Atomic Structure and the Periodic Table

AQA Chemistry topic 1
1.1 - Atoms, elements and compounds
Everything in the universe is basically made up of atoms. An atom is the smallest part of an element that can exist. This is what they “look” like:

**ELECTRON** - negative, mass nearly nothing

**PROTON** - positive, same mass as neutron ("1")

**NEUTRON** - neutral, same mass as proton ("1")
Elements

If a solid, liquid or gas is made up of only one type of atom we say it is an element. For example, consider a tripod made up of iron:

These atoms are ALL iron - there's nothing else in here
# Elements and symbols that you should know:

## Part 1 - The obvious ones:

<table>
<thead>
<tr>
<th></th>
<th>Element</th>
<th>Symbol</th>
<th></th>
<th>Element</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hydrogen</td>
<td>H</td>
<td>8</td>
<td>Oxygen</td>
<td>O</td>
</tr>
<tr>
<td>2</td>
<td>Helium</td>
<td>He</td>
<td>9</td>
<td>Fluorine</td>
<td>F</td>
</tr>
<tr>
<td>3</td>
<td>Lithium</td>
<td>Li</td>
<td>10</td>
<td>Neon</td>
<td>Ne</td>
</tr>
<tr>
<td>4</td>
<td>Beryllium</td>
<td>Be</td>
<td>11</td>
<td>Magnesium</td>
<td>Mg</td>
</tr>
<tr>
<td>5</td>
<td>Boron</td>
<td>B</td>
<td>12</td>
<td>Aluminium</td>
<td>Al</td>
</tr>
<tr>
<td>6</td>
<td>Carbon</td>
<td>C</td>
<td>13</td>
<td>Silicon</td>
<td>Si</td>
</tr>
<tr>
<td>7</td>
<td>Nitrogen</td>
<td>N</td>
<td>14</td>
<td>Phosphorus</td>
<td>P</td>
</tr>
</tbody>
</table>
Some more obvious ones:

15) Sulphur  S  18) Calcium  Ca
16) Chlorine  Cl  19) Zinc  Zn
17) Argon  Ar

The less obvious ones:

1) Sodium  Na  6) Tin  Sn
2) Potassium  K  7) Gold  Au
3) Iron  Fe  8) Mercury  Hg
4) Copper  Cu  9) Lead  Pb
5) Silver  Ag
The periodic table arranges all the 100 or so elements in groups according to their properties.

Vertical columns are called GROUPS

Horizontal rows are called PERIODS
Compounds are formed when two or more elements are chemically combined by sharing or giving of electrons. Some examples:

- Glucose
- Methane
- Sodium chloride (salt)

Compounds can only be separated back into elements using a chemical reaction.
Some simple compounds...

Methane, CH$_4$
Water, H$_2$O
Carbon dioxide, CO$_2$
Ethyne, C$_2$H$_2$
Sulphuric acid, H$_2$SO$_4$

Key
- Hydrogen
- Oxygen
- Carbon
- Sulphur
Balancing equations

Consider the following reaction:

\[
\text{Na} + \text{H}_2\text{O} \rightarrow \text{NaOH} + \text{H}_2
\]

This equation doesn’t balance - there are 2 hydrogen atoms on the left hand side (the “reactants” and 3 on the right hand side (the “products”).
We need to balance the equation:

Sodium + water $\rightarrow$ sodium hydroxide + hydrogen

Now the equation is balanced, and we can write it as:

$$2\text{Na}_\text{(s)} + 2\text{H}_2\text{O}_\text{(l)} \rightarrow 2\text{NaOH}_\text{(aq)} + \text{H}_2\text{(g)}$$
Some examples

\[
\begin{align*}
2Mg & + O_2 \rightarrow 2MgO \\
Zn & + 2HCl \rightarrow ZnCl_2 + H_2 \\
2Fe & + 3Cl_2 \rightarrow 2FeCl_3 \\
NaOH & + HCl \rightarrow NaCl + H_2O \\
CH_4 & + 2O_2 \rightarrow CO_2 + 2H_2O \\
Ca & + 2H_2O \rightarrow Ca(OH)_2 + H_2 \\
2NaOH & + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O \\
2CH_3OH & + 3O_2 \rightarrow 2CO_2 + 4H_2O
\end{align*}
\]
Naming compounds

