Cambridge A-Level Chemistry Study Notes

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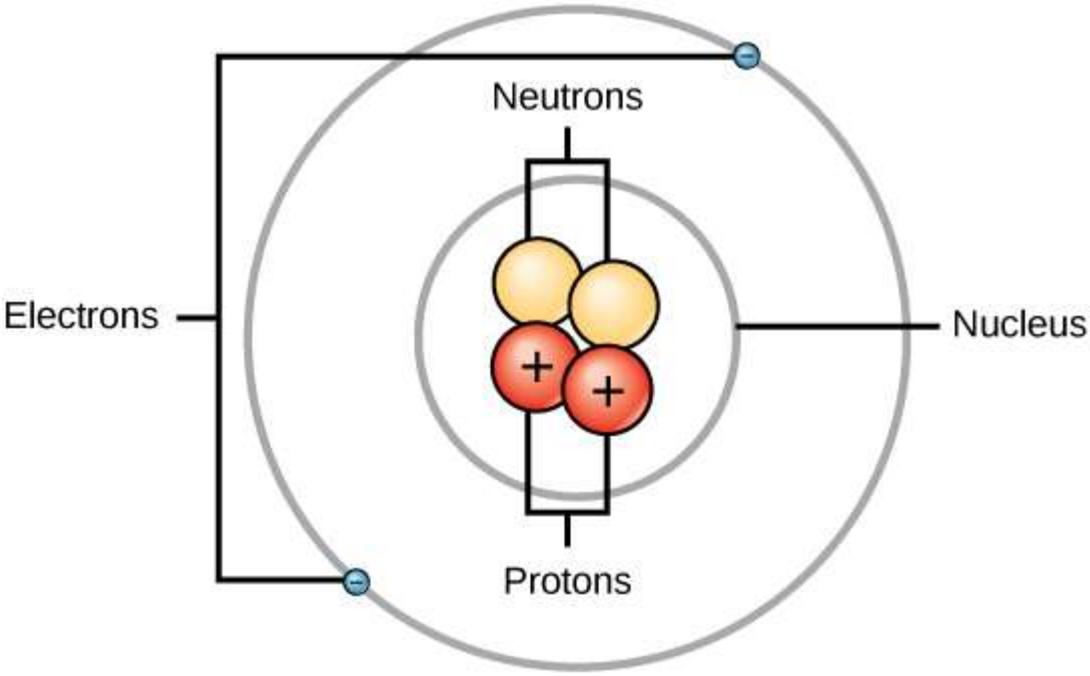
Matter

Atoms consist of three basic particles: protons, electrons, and neutrons. The nucleus (centre) of the atom contains the protons (positively charged) and the neutrons (no charge). The outermost regions of the atom are called electron shells and contain the electrons (negatively charged). Atoms have different properties based on the arrangement and number of their basic particles.



Protons, Neutrons, and Electrons			
	Charge	**Mass (amu)**	**Location**
Proton	+1	1	nucleus
Neutron	0	1	nucleus
Electron	–1	0	orbitals

Isotopes

Isotope, one of two or more species of atoms of a chemical element with the same atomic number and position in the periodic table and nearly identical chemical behaviour but with different atomic masses and physical properties. Every chemical element has one or more **isotopes**.

- Proton number is the same as the other forms or isotopes.
- Electron number is the same as the other forms or isotopes.
- Neutron number is different than the other forms or isotopes.
- Different atomic mass (due to the different number f neutrons)
- Different isotopes have different characteristics and uses.
- Some isotopes are found in nature whereas some are man-made for certain purposes.

https://youtu.be/xjY5p-1CDr8

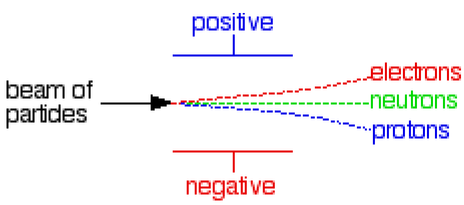
Behaviour of protons, neutrons, and electrons in electric field

If a beam containing each of these particles is passed between two electrically charged plates—one positive and one negative—the following are observed:

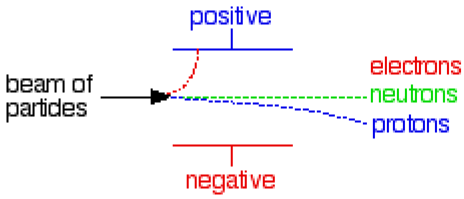
- Protons are positively charged and are thus deflected on a curving path towards the negative plate.
- Electrons are negatively charged and are deflected on a curving path towards the positive plate.
- Neutrons have no charge and continue in a straight line.

The exact way these events occur depends on whether the particles have the same energy.

Particles with the same energy:



Particles with the same speed:



If beams of the three particles, all with the same speed, are passed between two electrically charged plates:

- Protons are deflected on a curved path toward the negative plate.
- Electrons are deflected on a curved path toward the positive plate.
- Neutrons continue in a straight line.

If the electrons and protons travel with the same speed, then the lighter electrons are deflected far more strongly than the heavier protons.

Distribution of mass and charges within an atom

Since the nucleus contains protons and neutrons, most of the mass of an atom is concentrated in its nucleus. **Protons and electrons** have electrical charges that are equal and opposite.

Determining numbers of protons and neutrons

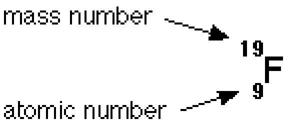
Number of protons = ATOMIC NUMBER of the atom

The atomic number is also given the more descriptive name of proton number.

Number of protons + number of neutrons = MASS NUMBER of the atom

The mass number is also called the nucleon number.

This information can be expressed in the following form:



The atomic number is the number of protons (9); the mass number counts protons + neutrons (19). If there are 9 protons, there must be 10 neutrons adding up to a total of 19 nucleons in the atom.

The atomic number is tied to the position of the element in the periodic table; the number of protons therefore defines the element of interest. If an atom has 8 protons (atomic number = 8), it must be oxygen. If an atom has 12 protons (atomic number = 12), it must be magnesium.

