Chemistry

States of matter

Kinetic theory explains the differences in physical properties of solids, liquids and gases by referring to the arrangement and motion of particles.

Solids	Liquids	Gases
Have fixed shaped	Flow to take the shape of the container	Flow to take the shape of the container
Have fixed volume	Have fixed volume	No fixed volume
Not compressible	Moderately compressible	Highly compressible
Very high density	Medium density	Low density
Particles are arranged in a regular pattern and vibrate about a fixed point	Molecules are randomly arranged and move around each other	Molecules are randomly arranged and move quickly in all directions
Particles have low energy	Particles have greater energy	Particles have highest energy

Interconversion of state means the change of matter from one state to another due to changes in temperature or pressure.

Evaporation	The process when liquid changes into gas, on heating
Condensation	The process when gas changes into liquid, on cooling
Freezing	The process when a liquid changes into solid at a constant temperature called the melting / freezing point (m.p.)
Melting	The process when a solid changes into liquid at a constant temperature called the melting / freezing point (m.p.)
Boiling	The process when a liquid changes into a gas at a constant temperature

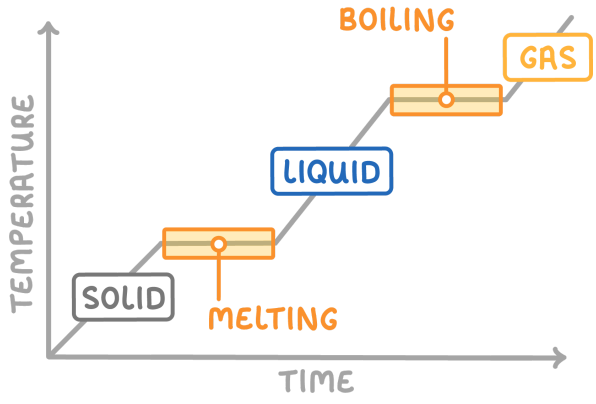
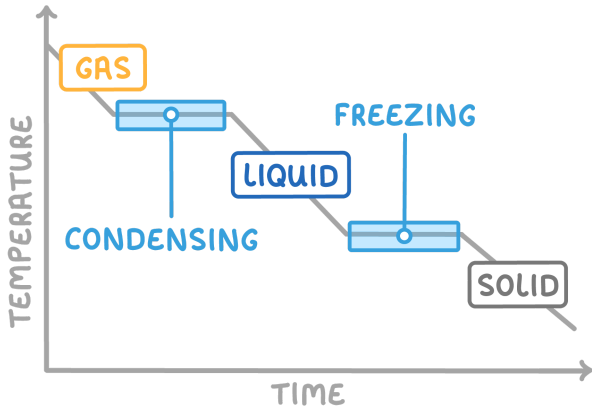
	called the boiling point (b.p.)

Evaporation vs boiling

Evaporation	Boiling
Occurs at a range of temperatures between the melting and the boiling point	Only happens at the boiling point (specific temperature at which a liquid changes into a gas)
Happens only at the surface	Happens throughout the liquid
Bubbling effect is not necessary	A boiling liquid bubbles

Factors affecting the rate of evaporation:

Temperature of the liquid Increased temperature means increased kinetic energy. This means molecules with more energy are more likely to overcome the intermolecular forces holding them and escape the surface ● Therefore higher temperature leads to higher rate of evaporation
Surface area of the liquid Molecules only escape the intermolecular forces of attraction at the surface. ● Therefore a larger surface area leads to a higher rate of evaporation
Air movement Air movement carries away the water vapour which has just evaporated. This replaces the air above the liquid with drier air, which accepts water vapour more easily ● Therefore increasing air movement increases rate of evaporation

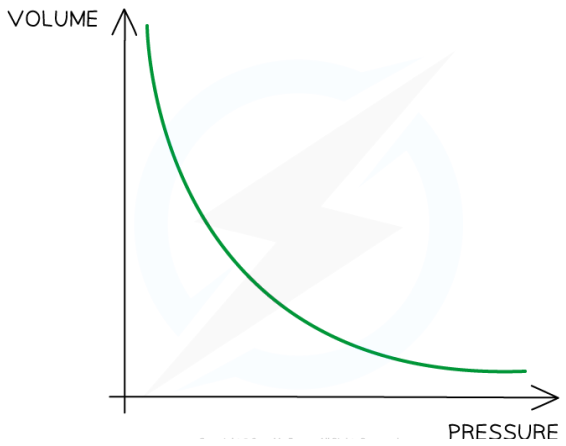
HEATING CURVE	COOLING CURVE
	

BOYLE'S LAW

Boyle's law states that the volume of a fixed mass of gas is inversely proportional to its pressure, provided its temperature remains constant

If the temperature T of an ideal gas is constant, then **boyle's law** is given by:

$P \propto \frac{1}{V}$	**pV = constant** Constant because if pressure is increased volume decreases (vice-versa)	**$p_1V_1 = p_2V_2$** P_1 = initial pressure V_1 = initial volume P_2 = final pressure V_2 = final volume



NOTE: the curve 'tends towards zero' meaning the curve gets closer and closer but never touches the axis, or zero.

