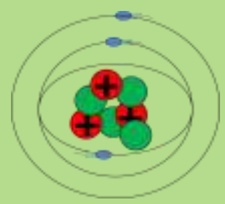
Atomic Structure, Reactions and Compounds

All substances contain atoms.
All atoms contain sub-atomic particles and different atoms contain different numbers of these particles.
The principal sub-atomic particles are protons, neutrons and electrons.
Why and how substances react is related to their atomic structure.

Basic Atomic Structure



Lithium Atom

Atom: ***the smallest particle of matter that can exist by itself***

- The atom consists of a **very small, dense central core** called the **nucleus**
- The nucleus consists of **protons and neutrons**
- All atoms have **electrons orbiting the nucleus in shells**

Sub-atomic Particle	***Mass***	***Charge***	***Location***
Proton	**1 atomic mass unit**	**Positive (1+)**	**In Nucleus**
Neutron	**1 amu**	**No chrge (neutral)**	**In Nucleus**
Electron	**10.00055 amu**	**Negative (1-)**	**Orbiting the Nucleus**

- **Atomic Number:** the **number of Protons** in a nucleus
- **Neutral Atom:** atoms **are neutral** because **they have the same number of protons and electrons and so their charges cancel out**
- **Number of Electrons = Atomic Number**
- **Number of Neutrons = Mass Number– Atomic Number**

23	*Mass Number*	*Number of Protons plus Neutrons*	11 P and 12 N
Na	Symbol	Sodium	
11	*Atomic Number*	*Number of protons (and electrons)*	11 P (6 e^-)
40	*Mass Number*	*Number of Protons plus Neutrons*	20 P and 20 N
Ca	Symbol	Calcium	
20	*Atomic Number*	*Number of protons (and electrons)*	20 P (20 e^-)
14	*Mass Number*	*Number of Protons plus Neutrons*	7 P and 7N
N	Symbol	Nitrogen	
7	*Atomic Number*	*Number of protons (and electrons)*	7 P (7 e^-)
35	*Mass Number*	*Number of Protons plus Neutrons*	7 P and 18 N
Cl	Symbol	Chlorine	
17	*Atomic Number*	*Number of protons (and electrons)*	17 P (17 e^-)

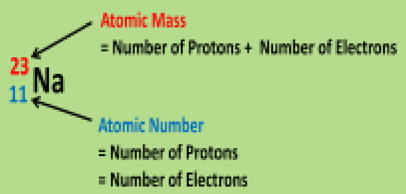
Electronic Structure

- This describes the arrangement of electrons in shells around the nucleus
- The electrons are placed in shells starting from the shell nearest the nucleus and moving out to the next shell once that shell is full
  - **First Shell can hold up to 2 electrons**
  - **Second Shell can hold up to 8 electrons**
  - **Third shell can hold up to 8 electrons**
  - **The remainder go into the fourth shell**

Bohr Model of Atom

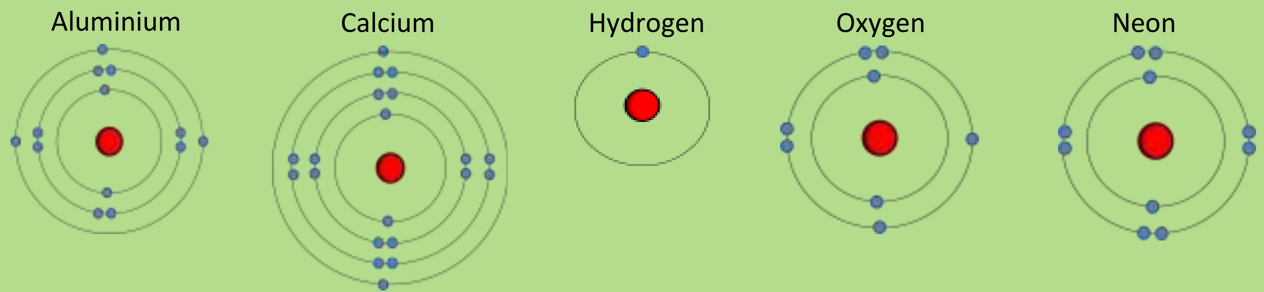
Bohr Diagram: a diagram showing the **arrangement of electrons in an atom**

