

ZNOTES.ORG

UPDATED TO 2022 SYLLABUS



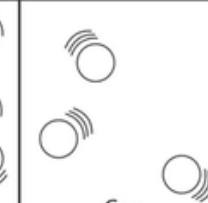
CAIE IGCSE

CHEMISTRY (0620)

SUMMARIZED NOTES ON THE THEORY SYLLABUS

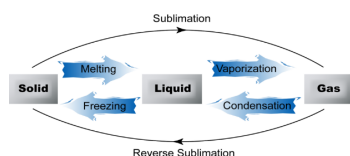
1. The Particulate Nature of Matter

1.1. Kinetic Particle Theory

| | | |
|--|---|---|
|  |  |  |
| Solid | Liquid | Gas |
| Solid | Liquid | Gas |
| Strong intermolecular forces | Weaker intermolecular forces than solids | Almost no intermolecular forces |
| Fixed lattice arrangement | No fixed arrangement; particles can move and slide over each other | Particles far apart and move quickly |
| Particles vibrate in fixed position; fixed shape and volume | Particles slide; fixed volume | Random movement; no fixed shape or volume |

- When a solid is heated, the particles gain sufficient energy to overcome the strong intermolecular forces. The particles eventually can slide over each other in a more random motion- solid expands until the structure is broken at m.p.
- When a liquid is heated to its b.p, the particles overcome the relatively weaker intermolecular force to escape the liquids surface and move around in continuous rapid motion – the liquid has boiled
- In the vapor, the particles move in rapid random motion. This movement is due to the collision of vapor particles with air particles.
- When gaseous particles are heated in a closed environment, the increase in kinetic energy causes increased collisions with other particles as well as the walls of the container- pressure increases.

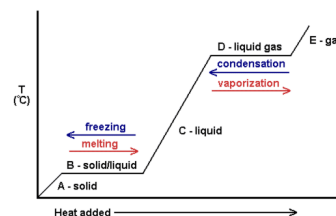
1.2. States of Matter



| Process | Change | Heat Energy | Exo/endothermic |
|------------|--------|-------------|-----------------|
| Melting | S -> L | Gained | Endothermic |
| Boiling | L -> G | Gained | Endothermic |
| Condensing | G -> L | Lost | Exothermic |

| Process | Change | Heat Energy | Exo/endothermic |
|---------------------|--------|-------------|-----------------|
| Freezing | L -> S | Lost | Exothermic |
| Sublimation | S -> G | Gained | Endothermic |
| Reverse sublimation | G -> S | Lost | Exothermic |

1.3. Heating Curve



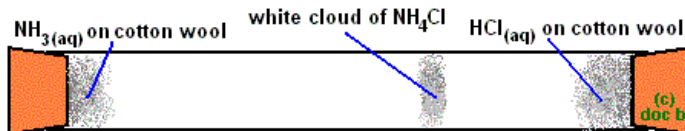
1.4. Brownian motion and Diffusion

1. Brownian motion:

- It is the random movement of particles in a liquid or a gas caused due to collision with smaller, invisible particles
- Evidence:
In liquid- Pollen grains in water
In gases- Smoke in air

1. Diffusion

- It is the spreading of one substance (liquid or gas) through another from a region of high concentration to a region of low concentration due to the continuous random motion of particles.
- Evidence for diffusion:
In liquids: potassium manganate (VII) in a beaker of water
In gases: a gas jar of air and a gas jar of bromine connected
- Factors that affect the rate of diffusion:
Temperature increases → rate of diffusion increases
Lower relative molecular mass → rate of diffusion is higher






2. Experimental Techniques

2.1. Measurement

| Variable | Unit | Apparatus |
|-------------|---------|---|
| Time | min/sec | Stopwatch |
| Temperature | °C | Thermometer [liquid in glass, thermistor or thermocouple] |
| Mass | grams | Balance |


Measuring Volume in liquids:

Approximate measure to most accurate measure

| Name | Measuring Cylinder | Pipettes [fixed volumes] | Burettes [variable volume] |
|-------|---|---|---|
| Image |  |  |  |

Measuring Volume in gases:

A calibrated gas syringe is used to gradually measure the volume of gases



2.2. Criteria of Purity

Purity in substances

- Assessing purity

| | |
|-------------------|-----------------------------------|
| Pure substances | Have a definite, sharp m.p./b.p. |
| Impure substances | Have a lower m.p and a higher b.p |

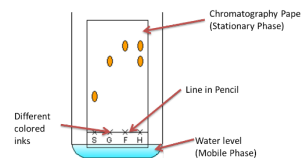
This assessment of substance purity is important, especially in food consumption, as its intake can be dangerous.

Paper chromatography:

Method used to separate substances in a solvent with different solubilities

- Drop substance onto the start line (pencil) drawn on chromatography paper
- Paper is placed in beaker with solvent; the paper must touch the surface of the solvent while the line must be above the liquid
- Solvent travels up the paper by capillary action
- Different solubilities lead to different travel rates [high solubility-> high travel rate]

- Stationary phase is material on which separation takes place
- Mobile phase consists of the mixture you want to separate, dissolved in a solvent.



- Interpreting simple chromatograms: Chromatograms are the visual outputs on the chromatography paper
 - Number of rings/dots = number of substances
 - If two dots travel the same distance up the paper they are the same substance.
- Retention Value: Used to identify a substance, calculated by the formula:

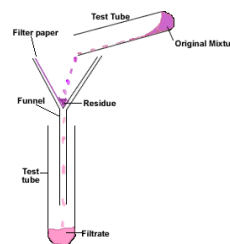
$$R_f \text{ Value} = \frac{\text{Distance moved by solute}}{\text{Distance moved by solvent}}$$

- Locating Agents Used to make colorless chromatograms visible
 - Dry paper in oven
 - Spray it with locating agent
 - Heat it for 10 minutes in oven

2.3. Filtration

Used to separate a solid from a liquid

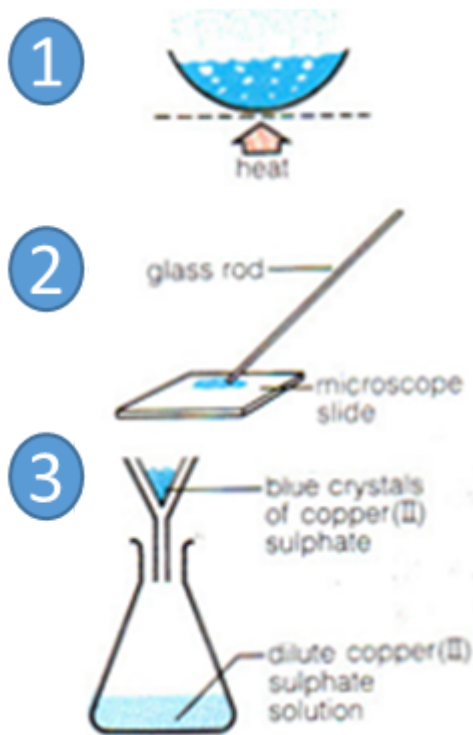
- Mixture goes through a funnel with filter paper, into a flask.
- Insoluble residue remains in the funnel
- Filtrate goes through and collects in flask



