Chemical Equilibrium Systems

- **Explain how collision theory can be used to predict the effects of concentration, temperature, pressure, the presence of catalysts and surface area of reactants on the rates of chemical reactions.**

Collision theory
All particles are in constant motion and in order for particles to react and form products they must collide with enough energy and appropriate orientation to overcome the activation energy.

Concentration
-As concentration is increased, there will be more particles in a given space.
-More likely those particles will collide with each other
-So there will be more collisions
-Increased rate of reaction

Pressure
-The pressure of a gas is due to the particles colliding with the walls of containers
- As pressure increases, there are more particles in a given space
- Concentration of the particles increases so particles collide more often
-Rate of reaction increases

Temperature
-As the temperature increases, the average kinetic energy of particles increases
-A larger proportion of particles will have enough energy to overcome activation energy.
-More successful collision occur that break pre existing bonds and form new ones
-Rate of reaction increases

Surface Area
-In a solid, only the particles on the surface experience collisions.
-The greater the surface area, the more collisions experienced
-Rate of reaction increases

Catalyst
-Catalysts provide an alternative reaction pathway with lower activation energy for the reaction to occur

-A large proportion of particles will have enough energy to overcome the activation energy
-Rate of reaction increases.
-Enzymes are biological catalysts. They are proteins that function in living organisms.

-Ionic reactions are instantaneous since they don't involve bond breaking and bond formation and also because the electrostatic attractions between oppositely charged ions are strong.

$$AgCl \rightleftharpoons Ag^+ + Cl^-$$
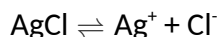
-Molecular reactions are slow since they involve bond breaking and bond formation of strong covalent bonds.

$$O_2 + 2H_2 \rightleftharpoons 2H_2O$$
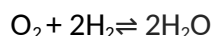
- **Chemical systems include physical change and chemical change and are either called an 'open system' or a 'closed system'.**

Physical change
-Reactants don't produce new substances
-Physical properties change
-Can be reversed

Chemical change
-Reactants produce new substances
-Atoms rearrange and form products that are different from reactants
-Substances have different physical and chemical properties
-Usually cannot be reversed

Closed system
-Allows energy to be exchanged with surroundings.

Open system
-Allows energy and matter to be exchanged with surroundings

- **Observable changes in chemical reactions and physical changes can be described and explained at an atomic and molecular level**

When HCL is added to solution it is broken up into its individual ions H^+ and Cl^-. This process is called **ionization**.

In reversible reactions precipitate can form as well and that can be a reason why forward/reverse happens.

When explaining changes to equilibrium reactions.

1. **What the system will try to do about imposed change.**
2. **Which reaction is favored/why reaction favored**
3. **The equilibrium shift**
4. **The concentration increase**
5. **Observation**

- **Overtime, In a closed system, reversible physical and chemical reactions may reach a state of dynamic equilibrium, with the relative concentrations of products and reactants defining the position of the equilibrium.**

-Forward reactions, the reactants form products
-Reverse reactions, the products form reactants

$$3H_2 + N_2 \rightleftharpoons 2NH_3$$
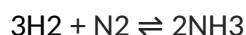
1. Hydrogen and nitrogen form ammonia   2.Ammonia forms hydrogen and nitrogen.

-In a closed system where products form reactants and reactants form products, the reaction doesn't go to completion; it's in a steady state. It's in dynamic equilibrium.
-Systems in steady states have constant properties.

1. The concentration of reactant particles is initially high so a forward reaction takes place
2. As the concentration of the reactant particles decreases, the concentration of product particles increases
3. The concentration of product particles is now high so a reverse reaction starts to take place.
4. This is will continue until the rate of the forward reaction is the exact same as the reverse reaction

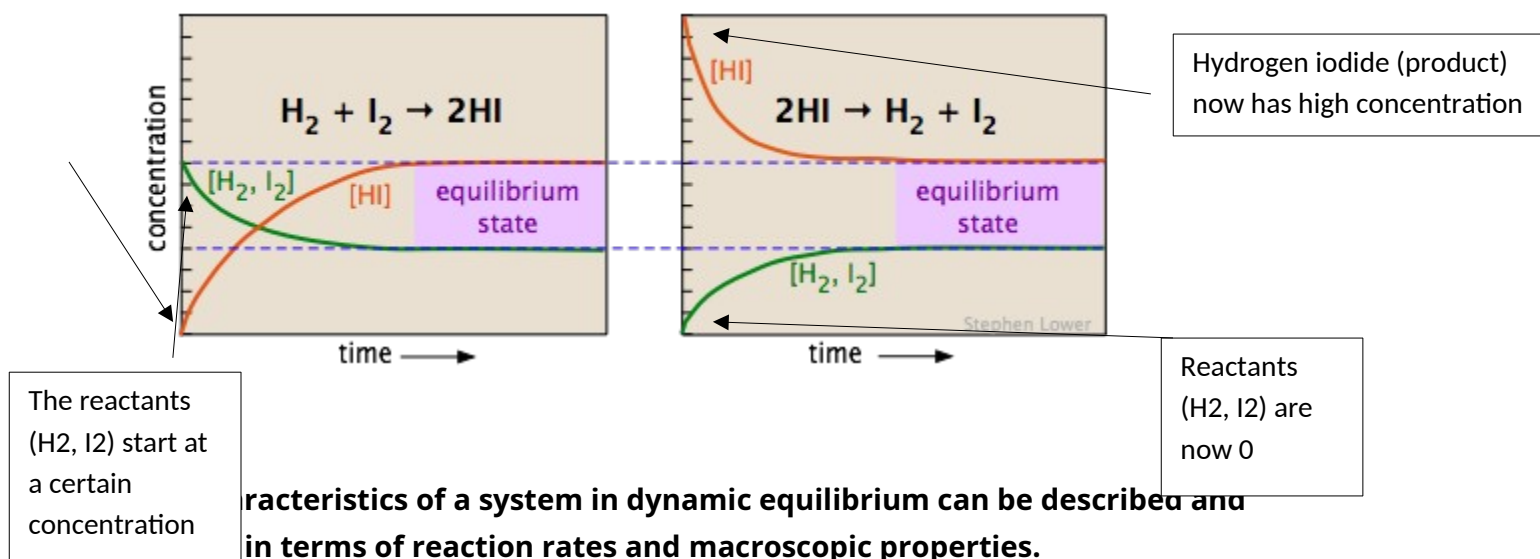In summery a reaction will reach dynamic equilibrium if:

-It is a closed system
-It is a reversible reaction
-The rate of forward reaction is equal to rate of reverse reaction.
-The concentration of the reactants and products is constant.
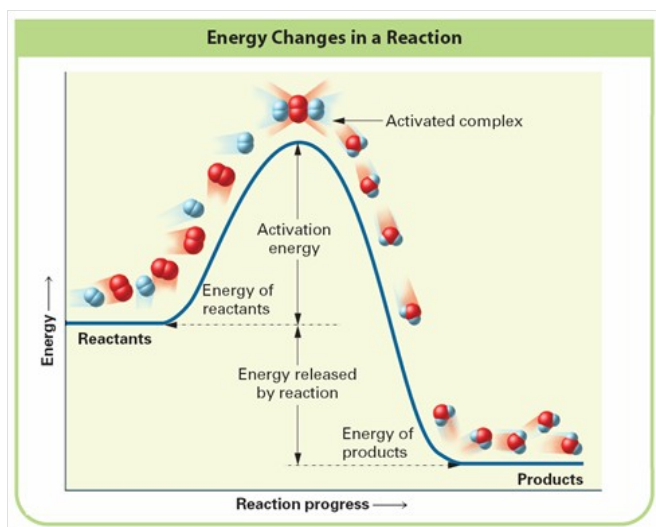-It's in a steady state, macroscopic properties are constant (visible properties)

Hydrogen Iodide (product) starts at 0

$H_2 + I_2 \rightarrow 2HI$

$[H_2, I_2]$

$[HI]$

equilibrium state

time

$2HI \rightarrow H_2 + I_2$

$[HI]$

equilibrium state

$[H_2, I_2]$

time

Stephen Lower

Hydrogen iodide (product) now has high concentration

The reactants (H2, I2) start at a certain concentration

Reactants (H2, I2) are now 0

aracteristics of a system in dynamic equilibrium can be described and
in terms of reaction rates and macroscopic properties.