DIFFUSION

Diffusion is the movement of particles from a region of higher concentration to a region of lower concentration

Occurs in gases and liquids (fluids)

Happens **spontaneously** and **does NOT require energy**

➔ The more the **molecular mass**, the slower the rate of diffusion

Atomic structure & the periodic table

An **element** is a substance made of atoms that contain the same number of protons and cannot be split into anything simpler.
A **compound** is a substance made of two or more different elements chemically combined together
A **mixture** is a combination of two or more substances (compounds / elements) that are not chemically combined

SUBATOMIC PARTICLES

	Electron	**Proton**	**Neutron**
Relative mass	1 / 1848 (negligible)	1	1
Relative charge	-1	+1	0 (neutral)
Location	Orbital / orbit / shell	Nucleus	Nucleus

Electronic configuration is the arrangement of electrons in shells

- Maximum number of electrons in **1st shell** = 2
- Maximum number of electrons in **2nd shell** = 8
- Maximum number of electrons in **3rd shell** = 8

The **group number** gives the number of outer electrons
The **period number** gives the number of shells / orbits / orbitals

An **isotope** is an atom of an element containing the same number of protons but a different number of protons.

Relative atomic mass is the average mass of an isotope of an atom compared to 1/12th the mass of an atom of carbon-12

$$A_r = \frac{(\%\ of\ Isotope\ 1 \times mass\ of\ Isotope\ 1) + (\%\ of\ Isotope\ n \times mass\ of\ Isotope\ n)}{100}$$

Ions & Ionic bonds

An **ion** is an electrically charged atom or group of atoms formed by the loss or gain of electrons

Anion	Negatively (-) charged	Formed by the gain of electrons	Most non-metals
Cation	Positively (+) charged	Formed by the loss of electrons	Most metals

A **dot and cross diagram** shows the transfer of electrons between atoms to form ions in an ionic bond.

Ionic bonds involve the transfer of electrons from one atom to another.

- Ionic compounds are held together by strong **electrostatic forces of attraction** between oppositely charged ions
- **Giant ionic lattices** are formed by ionic compounds consisting of a regular arrangement of alternating positive and negative ions

Property	**Reason**
High melting and boiling points	Huge amount of energy is needed to overcome the strong electrostatic forces of attraction
Usually solid at RTP	Regular arrangement of ions in a lattice
Soluble in water	Water is attracted to charged ions so they dissolve
Ionic compounds when molten or aqueous can conduct electricity	In an ionic solution, the movement of ions as they are free to move, allows electrical current to flow

Covalent bonds

Covalent bond is a type of chemical bond where atoms share pairs of electrons with each other.

The smallest molecule is hydrogen, H_2.

Property	**Reason**
Neighbouring molecules that are covalently bonded have low melting and boiling point	They have weak **intermolecular forces** acting between molecules so not much energy is needed to overcome this force. • **Remember:** when a covalent compound boils or melts, the intermolecular forces (between molecules) break not the covalent bond (between atoms)
Poor conductors of electricity	There are no free electrons or ions to carry the charge
Often gases or liquids at RTP	

Simple molecular structures are small molecules with covalent bonds, which have weak forces between the molecules (intermolecular forces)

NOTE: the **atoms** within covalent compounds are held together by **covalent bonds** while the **molecules** in a covalent substance are attracted to each other by **intermolecular forces**

GIANT COVALENT STRUCTURES

Giant covalent structures are giant lattices consisting of a huge number of non-metals atoms strongly covalently bonded in a fixed ratio.

Allotropes are different structural forms of the same element.

