Atomic Structure and the Periodic Table

Atomic Structure

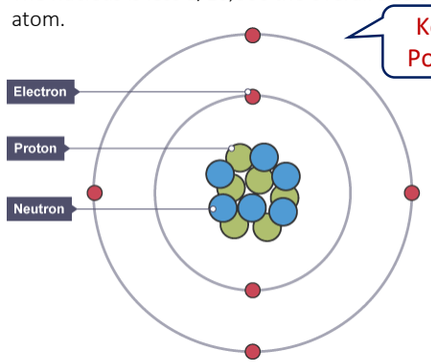
Keyword	Definition
Atom	The smallest part of an element that can exist.
Atomic Number	Number of protons in an element.
Compound	A substance with two or more elements chemical bonded to each other.
Electron	A negatively charged subatomic particle. Has a very small relative atomic mass. Orbits the nucleus of an atom.
Element	A substance comprising only one type of atom. Each atom has the same number of protons.
Energy level (shells)	Shells surrounding the nucleus that the electrons occupy.
Ion	An atom or group of atoms which has gained or lost electrons to become charged.
Isotope	A group of atoms with the same number of protons but different numbers of neutrons.
Mixture	Two or more elements or compounds that are not chemically bonded to one another.
Neutron	A neutrally charged subatomic particle. Has a relative atomic mass of 1. In the nucleus of an atom.
Nucleus	Found in the centre of an atom. Comprises protons and neutrons (except hydrogen, which is just one proton and no neutrons).
Proton	A positively charged subatomic particle. Has a relative atomic mass of 1. In the nucleus of an atom.
Relative Atomic Mass	The number of protons and neutrons in an atom.

AS 01/06. The Atom

A

- Has a central nucleus surrounded by electrons arranged in shells.
- The nucleus comprises protons and neutrons.
- The nucleus is less 1/10,000 the overall size of the atom.

Key Point



- The remaining space between the electron and nucleus is empty.

AS06. The Subatomic Particles: Protons, Neutrons and Electrons

D

Particle	Atomic Mass	Relative Charge
Proton	1	+1
Neutron	1	0
Electron	1/1840	-1

Calculating Numbers of Subatomic Particles

The symbol of an atom has two numbers:

- The larger number is the relative atomic mass (RAM).
- The smaller number is the atomic (proton) number.

Number of protons = the atomic number.
Number of neutrons = RAM – the atomic number.
Number of electrons = the atomic number.

Key Point

Example, sodium (Na):
Number of protons = 11
Number of neutrons = 23 – 11 = 12
Number of electrons = 11

AS09. Isotopes

A

- Atoms of the same element must have the same number of protons.
- The may have **different numbers of neutrons.** These are known as **isotopes**.
- Isotopes have:
  - The same atomic numbers.
  - Different relative atomic masses.
- e.g. Hydrogen:

Isotope	Protons	Neutrons	RAM
$^{1}_{1}H$	1	0	1
$^{2}_{1}H$	1	1	2
$^{3}_{1}H$	1	2	3

AS08. Ions

A

- An atom or group of atoms that has **gained or lost electrons** to form a full outer shell.
- Therefore it becomes **charged**.
- See the Bonding, Structure and Properties of Matter Knowledge Organiser for more details on Ions.

AS07. Electronic Configuration

A

- Electrons sit into **shells**, or **energy levels**, around the nucleus.
- Electrons occupy the lowest energy levels, nearest the nucleus, first.
- When the shell is full, electrons occupy the next shell.

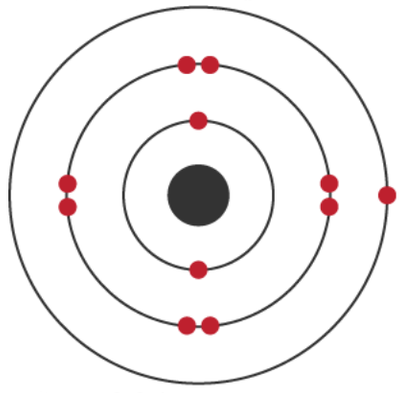
Energy level (shell)	Maximum number of electrons
First	2
Second	8
Third	8

Example: Sodium

- Atomic number = 11. Therefore, 11 electrons.
- Electrons 1 and 2 go into the first energy level.
- Electrons 3, 4, 5, 6, 7, 8, 9, 10 go into the second energy level.
- The remaining electron 11 goes into the third energy level.