-Forward reaction rate is equal to reverse reaction rate.
-Concentration of products and reactants is constant.
-Macroscopic properties are constant such as: colour, state, volume, electrical conductivity, gas pressure.

• **The effect of changes in temperature of systems at equilibrium can be predicted by the enthalpy changes of forward and reverse reactions; this can be represented on energy profile diagrams and explained by changes in the rates of forward and reverse reactions.**

-The amount of energy required to break pre-existing bonds of reactants to form new ones is called activation energy
-It is the difference in energy between reactants and activated complex
(Activated complex – Reactants = Ea)
-Reverse reactions occur when activation energies of both the forward and reverse reaction is similar or low enough for sufficient particles to collide to have successful collisions.

Energy Changes in a Reaction

- Activated complex
- Activation energy
- Energy of reactants
- Reactants
- Energy released by reaction
- Energy of products
- Products
- Reaction progress ⟶
- Energy ⟶

- **The relative amounts of reactants and products (equilibrium position) can be predicted qualitatively using equilibrium constants (kc)**

- The equilibrium constant (kc) is a mathematical ratio between the concentration of reactants and products for a reaction at a certain temperature during equilibrium.

-Changing the concentration of a system will not affect the equilibrium constant as the system will establish an equilibrium that has different concentration but they will be the same ratio so equilibrium expression (k value) is not changed.

-Changing the temperature changes the equilibrium constant because the energy levels is not the same on both sides of the reaction since one side is endothermic and the other is endothermic. So a side's rate of reaction will be faster and that changes the ratios so that alters the equilibrium constant.
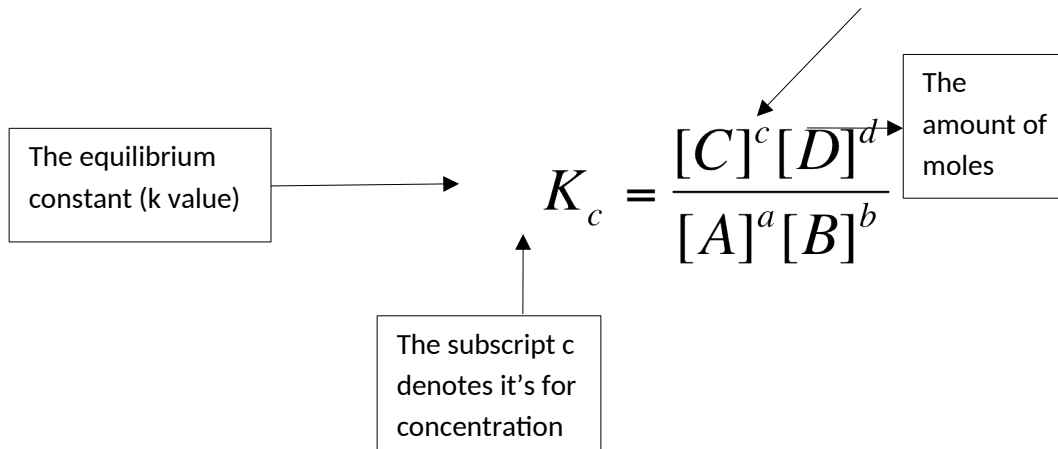
-If the equilibrium constant (kc) is <1 then reactants are favored so reverse reaction takes place.

-If the equilibrium constant (kc) is >1 then products are favored so forward reaction takes place.

-The equilibrium constant is calculated using the reactants and products concentration in a reaction.

The concentration on mol litre^{-1}

The products are over the reactants   aA + bB ⇌ cC + dD

The equilibrium constant (k value)

The amount of moles

$$K_c = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

The subscript c denotes it's for concentration

-Only gases and aqueous solutions concentration is used in the equilibrium constant.

-Solids and liquids cannot be used in the equilibrium expression. Since their concentration doesn't change.

-Remember to always check if the reaction contains solids or liquids.

-Yield refers to how much products can be produced.

- **The effects of changes in temperature, concentration of species in solution, partial pressure of gases, total volume and the addition of a catalyst on equilibrium systems can be predicted using Le Chatelier's principle.**

-Le Chateliers principle states that if a system at equilibrium experiences a change of concentration, temperature or pressure, the system will re-establish the equilibrium so as to partially counter act the imposed change.

Note: Le Chateliers principle provides a simple way to explain what happens when a change is imposed on a chemical system.

Pressure

When the <u>pressure is increased</u> on a system, the system will try to <u>decrease the pressure</u> so the equilibrium will shift <u>to the side which has fewer particles.</u>

When the <u>pressure is decreased</u> the system will try to <u>increase the pressure</u> so the equilibrium will shift to the <u>side which has a greater proportion of particles.</u>

Temperature

When the <u>temperature is increased</u> on a system, the system will try to <u>decrease the temperature</u> so the system will shift <u>to the side which has less heat.</u>

When the <u>temperature is decreased</u> on a system, the system will try to <u>increase the temperature</u> so the system will shift <u>to the side which has more heat.</u>

Concentration

When the <u>concentration of a molecule is increased</u>, the system will try to <u>decrease its concentration</u> so the equilibrium will shift to the side which <u>decreases its concentration</u>.

When the <u>concentration of a molecule is decreased</u>, the system will try to <u>increase its concentration</u> so the equilibrium will shift to the side which <u>increases</u> its concentration.

- **The effects of changes in temperature, concentration and volume of solutions and partial pressures of gases on chemical systems initially at equilibrium can be predicted and explained by applying collision theory to the forward and reverse reactions.**

Collision theory
Collision theory states that all particles are in constant motion and in order for particles to react they have to collide with sufficient amount of energy called activation energy to break pre existing bonds and form new ones.

If the <u>forward reaction </u>is favored equilibrium is shifted to the <u>right as more products are produced</u>.

If the <u>reverse reaction</u> is favored the equilibrium is shifted to the <u>left as more reactants are produced</u>.

If the concentration, temperature or pressure of gases is changed; the concentration of reactants and products is changed so they are no longer constant. This means equilibrium has changed.

Concentration

If reactants concentration is increased, the rate of reaction of reactants making products increases since there are more particles colliding with each other. So the rate of forward reaction is increased while the reactants concentration decreases so equilibrium gets shifted to the right.

As the products increase in concentration, the products collide with each other so the rate of reverse reaction increases and reactants increase in concentration while products concentration decreases.

This trend continues until the system has established a new equilibrium where the concentrations of reactants and products are constant and the rate of the forward and reverse reactions is equal.

Partial pressure of gases can be used to indicate concentration. Partial pressure is proportional to concentration so they make the same changes as each other.

Volume

If the volume changes for a system, the concentrations of the reactants and products change. So rate of reaction for each one changes. Whichever one has the highest rate of reaction it will be favored.

Make sure to use ratios to determine which reaction will be favored in relation to volume and pressure

For example: the reaction **3**H_2 + N_2 ⇌ **2**NH_3 has a **4:2** ratio as there are **4 moles** of reactants and **2 moles** of products

If volume is increased, the pressure is decreased; so the rate of forward and reverse reaction decreased but so rate of forward reaction will decrease more since it has more moles so reverse reaction will be favored and equilibrium gets shifted to the left.