2.4. Crystallization

Used to separate dissolved solid from solution

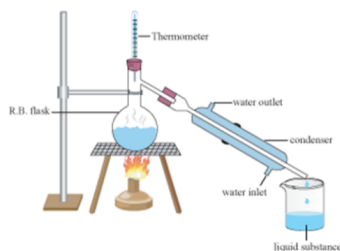
- Solution is heated to increase concentration (solvent evaporates)
- A drop of solution is placed on a slide to check for crystal formation
- Solution is left to cool and crystallise.
- Crystals are filtered from solution; washed with distilled water



2.5. Simple Distillation

Used to separate a solvent from a solution

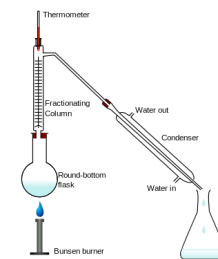
- Impure liquid is heated in a round bottom flask
- When it boils, the steam rises into the attached condenser
- Condenser cools the steams to a pure liquid and it drops into the beaker



2.6. Fractional Distillation

Used to separate miscible liquids

- Mixture is heated
- Substances, due to their different boiling points, rise in different fractions
- A mixture of gases condense on the beads in the fractional column.
- The beads are heated to the boiling point of the lowest substance, so that substance being removed cannot condense on the beads.
- The other substances continue to condense and will drip back into the flask.
- The beaker can be changed after every fraction



2.7. Separating Mixture of Two Solids

- Can be done by dissolving one in an appropriate solvent
- Then filter one and extract other from solution by evaporation
- If one solid is magnetic, can use a magnet e.g. sand and iron fillings

| Solvent | It dissolves... |
|--------------|--|
| Water | Some salts, sugar |
| White spirit | Gloss paint |
| Propanone | Grease, nail polish |
| Ethanol | Glues, printing inks, scented substances |

3. Atoms, Elements and Compounds

3.1. Atomic Structure and the Periodic Table

| Particle | Relative charge | Mass (atomic mass) |
|----------|-----------------|--------------------|
| Proton | +1 | 1 |
| Neutron | 0 | 1 |
| Electron | -1 | $\frac{1}{1837}$ |

- **Proton number:** number of protons in an atom [atomic number]
- **Nucleon number:** total number of protons and neutrons in the nucleus of an atom [mass number]

Electronic Configuration

- Electrons are arranged in electron shells.
- Electron shell structure: 2, 8, 18.
- Atoms want to have full outer shells (full set of valency electrons), this is why they react.
- Noble gases have full outer shells so they have no need to react.

Structure of the Periodic Table

- The number of protons in each element increases by 1 across each row

- Period number is the number of occupied shells in an element
- Group number is the number of electrons in the outermost shell
- **Isotopes:** atoms of the same element which have the same protons number, but a different nucleon number. They have the same chemical properties due to same number of outermost shell electrons.
 - E.g. Carbon 12 and Carbon 14.
 - Two types: Non-radioactive isotopes and radioactive-isotopes (unstable atoms that break down and produce radiation)
 - Medical use: cancer treatment (radiotherapy) – rays kill cancer cells using cobalt-60
 - Industrial use: to check for leaks – radioisotopes (tracers) added to oil/gas. At leaks radiation is detected using a Geiger counter.

3.2. Bonding: the Structure of Matter

1. **Element:** Pure substance consisting of one type of atom
2. **Mixture:** two or more elements mixed together but not chemically combined
3. **Compound:** substance in which two or more different elements are chemically combined
4. **Alloy:** Mixture of two or more elements in which at least one is a metal, eg. brass (copper and zinc)

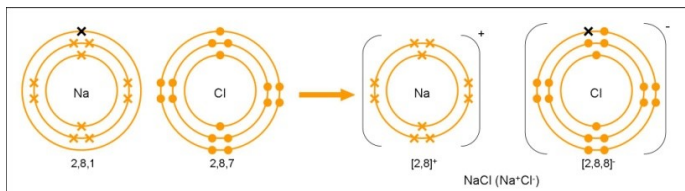
| Metals | Non-metals |
|---------------------------------------|---|
| Good conductors of heat & electricity | Poor conductors of heat & electricity (except graphite) |
| High m.p. and b.p. | Lower m.p. and b.p. than metals |
| High density | Low density |
| Forms basic oxides | Forms acidic oxides |
| Forms cations in reactions | Forms anions in reactions |
| Malleable and ductile | Not malleable or ductile |

3.3. Ions and Ionic Bonds

Ionic bonding: Electrostatic force of attraction between a lattice of alternating positive and negative ions

- Chemical bonds are formed by transfer of electrons from one atom to another
- Metals lose electrons to form cations; non-metals gain electrons to form anions
- Positive cations & negative anions attract to each other
- Strong electrostatic force of attraction between positive cations and negative anions is called ionic bonding

Ionic bonding between Group I metal and Group VII non-metal



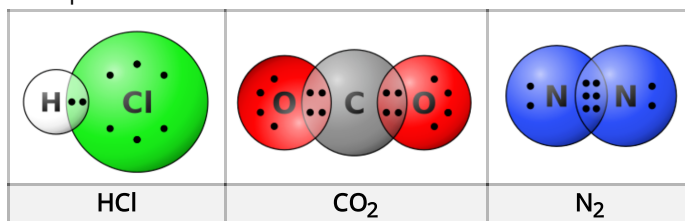
| Property | Reason |
|---|----------------------------|
| Form giant lattice | Cations and anions attract |
| High m.p. and b.p. | Strong bonds between ions |
| Don't conduct electricity when solid | Ions can't move |
| Conduct electricity when molten/aqueous | Ions can move |
| Usually soluble in water | Not required |

3.4. Molecules and Covalent Bonds

Covalent bonding: When atoms share electrons to obtain a full outer shell electron configuration; only between non-metals.

| Single Bond | Double Bond | Triple Bond |
|------------------------------|------------------------------|------------------------------|
| | | |
| 2e shared (1 from each atom) | 4e shared (2 from each atom) | 6e shared (3 from each atom) |

Examples:

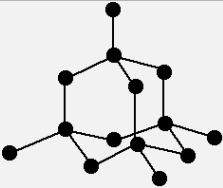
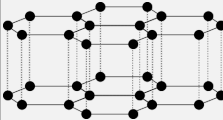
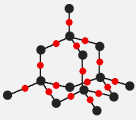


| Covalent bonding | Ionic bonding |
|----------------------------|----------------------------|
| Mostly volatile | Mostly non-volatile |
| Insoluble in water | Soluble in water |
| Poor electrical conductors | Good electrical conductors |

Covalent bonds, due to the sharing of electrons between atoms, have weaker attractive forces than ionic bonds. Thus they have lower melting and boiling points.