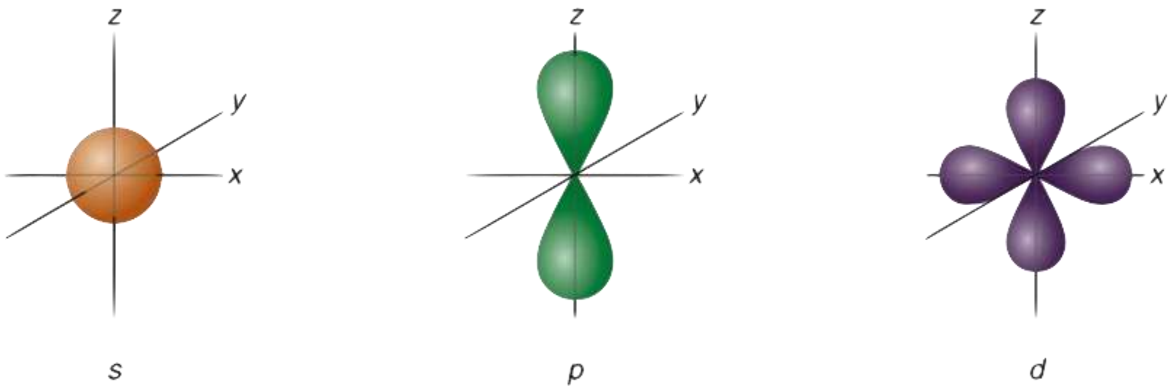
Shapes of Orbital Chemistry (shapes of s, p and d orbitals)

There are four different kinds of orbitals, denoted s, p, d and f each with a different shape. Of the four, s and p orbitals are considered because these orbitals are the most common in organic and biological chemistry.

An s-orbital is spherical with the nucleus at its centre, a p-orbitals is dumbbell-shaped, and four of the five d orbitals are cloverleaf shaped.

The fifth d orbital is shaped like an elongated dumbbell with a doughnut around its middle.

The orbitals in an atom are organized into different layers or electron shells.



Factors influencing ionisation energy

- **Size of atom**
  - As atomic size increases, the attraction of the positive nucleus for the negative electron decreases and less energy is required to remove an electron.
  - This means that the ionisation energy **decreases.**
- **Nuclear charge**
  - When nuclear charge increases, the attraction for the outermost electron increases and more energy is required to remove an electron.

    - This means that the ionisation energy **increases.**
- **Screening effect or shielding effect**
    - The outermost electron is screened or shielded from the attraction of the nucleus by the repelling effect of the inner electrons.
    - When shielding increases, the attractive of the positive nucleus for the negative electron decreases and less energy is required to remove an electron.
    - This means that the ionisation energy **decreases.**

Successive ionisation energies

First ionisation energy is defined as the amount of energy required to *remove one mole of electron* from each atom in a mole gaseous atom producing *one* mole of gaseous cations.

$X(g) \rightarrow X^{+}(g) + e^{-}$ $\Delta H_1 = 1_{st}$ ionisation energy = +ve

Successive ionisation energies of an element increase with the removal of each electron.

This is because the remaining electrons are attracted more strongly by the constant positive nuclear charge in the nucleus of the atom.

The number of ionisation energies that an element can have is always equal to its atomic number.

Structure and properties

Chemical bonding: is lasting attraction between atoms, ions or molecules that enables the formation of chemical compounds.

The bond may result from the electrostatic force of attraction between oppositely charged ions as in ionic bonds or through the sharing of electrons as covalent bonds.

4 types of chemical bonding

1. Ionic bonding
    a. It is the complete transfer of valence electrons between atoms. It is a type of chemical bond that generates two oppositely charged ions.
2. Metallic bonding
    a. This force holds atoms together in a metallic substance.
3. Covalent bonding
    a. It is a chemical bond that involves the sharing of electron pairs between atoms.
4. Dative covalent bonding
    a. Also known as coordinate bond in which both electrons come from the same atom. The atoms are held together because the electron pair attracted by both the nuclei.

Bond polarity and bond energy

Polar bonds typically have unequal sharing of electrons within a bond leads to the formation of an electric dipole.

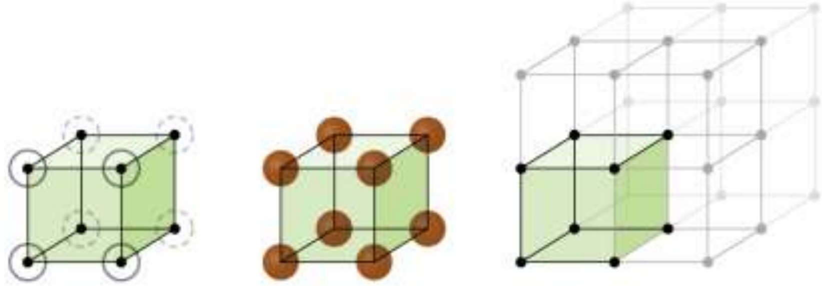
To determine the electron sharing between two atoms, a table of electronegativities can determine which atom will attract more electron density.

Bonds can fall between one of two extremes, from completely nonpolar to completely polar.

Intermolecular forces

They are the forces of attraction or repulsion which act between neighbouring particles.