Adding or removing water to the system will be change the concentration of all systems so it has the same effect as changing the volume. Adding water will decrease the concentration and vice versa.

If the reaction has the same number of moles on each side, it has the same ratio. Changing the concentration of all the aqueous substances will cause no effect to the equilibrium as the concentration is constant and no reaction will be favored.

Temperature

In a reverse reaction the reaction in one direction will be exothermic and the reaction in the other direction is endothermic.

The activation energy (E_a) calculated by subtracting the enthalpy of reactants from the activated complex (the highest point of enthalpy)

Activation energy (E_a) = Activated complex – Reactants enthalpy

An endothermic reaction has higher activation energy than an exothermic reaction.

Increasing the temperature of a system will increase the rate of reaction of both forward and reverse reactions. The endothermic reaction absorbs the energy to overcome the activation energy so its rate of reaction increases more so endothermic reaction is favored. As more product of endothermic reaction is produced, the reverse exothermic reaction rate increases. This trend continues until equilibrium is reached.

When temperature decreases both the forward and reverse rate of reaction decreases but the endothermic rate of reaction decreases more as it needed energy to overcome its activation energy and form its products.

The exothermic reaction has lower activation energy so its reaction is favored so more products of the exothermic reaction are produced. As more products of the exothermic reaction are produced, the reverse reaction takes place. This trend continues until equilibrium is reached.

Ocean acidification

As the gaseous CO_2 concentration increases in the atmosphere from forest deforestation and burning of fossil fuels such as coal, oil and natural gas. The gaseous CO_2 dissolves in the ocean water to become aqueous CO_2 which then reacts with H_2O to form H_2CO_3 (carbonic acid). The carbonic acid then disassociates into HCO_3 and H_3O^+ ions. The HCO_3 ions disassociate even further into CO_3 and H^+ ions.

The increase in H_3O^+ ions decreases the pH of the ocean so the acid levels rise. The H_3O^+ ions react with the CO_3 ions to form HCO_3 naturally. But an increase in H_3O^+ ions will cause too much CO_3 ions to form into HCO_3; which decreases the CO_3 concentration and CO_3 is needed for shell calcification.

 So an increase in CO_2 in the atmosphere is detrimental to the ocean life as it interferes with the calcification process.


Acids and bases

- **Acids are substances that act as proton donors and can be classified as monoprotic or polyprotic, depending on the number of protons available for the donation. Bases are proton acceptors.**

-Acids that donate 1 hydrogen molecule are known as monoprotic such as HCL, HCO_3 etc.
-Acids that donate more than 1 hydrogen molecule are known as polyprotic such as H_2CO_3, H_2SO_4 etc.

Most acids are molecular. They ionize in aqueous solution to release H^+ which attaches to H_2O to form H_3O^+.

Acid + H_2O → H_3O^+ + negatively charged ion

$H_2SO_4 + 2H_2O$ → $2H_3O^+ + HSO_4^{2-}$
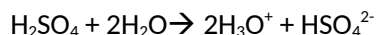
Water is self ionizing and can act as an acid or a base, it is amphoteric and amphiprotic. A few water molecules ionize to form H_3O^+ and OH^-. This is a reversible reaction. $2H_2O \rightleftharpoons H_3O^+ + OH^-$

Strong acids ionize completely; HCl, H_2SO_4, HNO_3, $HClO_3$, $HClO_4$,
Weak acids ionize partially so molecules will be dominant; H_2CO_3, CH_3COOH^-, HF, $C_6H_8O_7$

A base is a substance that accepts protons. A base can be referred to an alkali, which means a base that is soluble in water. Bases produce OH^- when ionised in water. The OH^- reacts with H^+ to form H_2O.

Strong bases disassociate completely; $NaOH$, $LiOH$, KOH, $Ba(OH)_2$, Na_2O, $Sr(OH)_2$, $Ca(OH)_2$, $Ba(OH)_2$
Weak bases partially disassociate so molecules will be dominant; NH_3, CH_3NH_2

- **The relationship between acids and bases in equilibrium systems can be explained using the Brownsted-Lowry model and represented using chemical equations that illustrate the transfer of protons between conjugate acid-base pairs.**

The Arrhenius theory states: The Bronsted-lowry theory states:

An acid gives H^+ an acid donates H^+
A base gives OH^- A base accepts H^+

A reversible reaction involving an acid or a base includes a **conjugate pair** in which one pair is either the 'acid that has turned into a base' or a 'base that has turned into an acid'.

For example; $H_2SO_4 + H_2O \rightleftharpoons H_3O^+ + HSO_4^{2-}$

The acid H_2SO_4 donates a proton to form a conjugate base HSO_4^{2-}. This is a **conjugate pair**.

The base H_2O accepts a proton to form a conjugate acid H_3O^+. This is a **conjugate pair.**

Amphoteric is a substance that can act as an acid or base. eg. Oxides of Zn
Amphiprotic is a substance that can donate or accept a proton. eg. H_2O

Strong acids and bases have **weak conjugate pairs**
Weak acids and bases have **strong conjugate pairs** EXCEPT NH_4^+

- **The pH scale is a logarithmic scale and the pH of a solution can be calculated from the concentration of hydrogen ions using the relationship pH=-log [H₃O⁺] or [H₃O]=10⁻ᵖᴴ**

The pH is a measure of acidity. It is a measure of the number of hydronium ions in a solution. A pH that is <7 is acidic, A pH that is >7 is basic and a pH that is 7 is neutral.

A solution is neutral with the H_3O^+ concentrations equals the OH^- concentration. The pure water is neutral but its pH varies with temperature since K_w of 1x10^-14 is changed during a temperature change. The H_3O^+ ion concentration increase with temperature increase.

pH is a logarithmic scale which means a drop of 1 means the hydronium concentration has increased 10 times

The concentration of hydronium ions can vary greatly with an extremely large range of 10M to 10^{-15}M so the convenient pH scale is used instead. M stands for Molarity, which is a measure of concentration.

The concentration of hydrogen ions in a solution or 'pH' depends on the **concentration** of a solution (concentrated or dilute), the **strength** of an acid (strong or weak), the number of protons the acid has to **donate**, (monoprotic, diprotic, triprotic) and the **temperature** of the solution (ionisation occurs more readily at higher temperatures). A good acronym is **S.C.N.T**

S - Strength of an acid
C - Concentration of solution
N- Number of protons donated
T- Temperature of the solution

We can use pH = -log [H_3O^+] and pOH= -log [OH^-] or [H_3O^+]= 1x10⁻ᵖᴴ and [OH^-]=1x10⁻ᵖᴼᴴ If we are given any information about the concentrations of either.

- **Water is a weak electrolyte; the self ionisation of water is represented by K$_w$ = [H₃O⁺][OH⁻] where K$_w$=1x10⁻¹⁴ at 25˚C**

The **size**, **shape** and **polarity** of water molecules make it possible for them to pack closely around solute particles such as ions or molecules. So water is a very good solvent.

Substances that dissolve in H_2O to form ions are called **electrolytes**.

Strong electrolytes:
Strong acids and bases since they ionise and disassociate completely in water to form individual ions so they are good conductors of electricity.

Weak electrolytes:

Weak acids and bases since they ionise and disassociate partially in water to form some ions but mostly molecules so they are weak conductors of electricity.

Non Electrolytes

Molecules such as glucose and protein do not ionise in water so they are non conductors of electricity.

The self ionisation of water produces a very little amount of H_3O^+ to it is a very weak conductor of electricity, it is a weak electrolyte.

Pure water always has the $[H_3O^+]$ = $[OH^-]$ no matter what the K_w value is.

If the water is unpure then substances most of the time have the $[H_3O^+] \neq [OH^-]$.