Key Point

- Can be represented as a diagram:



- Or written as 2, 8, 1.

NOTE: You only need to know about the first twenty elements.

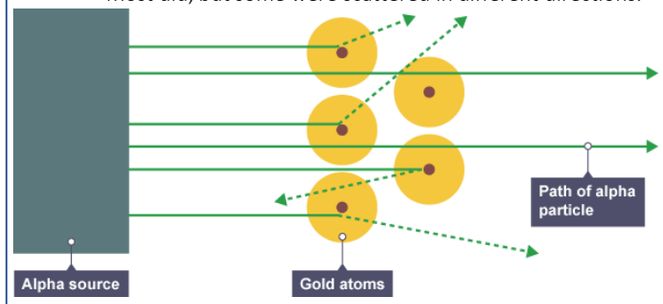
- The configuration of potassium is 2, 8, 8, 1.
- The configuration of Calcium is 2, 8, 8, 2.

AS 05. Models of the Atom

C

1. **The Plum Pudding Model – J.J. Thompson**
   Spheres of positive charge with negative electrons dotted randomly amongst it.

2. **The Nuclear Model – Ernest Rutherford**
   - Carried out the **gold foil experiment**.
   - He fired **positively charged** alpha particles at a thin sheet of gold foil.
   - Expected all particles to go straight through.
   - Most did, but some were scattered in different directions.



   - Rutherford concluded that:

Key Point

   - The mass of an atom is concentrated in the centre of the atom – the **nucleus**.
   - The nucleus is **positively charged**.

3. **Electron Shells – Niels Bohr**
   - Determined that **electrons are held in shells**, or energy levels.
   - Determined that **protons**, with a positive charge, are in the nucleus of each atom.

4. **Neutrons – James Chadwick**
   - Discovered particles with a mass but no charge.
   - Named these particles **neutrons**.

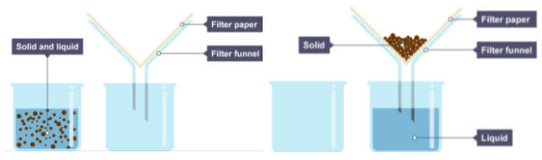
Useful YouTube links:

AS | Isotopes | Ions | Electron Config. | Dev. the atom

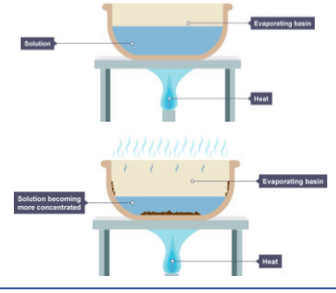
AS 03. Separating Mixtures

B

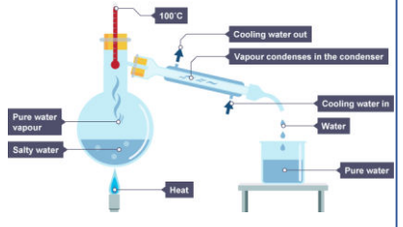
Filtration
Separates an insoluble solid from a liquid.



Crystallisation
Separates a soluble solid from a solution.



Distillation
Separates mixtures of liquids of different boiling points.



Relevant Modules: All of Chemistry. Physics – Particle Model of matter & Atomic Structure and Radioactivity.

Atomic Structure and the Periodic Table

Groups of Elements

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Proton	A positively charged subatomic particle. Has a relative atomic mass of 1. In the nucleus of an atom.
Relative Atomic Mass	The number of protons and neutrons in an atom.

F

AS 11. Group 0 – The Noble Gases

He
Ne
Ar
Kr
Xe
Rn
Og

- Have a full outer shell so are **unreactive**; they are inert elements; and,
- They exist as **single atoms**.
- Going down the group boiling point increases because:
  - Atoms are larger.
  - Intermolecular forces between atoms increase.
  - So more energy is required to overcome them.

F

AS 12/14. Group 1 – The Alkali Metals

Li
Na
K
Rb
Cs
Fr

Physical Properties:
- Are **soft** – get softer going down group.
- Have relatively **low melting points**.
- Have **low densities** – they float on water – increases going down group.