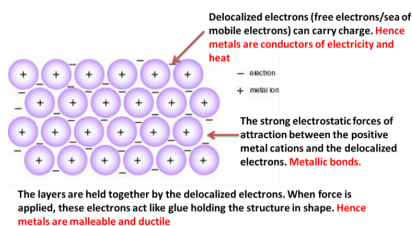
3.5. Macromolecules

| Diamond | Graphite | Silicon Dioxide |
|---------|----------|-----------------|
|---------|----------|-----------------|

| Diamond | Graphite | Silicon Dioxide |
|--|---|--|
|  |  |  |
| 1 carbon atom bonded to 4 carbon atoms [tetrahedral structure] | 1 carbon atom bonded to 3 carbon atoms [hexagonal layers] | Each silicon is bonded to 4 oxygen atoms, and each oxygen is bonded to 2 silicon atoms [tetrahedral structure] |
| High m.p. and b.p | High m.p. and b.p | High m.p. and b.p |
| no free electrons | Conducts electricity (free electrons) | no free electrons |
| Used for cutting as it is strongest known substance | Used in pencil lead and as a lubricant | Used in production of glass |

3.6. Metallic Bonding

Metallic bonding: An electrostatic force of attraction between a lattice of positive metal ions and a sea of mobile electrons



4. # Stoichiometry

- Valencies of each elemental group

| Group | Valency |
|-------|---------|
| I | 1 |
| II | 2 |
| III | 3 |
| IV | +/- 4 |
| V | -3 |
| VI | -2 |
| VII | -1 |
| VIII | 0 |

- Valencies of common ions

| Name | Formula | Valency |
|-------------|------------------------------|---------|
| Iron (II) | Fe ²⁺ | +2 |
| Copper (II) | Cu ²⁺ | +2 |
| Ammonium | NH ₄ ⁺ | +1 |

| Name | Formula | Valency |
|-----------|--------------------------------|---------|
| Nitrate | NO ₃ ⁻ | -1 |
| Hydroxide | OH ⁻ | -1 |
| Carbonate | CO ₃ ²⁻ | -2 |
| Sulphate | SO ₄ ²⁻ | -2 |
| Silicate | SiO ₃ ²⁻ | -2 |
| Phosphate | PO ₄ ³⁻ | -3 |

4.2. Word equations

- Balancing equations: A chemical equation is balanced when there are equal number of atoms and charges on both sides of the equation
- State symbols:
 - (s) = solid
 - (l) = liquid
 - (g) = gas
 - (aq) = aqueous solution
- Names of compounds
 - Compound ending with **-ide** only contain two different elements
 - Compound ending with **-ate** contain oxygen

4.3. Masses

- Relative atomic mass (A_r):** mass of one atom of an element relative to one twelfth of the mass of one atom of Carbon-12
- Relative molecular mass (M_r):** sum of relative atomic masses of all the atoms in one molecule of the compound

4.4. The Mole Concept

- A mole of a substance is the amount that contains the same number of units as the number of carbon atoms in 12 grams of carbon-12
- A mole is the A_r or M_r expressed in grams e.g. 1 mole of Carbon-12 is equal to 12 grams.
- It is equal to 6.02 × 10²³ particles, this number is called Avogadro's constant.

4.5. Number of Moles

$$\text{Number of Moles} = \frac{\text{mass}}{\text{molar mass}}$$

4.6. Moles in Gases

$$\text{Volume} = \text{No. of Moles} \times 24\text{dm}^3 \text{ at r.t.p (room temperature)}$$

4.7. Concentration

$$\text{Concentration} = \frac{\text{no. of moles}}{\text{volume}}$$

- Moles per dm^3
 - $1 \text{ mol}/\text{dm}^3 = 1 \text{ M}$
- Grams per dm^3 , g/dm^3

4.8. Molecular Formulae

- It shows the actual number of atoms in one molecule of a substance.

4.9. Empirical Formulae

- This is the simplest ratio of the atoms in a compound
- For example:
 - Molecular formula of ethane = C_2H_6
 - Empirical formula of ethane = CH_3
- To find out the empirical formula you:
 - Make the percent ratio into the simplest whole number ratio (NOTE: if given %s, use them as grams)
 - Divide the coefficients of each element symbol by the lowest coefficient

4.10. Percentages

- Percentage purity = $\frac{\text{mass of product (pure)}}{\text{mass of compound (impure)}} \times 100$
- Percentage yield = $\frac{\text{actual mass obtained}}{\text{calculated mass}} \times 100$

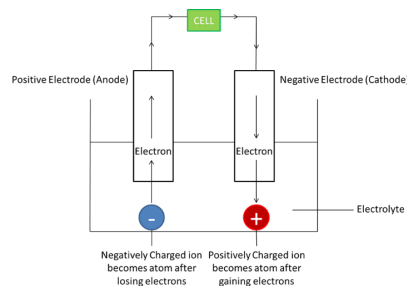
5. Electricity and Chemistry

Electrolysis:

- It is the breakdown of an electrolyte- ionic compound, molten or aqueous solution- by passing an electric current
- This is possible due to the presence of mobile electrons

| Components of Electrolysis | Definition |
|----------------------------|---|
| Electrodes | Metal or graphite rods that aid the flow of electricity in and out of the electrolyte 1. Anode: Positive electrode 2. Cathode: Negative Electrode |
| Anion | Negatively charged ion that moves to anode |
| Cation | Positively charged ion that moves to cathode |

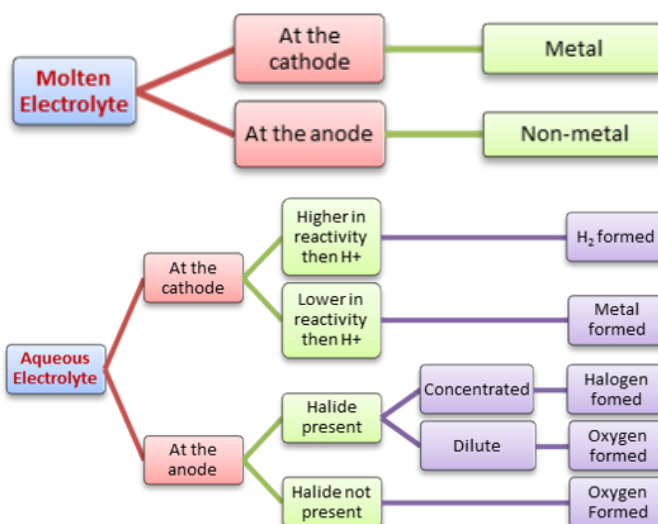
- Note: **Reactive** electrodes take part in the reaction while **inert** electrodes do not