Lattice structure of solids



Bonding and physical properties

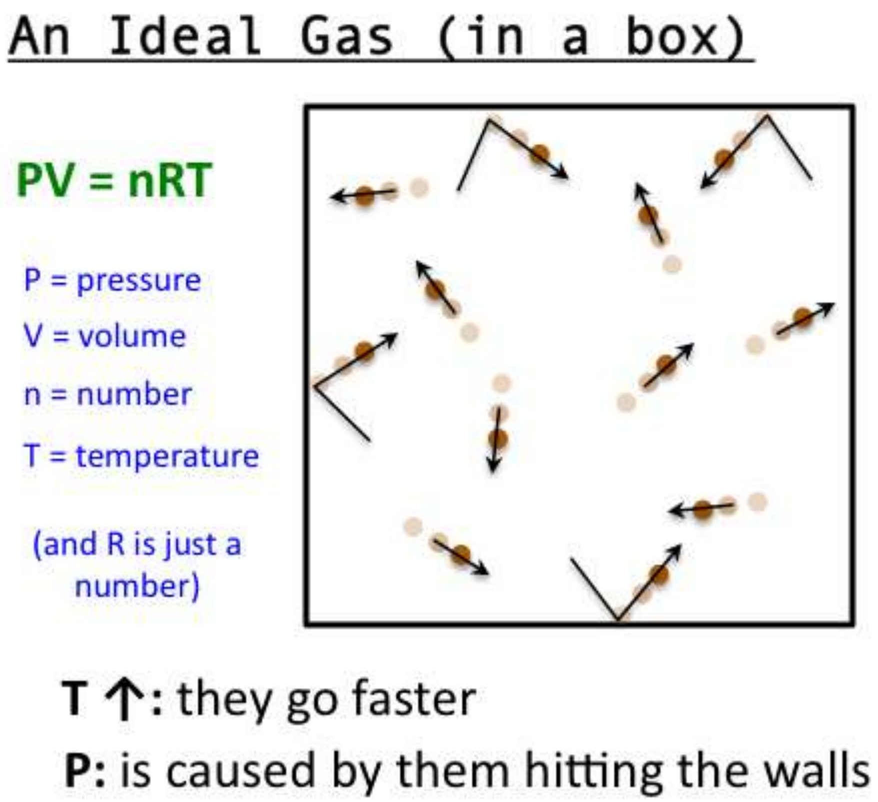
Chemical bonds are the electrical forces of attraction that hold atoms or ions together to form molecules.

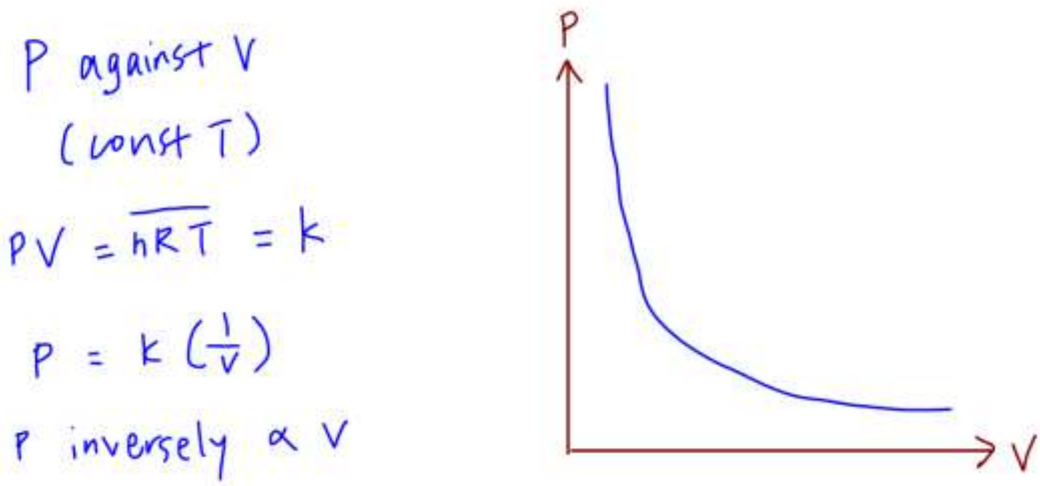
Properties of a bond

	GIANT LATTICE			MOLECULAR (COVALENT)	
	Ionic	**Covalent**	**Metallic**	**Macromolecular**	**Simple Molecular**
What substances have this sort of structure?	Compounds of metals and non-metals.	Some elements in group IV and some of their compounds.	Metals	Polymers	Some non-metal elements and some metal/non-metal compounds.
Examples.	Sodium chloride, calcium oxide.	Silicon (IV) oxide, diamond, graphite.	Copper, iron	Polythene, proteins.	Carbon dioxide, chlorine, water.
What type of particles does it contain?	Ions.	Atoms.	Positive ions surrounded by delocalised electrons.	Long-chained molecules.	Small molecules.
How are the particles bonded together?	Strong ionic bonds.	Strong covalent bonds	Strong metallic bonds.	Weak intermolecular forces between molecules. Strong covalent bonds within molecules.	Weak intermolecular forces between molecules Strong covalent bonds within each molecule
Properties:					
Melting/boiling point.	High.	Very High.	Generally High.	Moderate (often decomposes on heating).	Low.
Hardness.	Hard, but brittle.	Very Hard	Hard, but malleable	Soft, but often flexible	Soft.
Electrical conductivity.	Conducts when molten or dissolved in water.	Do not normally conduct.	Conduct.	Do not normally conduct.	Do not conduct.
Solubility in water.	Often soluble.	Insoluble.	Insoluble.	Sometimes soluble.	Usually soluble.
Solubility in non-polar solvents (benzene, hexane etc.)	Insoluble.	Insoluble.	Insoluble.	Sometimes soluble.	Usually soluble.

Gaseous State

The ideal gas law states that **PV = nRT**, where P is the absolute pressure of a gas, V is the volume it occupies, N is the number of atoms and molecules in the gas, and T is its absolute temperature.





Theory of acids and bases

There are **multiple definitions** of acids and bases. The narrowest definition is the Arrhenius theory definition, which is primarily concerned with aqueous solutions.

Arrhenius

An Arrhenius acid increases the concentration of H^+ or H_3O^+ (hydronium) ions.

Brønsted-Lowry

Brønsted-Lowry **acid** is any species that donates a proton to another molecule.

Brønsted-Lowry **base** is any species that accepts a proton to another molecule.

Lewis

Acids are electron pair acceptors. Acid is able to form a covalent bond with whatever supplies the electrons. Bases are electron pair donors.

Tips for remembering the difference.

Arrhenius < **B**rønsted-Lowry < **L**ewis

The first definition is the narrowest where Arrhenius only talks about aqueous solutions. Then we have Brønsted-Lowry which indicates that any substance that donates a proton is an acid, and anything that accepts is a base. Lastly, we have Lewis, with the broadest definition, stating that any electron pair acceptor is Lewis acid and an electron pair donor is Lewis base.

Periodic table

Dalton

Table based on the mass of elements measured from various chemical reactions

Newlands Octaves

Based on his observations that every 8th element were similar

Mendeleev

Arranged 50 known elements by atomic mass, but left gaps so there was a pattern in chemical and physical properties

Called a periodic table because similar properties occur at regular intervals.