Reactivity increases going down group 1.This is because:
- The outer shell electrons are further away from the nucleus.
- The force of attraction between the outer shell electron and nucleus decreases.
- The outer shell electron can be lost more easily.

Chemical Reactions

- All group 1 metals have one electron in their outer shell so all react in similar ways.

Reactions with water:
- **Form a metal hydroxide** when reacted with water. E.g.

  sodium + water → sodium hydroxide + hydrogen

  $2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$
- Metal hydroxides are bases – they dissolve in water to form an alkali solution – hence the group 1 metals are called the alkali metals.

You must be able to describe the reactions of Lithium, sodium, and potassium with water:

Element	Observation when added to water
Lithium	Fizzes steadily; slowly becomes smaller until it disappears
Sodium	Fizzes rapidly; melts to form a ball; quickly becomes smaller until it disappears
Potassium	Burns violently with sparks and a lilac flame; quickly melts to form a ball; disappears rapidly, often with a small explosion

- Metal hydroxides are bases – they dissolve in water to form an alkali solution – hence the group 1 metals are called the alkali metals.

Reactions with Oxygen
- Form a **metal oxide** with reacted with oxygen in the air. E.g.

  sodium + oxygen → sodium oxide

  $4Na(s) + O_2(g) \rightarrow 2Na_2O(s)$
- Alkali metals react vigorously when heated and placed in a oxygen jar.

Reactions with Chlorine
- Form a **metal chloride** when reacted with chlorine. E.g.

  sodium + chlorine → sodium chloride

  $2Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$
- Alkali metals react vigorously with chlorine and form a white solid.

F

AS 13/14. Group 7 – The Halogens

F
Cl
Br
I
At
Ts

Physical Properties:
- Exist as simple **diatomic** molecules e.g. F_2, Cl_2, Br_2. Each atom is bound by a single covalent bond to one other atom.

Element	Colour	State
Chlorine	Pale green	Gas
Bromine	Brown	Liquid
Iodine	Purple-black	Solid

Melting and boiling points increase going down group 7. This is because:
- Atoms are larger.
- Intermolecular forces between atoms increase.
- So more energy is required to overcome them.

Reactivity decreases going down group 7. This is because:
- The outer shell electrons are further away from the nucleus.
- The force of attraction between the outer shell electron and nucleus decreases.
- An extra electron, required to give the atom a full outer shell, is more difficult for the atom to gain.

Chemical Reactions

- All group 7 elements have seven electrons in their outer shell so all react in similar ways.

Reactions with metals:
- React with metals to form salts. E.g.

  sodium + chlorine → sodium chloride

  $2Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$

Reactions with non-metals:
- Reacts with hydrogen to form a hydrogen halide. E.g.

  hydrogen + chlorine → hydrogen chloride

  $H2(g) + Cl_2(g) \rightarrow 2HCl(g)$
- Hydrogen halides are gases at room temperature but dissolve in water to form acids.

Displacement Reactions
- More reactive halogens displace less reactive halogens from their compound. E.g.

  chlorine + potassium iodide → potassium chloride + iodine

  $Cl_2(aq) + 2KI(aq) \rightarrow 2KCl(aq) + I_2(aq)$

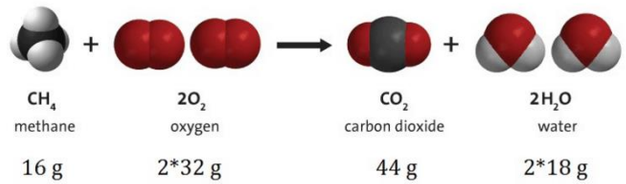
A

AS 02. Chemical Equations

- During a chemical reaction, atoms or ions separate from one another and re-join in different ways.
- Represented as **word** or **symbol** equations.
- **Reactants** react together. They go on the **left** of an equation.
- **Products** are made in a chemical reaction. They go on the **right** of an equation.

Reactants → Products

Balanced Chemical Equations
- Uses the **formulae** of reactants and products.
- Relies on the L**aw of Conservation of Mass** – no atoms are lost or made during a chemical reaction.
- E.g. complete combustion of methane in oxygen:



- On both sides of the equation there are the same number of each atom; 1 C, 4 Os, 4 Hs.