5.2. Principle

- Reduction** of positive cations happens at the cathode
 - Oxidation** of negative anions happens at the anode
- For example:

- At the anode: $2\text{Cl}^- \rightarrow \text{Cl}_2 + 2\text{e}^-$
- At the cathode: $2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2$



5.3. Examples of Electrolysis

| Electrolyte | At cathode | At anode |
|--------------------------------------|------------|----------|
| Molten lead (II) bromide | Lead | Bromine |
| Concentrated hydrochloric acid | Hydrogen | Chlorine |
| Concentrated aqueous sodium chloride | Hydrogen | Chlorine |
| Dilute sulfuric acid | Hydrogen | Oxygen |

5.4. Voltaic Cell

- Used to produce electrical energy from chemical energy
- The electrodes are made from metals with different reactivity
 - Negative electrode: More reactive metal, ex. Zinc
 - Positive electrode: Less reactive metal, ex. Iron
- Electrolyte is a strong acid, ex. sulfuric acid
- The negative electrode loses electrons; these flow through the simple circuit to the positive electrode to produce voltage. This is measured on the attached voltmeter.

Note: The greater the difference in reactivity, the greater voltage produced

5.5. Electroplating

The process of coating the surface of a metal (more reactive) with another metal (less reactive) using electrolysis

- Components:
 - Anode: pure metal being used to electroplate the object
 - Cathode: object being electroplated
 - Electrolyte: aqueous solution of the soluble salt of pure metal (same as anode)
- Used to:
 - Prevent corrosion
 - Enhance appearance

| Conductors | Insulators |
|---|---|
| Allow the passage of electrical charge | Resist the passage of electrical charge |
| Aluminum [low density, non-corrosive, cheaper than copper]: used in electricity cables with a steel core and plane bodies | Plastics for casing in wires |
| Copper [malleable]: used in electrical wires | Ceramics used to support cables in electricity pylons |

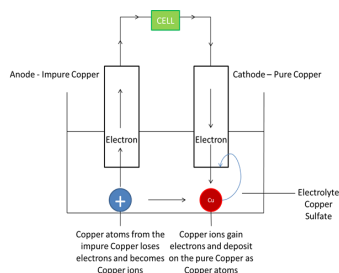
5.6. Refining Metals

- Cathode: thin strip of pure metal
- Anode: impure metal
- Electrolyte: Aqueous Salt Solution of metal

Example:

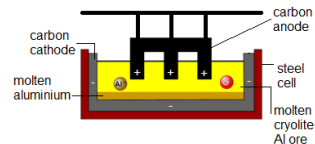
- The refining of copper:** Impure copper as the anode and pure copper as the cathode; the aqueous copper (II) sulfate helps the copper ions move from the anode to the cathode. Here the ions gain electrons and become copper atoms, making the pure copper cathode thicker.

- Reaction at Anode: $\text{Cu} - 2\text{e}^- \rightarrow \text{Cu}^{2+}$ (mass decreases)
- Reaction at Cathode: $\text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu}$ (mass increases)



5.7. Extraction of Aluminum

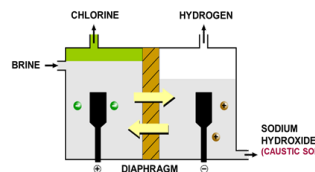
- The main ore of aluminum is bauxite – high m.p.
- Aluminum (III) oxide (alumina) is dissolved in molten cryolite (Na_3AlF_6) – this mixture has a lower m.p. (industrially preferred)



- During electrolysis aluminum ($\text{Al}^{3+} + 3\text{e}^- \rightarrow \text{Al}$) is produced at the carbon cathode and oxygen ($2\text{O}^{2-} - 4\text{e}^- \rightarrow \text{O}_2$) at the carbon anode.
- Due to the high temp. the oxygen reacts with the carbon in the graphite anode to form CO_2 and so anode has to be periodically replaced

5.8. Electrolysis of Brine

- Brine is concentrated aqueous NaCl solution
- Ions present: Na^+ , H^+ , Cl^- and OH^-



| At the anode | At the cathode |
|----------------------------------|--|
| Made of titanium | Made of steel |
| Cl^- ions; Chlorine gas | Hydrogen cations reduced to H_2 molecules |

Unreacted ions (Na^+ , H^+ and OH^-) move through porous membrane due to difference in liquid pressure

Left Na^+ and OH^- which form aqueous sodium hydroxide

6. Chemical Energetics

6.1. Energetics of a Reaction

Chemical reactions involve a transfer of energy between the system (the chemical reaction) and its surroundings.

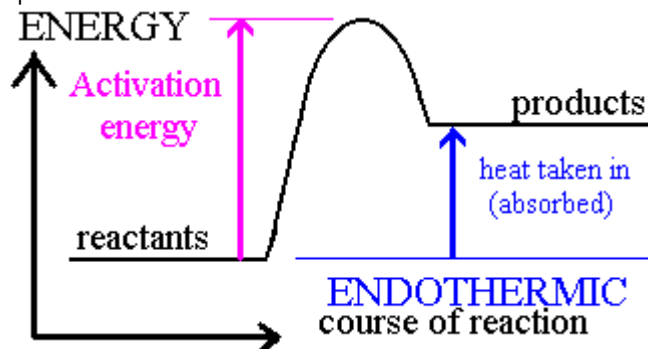
| Exothermic reaction | Endothermic reaction |
|---|---|
| Heat energy is released into the surroundings | Heat energy is absorbed from the surroundings |
| Bond making reactions | Bond breaking reactions |
| Surrounding temperature increases | Surrounding temperature decreases |

6.2. Energy Level Diagrams

- Energy level diagrams are a representation of chemical reactions that include the relative energies of the reactant and product.
- The energy change of a reaction is represented through the difference in height between the reactant and its product.
- Activation energy (E_a) is the minimum energy required for the reaction to take place

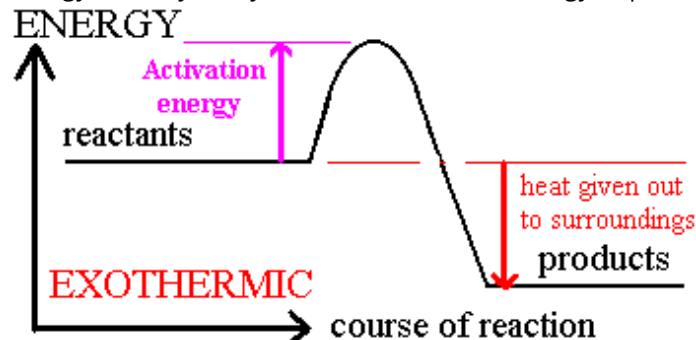
Endothermic energy level diagram:

Energy is gained by the system; higher activation energy required



Exothermic energy level diagram:

Energy is lost by the system; lower activation energy required



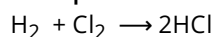
6.3. Bond Energy

- This is the amount of energy required or released when a bond is formed or broken respectively. The unit measure of this energy is kJ/mol.
- The energy change in a reaction is calculated using the following formula:

$$\Delta H = \text{Bond Breaking} - \text{Bond Forming}$$

- If overall heat energy value is negative, reaction is exothermic
- If overall heat energy value is positive, reaction is endothermic

Example



| Bond | Bond energy (kJ/mol) |
|---------|----------------------|
| H - H | 436 |
| Cl - Cl | 243 |

| Bond | Bond energy (kJ/mol) |
|--------|----------------------|
| H - Cl | 432 |

Bond breaking $\rightarrow 436 + 243 = 679$ kJ/mol

Bond forming $\rightarrow 2(432) = 864$ kJ/mol

Thus,

$\Delta H \rightarrow 676 - 864 = -185$ kJ/mol

The reaction is exothermic in nature

6.4. Production of Energy

- A fuel is a substance that can be used as a source of energy.
- Burning fuels (like oil) to form oxides is an exothermic reaction.
- The heat from burning fuels is used in power plants to create steam from water and turn turbines.
- A combustion process requires the presence of a fuel, oxygen and heat.
- A good fuel must:
 - Be cheap
 - Be available in large quantities
 - Be a liquid at room temperature
 - Have high efficiency (produce a large amount of energy)
 - Not produce polluting gases

6.5. Hydrogen

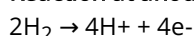
- Produced by reacting methane gas with steam
- Used in fuel cells and rockets

| Advantages | Disadvantages |
|-----------------------------|---|
| Releases a lot of energy | Difficult to transport as it is a gas at room temperature |
| Does not produce pollutants | Forms explosive mixture with air when stored under pressure |
| Renewable and abundant | Is expensive to produce (requires a lot of energy) |

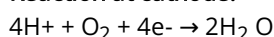
6.6. Fuel Cell

- In this electrochemical cell, fuel loses electrons at one porous electrode while oxygen gains electrons at the alternate porous electrode.
- The product is water: $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$

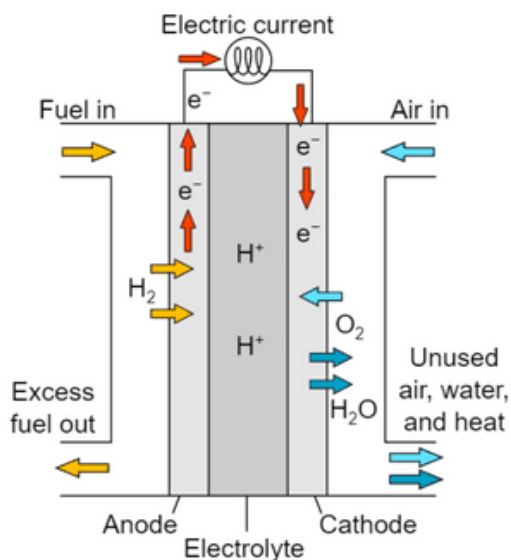
Reaction at anode:



Reaction at cathode:



The flow of the electrons, through the electric circuit, from the cathode to the anode generates a current. This cell is used to drive electric motors in the automotive industry.



6.7. Radioactive Isotopes

- Uranium-235 can be used in nuclear power stations to produce electricity
- The radioactive isotope is bombarded by neutrons resulting in a lot of heat being produced
- Small amount of radioactive fuel produces large amount of heat
- Advantages: lots of energy is from a small amount and no CO₂
- Disadvantage: radioactive waste produced and non-renewable

7. Chemical Reactions

| Physical change | Chemical change |
|--|---|
| Reaction is easily reversible | Reaction is harder to reverse |
| Product has no new chemical properties | Chemical product has different properties |
| Ex. dissolving solute in a solvent | Energy change [exothermic/endothermic] |

7.2. Rates of Reaction

Collision Theory

Successful collisions have enough activation energy at moment of impact to break pre-existing bonds and form new bonds

Rates of reaction

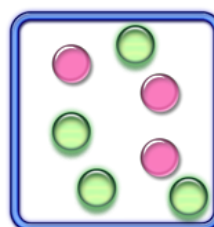
- The measure of the speed of the collision
- Calculated by concentration of reactant used up or product produced per unit time

- Unit = (mol/dm³)/s

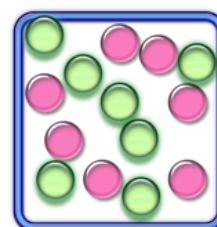
7.3. Concentration

Increasing concentration of reactants increases rate of reaction

- Higher concentration reactants contain more particles per unit volume; this increases successful collision rate leading to an increased rate of reaction.



Less particles, less frequent and successful collision

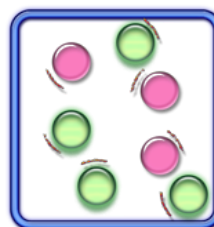


More particles, more frequent and successful collision

7.4. Temperature

Increasing temperature increases the rate of reaction

- Increased temperatures leads to increased average kinetic energy of particles. Particle movement produces energy greater than/equal to activation energy; increased successful collision rate leads to an increased rate of reaction.



Particles have less energy, less frequent and successful collision



Particles have high energy, more frequent and successful collision

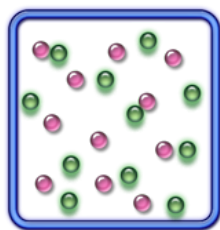
7.5. Particle Size

Decreasing the particle size increases the rate of reaction

- Decreasing particle size increases surface area; more reactant particles exposed to collide so the successful collision rate increases. This results in an increased rate of reaction



Less particles, less frequent and successful collision



More particles, more frequent and successful collision

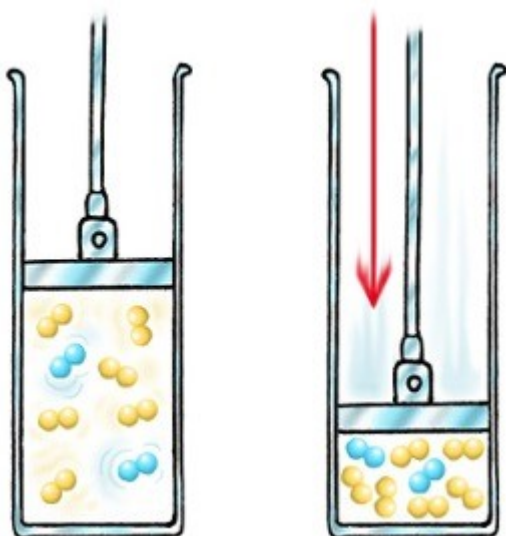
Explosive combustion

- Fine particles are combustible in air due to larger surface area
- The rate of reaction is high making them explosive
- Examples: methane gas in coal mines and flour milling

7.6. Pressure

Increasing the pressure in a gaseous system increases the rate of reaction

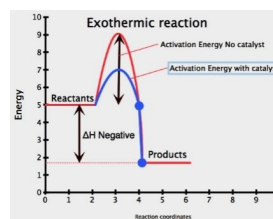
- The distance between particles is reduced under pressure
- There are more particles per unit volume; the successful collision rate increases, resulting in an increased rate of reaction.