Pure water ≠ pH of 7 since at higher temperature the self ionization constant increases and at lower temperatures the self ionization constant decreases.
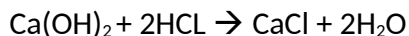
- **K_w can be used to calculate the concentration of hydrogen ions or hydroxide ions in solutions of strong acids or bases**

The **ionisation constant (K_w)** is 10^{-14}= $[H_3O^+]$ $[OH^-]$. It is derived from the equilibrium constant of the ionisation of water at 25°C and 100kps

So if the concentration of either hydroxide or hydronium ions is known. We can calculate the concentration of the hydroxide or hydronium ions if we know 2 of the unknowns. This is very simple to do. What if we had a limiting reaction and we had to calculate the moles?

E.g. 10 grams of $Ca(OH)_2$ is added to 200mL of 0.4 $molL^{-1}$ of HCL. Calculate the pH of the solution resulting from this reaction. Assume the volume of the mixture has not changed.

1. Balance the equation
   $Ca(OH)_2 + \underline{2}HCL \rightarrow CaCl + \underline{2}H_2O$
2. Calculate the moles of hydrogen ions and hydroxide ions

   m/M=n so 10 / 74.096 = 0.135 x 2 =0.27mol[OH^-]

   C=n/v = 0.2 x 0.4 x 2 = 0.08mol [H_3O^+]

   > Multiply by 2 since there are 2 hydroxides in $Ca(OH)_2$

3. Find out the excess reactant

   1 mole of $Ca(OH)_2$ needs to react with 2 moles of HCL.

   Multiply moles of $Ca(OH)_2$ by how many moles of HCL you need.

   We have 0.27 moles [OH] and we need 0.54 moles of HCL for the reaction to take place.

   But we only have 0.08 moles of H_3O^+ so HCL is the limiting reagent. Therefore, $Ca(OH)_2$ is the excess reactant.

4. Convert moles into concentration
   0.27-0.08=0.19 mol [OH^-] 0.19/0.2=0.95 mol L^{-1}[OH^-]

5. Calculate the pH
   10^{-14}/0.95= 1.05263×10^{-14} -log 1.05263×10^{-14} = 13.97 pH (extremely basic)

- **The strength of acids is explained by the degree of ionisation at equilibrium in aqueous solution which can be represented by chemical equations and acidity constants (K_a)**

Determining the K_a of an acid is determined only when the solution is dissolved in water.

$HF_{(aq)}+H_2O_{(l)} \rightarrow H_3O_{(aq)}+F^-_{(aq)}$ K_a = [H_3O][F^-]/[HF]
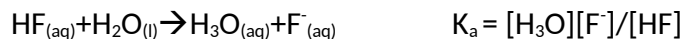
The first dissociation content always has a higher K_a value since the acid is strongest. The K_a value becomes a lower value because the initial acids turn into weaker acids and the proton becomes more difficult to donate.

A strong acid is one that ionises completely, donating protons freely. The reaction goes to completion so it has a high K_a value since all the reactants turn into products. For strong acids, the reaction is shown with a '$\rightarrow$' The K_a of a strong acid is >10^3. The first release of the proton is done easily.

A weak acid does not ionise completely, it doesn't donate much protons. The acid partially ionises so it has a low K_a value. For weak acids, the reaction is shown as '$\rightleftharpoons$' since the reaction does not go to completion. The K_a of weak acid is $<10^{-3}$. The weaker the acid, the stronger it's conjugate base. So the reverse reaction is favored and the K_a value decreases.

Use the **ICE** method when calculating acid disassociation constants.
Initial, Change, Equilibrium

The percentage ionization is the percentage of acid that has ionized in water.
It is calculated by the equation below.
(Equilibrium (final) concentration of conjugate base/Initial concentration of acid) x 100 = Ionisation %

- **Acid-base indicators are weak acids or weak bases, in which the acidic form is a different colour from the basic form.**

Indicators are either weak acids and their conjugate base or a weak base and its conjugate acid. The acid is differently coloured from its base. Indicators are added to solution and change colour according to the pH of a solution.

Indicators can be sold as solutions or dried onto paper strips. Plants can also be used as natural indicators due to the dyes they contain.

Some common indicators are;
Methyl orange – red to yellow   **Bromothymol blue** – yellow to blue   **Phenolphthalein** – colourless to pink

Universal indicator is a mixture of several dyes. It goes through the colours of the rain bow (ROYGBP)

Indicator molecules always have complicated formulas so they can be shown as 'HIn'. 'H' represents a hydrogen atom and 'In' represents the rest of the molecule. Indicator molecules ionise in solution and they are always a reversible reaction.

$$HIn \rightleftharpoons H^+ + In$$

| Yellow | | Blue |

In an acidic solution the H_3O^+ ions will react with the indicator ions to form the indicator molecule so the reverse reaction is favoured and the solution becomes yellow.

In a basic solution the OH^- ions will neutralize the H_3O^+ Ions in the solution so the forward reaction would be favoured and the solution would become blue.

Indicators are used in the following situations;

1. Testing the acidity/basicity of soil

2. Checking the pH of water is swimming pools

3. Checking pH of aquarium water

4. Finding the end point of an acid-base titration

- **Buffer solutions are conjugate in nature and resist changes in pH when small amounts of strong acid or base is added to solution; buffering capacity can be explained qualitatively; Le chateliers principle can be applied to predict how buffers react to the addition of hydroxide and hydronium ions.**

A buffer is usually a weak acid and its conjugate base or a weak base and its conjugate acid. Buffers work by reacting with most of the hydroxide or hydronium ions being added to a solution.
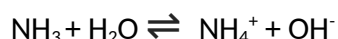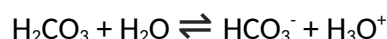
Acidic buffers are weak acid and one of their salts and Basic buffers are a weak base and one of their salts. Examples of buffers include:

(CH_3COOH/CH_3COONa) Acetic acid/Sodium acetate
$(H_2CO_3/NaHCO_3^-)$ Carbonic acid/Sodium bicarbonate
(NH_3/NH_4CL) Ammonia/Ammonium chloride

Buffers are reversible reactions. (Do not include the spectator ions)

Ex. $CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$

$H_2CO_3 + H_2O \rightleftharpoons HCO_3^- + H_3O^+$

$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$

Buffer capacity refers to the amount of H_3O^+ or OH^- the buffer solution can consume before it cannot maintain the pH. The capacity depends on the amount of moles the buffer contains.

For example.

$$CH_3COOH + H_2O = CH_3COO^- + H_3O^+$$
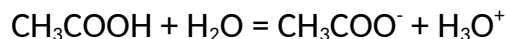
| 0.05 moles | 0.04 moles |

If 0.06 moles of NaOH was added to the solution when there is just 0.05 moles of CH_3COOH to produce H_3O^+; the buffer capacity would be exceeded and the pH would change rapidly without the assistance of the buffer.

To **increase buffer capacity to maximum**; the **concentration** of the **conjugate base** and **conjugate acid** would need to be equal

- **The hydrolysis of salts of weak acids and bases can be represented using equations; the bronsted-lowry model can be used to explain the acidic, basic and neutral nature of salts derived from bases and monoprotic and polyprotic acids.**

Hydrolysis is the process of reacting a salt with H_2O to produce H_3O ions or OH^- ions

Salts are composed of an anion and a cation. They are formed from the reaction of acids and bases.

An **acidic salt** is formed when a **strong acid reacts with a weak base.** The salt is acidic since there is an excess of hydronium ions
A **basic salt** is formed when a **weak acid reacts with a strong base.** The salt is basic since there is an excess of hydroxide ions.

A **neutral salt** is formed when **acids and bases of similar strength react with each other.** Since the hydroxide and the hydronium ions have similar concentrations.

The way to find out whether a salt is acidic, basic or neutral is to react it with water and check the strength of the acid and base.