Periodic Table

Mendeleev's table was bases for the modern periodic table which is now arranged by atomic number

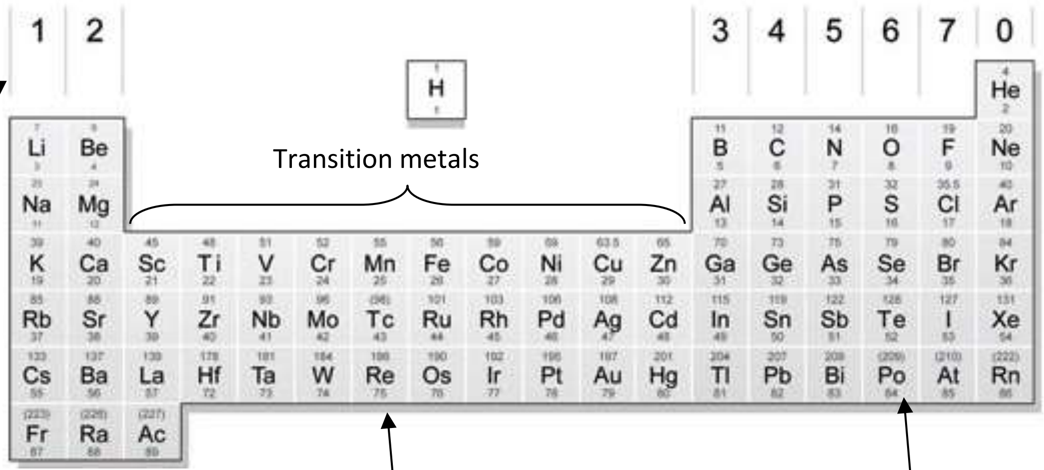
Column – Groups

Same number of electrons in outer shell. Group 1 – 1

The modern periodic table can be seen as an arrangement of the elements in terms of their electronic structures.

Rows – Periods

Outer electron in same energy shell



Group 1 – Alkali Metals

●Reactivity INCREASES down the group.

Atoms get bigger so more shells so outer electron further from nucleus so lost easier

●Melting/boiling point DECREASE down group

●React with water to release hydrogen and form hydroxides which dissolve in water making alkaline solutions

●Reacts with non-metals to form ionic compounds which are white solids that dissolve

Transition Metals

●Similar properties and some special properties because a lower energy level (inner shell) is being filled in the atoms of the elements

●Compared with Group 1:

★have higher melting points (except for mercury) and higher densities

★are stronger and harder

★are much less reactive and so do not react as vigorously with water or oxygen.

●Many transition elements have ions with different

Group 7 - Halogens

●Reactivity DECREASES down the group.

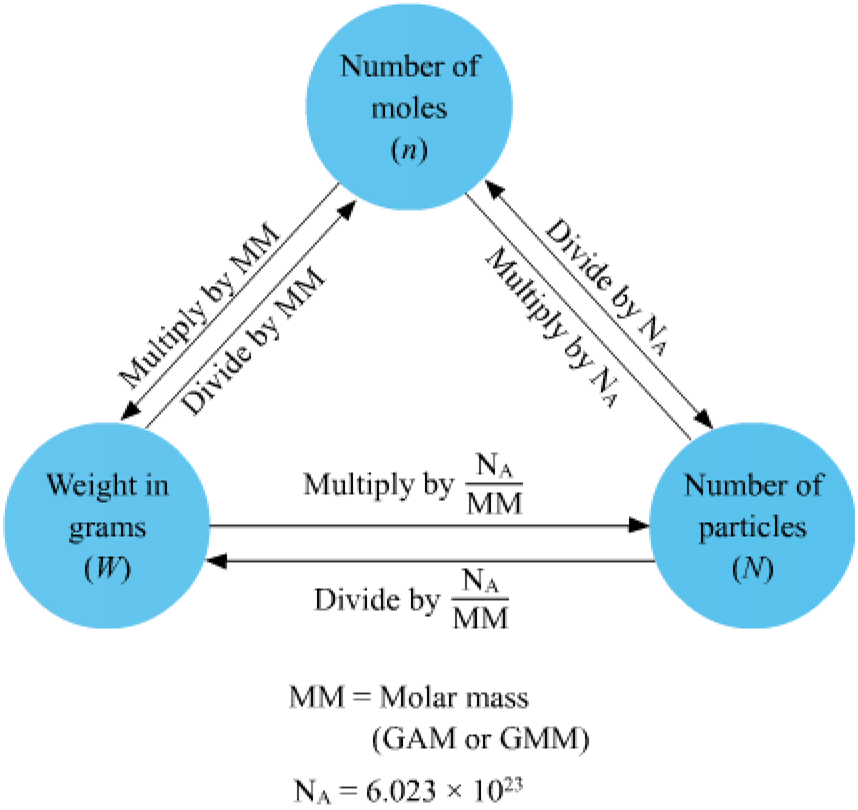
Atoms get bigger so more shells so outer electrons further from nucleus so harder to gain extra electron

●Melting/boiling point INCREASE down group

●A more reactive halogen can displace a less reactive halogen from an aqueous solution.

●Have coloured vapours and exist as diatomic molecules Cl_2

●Forms simple covalent molecules with other non-metals.