7.7. Catalyst

- A catalyst is a substance (usually a transition metal) which speeds up a chemical reaction, but remains unchanged at the end
- Adding a catalyst increases the rate of reaction
- A catalyst allows the reaction to go by an alternative pathway with lower activation energy
- More particles will have an energy greater than or equal to the activation energy, therefore successful collision rate increases resulting in increased rate of reaction
- For gaseous reactants, if catalyst is solid metal, the catalyst provides a surface for reaction to take place on

- The larger the surface area of the metal catalyst, the larger the area for reaction to take place therefore higher rate of reaction



- Enzymes are biological catalysts which speed up reactions but remain chemically unchanged at the end
- Enzymes function best at optimum temperature and pH level otherwise they may denature and completely stop functioning

7.8. Measuring Rates of Reaction Experimentally

Interpreting graphs:

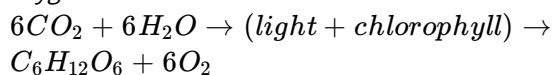
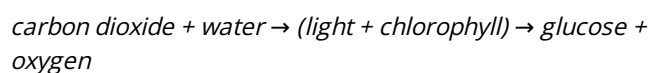
A graph with a steeper gradient at the beginning and reaching a horizontal gradient faster depicts a high rate of reaction.

| Gas Evolved | Mass Loss | Colour Change |
|---|---|---|
| <p>Volume of gas produced (cm³)</p> <p>Time (min)</p> | <p>Mass of system (g)</p> <p>Time (min)</p> | |
| <p>If a gas evolves, measure volume of gas produced per unit time using a gas syringe</p> | <p>If a gas evolves, measure loss in mass \n per unit time by placing on a balance then putting \n a cotton wool on top to allow gas to pass but not to enter</p> | <p>If a colour change , measure the time taken to turn cloudy</p> |

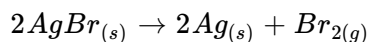
7.9. Photochemistry

A photochemical reaction is one where light causes a reaction to occur. The higher the light intensity the higher the rate of the reaction.

1. **Photosynthesis:** light provides energy for the reaction and chlorophyll is a dye that absorbs light.



2. **Silver salts in photographic film:** Silver bromide breaks down, where light strikes the film, so silver is reduced. Silver ions are reduced to silver.



7.10. Reversible Reactions

- In reversible reactions, the products can then react with each other or decompose to form the reactant molecules
- Example: $CuSO_4 \cdot 5H_2O$ (blue) \rightleftharpoons $CuSO_4$ (white) + H_2O
- (anhydrous by heating; hydrated form by adding water)

There are two types of equilibrium: static and dynamic.

- At dynamic equilibrium:
 - Rate of forward reaction = rate of reverse reaction
 - Concentrations of all reactants and products remain constant
 - System is closed, and on large scale everything is constant

7.11. Equilibrium

- Le Châtelier's Principle:** if conditions of an equilibrium are changed, the position of equilibrium moves to oppose change
- Temperature:** Temperature lowered; equilibrium moves in exothermic direction. Temperature raised; equilibrium moves in endothermic direction.
- Pressure:** Pressure raised; equilibrium moves to side with fewest gas molecules. Pressure lowered; equilibrium moves to side with most gas molecules.
- Concentration:** Decreasing reactant concentration or increasing product concentration; equilibrium moves to reactant side. Increasing reactant concentration or decreasing product concentration; equilibrium moves to product side.

7.12. Redox

- A reaction in which oxidation and reduction occur at the same time is a redox reaction.

| Oxidation | Reduction |
|-------------------|-------------------|
| Loss of electrons | Gain of electrons |
| Gain of oxygen | Loss of oxygen |
| Loss of hydrogen | Gain of hydrogen |

Note: Roman numerals next to an element's name are the oxidation state of the ion, eg. Iron (II) and Iron (III). The reaction product formula depends on this.

Reducing agents are oxidized and oxidizing agents are reduced

Identifying redox reactions

1. Oxidation state:

Oxidation state highlights electron movement in an reaction eg. $CuO + Mg \rightarrow MgO + Cu$

$Cu^{2+} + Mg \rightarrow Mg^{2+} + Cu$ [oxide is a spectator and is removed as it doesn't change its oxidation state]

Here copper (II) is reduced while magnesium is oxidized; the reaction is redox

2. Indicators

- Potassium manganate (VII) is an oxidising agent; when added to a reducing agent changes from purple to colourless
- Potassium iodide is a reducing agent; when added to an oxidising agent changes colorless to red-brown

8. Acids, Bases and Salts

8.1. Properties of Acids

An acid is a substance that produces hydrogen ions (H^+) when dissolved in water. Acids are proton donors.

Indicators

- Have pH between 1 (strong) and 6 (weak)
- Turns blue litmus red
- Turns methyl orange indicator red

Strong acids completely ionize in water producing lots of H^+ ions

Weak acids partially ionize in water producing few H^+ ions

Chemical properties

- Acid + metal \rightarrow salt + hydrogen gas
- Acid + base \rightarrow salt + water
- Acid + metal carbonate \rightarrow salt + carbon dioxide + water

8.2. Properties of Bases

Bases are substances which neutralize acids to form a salt and water only. They are proton acceptors (form OH^- ions) and are mainly water insoluble.

Indicators

- Have pH between 8 (weak) and 14 (strong)
- Turns red litmus blue
- Turns methyl orange indicator yellow

Strong alkalis completely ionize in water producing lots of OH^- ions

Weak alkalis partially ionize in water producing OH^- ions

Chemical properties

- Base + acid → salt + water (+ CO₂ when base is a metal carbonate)
- Base + ammonium salt → salt + ammonia gas + water

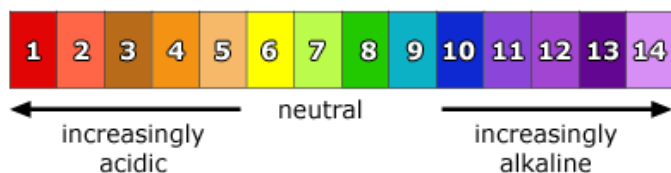
8.3. Neutral

- Neutral substances are pH 7.
- Acidity in soil:
Optimal plant growth requires a soil pH between 5 and 8. Soil pH imbalance to be too acidic reduces plant growth yield. Soil acidity is neutralized by adding lime or powdered limestone.