Ex. When sodium chloride is dissolved in water it ionizes

$NaCl \rightarrow Na^+ + Cl^-$

$H_2O \rightarrow H^+ + OH^-$

That Na ions are attracted to OH ions so it forms NaOH which is a strong base
The Cl ions are attracted to the H^+ ions so it form HCL which is a strong acid

The concentrations of hydroxide and hydronium is equal so solution is neutral

Or you can simple write this equation $NaCl + H_2O \rightarrow NaOH + HCL$ and because both the acid and base are strong the salt is neutral.

Super acids are acids that are stronger than 100% pure sulphuric acid. They are very toxic and volatile substances, they are extremely corrosive. An example is fluoroantimonic acid. They can be used to acidify organic compounds such as hydrocarbons which are very poor proton acceptors.

NOA - Non metal oxides are acidic

MOB - Metal oxides are basic

- **Volumetric analysis methods involving acid-base reactions rely on the identification of an equivalence point by measuring the associated change in pH, using appropriate acid-base indicators or pH meters, to reveal an observable end point.**

Volumetric analysis is a quantitative analysis which is used to find out the unknown concentration of a known volume of a substance by using a substance with a known concentration.

Titration is used to find the concentration in Moles/Litre of a solution. You add a solution of known concentration to a solution of unknown concentration but known volume until the acid and base have neutralised.

The point where the reaction is complete is called an **equivalence point.**

In acid-base titrations the solution is always colourless and there's no precipitate so an indicator is used. When a permanent colour change occurs; it is called the **end point**. The equivalence point and the endpoint should usually be at the same paint. But some error may occur.

Titration with weak acid and weak base is not used as there is no rapid change that indicates an equivalence point.

<u>**Standard solution**</u>
Standard solution is a solution which has a concentration that is known accurately. If you want to find the concentration of an unknown solution; you use a standard solution such as a primary standard or a secondary standard.

A **primary standard** solutions when you make up a standard by dissolving a small amount of mass into a small amount of solvent and making the volume up to a measured volume, usually 500mL. This is what volumetric flasks are used for. It is a chemical which;
-Can be obtained in a pure form.
-Has a known chemical formula.
-Is stable and does not change when exposed to air.
-Is soluble.
-Has a high molar mass
-Is anhydrous

An example is Na_2CO_3. NaOH reacts with oxygen in the air so it is unstable and not used as P.S.

Secondary standard is when you have found the concentration of the standard by a past titration.

The most commonly used standard solutions are sodium carbonate (Na_2CO_3) for basic solutions and hydrated oxalic acid ($C_2H_2O_4$) for acidic solutions.

The burette and pipette should always be rinsed with the solution that will be used. The other instruments need to be rinsed with distilled water.

How to titrate a solution:

The most common titration reaction is $Na_2CO_3 + 2HCL \rightarrow H_2CO_3 + 2NaCl$
In this case, the primary standard is Na_2CO_3 and the solution with the unknown concentration is the HCL.

The HCL is put into a burette and is released into a solution of Na_2CO_3 until colour changes become evident; this is when slow titration of drop by drop occurs until there is a permanent change in colour of the indicator. The volume that is used to reach the equivalence point is used to calculate the concentration of the HCL solution that has the unknown concentration using the equation $C_1V_1=C_2V_2$ Since the same number of moles that was poured in the burette should be in the conical flask.

- **Data obtained from acid-base titrations can be used to calculate masses of substances and concentrations and volumes of solutions involved.**

3 titrations have been performed and an average of 20.1mL of HCL was used to reach the end point of the Na_2CO_3 titration. This means the stoichiometric ratios of moles have been reached when 0.0201L of HCl is neutrilised with Na_2CO_3.

The balanced equation of the reaction is **2**HCL + Na_2CO_3 → **2**NaCl + H_2CO_3

Na_2CO_3: V= 0.02L   HCL: V=0.021L

C=0.042 $molL^{-1}$ C=?

2 moles of HCL reacts with 1 mole of Na_2CO_3 so the moles of Na_2CO_3 is multiplied by 2

$2n(Na_2CO_3)$ =n(HCL)   2(0.02x0.042) =(0.021xC)   0.00168=0.021C   0.00168/0.021= **0.08 mol L^{-1}**

From the titration we have found out that the concentration of HCL is 0.08$molL^{-1}$

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OXIDATION AND REDUCTION

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- **Oxidation-reduction (redox) reactions involve transfer of one or more electrons from one species to another. Oxidation and reduction can be represented by half equations and redox equations**

Redox reactions are reactions in which electrons are transformed from one species to another. They are composed of a **reduction reaction** and an **oxidation reaction**. These cannot happen without the other and are known as half reactions. An **oxidation** reaction **loses electrons** and a **reduction** reaction **gains electrons**. They are common types of reactions that happen.

- **A range of reactions involve the oxidation of one reaction and the reduction of another species including metal displacement, combustion, corrosion, metal and dilute acid reactions, Active metals with H_2O reactions, metal and non metal reactions, electrochemical reactions..**

To find out what is being oxidised or reduced you check if each atom's oxidation number has increased or decreased.
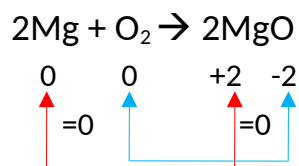
Combustion reactions

Combustion involved a hydrocarbon reacting with oxygen to form carbon dioxide and water.

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

-4 + 4   0   +2 -2   +4 -4

  0   0   0   0
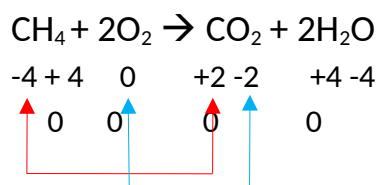
C is oxidized
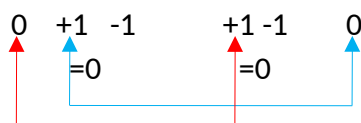O_2 is reduced

Corrosion reactions

Corrosion reactions involve a metal reacting with the oxygen in the air to form a metal oxide which can rust.

$2Mg + O_2 \rightarrow 2MgO$

0   0   +2 -2

=0   =0

Mg is oxidized
O_2 is reduced

Metal displacement reactions

In metal displacement reactions the more reactive more takes the place of the less reactive metal.

$K + NaNO_3 \rightarrow KNO_3 + Na$

0 +1 -1   +1 -1   0
=0   =0

K is oxidized

Na is reduced

When writing half equations (individual reduction reaction and oxidation reaction). You ignore spectator ions and you add H_2O to the side lacking oxygen and the add H^+ to the side lacking hydrogen. You then add electrons to the side that has higher oxidation state to balance charges out on both sides and make them even.

When adding the reduction and oxidation reactions together to make full equation. You have to cancel out the added out electrons by multiplying both reactions by a common factor.

- **The relative strength of oxidising and reducing agents can be determined by comparing standard electrode potentials, and can be used to predict reaction tendency.**

   The standard electrode potentials are used to see which species are best electron gainers/oxidants/oxidising agents by going up the list and which are the best electron losers/reduction agents/reductants by going down the list. A lower metal will displace a higher metal. The activity series starts from the bottom up.