Number of
moles
(n)
Multiply by MM
Divide by MM
Divide by N_A
Multiply by N_A
Weight in
grams
(W)
Multiply by N_A/MM
Divide by N_A/MM
Number of
particles
(N)
MM = Molar mass
(GAM or GMM)
N_A = 6.023 × 10^23

Chemical Energetics: Thermochemistry and Thermodynamics

There are 3 sections in Chemical Energetics, namely:

- Enthalpy Changes, ΔH
- Entropy Changes, ΔS
- Gibbs Free Energy, ΔG

Enthalpy Changes, ΔH

Change of formation

Energy **change** when **1 mole of the compound** is formed from i**ts constituent elements** under **standard conditions.**

e.g. H_2 (g) + 1/2 O_2 (g) → H_2O (l) $\Delta H_f^\theta(H_2O)$

Change of combustion

Energy **released** when **1 mole of a substance** is **completely burned** in **oxygen** under **standard conditions.**

e.g. C_2H_4 (g) + 3 O_2 (g) → 2 CO_2 (g) + 2 H_2O (l) $\Delta H_c^\theta(C_2H_4)$3

Change of Neutralisation, ΔH_{neu}^θ

Energy **released** when **1 mole of water** is formed in the **neutralisation between an acid and an alkali** under **standard conditions**

e.g. HCl (aq) + NaOH (aq) → NaCl (aq) + H2O (l) ΔH_{neu}^θ

Change of Atomisation, ΔH_{atom}^θ

Energy a**bsorbed** when an **element** is converted into **1 mole of free gaseous atoms** under **standard conditions**

e.g. 1/2 O_2 (g) → O (g) ΔH_{atom}^{θ}(O)

Change of Hydration, ΔH_{hyd}^{θ}

Energy **released** when **1 mole of the gaseous ion** is **dissolved in large amount of water** under **standard conditions**

e.g. Na^+ (g) + water → Na^+ (aq) ΔH_{hyd}^{θ}(Na^+)

Change of Solution, ΔH_{soln}^{θ}

Energy **change** when **1 mole of a substance** dissolves in such a **large volume of solvent** that **addition of more solvent produces no further heat change** under **standard conditions**

e.g. NaCl (s) + water → Na^+ (aq) + Cl^- (aq) ΔH_{soln}^{θ}(NaCl)

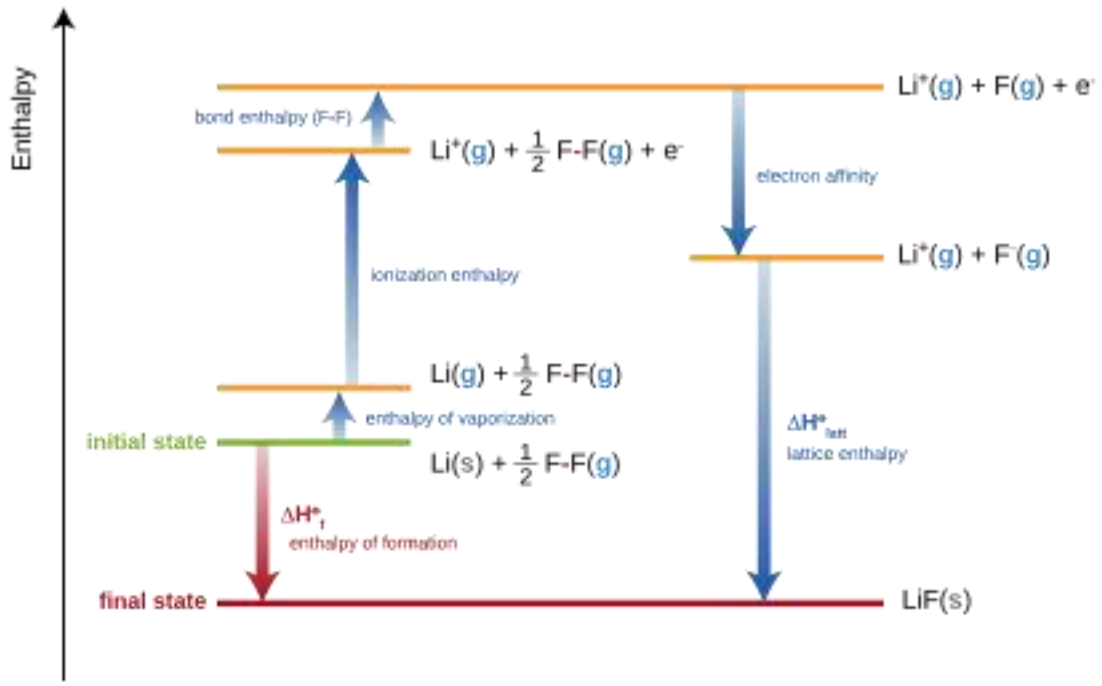
Hess's Law

Hess's Law of Constant Heat Summation (or just **Hess's Law**) states that regardless of the multiple stages or steps of a reaction, the total enthalpy change for the reaction is the sum of all changes. This law is a manifestation that enthalpy is a state function.

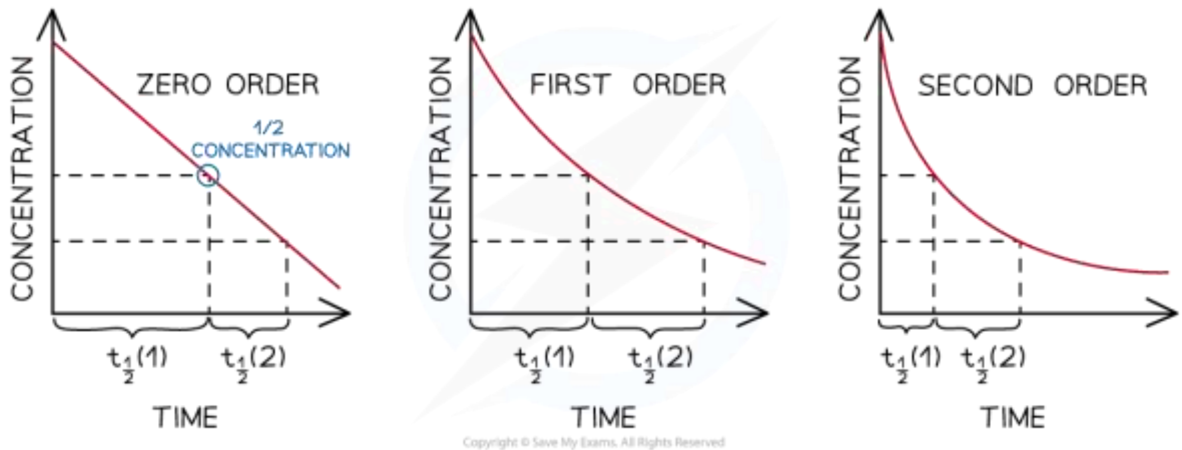
The heat of any reaction ΔH∘fΔHf° for a specific reaction is equal to the sum of the heats of reaction for any set of reactions which in sum are equivalent to the overall reaction.