Sodium Na

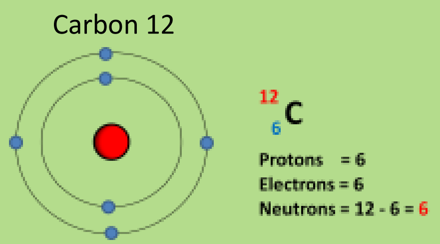


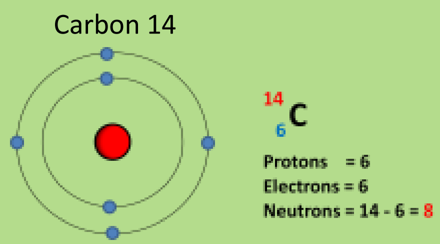
Bohr Diagram of a Sodium Atom

More Bohr Diagrams



Isotopes: ***atoms of an element which have the same number of protons but different numbers of neutrons***





Noble Gases

- **Do not react**
- They each have **a full outer shell of electrons**
- This makes them **very stable (unreactive)**

Bonding

Molecule: ***a group of atoms chemically joined or***
the smallest particle of a compound that shows the properties of that compound

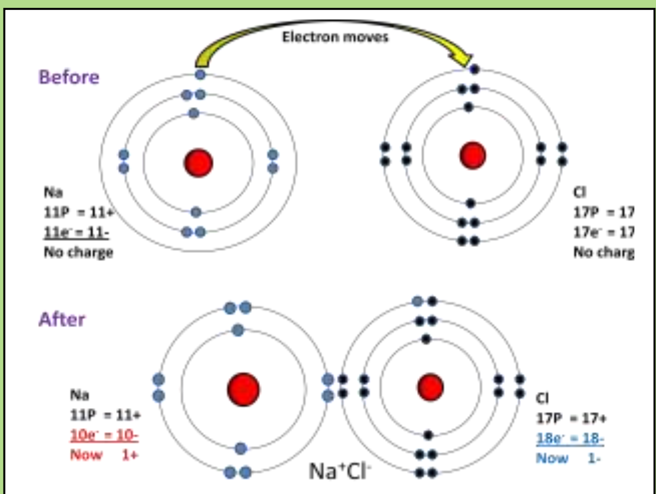
- When atoms bond they are **trying to get a full outer shell**
- So that they will be **stable like the noble gases**

There are **two types of bonds** used when forming compounds

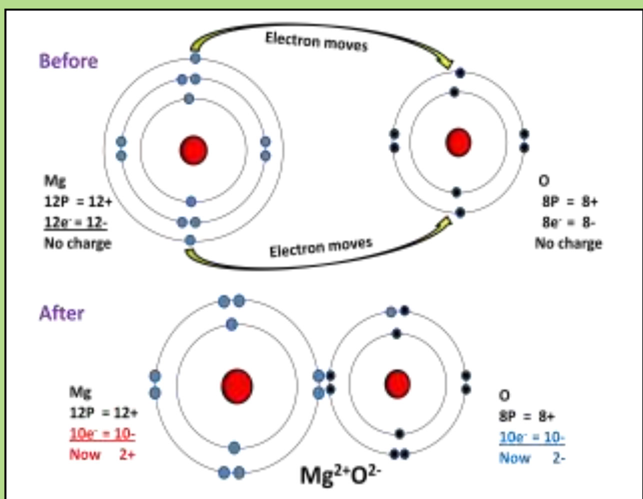
Ionic Bonds

- One type of atom **loses electrons to get a full outer shell** and becomes **positively charged**
- The other type of atom **gains electrons to get full outer shell** and becomes **negatively charged**
- These two **opposite charges attract** each other and form an **ionic bond**
- **Ion:** ***is an atom (or group of atoms) with a charge***