TABLE 17.1 Standard Reduction Potentials at 25 °C

	Reduction Half-Reaction	$E°$ (V)	
Stronger oxidizing agent	$F_2(g) + 2 e^- \longrightarrow 2 F^-(aq)$	2.87	Weaker reducing agent
	$H_2O_2(aq) + 2 H^+(aq) + 2 e^- \longrightarrow 2 H_2O(l)$	1.78	
	$MnO_4^-(aq) + 8 H^+(aq) + 5 e^- \longrightarrow Mn^{2+}(aq) + 4 H_2O(l)$	1.51	
	$Cl_2(g) + 2 e^- \longrightarrow 2 Cl^-(aq)$	1.36	
	$Cr_2O_7^{2-}(aq) + 14 H^+(aq) + 6 e^- \longrightarrow 2 Cr^{3+}(aq) + 7 H_2O(l)$	1.33	
	$O_2(g) + 4 H^+(aq) + 4 e^- \longrightarrow 2 H_2O(l)$	1.23	
	$Br_2(aq) + 2 e^- \longrightarrow 2 Br^-(aq)$	1.09	
	$Ag^+(aq) + e^- \longrightarrow Ag(s)$	0.80	
	$Fe^{3+}(aq) + e^- \longrightarrow Fe^{2+}(aq)$	0.77	
	$O_2(g) + 2 H^+(aq) + 2 e^- \longrightarrow H_2O_2(aq)$	0.70	
	$I_2(s) + 2 e^- \longrightarrow 2 I^-(aq)$	0.54	
	$O_2(g) + 2 H_2O(l) + 4 e^- \longrightarrow 4 OH^-(aq)$	0.40	
	$Cu^{2+}(aq) + 2 e^- \longrightarrow Cu(s)$	0.34	
	$Sn^{4+}(aq) + 2 e^- \longrightarrow Sn^{2+}(aq)$	0.15	
	$2 H^+(aq) + 2 e^- \longrightarrow H_2(g)$	0	
	$Pb^{2+}(aq) + 2 e^- \longrightarrow Pb(s)$	- 0.13	
	$Ni^{2+}(aq) + 2 e^- \longrightarrow Ni(s)$	- 0.26	
	$Cd^{2+}(aq) + 2 e^- \longrightarrow Cd(s)$	- 0.40	
	$Fe^{2+}(aq) + 2 e^- \longrightarrow Fe(s)$	- 0.45	
	$Zn^{2+}(aq) + 2 e^- \longrightarrow Zn(s)$	- 0.76	
	$2 H_2O(l) + 2 e^- \longrightarrow H_2(g) + 2 OH^-(aq)$	- 0.83	
	$Al^{3+}(aq) + 3 e^- \longrightarrow Al(s)$	- 1.66	
Weaker oxidizing agent	$Mg^{2+}(aq) + 2 e^- \longrightarrow Mg(s)$	- 2.37	Stronger reducing agent
	$Na^+(aq) + e^- \longrightarrow Na(s)$	- 2.71	
	$Li^+(aq) + e^- \longrightarrow Li(s)$	- 3.04	

Table 17-1 Chemistry, 5/e
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- **Electrochemical cells, including galvanic and electrolytic cells, consist of oxidation and reduction half-reactions connected via an external circuit through which electrons move from anode (oxidation reaction) to cathode (Reduction reaction).**

Galvanic cell/voltaic cell

A galvanic cell converts chemical potential energy to electric current through redox reactions. It uses spontaneous redox reactions to produce current. Battery is an example.

It consists of two beakers where a 1M solution is found and a cathode is in one and an anode is in another. The anode and cathode is connected by electrical wire and the two beakers solution has a salt bridge which consists of a nitrate salt.

The cathode is the reduction part and consists of a metal that gains electrons such as Ag or Sn and they gain mass since the incoming electrons react with the Ag or Sn ions in the solution to form solid metal. The electrodes can also be inert conductors such as platinum or graphite for Sn^{+2} and Sn^{+4} and gas being bubbled in.

The anode is the oxidation part that loses electrons and is usually made from metal such as Fe or Pb. The anode loses mass since the metal loses electrons to constantly form ions in solution.

The salt bridge consists of anions and cations. The positive ions of salt bridge will react with negative ion of solution and the negative ion of salt bridge will react of positive ions of the solution. This allows the electrons to travel through the electrical wires to the cathode.

Electrolytic cell

Electrolytic cells use external current by the use of a battery to provide the energy to force non-spontaneous redox reactions to occur. They are used in many industrial situations from metal plating to metal extraction and refining.

The positive anode side of the battery pulls electrons in and the negative side of the battery pushes electrons out. The metal that will become oxidised or reduced will depend on which side the battery is facing.

With this process, it can allow sodium ions to gain electrons and chloride ions to lose electrons in the electrolysis of NaCl

It also allows H_2O to run into H_2 and O_2

This is done by putting two electrodes in a beaker of water and connecting the two electrodes to a battery. The negative side of the battery is where reduction occurs since electrons are repulsed and the positive side of a battery is where oxidation occurs because electrons are attracted to the positive side.

An electrolyte has to be added to solution so electrons can flow in the water. The reaction is represented as:

$$2H_2O \rightarrow 2H_2 + O_2$$

+1 -1   0   0
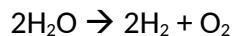
Hydrogen is reduced and oxygen is oxidised so the battery is positioned in a way so that oxygen is connected to the positive side of battery and hydrogen to negative side to battery so that H_2 and O_2 is produced.

The amount of hydrogen produced will be twice the amount of oxygen produced.

The negative E˚cell value tells us that this is not a spontaneous reaction and that this is the amount of voltage needed for the reaction to occur.
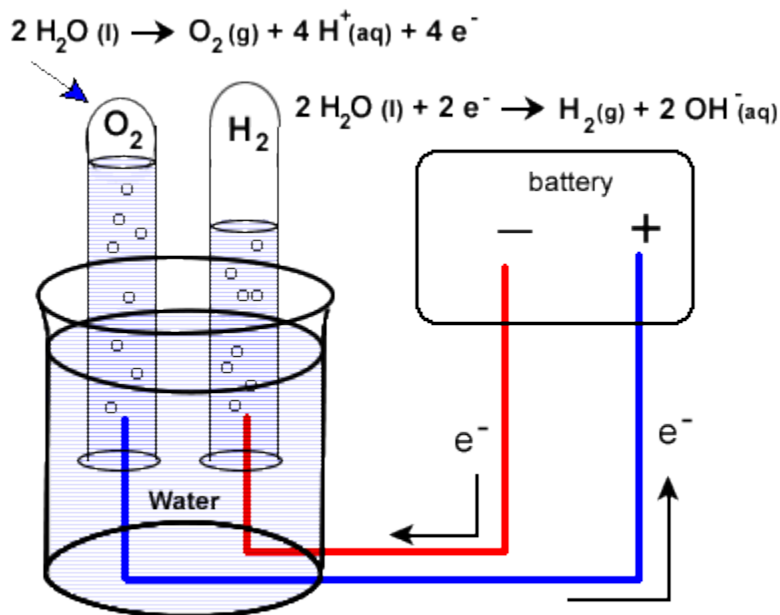
Molten salt is the liquid form of ionic compounds and the temperature for molten form to be reached is usually over 700˚C. The reason for molten salts is that there is competing reactions occurring. It is used industrially to extract elements from salts. Such as NaCl or $MgCl_2$. One of the elements will be formed into gas and the other into liquid or solid.

- **The electric potential difference of a cell under standard conditions can be calculated from standard electrode potentials; these values can be used to compare the voltage generated by cells constructed from different materials.**

The way the electric potential difference of a cell is calculated is by the following procedure:

1. Write down the reactions from SRP list as they are

   Eg. $F_2 + 2e^- \rightarrow 2F^-$ $E° = +2.87$

       $Pb^{2+} + 2e^- \rightarrow Pb$ $E°=-0.13$
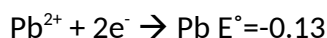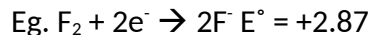
2. Flip the reaction that is lower on the standard reduction potential list as an oxidation reaction.

   $Pb \rightarrow Pb^{2+} + 2e^-$ $E°= +0.13$
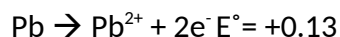
3. Add the reactions together including the E° value making sure to cancel out the electrons.