Rule 1 - If two identical elements combine then the name doesn't change

This happens with the following elements:

1) $H_2$
2) $N_2$
3) $O_2$
4) $F_2$
5) $Cl_2$
6) $Br_2$

These elements always go around in pairs. For example, hydrogen looks like this:
Naming compounds

Rule 2 - When two elements join the end is usually ______ide.

e.g. Magnesium + oxygen → magnesium oxide

1) Sodium + chlorine
2) Magnesium + fluorine
3) Lithium + iodine
4) Chlorine + copper
5) Oxygen + iron
6) KBr
7) LiCl
8) CaO
9) MgO₂
10) KF
Rule 3 - When three or more elements combine and two of them are hydrogen and oxygen the name ends with hydroxide.

e.g. Sodium + hydrogen + oxygen → Sodium hydroxide

1) Potassium + hydrogen + oxygen
2) Lithium + hydrogen + oxygen
3) Calcium + hydrogen + oxygen
4) Mg(OH)$_2$
Naming compounds

Rule 4 - When three or more elements combine and one of them is oxygen the ending is _____ate

e.g. Copper + sulphur + oxygen \(\rightarrow\) Copper sulphate

1) Calcium + carbon + oxygen
2) Potassium + carbon + oxygen
3) Calcium + sulphur + oxygen
4) Magnesium + chlorine + oxygen
5) Calcium + oxygen + nitrogen
6) AgNO₃
7) H₂SO₄
8) K₂CO₃
## Simple formulae to learn

<table>
<thead>
<tr>
<th>&quot;Covalent&quot; formulae</th>
<th>&quot;Ionic&quot; formulae</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂O</td>
<td>NaCl</td>
</tr>
<tr>
<td>CO₂</td>
<td>CaCl₂</td>
</tr>
<tr>
<td>NH₃</td>
<td>MgO</td>
</tr>
<tr>
<td>H₂</td>
<td>HCl</td>
</tr>
<tr>
<td>O₂</td>
<td>H₂SO₄</td>
</tr>
<tr>
<td>N₂</td>
<td>HNO₃</td>
</tr>
<tr>
<td>SO₂</td>
<td>NaOH</td>
</tr>
<tr>
<td></td>
<td>Ca(OH)₂</td>
</tr>
<tr>
<td></td>
<td>CaCO₃</td>
</tr>
<tr>
<td></td>
<td>Al₂O₃</td>
</tr>
<tr>
<td></td>
<td>Fe₂O₃</td>
</tr>
</tbody>
</table>
Mixtures

A mixture like this is formed when two or more elements are mixed together but NOT chemically combined.

The chemical properties of the salt and water remain unchanged.
Element, mixture or compound?

Salty water

Hydrogen

Hydrochloric acid

Air

Diamond

Sodium chloride (salt)
In this practical we tried to separate rock salt - a mixture of ____ and sand. To do this we followed four steps:

1) We ground the rock salt using a ______ and mortar,
2) We dissolved the mixture,
3) We _________ it,
4) We evaporated the remains.

The sand didn’t __________, so we were able to filter it out. The salt did dissolve, so we had to __________ the remains to get the salt back.

**Conclusion:** Filtration can be used to remove something that **doesn’t** dissolve and evaporation can be used to separate something that **does** dissolve.