DIAMOND

Uses	Cutting tools
Structure	each carbon atom bonds with four other carbons, forming a tetrahedron

Property	Reason
Does not conduct electricity	All the outer shell electron are held in covalent bonds, so there are no delocalised (free) electrons to carry the charge
High melting point	Strong covalent bonds that require huge amounts of energy to be broken
Hard	Its rigid, tetrahedral structure contains many covalent bonds that requires a lot of energy to be broken

GRAPHITE

Uses	pencils, industrial lubricant, inert electrodes and locks
Structure	Graphite consists of hexagonal layers of carbon where each carbon is linked with three other carbons (one free/delocalised electron per carbon)

Property	Reason
Conducts heat & electricity	One free or delocalised electron per carbon atom to carry the charge
High melting points	Strong covalent bonds that require huge amounts of energy to be broken
Slippery	Graphite is arranged in layers. Although the atoms within the layers are joined by strong covalent bonds, the layers have only weak intermolecular forces between them. As a result the layers can slide over each other

SILICON OXIDE (SiO_2)

Also known as **silicon dioxide or silica**

Silicon (IV) oxide is a macromolecular compound, which occurs naturally as sand or quartz.

A **macromolecular compound** is a substance composed of very large molecules with a repeating structure

Uses	Sandpaper and lining the inside of furnaces
Structure	➔ Each silicon atom is bonded with 4 oxygen atoms and each oxygen is bonded with 2 silicon atoms, forming a tetrahedron similar to diamond ➔ It has similar properties to diamond as well (does not conduct electricity, hard, insoluble in water, high melting and boiling point)

Metallic bonding

Metallic bonding is the strong electrostatic forces of attraction between delocalised electrons and positively charged metal ions

- Metals structures are positive ions arranged in a regular pattern with a “sea” of delocalised electrons moving freely between them.

Property	**Reason**
Conducts heat & electricity	Has free or delocalised electrons in the structure to carry the charge
Have high melting and boiling points	Contains many strong metallic bonds which require a lot of energy to overcome
Malleable and ductile	Layers of positive ions can slide over each other

Stoichiochemistry

Relative molecular mass is the sum of all of the relative atomic masses of all the atoms in a molecule.

The **relative formula mass** is used when referring to the total mass of an ionic compound

The **law of conservation of mass** tells us that mass cannot be created nor destroyed:

Total mass of reactants = Total mass of products

In the full ionic equation:

- Ions that participate in the equation and change state form part of the net ionic equation
- Ions that have not changed state are spectator ions

The **mole**, symbol mol, is the measure of the amount of substance in chemistry

The mass of one mole of a substance is known as the **molar mass** (same as relative atomic, formula or molecular mass measured in grams)

Number of moles = Mass / Molar mass

One mole contains 6.02 x 10^{23} particles. This number is known as **avogadro constant**

Number of molecules = Avogadro constant x moles

At room temperature (and pressure, the volume occupied by one mole of any gas is **24dm^3 or 24,000cm^3**. This is known as the **molar gas volume at RTP.**

Volume = Moles x Molar volume (24 dm^3)

The reactant that is used up first is the **limiting reactant** as it limits the duration and hence the amount of product that a reaction can produce.

The amount of product is therefore directly proportional to the amount of limiting reactant added

Concentration refers to the amount of solute there is in a specific volume of solvent

- A **solute** is a solid substance that dissolves in liquid.
- A **solvent** is the liquid that a solute dissolves in.
- A **solution** is the mixture formed when a solute dissolves in a solvent

Concentration can be measured using both, the mass and no. of moles:

$$\text{concentration (g / dm}^3\text{)} = \frac{\text{mass of solute (g)}}{\text{volume of solution (dm}^3\text{)}}$$

$$\text{concentration (mol/dm}^3\text{)} = \frac{\text{number of moles of solute (mol)}}{\text{volume of solution (dm}^3\text{)}}$$

TITRATION CALCULATIONS

Titrations are a method of calculating the concentration of solutions.

Acid-base titrations are used to determine how much alkali is needed to neutralise a quantity of acid, vice-versa.

You may be asked:

- Moles present in a given amount
- Concentration or volume required to neutralise the acid/base

You can calculate the unknown variable by:

$$\text{concentration (mol/dm}^3\text{)} = \frac{\text{number of moles of solute (mol)}}{\text{volume of solution (dm}^3\text{)}}$$

EMPIRICAL & MOLECULAR FORMULA

The **empirical formula** is the simplest whole number ratio of the atoms of each element present in one molecule or formula unit of the compound

The molar ratio must be a whole number.