Born-Haber cycles

The Born–Haber cycle is **an approach to analyze reaction energies.**



Reaction Kinetics



Activation energy

In chemistry and physics, **activation energy** is the minimum amount of energy that must be provided to compounds to result in a chemical reaction.

Factors that affect reaction rate

1. Reactant concentrations

2. Surface area

3. Pressure

4. Temperature

5. Presence or absence of a catalyst

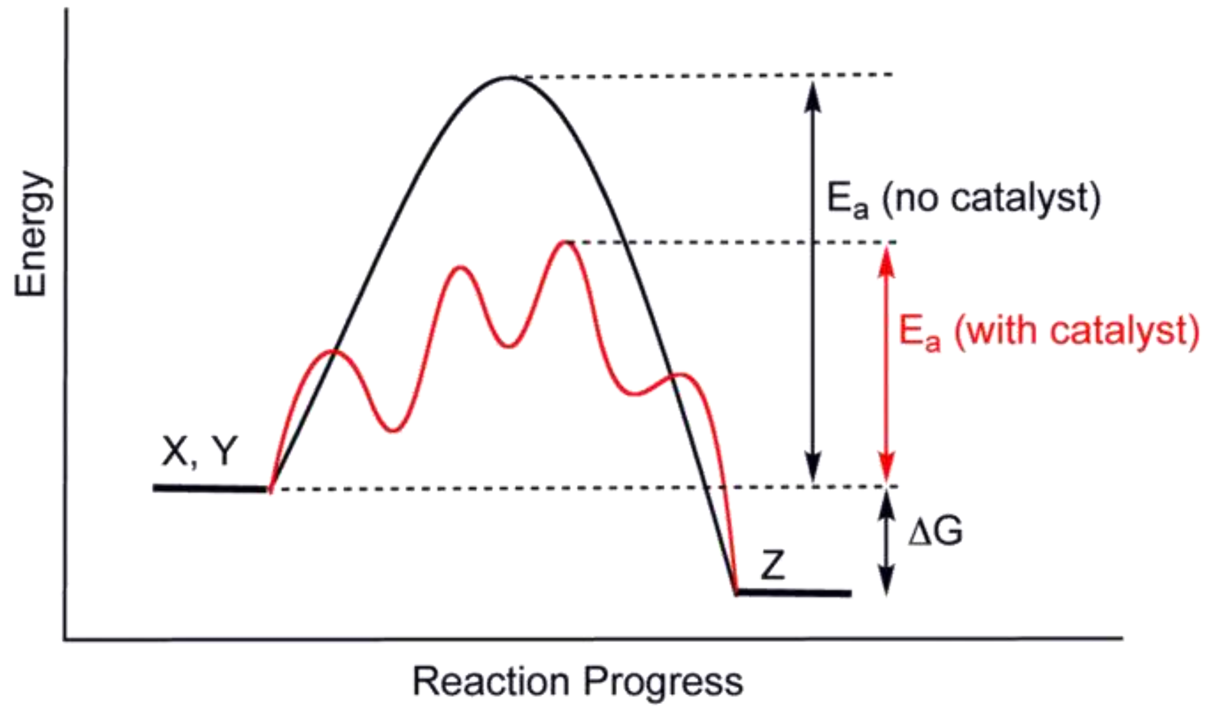
6. Nature of reactants

GCSE Chemistry - Factors Affecting the Rate of Reaction #40

https://youtu.be/-4HXaUBbv04

Homogeneous and heterogeneous catalysis

Catalysts can be classified into two types: homogeneous and heterogeneous. Homogeneous catalysts are those which exist in the same phase (gas or liquid) as the reactants, while heterogeneous catalysts are not in the same phase as the reactants. Typically, heterogeneous catalysis involves the use of solid catalysts placed in a liquid reaction mixture.