**Words** - filtered, salt, pestle, evaporate, dissolve
This apparatus can be used to separate water and ethanol because they have different boiling points. The ethanol will evaporate first, turn back into a liquid in the condenser and collect in the beaker. The water remains in the round flask, as long as the temperature does not exceed water’s boiling point. This method can be used to separate any liquids with different boiling points such as the fractional distillation of crude oil.
Chromatography can be used to separate a mixture of different inks. Some example questions...

1) Ink X contains two different colours. What are they?

2) Which ink is ink Z made out of?
1) A mixture containing something that DOES dissolve can be separated using __________

2) A mixture of liquids with different boiling points can be separated using __________

3) A mixture of different inks can be separated using __________

4) A mixture containing something that DOES NOT dissolve can be separated using __________

Distillation, chromatography, evaporation or filtration?
The Development of Atomic Structure Theory

Task: Find out how the following people have contributed to our understanding of atomic theory, including what they discovered and how their ideas were proved:

John Dalton
JJ Thomson
Ernest Rutherford
Neils Bohr
James Chadwick
The Development of Atomic Structure Theory

John Dalton
I proposed that all matter is made up of atoms - the smallest thing possible.

Ernest Rutherford
I discovered electrons and therefore proved that atoms can be made of smaller things.
I showed that the atom was made of a small central nucleus with electrons orbiting it.
I showed that these electrons orbit at specific distances from the atom.

JJ Thomson

James Chadwick
I showed that there are neutrons in the nucleus as well as protons.

Neils Bohr
The structure of the atom

ELECTRON - negative, mass nearly nothing

The nucleus is around 10,000 times smaller than the atom! The diameter of the nucleus is around $10^{-14}$ m.

PROTON - positive, same mass as neutron ("1")

The nucleus - this contains most of the mass in an atom

NEUTRON - neutral, same mass as proton ("1")

Atoms always have the same number of protons and electrons so they are neutral overall. The atom is around 0.1 nm big (i.e. $10^{-10}$ m).
A hundred years ago people thought that the atom looked like a “plum pudding” – a sphere of positive charge with negatively charged electrons spread through it...

Ernest Rutherford, British scientist:

I did an experiment (with my colleagues Geiger and Marsden) that proved this idea was wrong. I called it the “Scattering Experiment”
The Rutherford Scattering Experiment

Alpha particles (positive charge, part of helium atom)

Thin gold foil

Most particles passed through, 1/8000 were deflected by more than 90°

Conclusion - atom is made up of a small, positively charged nucleus surrounded by electrons orbiting in a “cloud”.
## The structure of the atom

### Particle Table

<table>
<thead>
<tr>
<th>Particle</th>
<th>Relative Mass</th>
<th>Relative Charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proton</td>
<td>1</td>
<td>+1</td>
</tr>
<tr>
<td>Neutron</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Electron</td>
<td>1/2000 (i.e. 0)</td>
<td>-1</td>
</tr>
</tbody>
</table>

**MASS NUMBER** = number of protons + number of neutrons

**SYMBOL**

**ATOMIC NUMBER** = number of protons. All atoms of a particular element must have the same number of protons.
Mass and atomic number

How many protons, neutrons and electrons?

H 1
B 11
O 16
Na 23
Cl 35
U 238
An isotope is an atom with a different number of neutrons:

Notice that the mass number is different. How many neutrons does each isotope have?

Each isotope has 8 protons — if it didn’t then it just wouldn’t be oxygen any more.
Consider an atom of Potassium:

Potassium has 19 electrons. These electrons occupy specific energy levels “shells”...

The inner shell has ___ electrons
The next shell has ___ electrons
The next shell has ___ electrons
The next shell has the remaining ___ electron

Electron structure = 2,8,8,1
Electron structure

Draw the electronic structure of the following atoms:

- **N**
  - Electron structure: 2,5
  - Nucleus: 14, 7

- **Mg**
  - Electron structure: 2,8,2
  - Nucleus: 24, 12

- **Ca**
  - Electron structure: 2,8,8,2
  - Nucleus: 40, 20
1.2 - The Periodic Table
Periodic Table Introduction

How would you arrange these elements into groups?
### Fact 1: Elements in the periodic table are arranged in order of proton number:

E.g. Lithium has 3 protons while Beryllium has 4.
**Fact 2:** Elements in the same group have the same number of electrons in the outer shell (this corresponds to their group number).