1. Element	C	H	O
2. Value	31.58	5.26	63.16
3. Relative atomic mass	12	1	16
4. Moles = $\frac{\text{mass}}{A_r}$	$\frac{31.58}{12} = 2.63$	$\frac{5.26}{1} = 5.26$	$\frac{63.16}{16} = 3.95$
5. Ratio (divide by smallest)	$\frac{2.63}{2.63} = 1$	$\frac{5.26}{2.63} = 2$	$\frac{3.95}{2.63} = 1.5$
5. Whole number ratio	1 x 2 = 2	2 x 2 = 4	1.5 x 2 = 3
6. Answer	The empirical formula is $C_2H_4O_3$		

PERCENTAGE YIELD

Yield is the term used to describe the amount of product we get from a reaction.

We never get a 100% yield for the following reasons:

1.) Some reactants may be left behind the reaction
2.) The reaction may be reversible and in these reactions a high yield is never possible
3.) Some products may be lost during separation and purification stages (filtration/distillation)
4.) Products may be lost during transfer from one container and another

Calculations:

Percentage yield compares the actual yield with the theoretical yield

- **Actual yield** is the recorded amount of product obtained
- **Theoretical yield** is the amount of product that would be obtained under perfect practical and chemical conditions

$$\textbf{Percentage yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100$$

PERCENTAGE COMPOSITION

The percentage composition is a way to express the mass of each element as a percentage of the total mass of the compound.

Percentage composition of an element = $\frac{\text{total mass of the element in the compound}}{\text{relative formula mass of the compound}} \times 100$

PERCENTAGE PURITY

Percentage purity = $\frac{\text{mass of pure substance}}{\text{total mass of substance}} \times 100$

Organic chemistry

A **hydrocarbon** is a compound containing only carbon and hydrogen atoms

- ➔ A **displayed formula** represents the spatial arrangement of atoms and bonds in a compound
- ➔ **Structural formula** represents the arrangement of atoms in a compound but most of the actual covalent bonds are omitted. Only double and triple bonds are shown
- ➔ **Molecular formula** shows the actual number of atoms of each element in a compound
- ➔ A **general formula** shows a ratio of atoms in a family of organic compounds in terms of 'n' where n is a variable

Alkanes	C_nH_{2n+2}
Alkenes	C_nH_{2n}
Alcohols	$C_nH_{2n+1}OH$
Carboxylic acid	$C_nH_{2n+1}COOH$

Structural isomers are compounds having the same molecular formula but a different structural formula

A **homologous series** is a family of organic compounds having similar features and chemical properties because of the presence of the same functional groups

- same general formula
- Same functional group
- A clear trend in physical properties
- Similar chemical properties

- The difference in the molecular formula between one member and the next is CH_2.

Saturated compounds are molecules in which all carbon-carbon bonds are single bonds

Unsaturated compounds are molecules in which one or more carbon-carbon bonds are double or triple bonds

ALKANES

Alkanes are generally unreactive compounds.

Substitution reactions (photochemical reaction)	Alkanes undergo substitution with halogen in the presence of ultraviolet radiation. This is known as **photochemical reactions.** ➔ The ultraviolet radiation provides activation energy
Complete combustion	Alkanes undergo **complete combustion** to give carbon dioxide and water
Cracking	**Cracking** is the process by which a larger saturated compound (alkane) is broken down into smaller, more useful compounds some of which is an unsaturated compound (alkene) ➔ Catalytic cracking is the process of cracking (definition) using a temperature of 600 - 700^o C and a catalyst of zeolite

ALKENES

Alkenes are more reactive than alkanes due to the presence of a double bond

Addition reactions	An addition reaction is a reaction in which atoms of a simple molecule are added across the C=C double bonds of an alkene ➔ Have only one product
Bromination (bromine water test)	Bromine water is an orange-brown solution of bromine dissolved in water that is used to distinguish between alkanes and alkenes ● No change in colour when tested for alkanes ● Turns from orange-brown to colourless when tested for alkenes
Hydrogenation	Alkenes undergo addition reaction with hydrogen to form an alkane

	Alkenes + hydrogen → Alkane ➔ Requires nickel / palladium / platinum catalyst
Steam	When alkenes undergo addition reactions with steam, alcohol is formed **Alkenes + Steam → Alcohol**

Three fossil fuels are **natural gas, coal and petroleum** (main constituent is methane)

Fractional distillation is the process of separating the different fractions of crude oil based on their boiling points

As you move up a fractionating column the temperature decreases

Refinery gases	Domestic heating and cooking
Gasoline	Fuel for cars
Naphtha	Raw product for producing chemicals
Kerosene	Jet fuel (paraffin)
Diesel	Fuel for diesel engines
Fuel oil	Ships and power stations
Lubricating oil	For lubricants, polishes and waxes
Bitumen	For surfacing roads