- pH scale

pH is the concentration of H⁺ ions per dm³ of solution

Universal indicator solution is used to determine the pH of a substance by matching the color change to the pH color chart.



8.4. Types of Oxides

- Metal oxides are basic in nature e.g. iron oxide and magnesium oxide
- Non-metal oxides are acidic in nature e.g. sulphur oxide and carbon dioxide
- Aluminum, zinc and lead form amphoteric oxides e.g. zinc oxide
- Oxides that react with neither acids nor bases are neutral e.g. nitric oxide and carbon monoxide

8.5. Preparation of Soluble Salts

Method A: Neutralization

- Excess insoluble compound (metal/base/carbonate) reacts with acid whilst being heated
- Insoluble base is filtered out
- Solution is heated in an evaporating dish to form soluble salt crystals

Method B: Titration

- Phenolphthalein is added to an alkali (soluble base)
- Add acid to solution using burette; note volume of acid required for solution to change color
- Repeat without indicator using noted acid volume
- Heat in evaporating dish to form soluble salt crystals

8.6. Preparation of Salts

- A salt is a compound formed when all the hydrogen atoms of an acid are replaced by a metal.
- Naming salts involves 2 parts; the name of the metal and the acid ending
eg. calcium + hydrochloric acid = calcium chloride

| Type of Salt | Acid used |
|--------------|-------------------|
| Sulphate | Sulphuric acid |
| Nitrate | Nitric acid |
| Chloride | Hydrochloric acid |
| Ethanoate | Ethanoic acid |

- Salts can either be soluble or insoluble

| Soluble Salts | Insoluble Salts |
|---|---------------------------------|
| All sodium, potassium and ammonium salts | |
| All nitrates | |
| Chlorides | Except silver and lead |
| Sulphates | Except barium, lead and calcium |
| Potassium, sodium and ammonium carbonates | All other carbonates |

8.7. Preparation of Insoluble Salts

Method C: Precipitation

- 2 soluble salts added to water and mixed
Note: one soluble salt should always be a potassium or sodium solution (eg. potassium sulfate)
- Filter out and clean precipitate with distilled water
- Dry insoluble salt precipitate in oven

8.8. Test for Aqueous Cations

| Cation | with aqueous NaOH | with aqueous Ammonia |
|--|--|--|
| Aluminum (Al ³⁺) | White soluble precipitate, turns colorless in excess | White precipitate, insoluble in excess |
| Ammonium (NH ₄ ⁺) | Pungent ammonium gas produced turns damp red litmus blue | |
| Calcium (Ca ²⁺) | White precipitate, insoluble in excess | Faint or no precipitate |
| Copper (Cu ²⁺) | Blue precipitate, insoluble in excess | Blue precipitate, soluble in excess to give a dark blue solution |

| Cation | with aqueous NaOH | with aqueous Ammonia |
|--------------------------------|---|--|
| Iron(II) (Fe^{2+}) | Dirty green precipitate, insoluble in excess | Dirty green precipitate, soluble in excess |
| Iron(III) (Fe^{3+}) | Reddish-brown precipitate, insoluble in excess | Reddish-brown precipitate, insoluble in excess |
| Zinc (Zn^{2+}) | White precipitate, soluble and turns colorless in excess | White precipitate, soluble and turns colorless in excess |
| Chromium (Cr^{3+}) | Grey green precipitate, soluble to give dark green solution in excess | Grey green precipitate, insoluble in excess |

8.9. Test for Anions

Sulfate ions (SO_4^{2-}):

Add dilute nitric acid, then add aq. barium nitrate
White precipitate formed

Sulphite ions (SO_3^{2-}):

Add acidified potassium permanganate and heat
Color changes from pink to colorless

Halide ions:

Add nitric acid, then aqueous silver nitrate

| | |
|----------------------------|--------------------|
| Chloride (Cl^-) | White precipitate |
| Bromide (Br^-) | Cream precipitate |
| Iodide (I^-) | Yellow precipitate |

Nitrate ions (NO_3^-):

Add aqueous sodium hydroxide then add warm aluminum foil
Pungent gas produced, turns damp red litmus blue

Carbonate ions (CO_3^{2-}):

Add dilute hydrochloric acid
If bubbles/ gas produced turn limewater cloudy, carbonate ion present

8.10. Test for Gases

| Gas | Test and test result |
|----------------------------------|---|
| Ammonia (NH_3) | Damp red litmus paper turns blue |
| Carbon dioxide (CO_2) | Bubble gas through—from colorless to cloudy |
| Chlorine (Cl_2) | Bleaches red/blue litmus paper |
| Hydrogen (H_2) | Place lighted splint, squeaky pop |
| Oxygen (O_2) | Place glowing splint, splint relights |

9. The Periodic Table

- The Periodic table is a method of classifying elements.
- Elements are arranged in order of increasing atomic number (each preceding element has one more proton)
- Made up of rows called periods and columns called groups; the position of an element helps determine its electronic configuration
- Period number: number of electron shells
- Group number: number of valency electrons (outer shell electrons)
- Elements in the same group have similar chemical properties.

9.2. Periodic Trends

- Table moves from metals on the left to non-metals on the right.
- Down a group of metals, elements become more reactive
- With non-metals, going down a group, reactivity decreases

9.3. Alkali Metals

- Group I metals: Lithium, sodium and potassium

| Chemical Properties | Physical Properties |
|---|---|
| Readily react with oxygen and water; stored in oil | Good conductors of heat and electricity |
| React violently with chlorine | Soft and easy to cut |
| Burst into flames when heated with oxygen [red flame for lithium; yellow flame for sodium; lilac flame for potassium] | Shiny when freshly cut |
| Produce soluble white compounds. | Low melting and boiling points compared to most metals. |
| React with water to form alkaline metal and hydrogen gas | Low densities for metals |

- Predicting the properties of other Group I alkali metals: Rubidium, Caesium and Francium [reactivity increases down the group]

| Element | Reaction with water |
|----------|--|
| Rubidium | Explodes with spark Produces Rubidium hydroxide |
| Caesium | Violent explosion Produces caesium hydroxide |
| Francium | Cannot predictive due to radioactive reactivity |

9.4. Halogens

| Properties | Patterns |
|---|--|
| States and Colors, at RTP: Fluorine- Yellow gas Chlorine- Green gas Bromine- Red liquid Iodine- Black solid | Down the group; size, mass and density increase |
| Poisonous | Down the group, color darkens |
| Diatomic; form halide ions in displacement reaction | Reactivity decreases down the group, because it has to gain an electron, so the closer the electron is to the positive nucleus the more easily it will be gained, so atoms with fewer shells will react more easily. |
| Do not conduct electricity | melting point increases down the group |
| Brittle and crumbly when solid | |