State Symbols
- Represented in brackets after a chemical formula, they show the

Symbol	Meaning
(s)	Solid
(l)	Liquid
(g)	Gas
(aq)	Aqueous Solution (dissolved in water)

Balancing Equations
- A balanced chemical equation has the **same number of atoms of each element on both sides** of the equation.

1. Check to see if there are an equal number of atoms of each element on both sides. E.g. $N_2 + H_2 \rightarrow NH_3$
2. There are two nitrogen atoms on the left but only one on the right, so put a big 2 on the left of the NH_3. $N_2 + H_2 \rightarrow 2NH_3$
3. Check again. There are two hydrogen atoms on the left but (2 × 3) = 6 on the right, so put a big 3 in front of the H_2. $N_2 + 3H_2 \rightarrow 2NH_3$
4. Check again to see if there are equal numbers of each element on both sides. (Two nitrogen atoms and six hydrogen atoms).

Useful YouTube links:

Group 1 Elements | Group 7 Elements | Noble Gases | Equations

Required Practical: *none*

Atomic Structure and the Periodic Table

Development of the Periodic Table

Keyword	Definition
Atomic Number	Number of protons in an element.
Element	A substance comprising only one type of atom. Each atom has the same number of protons.
Energy level (shells)	Shells surrounding the nucleus that the electrons occupy.
Group	A column on the periodic table.
Nucleus	Found in the centre of an atom. Comprises protons and neutrons (except hydrogen, which is just one proton and no neutrons).
Period	A row on the Periodic Table.
Periodic Table	The arrangement of elements in order of their increasing atomic number.
Relative Atomic Mass	The number of protons and neutrons in an atom.

E

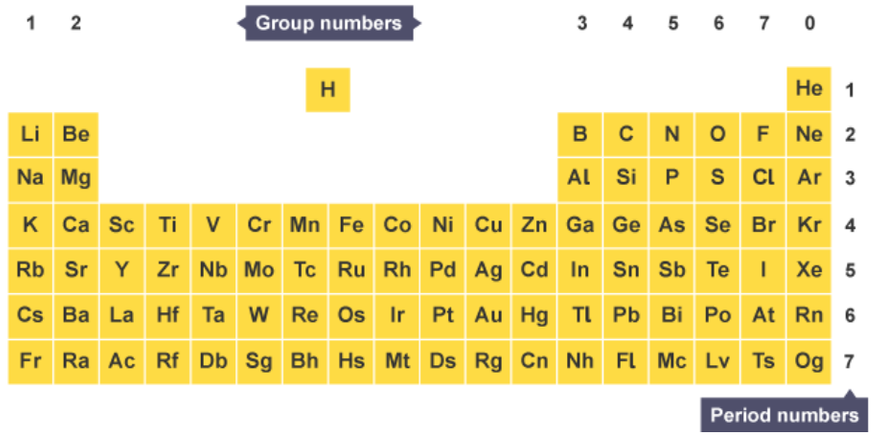
AS 10. Development of the Periodic Table

- Prior to the modern Periodic Table, efforts were made to order the elements according to their atomic weight, now referred to as the relative atomic mass.
- Early attempts at a periodic table were incomplete. Many elements were unknown, meaning that elements were placed in groups with other elements that were not similar.
- Russian Scientist **Dmitri Mendeleev** published his first periodic table in 1969.
- He arranged elements in order of increasing atomic weight, but importantly **left gaps for elements that were yet to be discovered**.
- Elements with **similar chemical properties arranged in vertical groups**.
- This meant that some elements were not in order of their atomic weight. This was later explained by the discovery of **isotopes.**

E

AS 10. The Modern Periodic Table

- Has rows known as Periods.
- Has columns known as Groups. Elements with similar chemical properties are in the same group.
- Elements placed in **order of increasing atomic number** (the number of protons in an atom of that element).



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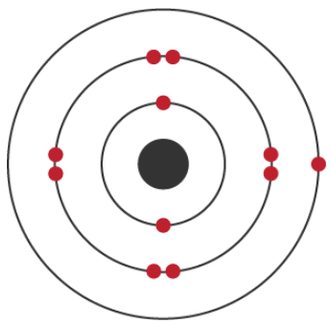
AS 11. Electron Structure and the Periodic Table

- With a bit of practice, the electron structure of an element can be quickly derived from the Periodic Table.
- The **period** an element is in indicates the **number of electron shells**.
- The **group** an element is in indicates the **number of electrons in the outer** shell.
  - *The **first period** only has two elements. Therefore the first electron shell **can only accommodate two electrons**.*
  - *The **second and third periods** have eight elements. Therefore the second and third electron shells **can accommodate eight electrons.***
- Example: Sodium, atomic number = 11, number of electrons = 11.
  - Sodium is in **period 3** so has **three electron shells**.
  - The first two shells will be filled with two and eight electrons respectively.
  - Sodium is in **group 1**, so has **one electron in its outer shell**.