Examples of Ionic Bonds



Sodium Chloride - NaCl

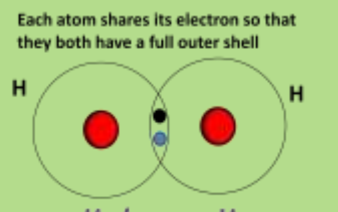


Magnesium Oxide - MgO

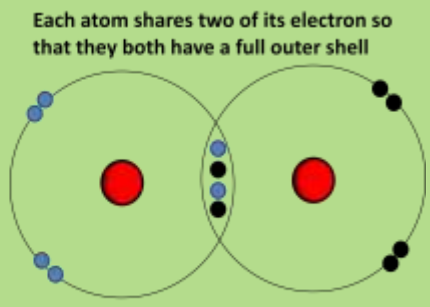
Covalent Bonds

- ***Atoms share electrons in pairs, one electron from each atom, to get a full outer shell***

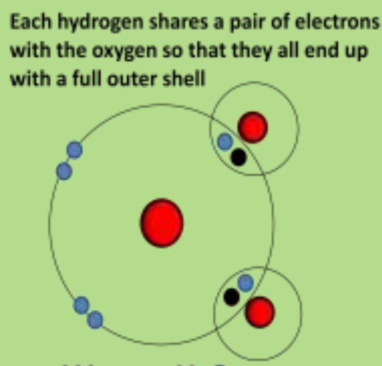
Examples of Covalent Bonds



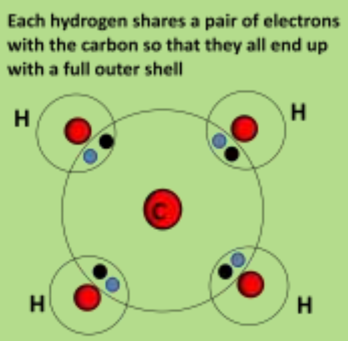
Hydrogen H_2



Oxygen O_2



Water H_2O



Methane CH_4

Note

The inner electron shells have been left out to make things clearer. You do not have to draw them

Properties of Ionic and Covalent Substances

Covalent Compounds	***Ionic Compounds***
Made of molecules	**Made of oppositely charged ions**
Usually Liquids or solids	**Usually crystalline solids**
Low melting and boiling points	**High melting and boiling points**
Usually insoluble in water	**Usually soluble in water**
Do not conduct electricity	**Conduct electricity when molten or dissolved in water**

Investigate the Ability of Ionic and Covalent Substances to Conduct Electricity

- Set up the apparatus as shown
- Pour in a **covalent compound** (e.g. pure water)
- Close the switch and record what happens

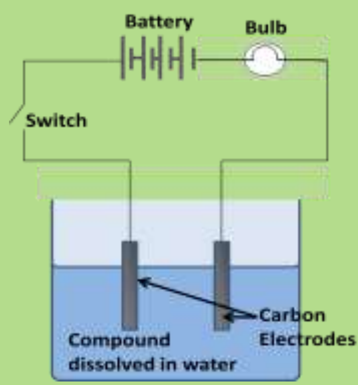
Result: the bulb does not light

- Empty the apparatus and replace with an **ionic compound** (e.g. salt solution)
- Close the switch and record what happens

Result: the bulb lights

- Empty the apparatus and repeat with a number of ionic and covalent compounds

Conclusion: ionic substances conduct electricity when in solution and covalent substances do not.



Rusting and Corrosion

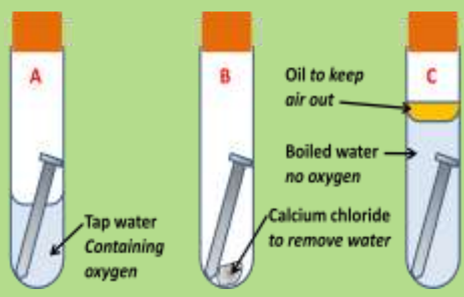
- Rusting as a **chemical process** in which iron becomes a **new compound**: **iron oxide**
- Rust **flakes off exposing more iron**
- Rusting **needs water and oxygen**
- The presence of **salt makes rusting worse**


Flaking Rust

Demonstrate that Oxygen and Water are Necessary for Rusting

- Set up the apparatus as shown
- Tube A has both **oxygen and water**
- Tube B has no water as **calcium chloride absorbs any water present**
- Tube C has **no oxygen** as **boiling removes the oxygen** and the **oil stops any getting back into the water**