- E.g. all group 1 metals have __ electron in their outer shell.
- These elements have __ electrons in their outer shells.
- These elements have __ electrons in their outer shell.
**The Periodic Table**

**Fact 3:** As you move down through the periods an extra electron shell is added:

- **E.g. Lithium has 3 electrons in the configuration 2,1**
- **Sodium has 11 electrons in the configuration 2,8,1**
- **Potassium has 19 electrons in the configuration __,__,__,
### The Periodic Table

**Fact 4:** (Most important) All of the elements in the same group have similar PROPERTIES. This is how I thought of the periodic table in the first place. This is called PERIODICITY.

<table>
<thead>
<tr>
<th>Li</th>
<th>Be</th>
<th>Na</th>
<th>Mg</th>
<th>K</th>
<th>Ca</th>
<th>Fe</th>
<th>Ni</th>
<th>Cu</th>
<th>Zn</th>
<th>Ag</th>
<th>Br</th>
<th>Kr</th>
<th>I</th>
<th>Xe</th>
</tr>
</thead>
<tbody>
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</tr>
</tbody>
</table>

E.g. consider the group 1 metals. They all:

1. Are soft
2. Can be easily cut with a knife
3. React with water
Development of the Periodic Table

1817: Johann Dobereiner developed the law of “triads” – he put elements together in groups of 3 according to their properties.

1864: John Newlands arranged the known elements in order of atomic mass and found out that every 8th element had similar properties:

Li  Be  B  C  N  O  F  Na  Mg  Al

1869: Dimitri Mendeleev arranged the known elements in order of mass but he also left in gaps and was able to predict the properties of unknown elements:

Li  Be  B  C  N  O  F  Na  Mg  Al

1913: Henry Moseley proposed the use of atomic number rather than atomic mass. Knowledge of the existence of isotopes also gave evidence to using proton number rather than mass.
Another fact: Most of the elements are metals:

These elements are metals – they form “positive ions”

These elements are non-metals – they form “negative ions”

This line divides metals from non-metals
Properties of metals

Metals have very high melting points (which means that they are usually _____) whereas non-metals will melt at lower ______________

All metals conduct heat and ______________ very well, whereas non-metals don’t (usually)

Metals are strong and ______ but bendable. Non-metals are usually _____ or they will snap.

Metals will _____ when freshly cut or scratched, whereas non-metals are usually dull.

Metals have higher _______ than non-metals (i.e. they weigh more)

Metals can be used to make ______ (a mixture of different metals)

*Words* - alloys, electricity, solids, weak, densities, temperatures, tough, shine
Group 0 - The Noble gases

Questions:

1) How many electrons do these elements have in their outer shell?

2) How does this affect their reactivity?
Some facts...

1) All of the noble gases have a full outer _______.

2) They all have _____ melting and boiling points and are inflammable.

3) They exist as single _______.

4) Their boiling point _______ as atomic mass increases.

5) Because they have a full outer shell, the noble gases are _______ and unreactive.

Words - neon, stable, low, shell, atoms, increases
Group 1 - The alkali metals

- Li
- Na
- K
- Rb
- Cs
- Fr
Group 1 - The alkali metals

Some facts...

1) These metals all have ___ electron in their outer shell.

2) They are not very __________

3) Reactivity increases as you go ________ the group.

4) They all react with water to form an alkali (hence their name) and ____________, e.g:

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

5) They form ionic compounds - white solids that dissolve in ______ to form __________ solutions (e.g. salt water).