   $F_2 + Pb \rightarrow Pb^{2+} + 2F^-$ E°cell = +3 volts

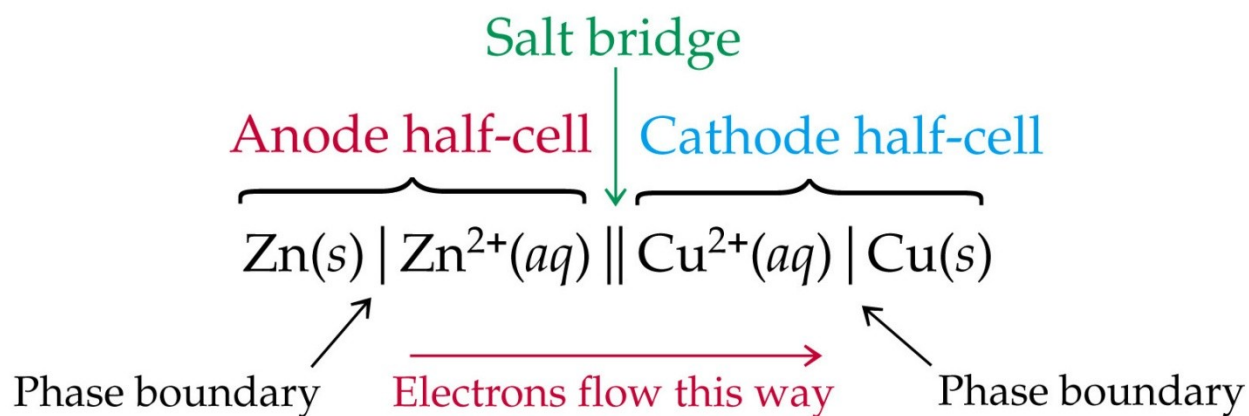   The following reaction would produce 3 volts!

   The E° value is dependent on 25°C temperature and 1 mol L^{-1} concentration and applies only to aqueous solutions.

   MAKE SURE TO BALANCE OVERALL EQUATIONS.

- **Cell diagrams can be used to represent electrochemical cells**

- **Fuel cells are electrochemical cells that convert chemical potential energy into electrical energy.**

  HYDROGEN FUEL CELLS

H_2 is introduced into the fuel cell where it will lose two electrons due to the platinum catalyst attached to the anode. This makes $2H^+$ and $2e^-$. The hydrogen ions will travel through the electrolyte to the cathode where they will gain 2 electrons and become H_2. Since the $2e^-$ that they initially lost go up and travel through an external circuit to reach the cathode and become attached to the $2H^+$ to form H_2. The H_2 molecules will attach to the O_2 molecules that are absorbed into the fuel cell from the air to produce water. The water must be removed otherwise the fuel cell becomes diluted and not as effective. The electrodes in fuel cells are porous and they have catalysts such as platinum, rhodium and nickel that allow the gaseous molecules to break down at a higher rate. Nanoparticles are also used to increase rate of reaction with gaseous molecules

Anode reaction: $H_2 \rightarrow 2H^+ + 2e^-$
Cathode reaction: $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$
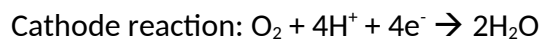
ALKALINE FUEL CELLS

H_2 is introduced into the fuel cell where it will react with OH^- to form H_2O and 2 electrons. These 2 electrons travel through the external circuit all the way to the positive electrode (cathode) where oxygen is reduced. This H_2O will then react with the incoming oxygen in the fuel cell and the 2 electrons to produce $4 OH^-$. The electrodes at porous carbon with catalyst Platinum/palladium coated on them. The electrolytes are Na^+, H_2O and OH^-.

Anode reaction: $H_2 + 2OH^- \rightarrow 2H_2O + 2e^-$
Cathode reaction: $2H_2O + 2e^- + O_2 \rightarrow 4OH^- + 2e^-$
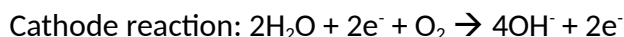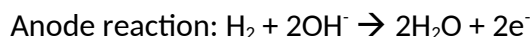
Advantages/Disadvantages and common uses of fuel cells.

Common uses are power for transportation, portable power generation and stationary power generation.

Advantages are that there is no CO_2 emission and it is very efficient.
Disadvantages are that they don't work at very low temperatures, few filling stations cell H_2 and they don't store energy.

To increase the voltage output of fuel cells you stack them together.

Scientists are researching and using nanoparticles to increase the surface area of catalysts. They are also researching materials they can use as catalysts other than platinum since it is cost heavy. Mixed metal nanoparticles using a nanostructure support of carbon is being investigated.

- **Dry cells convert chemical potential energy into electrical energy.**

Dry cells are batteries. The anode is a graphite (form of carbon) rod. The zinc casing or container is the cathode. The NH_4Cl, $ZnCl_2$ and MnO_2 is the thick jelly like paste that is the electrolyte. MnO_2 and Carbon surround the graphite rod.

$$\text{Anode reaction: } Zn \rightarrow Zn^{+2} + 2e^-$$
$$\text{Cathode reaction: } 2MnO_3 + 2e^- + 2NH_4Cl \rightarrow Mn_2O_3 + 2NH_3 + H_2O + 2Cl^-$$
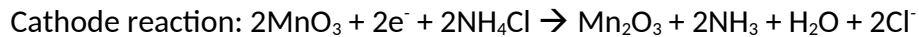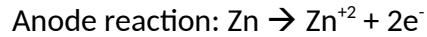
Common uses are batteries for wrist watches, calculators and hearing aids.

Advantages: stores energy, light in weight, is very small portable and is inexpensive
Disadvantages: Low charge capacity, doesn't work well in low temperatures and is unrechargable.

- **Lead acid accumulator converts chemical potential energy into electrical energy.**

This cell consists of a Pb negative terminal (anode) and PbO_2 positive electrode (cathode) and a dilute H_2SO_4 solution. The reactions occur during **discharge**, when battery is being used to start engine or using the radio when engine is not running.

This is the negative terminal (anode) reaction $Pb + HSO_4^- \rightarrow PbSO_4 + H^+ + 2e$
this is the positive terminal (cathode) reaction $PbO2 + HSO_4^- + 3H^+ + 2e^- \rightarrow PbSO_4 + 2H_2O$

The car alternator converts the mechanical energy from the vehicles pistons and crankshaft into electrical energy which is then supplied to the battery and also used to operate the vehicles electrical accessories. During the battery recharging state the above reaction are **reversed**.

Advantages/Disadvantages and common uses of lead-acid batteries.

Common uses are in automobile starting, lighting and ignition batteries. They are used in large power supplies for telephone and computer centres.

Advantages: low cost, reliable, can deliver high currents, many supplies worldwide

Disadvantages: very heavy and bulky, danger of overheating during charging, typical life cycle of 300 to 500 cycles, not suitable for fast charging.

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ORGANIC CHEMISTRY AND CHEMICAL SYNTHESIS

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- **Organic molecules have a hydrocarbon skeleton and can contain functional groups, including alkenes, alcohols, aldehydes, ketones, carboxylic acids, esters, amines and amides; functional groups are groups of atoms or bond within molecules which are responsible for the molecules characteristic chemical properties.**

Each functional group provides organic molecules with characteristic chemical properties and they each undergo specific reactions.

Alkenes (-ene):

Alkenes are when there is a double bond in the hydrocarbon molecules

Alcohols (-ol):
Alcohols are when a hydroxyl group (OH) attaches to the carbon.

Naming alcohols:
Number the amount of carbons on the longest chain containing OH group and write which carbon it's located at before the parent name ensuring it is the lowest possible number

Properties:
Alcohols have strong intermolecular bonds since the O has high electro negativity which causes the C-O and O-H bonds to be very polar. This allows hydrogen bonding to occur to other molecules. Hydrogen bonds are very strong so alcohols have high melting and boiling points. Smaller alcohols are more soluble since the OH group can form hydrogen bonds with water. As the compounds get larger, the hydrophobic non-polar hydrocarbon chain becomes larger than the hydrophilic polar OH group so the molecule becomes less soluble.

