and soluble ionic compounds.
- Upon reacting they gain electrons to form 1- hal**ide** ions e.g. F^- (fluoride), Cl^- (chloride), Br^- (bromide) and I^- (iodide).

Diatomic Molecules

- In their elemental form, halogens always exist as diatomic (two atom) molecules.
- This is because they covalently bond with themselves (share electrons) to achieve full outer shells:

X = F, Cl, Br or I



X_2

Reactivity decreases down group 7:

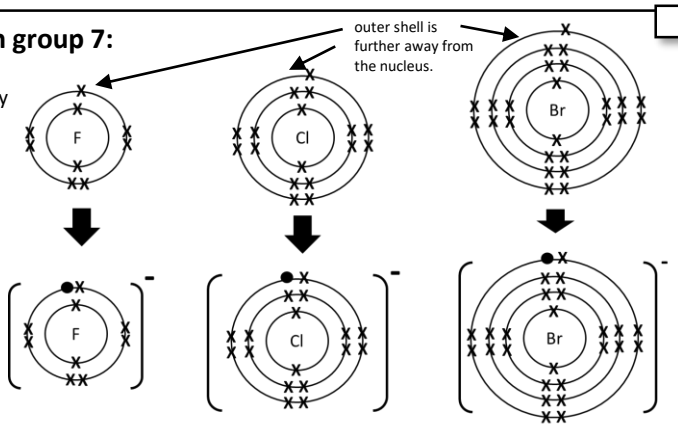
<u>Non-Metals gain electrons</u> when they react to achieve a <u>full outer shell.</u>

As you go down the group, <u>the outer shell is further away from the nucleus</u>.

This means it <u>experiences less electrostatic attraction</u>.

So <u>electrons are harder to gain.</u>

Therefore <u>reactivity decreases.</u>



Melting and boiling points:

The melting points increase down group 7, because, the mass of the molecules increases which increases the strength of intermolecular forces.

Displacement reactions:

Chlorine is higher up group 7 than bromine so is more reactive.

chlorine + potassium bromide → potassium chloride + bromine

Cl_2 (aq) + 2 KBr (aq) → 2 KCl (aq) + Br_2 (aq)

Chlorine has displaced (taken the place of) bromine from its compound.

Bromine is higher up group 7 than iodine so is more reactive.

bromine + sodium iodide → sodium bromide + iodine

Br_2 (aq) + 2 NaI (aq) → 2 NaBr (aq) + I_2 (aq)

Bromine has displaced (taken the place of) iodine from its compound.

Bromine is lower down group 7 than chlorine so is less reactive.

~~bromine + sodium chloride → sodium bromide + chlorine~~

~~Br_2 (aq) + 2 NaCl (aq) → 2 NaBr (aq) + Cl_2 (aq)~~

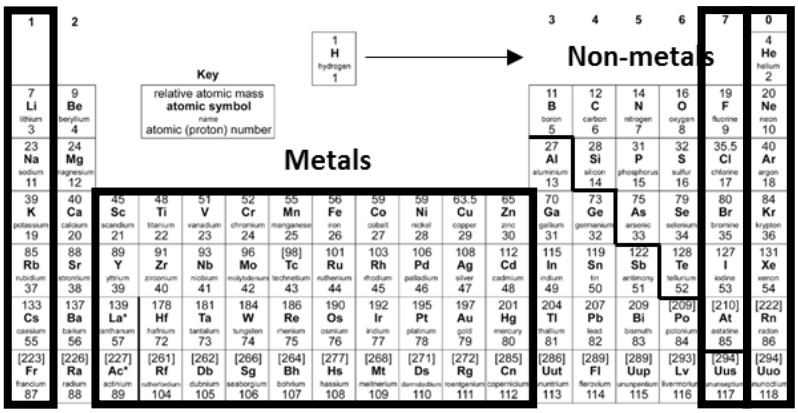
Bromine cannot displace chlorine as it's less reactive. No reaction occurs!

Overview

Group 7 Halogens

Group 1 Alkali Metals

Group 0 Noble Gases



Questions: The periodic table.

1. John Dalton, John Newlands and Mendeleev all arranged elements in order of what?
2. State two ways in which Mendeleev arranged his periodic table differently to Dalton and Newlands.
3. Which group was missing from Mendeleev's periodic table?
4. What is the modern periodic table arranged in order of?
5. State two ways that elements in the same group are similar?
6. Give the symbols of elements in group 1, and give the name of group 1.
7. Give the symbols of elements in group 7, and give the name of group 7.
8. Give the symbols of elements in group 0, and give the name of group 0.
9. Describe the trend in reactivity down group 1.
10. Describe the trend in reactivity down group 7.
11. What do group 1 elements react with?
12. What gas is produced when group 1 elements react with water?
13. When a group 7 element reacts with a group 1 element, a white compound is formed, what type of compound is this?
14. The group 7 elements all exist as **diatomic molecules**, what is meant by this?
15. When group 1 elements react, what happens to their outer shell electrons? And what charge ions do they form?
16. When group 7 elements react, what happens to their outer shell electrons? And what charge ions do they form?

17. Name the type of reaction occurring here:
Potassium bromide + chlorine → Potassium chloride + bromine

18. Why does the reaction in question 17 take place?

19. Complete the following word equations for displacement reactions (check that they will happen by comparing reactivities!).

a) Sodium iodide + chlorine → _____ + _____

b) Potassium iodide + bromine → _____ + _____

c) Potassium chloride + bromine → _____ + _____

20. Complete the following symbol equations for displacement reactions (check that they will happen by comparing reactivities!).

a) $2\ NaI + Cl_2 \rightarrow$ ____ + ____

b) $2\ KI + Br_2 \rightarrow$ ____ + ____

c) $2\ KCl + Br_2 \rightarrow$ ____ + ____

TRIPLE ONLY

21. Where are the transition metals found on the periodic table?
22. How are the transition metals different to the alkali metals?
23. Transition metals can form ions with different charges, what term is used to describe this property?
24. What are transition metals useful as?