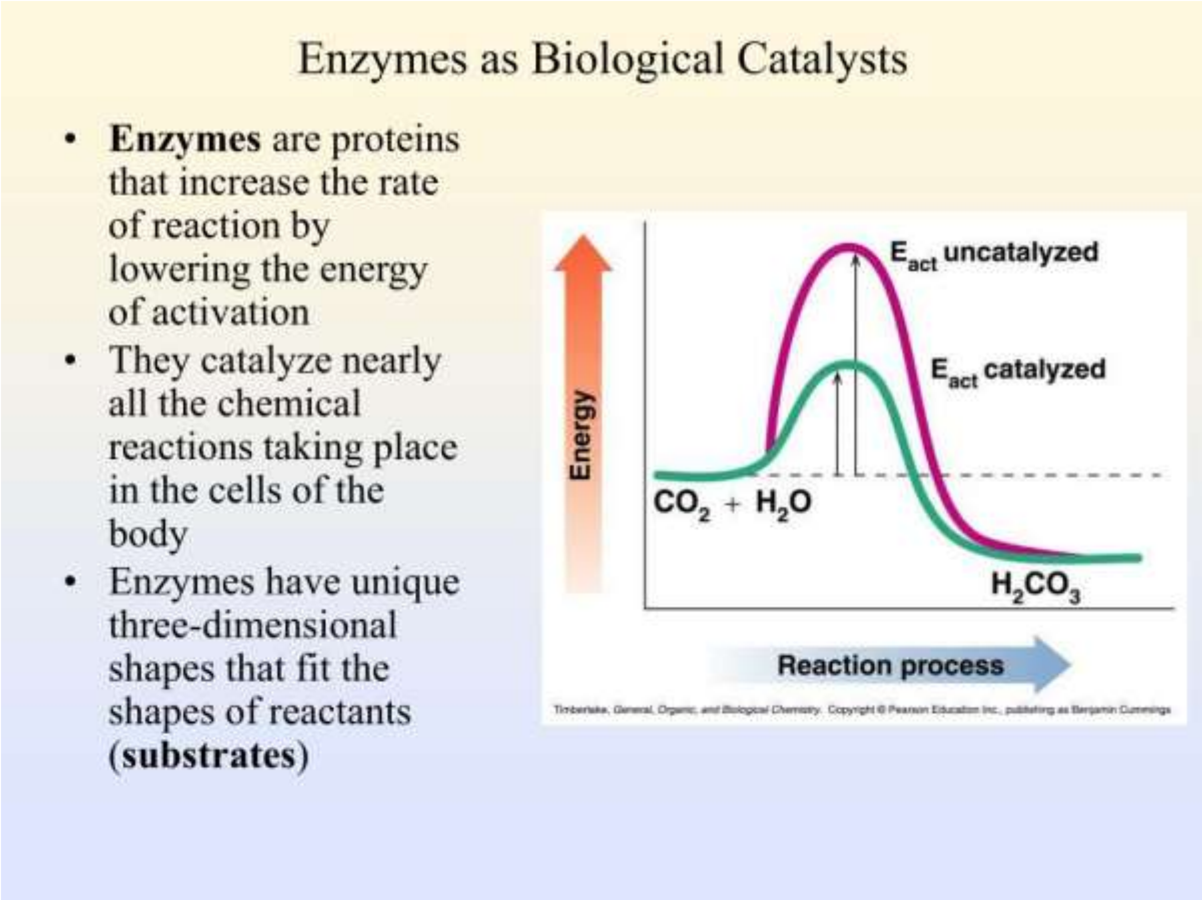


Heterogeneous catalysis is catalysis where the phase of catalysts differs from that of the reactants or products. The process contrasts with homogeneous catalysis where the reactants, products and catalyst exist in the same phase.

Heterogeneous catalysis is very important because it enables faster, large-scale production and the selective product formation.

Enzymes as biological catalysts

Enzymes are proteins functioning as catalysts that speed up reactions by lowering the activation energy. A simple and succinct definition of an enzyme is that it is a biological catalyst that accelerates a chemical reaction without altering its equilibrium. ... In the overall process, enzymes do not undergo any net change.

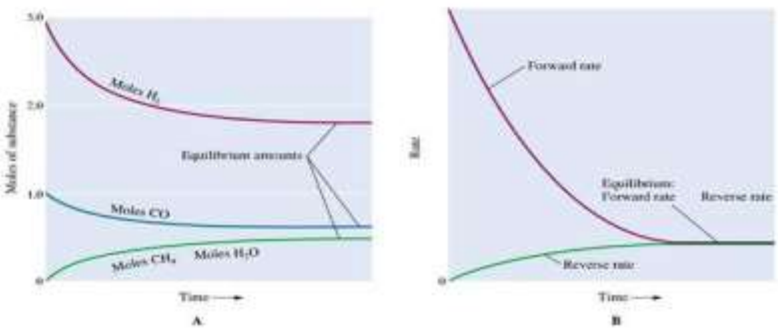


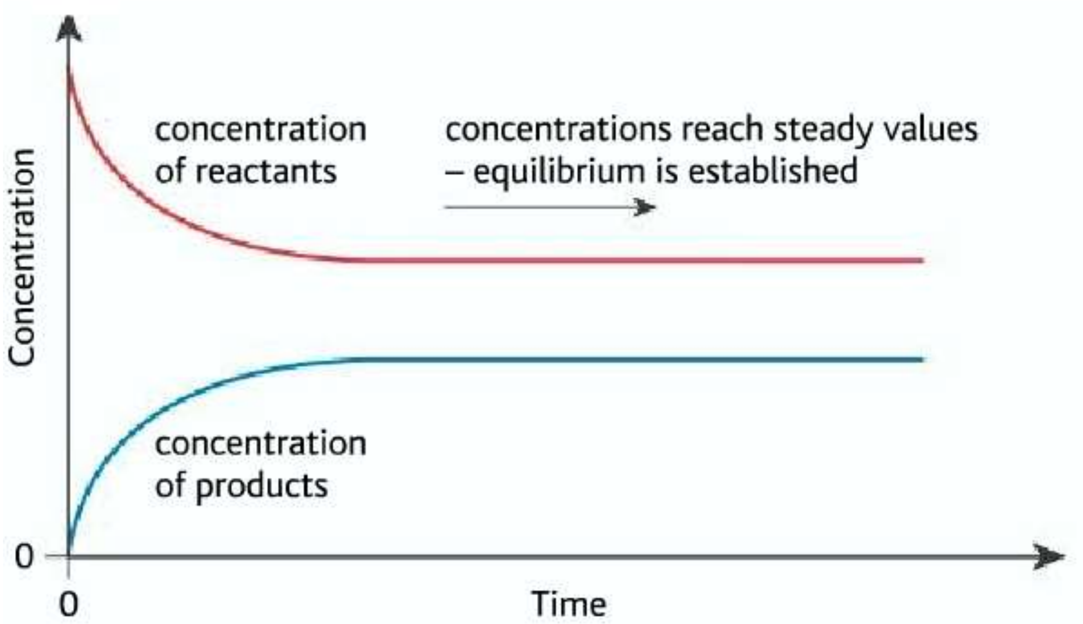
Chemical equilibria

When a reversible reaction happens in a closed container, it can achieve a dynamic equilibrium. At equilibrium: the rates of the forward and backward reactions are the same. the concentrations of the reactants and products remain constant (they do not change).

CHEMICAL EQUILIBRIUM – A DYNAMIC EQUILIBRIUM

- Upon addition of reactants and/or products, they react until a constant amount of reactants and products are present = equilibrium.
- Equilibrium is dynamic since product is constantly made (forward reaction), but at the same rate it is consumed (reverse reaction).