A primary alcohol has one carbon attached to the carbon that has the OH group, a secondary alcohol has 2 and tertiary has 3. The strength of the hydrogen bonding with other molecules depends on how available the OH group is for bonding with other molecules. The more available (primary and secondary) the more likely it will bond with other molecules.

A primary alcohol has the highest melting and boiling points since the OH group is most available for hydrogen bonding with other molecules.

Reactions:

Alcohols undergo combustion, dehydration, reacting with sodium and oxidation

Combustion: Alcohol burns readily in air (O_2) to form CO_2 and H_2O

Dehydration: Alcohol is heated with concentrated acid (sulphuric or phosphoric) to lose water and form alkene. The double bond takes the place starting on the carbon with the original alcohol.

React with sodium: Alcohol reacts with sodium to form Alkoxide anion (RO^-Na^+) and H_2.

Oxidation: Alcohol oxidises with acidified permanganate or dichromate. Primary alcohols are oxidised to form aldehydes which are then oxidised to form carboxylic acid. Secondary alcohols form ketones and tertiary alcohols cannot oxidise unless in extreme conditions since the C-C covalent bond is hard to break.

Aldehydes (-al):
Aldehydes are when hydrogen attaches to the carbon of a ketone group.

Properties:
Oxygen is more electronegative than carbon so The C=O and are very polar so hydrogen bonds can be formed with other molecules. This allows high melting and boiling points. It is always found at the end of the carbon chain. The boiling/melting points are still lower than alcohols with similar mass.

Reactions:
Aldehydes are formed when primary alcohols are oxidised. Aldehydes can be further oxidised to form carboxylic acid.

Ketones (-one):
Ketones are when a carbon is double bonded to oxygen. The C=O bond is polar so the molecules is able to form hydrogen bonds with other same molecules so it has high melting and boiling points.

Naming ketones:
 Number the amount of carbons on the longest chain containing C=O group and write which carbon it's located at before the parent name ensuring it is the lowest possible number.

Properties:
The C=O bond is highly polar and can form hydrogen bonds with other molecules making high melting and boiling points but it is still lower points to a alcohol with a similar mass.

Reactions:
Ketones are formed when secondary alcohols are oxidised. Ketones cannot be oxidised.

Carboxylic acid (-oic):
Carboxylic acids are when a hydroxyl group (OH) attaches to a carbon of a ketone group.

Properties:
The carboxylic acid group is monoprotic since the O-H bond is very polar so hydrogen bonds can be formed with other molecules. This allows high melting and boiling points. Carboxylic acids act just like regular acids. It is always found at the end of the carbon chain. The electrons spend more time with the electronegative oxygen in the O-H bond leaving the single hydrogen more easily drawn away by a base to leave its single electron behind.

The strength of the carboxylic acid can be greatly increased by adding a halogen substituent to the hydrocarbon chain. Dichloroethanoic acid is almost 3000 times stronger acid than mere Ethanoic acid.

Reactions:
Carboxylic acids react just like any other acids. They are substitution reactions.

Esterfication is when carboxylic acid and an alcohol produce an ester. This is a slow process so it is usually heated in the presence of an acid catalyst to speed the reaction.

Esters (-oate):
Esters are responsible for fragrance and flavours of many fruit and flowers. Esters are when oxygen is bonded to a ketone group. The C=O bond is polar so the molecules is able to form hydrogen bonds with other same molecules so it has high melting and boiling points. You can add an Ester with H_2O to get the original carboxyl acid and alcohol; this is called reverse esterfication

Naming Esters:
 The first part of the name is the alkyl group that's bonded to the single bonded oxygen and then the second part is the main chain with 'e' replaced with '–oate' at the end.

Properties:
The C-O and C=O bond make esters polar substances since oxygen is more electronegative. Esters are liquid at room temperature since there boiling and melting points are really low compare to carboxylic acis of similar mass. This is because there main intermolecular forces are dipole-dipole.

Esters are not very soluble in water because they don't have hydrogen bonds and they have long hydrophobic alkyl groups. They are soluble in organic solvents.

Reactions:
Esterfication is reversible when reacting with water both in **acidic** and **alkaline conditions**. The reaction with water replaces the single bonded oxygen with OH group and the alkyl group with the now single O gets a H

Esterfication in alkaline conditions forming a carboxylic anion and an alcohol is called saponification. This reaction is used to make soap.

Amines (-amine):
Amines are derivatives of ammonia and it is when NH_2 loses when or all of its hydrogen's to bond with carbon. Primary and secondary amides have an N-H group so it can form strong hydrogen bonds which allow high melting and boiling points. It is always found at the end of the carbon chain.

Naming amines:
Identify the names of the alkyl groups attached to the N in alphabetical order. Add di- or tri- if two or three of the alkyl groups are the same. Replace the main chains 'e' with '-amine'

Properties:
Nitrogen is highly electronegative so the –N-H bond is very polar. This allows hydrogen bonding to occur in primary and secondary amines. The hydrogen bonding formed by amines are weaker than hydrogen bonding formed by alcohols or carboxylic acids. Tertiary amines cannot form hydrogen bonds because they lack N-H bonds so they form considerably weaker bonds. Amines have ammonia-like smell and they are weak bases.

Reactions:
Amines are bases which undergo addition neutralization reactions with inorganic acids. Amines undergo condensation reactions with organic acids forming water.

Amides (-amide):

Amides are derivatives of carboxylic acid and they form when the OH group is replaced by nitrogen.

Naming amides: The main chain has the '-oic' replaced with '-amide'. The substituent alkyl groups are always attached to the nitrogen and are denoted by 'N-alkyl'. For example; N-ethyl or N-methyl or N-propyl

Properties:
Nitrogen and oxygen are highly electronegative so the –N-H and -C=O bond are very polar. This allows hydrogen bonding to occur between the Hydrogen of one molecules and the Oxygen of another. The hydrogen bonding formed by amides are weaker than hydrogen bonding formed by alcohols or carboxylic acids. Tertiary amines cannot form hydrogen bonds because they lack N-H bonds so they form considerably weaker bonds.

Reactions:
Primary amides react with water in acidic conditions to form a carboxylic acid and ammonium salt
Primary acis react with water in basic conditions to form an ester and ammonia

- **Isomers are compounds with the same molecular formulae but different structures; different types of isomerism include chain and position structural isomerisms and cis-tran isomerism (geometric isomerism)**

Isomers are compounds with the same molecular formula but different structures.

Chain isomerism (skeletal isomerism):
Chain isomerism is when components of the chain are moved to create different length parent chain

Position Isomerism:
When the position of the attached group is moved around the chain.

Cis-trans isomerism (geometric isomerism):

-Cis (same) isomerism
-Trans (opposite) Isomerism.
Carbon atoms on either side of the double bond can't rotate around the bond. Geometric isomerism is possible whenever each carbon on either side has at least one branch with a

substituent group. Whether a compound is cis or trans makes a great difference between the physical properties of the compound.

- **IUPAC nomenclature is used to name organic species, including those with a parent chain up to 8 carbon atoms.**

1-meth 2-eth 2-prop 4-but 5-pent 6-hex 7-hept 8-oct

1. The amount of carbons in the longest chain will be the main chain (parent chain)
2. Find out whether the molecules have single bonds, double bonds or triple bonds.
3. Start numbering the carbons starting with the substituent groups and double bonds being numbered the lowest.
4. Number out the carbons that have the substituent groups in alphabetical order.
5. The numbers represent which carbon has the substituent group such as alkyl or functional groups. The numbers are separated from letters by '-'.