Result: nail in test tube A rusts. B and C don't rust
Conclusion: oxygen and water are both needed for rusting



Preventing Rusting

- Rusting is **prevented** by keeping either **water or oxygen or both away from the iron**
- **Paint: keeps out air and water**
- **Oil: keeps out air and water**
- **Galvanising:** i.e. **covering with a layer of zinc, keeps out air and water**

Metals

Alkali Metals

- **Group I** of the Periodic Table
- They have **similar properties** because they all have **one electron in their outer shell**
- They are **soft** and can be cut with a knife
- When fresh they have a **metallic lustre** (sheen)
- They react rapidly with air and **quickly tarnish** (turn dull) each forming its oxide e.g. **sodium + oxygen = sodium oxide**
- They react rapidly with water forming hydrogen and a hydroxide
  - **Lithium + water → lithium hydroxide and hydrogen** (fast)
  - **Sodium + water → sodium hydroxide and hydrogen** (very fast)
  - **Potassium + water → Potassium hydroxide and hydrogen** (extremely fast, often catches fire and may explode)
- **Stored under oil to prevent reaction with air and water**
- As you go **down the group they become more reactive**

Potassium and water reacting

Alkaline Earth Metals

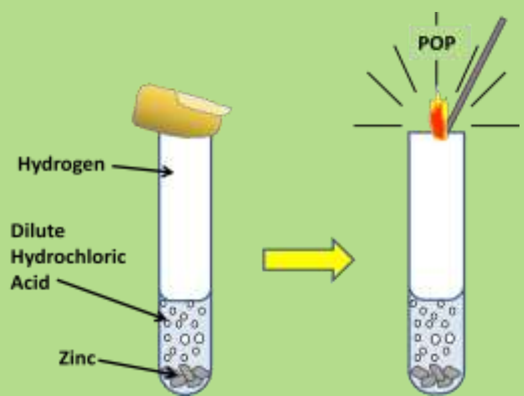
- The elements of **Group II** are the alkaline earth metals
- They are **less reactive than the alkali metals**

The Reaction between Zinc and HCl, and a Test for Hydrogen

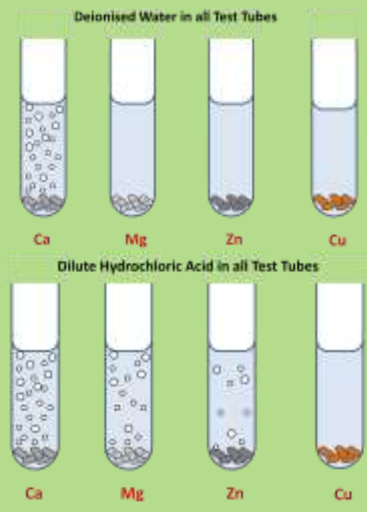
- Place some **dilute hydrochloric acid** in a test tube
- Add a little **zinc**
- **Place your thumb lightly over the mouth of the test tube** and wait a couple of minutes

Result: the test tube fills with **hydrogen gas**
Test: place a **lighted taper to the mouth of the test tube**.
Result: the gas burns with a **squeaky pop**
Conclusion: the gas is hydrogen

Zn	+	$2HCl$	→	$ZnCl_2$	+	H_2
Zinc	+	Hydrochloric acid		Zinc chloride		Hydrogen



Relative reactivities of Ca, Mg, Zn, and Cu based on their reactions with water and acid



Reaction with Water

- Place a sample of each metal **Ca, Mg, Zn, and Cu** in a test tube
- Add **water** to each test tube
- Note what happens

Result: Calcium reacts and produces hydrogen gas
Conclusion: Calcium is the most reactive of the four metals

Reaction with Dilute Hydrochloric Acid

- Place a sample of each metal **Ca, Mg, Zn, and Cu** in a test tube
- Add **dilute hydrochloric acid** to each test tube
- Note what happens

Result: Calcium reacts and produces lots of hydrogen gas bubbles

- **Magnesium produces bubbles but not as many as calcium**
- **Zinc produces bubbles but not as many as zinc**
- **Copper produces no bubbles**