Factors that affect chemical equilibrium

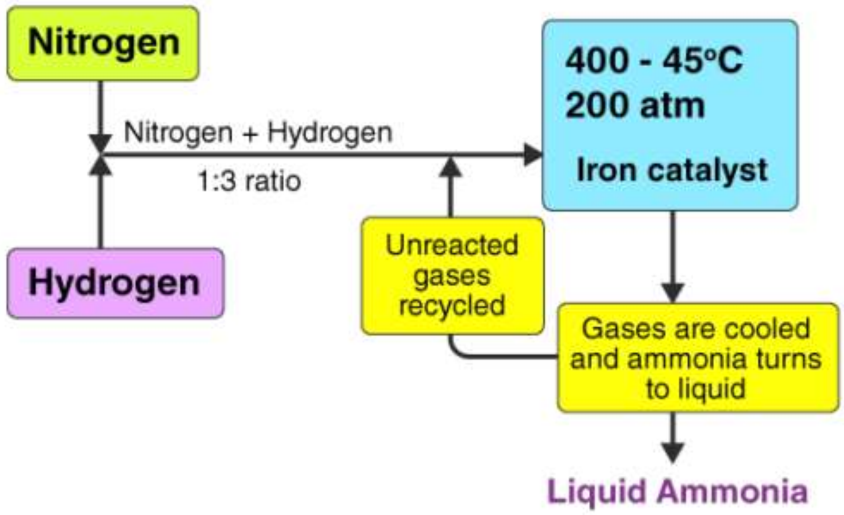
1. Disturbance in equilibrium
2. Changes in Concentration

3. Changes in Pressure

4. Addition of an inert gas

5. Changes in temperature

The Haber process



Test yourself!

Q1. State the distinguishing properties of solids, liquids, and gases.

A:

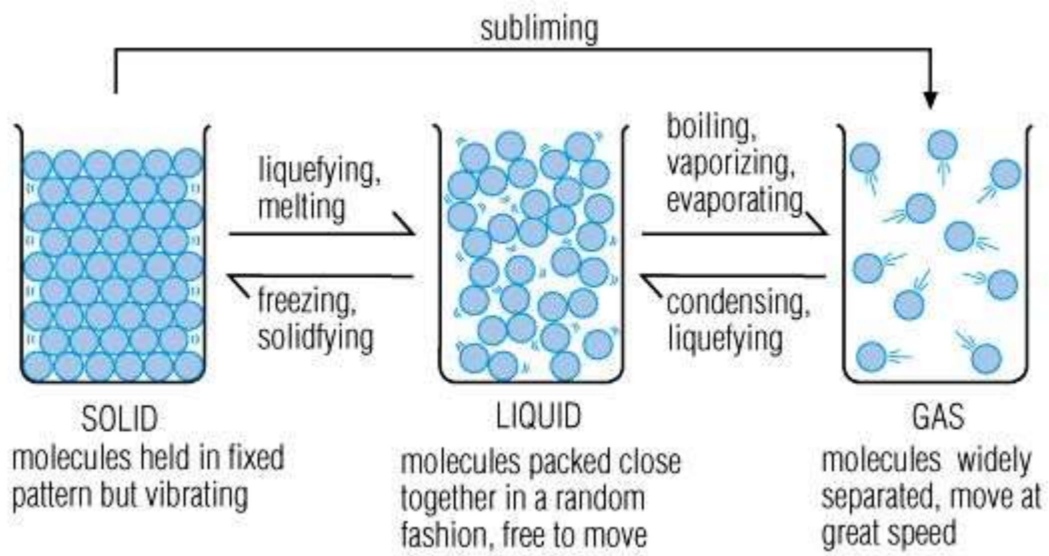
- The three states of matter are solid, liquid and gas
- Melting and freezing take place at the melting point
- Boiling and condensing take place at the boiling point

They can be represented by the simple model above; particles are represented by small solid spheres.

Solids- particles have a regular arrangement and are close together.

Liquids- particles have a random arrangement and are close together.

Gases- particles have a random arrangement and are spread apart.



Q2. Describe the structure of solids, liquids and gases in terms of particle separation arrangement and types of motion.

A:

Gas: particles have the most energy – shown by the diagram, as the particles are the most spread apart, motion is more random and frequent

Liquid: particles have more energy than those in a solid, but less than those in a gas

Solid has least energy – particles are not moving/are just vibrating.

Q3. Describe changes of state in terms of melting, boiling, evaporation, freezing, condensation and sublimation.

A:

Physical changes – therefore involves the forces between the particles of the substances, instead of these changes of state being chemical changes.

- Evaporation = happens at the surface, molecules have enough energy to evaporate – i.e. go from liquid to gas

- Freezing = liquid to solid

- Melting = solid to liquid

- Boiling = happens throughout the liquid, liquid to gas

- Condensation = gas to liquid

- Sublimation = solid to gas

Q4. Explain changes of state in terms of the kinetic theory.

A:

Kinetic theory can help to explain melting, boiling, freezing and condensing.

- The amount of energy needed to change state from solid to liquid and from liquid to gas depends on the strength of the forces between the particles of the substance

- The nature of the particles involved depends on the type of bonding and the structure of the substance.

- The stronger the forces between the particles the higher the melting point and boiling point of the substance.

- The more kinetic energy (from increased temperature) particles have, the more movement, which causes a change of state from (s) to (l) to (g)

Q5. Describe qualitatively the pressure and temperature of a gas in terms of the motion of its particles.

A:

The higher the pressure = the more motion of a gas' particles

The higher the temperature = the more motion of a gas' particles

Q6. Show an understanding of the random motion of particles in a suspension (sometimes known as Brownian motion) as evidence for the kinetic particle (atoms, molecules or ions) model of matter.

A:

Particles in liquids and gases (known as fluids) move randomly (this is called Brownian motion)

This happens because they collide with other moving particles in the fluid

This is evidence for the kinetic particle model of matter- it shows that there are individual particles that make up solids/liquids/gases

Q7. Describe and explain Brownian motion in terms of random molecular bombardment.

A:

Particles in liquids and gases move randomly because they are bombarded by the other moving particles in the fluid. Larger particles can be moved by light, fast-moving molecules.

Q8. State evidence for Brownian motion

A:

Robert Brown observed the random movement of pollen grains within water, which showed that there were separate particles within the water that were moving randomly and caused the grain to move (kinetic theory)

Q9. Describe and explain diffusion.

A:

Movement of particles from an area of high concentration to an area of low concentration

For this to work, particles must be able to move. Therefore, diffusion does not occur in solids, since the particles cannot move from place to place (only vibrate).A smell does not travel very fast, because the particles collide with particles of air, changing direction randomly when they collide, taking much longer to travel from place to place.

Q10: Describe and explain the dependence of the rate of diffusion on molecular mass.

A:

The smaller the molecular mass, the greater the average speed of the molecules (but all gases have the same average kinetic energy at the same temperature). Therefore, the smaller the molecular mass, the faster the gas diffuses.