Words - down, one, hydrogen, dense, colourless, water
# Properties of the Alkali Metals

<table>
<thead>
<tr>
<th>Element</th>
<th>Melting Point (°C)</th>
<th>Boiling Point (°C)</th>
<th>Density (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lithium</td>
<td>180</td>
<td>1340</td>
<td>0.53</td>
</tr>
<tr>
<td>Sodium</td>
<td>98</td>
<td>883</td>
<td>0.97</td>
</tr>
<tr>
<td>Potassium</td>
<td>64</td>
<td>760</td>
<td>0.86</td>
</tr>
<tr>
<td>Rubidium</td>
<td>39</td>
<td>688</td>
<td>1.53</td>
</tr>
<tr>
<td>Caesium</td>
<td>??</td>
<td>??</td>
<td>??</td>
</tr>
</tbody>
</table>
Consider a sodium atom:

Take away one of the electrons ("oxidation")

Now consider a potassium atom:

Take away one of the electrons

Potassium loses its electron more easily because its further away - potassium is MORE REACTIVE
Group 7 - The halogens

- F
- Cl
- Br
- I
- At
Group 7 - The Halogens

Some facts...

1) Reactivity ______ as you go down the group.

2) They exist as ______ molecules (so that they both have a full outer shell):

3) Because of this fluorine and chlorine are ______ at room temperature and bromine is a gas.

4) They react with metals to form ______ compounds, e.g. salt.

5) They form molecular compounds with other non-metallic compounds, e.g. ______.

Words - diatomic, liquid, decreases, water, ionic
## Properties of Group 7

<table>
<thead>
<tr>
<th>Element</th>
<th>Melting Point (°C)</th>
<th>Boiling Point (°C)</th>
<th>Density (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flourine</td>
<td>-220</td>
<td>-188</td>
<td>0.0016</td>
</tr>
<tr>
<td>Chlorine</td>
<td>-101</td>
<td>-34</td>
<td>0.003</td>
</tr>
<tr>
<td>Bromine</td>
<td>-7</td>
<td>59</td>
<td>3.12</td>
</tr>
<tr>
<td>Iodine</td>
<td>114</td>
<td>184</td>
<td>4.95</td>
</tr>
<tr>
<td>Astatine</td>
<td>??</td>
<td>??</td>
<td>??</td>
</tr>
</tbody>
</table>
Trends in Group 7

Consider a fluorine atom:

Fluorine

Add an electron ("reduction")

Fluoride ion

Now consider a chlorine atom:

Chlorine

Add an electron

Chloride ion

Chlorine doesn’t gain an electron as easily as fluorine so it is LESS REACTIVE
The halogens - some reactions

1) Halogen + metal:

\[
\text{Na} + \text{Cl} \rightarrow [\text{Na}^+][\text{Cl}^-]
\]

Note that the halogen will have a charge of -1

Halogen + metal $\rightarrow$ ionic salt

2) Halogen + non-metal:

\[
\text{H} + \text{Cl} \rightarrow \text{HCl}
\]

Halogen + non-metal $\rightarrow$ covalent molecule
# Displacement reactions

To put it simply, a MORE reactive halogen will displace a LESS reactive halogen from a solution of its salt.

<table>
<thead>
<tr>
<th>Decreasing reactivity</th>
<th>Potassium chloride $\text{KCl}_{(aq)}$</th>
<th>Potassium bromide $\text{KBr}_{(aq)}$</th>
<th>Potassium iodide $\text{KI}_{(aq)}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorine $\text{Cl}_2$</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bromine $\text{Br}_2$</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Iodine $\text{I}_2$</td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
1.3 - Properties of Transition Metals (Chemistry only)
1) They are all ______ and solid (except __________).
2) They are ____ reactive than the alkali metals.
3) They can form __________ compounds, usually _______.
4) They can be used as a ______ (a chemical that speeds up a reaction).
5) They have ______ melting points and densities compared to group 1.

Words - hard, coloured, higher, mercury, less, catalyst, insoluble