Conclusion: In order of decreasing activity Ca, Mg, Zn and Cu
(Equations not required)

Hydrocarbons

Hydrocarbons ***are compounds that are made of carbon and hydrogen only***


Oil Well - Gusher

- **Fossil fuels** are our main sources of hydrocarbons
- Made from the fossilised remains of plants and animals millions of years ago
  - **Coal**
  - **Crude oil**
  - **Natural gas** which is mainly **methane**
  - **Peat** *(much more recent 5 – 10,000 years ago)*
- **Not made any more** as conditions have changed
- **Limited supply (non-renewable)** so they will **run out** sometime
- Need to be **conserved**
- They are used as **fuels** and to **make plastics**
- Many contain **traces of sulphur**

Combustion of Fossil Fuels

- **We burn huge amounts of fossil fuels petrol, diesel, kerosene (jet fuel)**
- **Hydrocarbon + Oxygen $\rightarrow$ CO_2 + H_2O + heat when burned**
- CO_2 is a **greenhouse gas** and contributes to **global warming**
- CO_2 dissolves in rain to form **carbonic acid**. This is **not acid rain** (normal rain is slightly acidic)

Acid Rain


Corroded Statue

Cause

- The sulphur impurities in fossil fuels **produce SO_2 when they burn**
- **SO_2 dissolves in rain to form sulphuric acid** and this is **acid rain**

Effects

- **Kills plants**,
- **Kills fish** and other aquatic life
- **Reacts with limestone** dissolving it quickly and leading to **corrosion of buildings**
- Reacts with iron in cars and buildings causing corrosion
- **Reduces the fertility of agricultural land**


Dying Trees

Remedies

- Use **low sulfur fuels** e.g. natural gas
- **Acidified lakes** can be **improved by adding lime** (a base) which **neutralises** the acid

Plastics

- Substances that are **made from chemicals obtained from crude oil**
- **Good heat insulators**
- **Good electrical insulators**
- **Waterproof**
- **Strong and flexible**
- **Long lasting**
- **Resistant to chemical attack**

Everyday Applications of Plastics

Plastic	***Use***	***Properties on which use depends***
Polythene	**'Plastic' bags, squeezy bottles, lunchboxes**	**Flexible, strong, resistant to chemicals**
Rigid PVC	**Window and door frames, gutters, floor tiles**	**Weather resistant, long lasting**
Flexible PVC	**Electric wire insulation, hosepipes**	**Electrical insulator, flexible, long lasting**
Polystyrene	**Yoghurt pots, food containers**	**Strong (but brittle), waterproof**
Expanded Polystyrene	**Shock proof packaging of delicate objects, drink cups, insulation in cavity walls**	**Very good heat insulator, good shock absorber**
Nylon	**Tights, shirts, carpets, combs**	**Can be spun into fibres, dirt resistant**
Perspex	**Windows, light covers in cars**	**Tough, rigid, transparent, light**

Plastics and Pollution

- Substances which are **not broken down by bacteria, fungi** and other living organisms are said to be **non-biodegradable**
- They can **last for thousands of years** and can thus **cause pollution** e.g. plastic bags look terrible in hedges, can choke and kill animals, etc
- **Recycling reduces pollution**
- **Tax on plastic bags** has greatly reduced pollution

Role of Chemistry

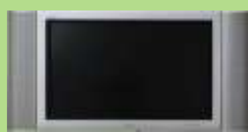
Chemistry affects most areas of our daily lives


- **Pharmacy**
  - Making **perfumes** and **soap**
  - Making **medicines**
- **Fuels**
  - **To keep us warm**
  - **Drive our vehicles**

- **Food**
  - Making **packaging** e.g. crisp packets
  - **Modifying food** e.g. turning vegetable oils into margarine

- **Agriculture**
  - Making **fertilisers**
  - Making **cleaning chemicals**

- **Building Industry**
  - Making **cement** and **concrete**
  - Making **PVC windows**, **doors** and **gutters**



- **Household Appliances**
  - Making **plastics for kitchen utensils**
  - **Television cases**