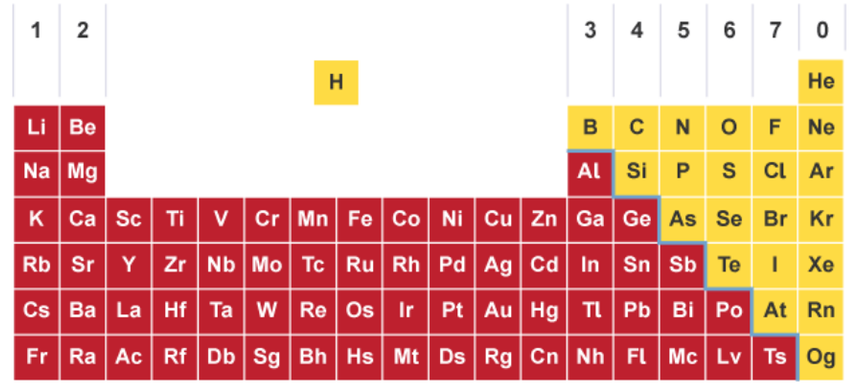


Note: You only need to know about the first twenty elements.

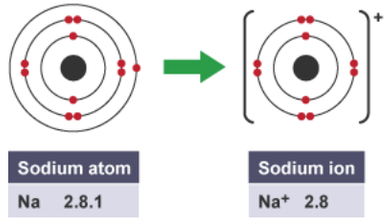
E

AS 11. Metals and Non-Metals

- Most elements are metals:



- During chemical reactions, **metals lose electrons to become positive ions**. E.g. Sodium:



- Non-metals **gain electrons to form negative ions** or **share electrons** in covalent bonds.

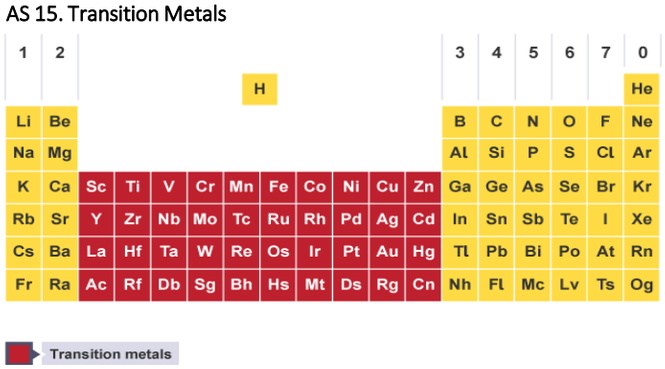
Physical and chemical properties of metals and non-metals

- Most metals have high melting and boiling points.
- Most non-metals have low melting and boiling points.

Metal (when solid)	Non-metals(when solid)
Good conductor of electricity	Poor conductor of electricity
Good conductor of heat	Poor conductor of heat
Shiny	Dull
High density	Low density
Malleable	Brittle
Ductile	Brittle

F

AS 15. Transition Metals



You must be able to refer to examples with chromium, manganese, iron, cobalt, nickel, copper.

They hare some **physical properties** with all metals:

- conduct electricity in solid and liquid states.
- shiny when freshly cut.

Compared to other metals, **most** transition metals have:

- higher **melting points**
- higher **densities**
- greater strength
- greater hardness

Reaction with oxygen and water:

- Less reactive than group 1 elements, reacting slowly or not at all.

Reaction with halogens:

- Some transition metals react slowly with halogens.

Ion Formation:

- Transition metals form different ions. Copper, for instance can form Cu^{+} and Cu^{2+} ions.

Compound formation:

- Most other elements form white compounds. Transition metals form coloured compounds.

Relevant Modules:

- Bonding
- Chemical

Useful YouTube links:

Dev P.T. | Metals/ Non-metals | Transition Metals