9.5. Transition Metals

- High melting points (except mercury)
- Malleable and ductile
- Good conductors of heat & electricity (silver is the best)
- High density
- Have no trend in reactivity
- Used as catalysts
- Form colored compounds
- Can form complex ions as they have variable valences

9.6. Noble Gases

| Properties | Uses |
|---|--|
| Density increases down the group | Helium- filling balloons and aircrafts because it is lighter than air and will not catch fire. |
| Monoatomic and colorless | Argon – filling (tungsten) light bulbs to stop the filament reacting with oxygen. |
| M.P. and B.P. increases down the group | Neon – is used in advertising signs because it glows red. |
| Don't conduct electricity | |
| Inert due to full outer shell electrons | |

10. Metals

10.1. Properties of Metals

Physical Properties

1. Good conductors of heat and electricity
2. High melting and boiling points
3. Malleable and Ductile
4. High densities
5. Solids at room temperature (except mercury)

Chemical Properties

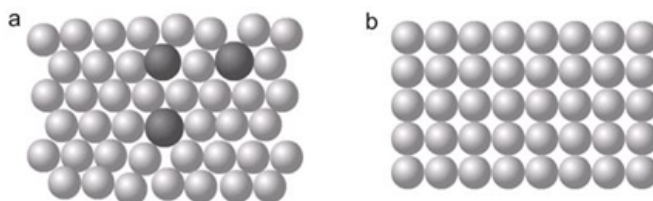
1. Form positive ions
2. Form basic oxides that dissolve in water

10.2. Alloys

- An alloy is a mixture of two or more metals, or a metal and non-metal
- Alloys are used because they have improved qualities for a particular job over the pure metals

| Alloy | Made from | Special Properties | Uses |
|-----------------|-----------------------------------|--|--|
| Brass | Copper and zinc | Stronger and more resistant to corrosion | Electrical fittings, car radiators |
| Bronze | Copper and tin | Harder, stronger and sonorous | Statues, springs, coins |
| Stainless steel | Iron, carbon, chromium and nickel | resistant to corrosion | Kitchen sinks, cutlery, surgical instruments |

- Metal alloys, due to the irregularity in atom sizes and structure which stop layers from sliding over each other, are stronger
- This is what the structure of an alloy (a) looks like, compared to a pure metal (b).



10.3. Reactivity Series

Note: Aluminum- despite its high placement in the reactivity series- is seemingly unreactive due to its protective aluminum oxide layer

| | |
|--|-------------------------------|
| General Reactivity series (descending order of reactivity) | Chemical reactivity of metals |
|--|-------------------------------|

| General Reactivity series (descending order of reactivity) | Chemical reactivity of metals |
|---|--|
| K - Potassium Na - Sodium Ca - Calcium Mg - Magnesium Al - Aluminum C - Carbon Zn - Zinc Fe - Iron Pb - Lead H - Hydrogen Cu - Copper Ag - Silver Au - Gold | Water: 1. metal + cold water → metal hydroxide + hydrogen 2. metal + steam → metal oxide + hydrogen |
| Everything above hydrogen can displace hydrogen from its acid, and hydrogen cannot reduce their oxides. | Oxygen: metal + oxygen → metal oxide |
| Metals above carbon, their oxides cannot be reduced by carbon | Dilute acids: In a metal and acid reaction, the hydrogen atom in the acid is replaced by the metal atom to form a product of salt and hydrogen |

10.4. Displacement Reactions

- In these reactions, metals compete for oxygen or anions
- Oxidization is the loss of electrons
- Reduction is the gain of electrons
- The more reactive metal will displace the less reactive metal from oxygen or an anion.
- If more reactive metal has oxygen or an anion, no reaction occurs
- The bigger the difference in reactivity between the two metals, the faster the reaction

| |
|---|
| Example: $Mg + O_2 \rightarrow 2MgO$ |
| Here Magnesium is oxidized while the Oxygen atom is reduced |

10.5. Thermal Decomposition

| Group | Metal Carbonate | Metal Hydroxide | Metal Nitrate |
|---------------------------------------|--------------------------------|-----------------------|--|
| Group I (except lithium) | Do not decompose | Do not decompose | Metal nitrite and oxygen |
| Group II, lithium & transition metals | Metal oxide and carbon dioxide | Metal oxide and water | Metal oxide, nitrogen dioxide and oxygen |

10.6. Extraction of Metals

- Process of separating a particular metal from its compound; metal ore
- Ores more difficult to decompose from gold to potassium (expensive)

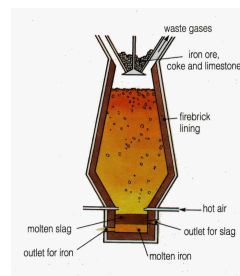
| Metal | Extraction Method |
|---|---|
| K - Potassium Na - Sodium Ca - Calcium Mg - Magnesium Al - Aluminum | Reduction via electrolysis |
| Carbon | |
| Zn - Zinc Fe - Iron Pb - Lead | Reducing via heating with Carbon or Carbon Monoxide |
| Hydrogen | |
| Cu - Copper Ag - Silver Au - Gold | Occur naturally |

10.7. Extraction of Iron

- Ore haematite (Fe_2O_3)
- Ore is crushed and mixed with carbon and limestone ($CaCO_3$) and transferred into the blast furnace

| |
|---|
| $C + O_2 \rightarrow CO_2$ (exothermic) |
| $CaCO_3 \rightarrow CaO + CO_2$ (thermal decomposition) |
| $CO_2 + C \rightarrow 2CO$ |

- Carbon monoxide reduces Iron(III) oxide from the ore to iron
 $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$
- The calcium oxide reacts with impurities like silica to form slag
 $CaO + SiO_2 \rightarrow CaSiO_3 + CO_2$
 Uses of slag include making roads and cement



10.8. Iron to Steel

- Molten iron from blast furnace is poured into an oxygen furnace.

- Powdered calcium oxide is added, and a jet of oxygen is turned on.
- The calcium oxide neutralizes acidic impurities, forming slag that is skimmed off and oxygen burns the other impurities away.
- The carbon content is checked continually until it is just right then the oxygen is turned off.
 - Mild Steel (0.25% carbon) – Used in machinery and car bodies
 - Medium carbon steel (0.5%) – Used in railway lines
 - High carbon steel (1.5% carbon) – Used in knives and blades

10.9. Extraction of Zinc

- Ore = Zinc Blende /Zinc Sulfide (ZnS)
 1. Zinc blende is roasted in air; produces zinc oxide and sulfur dioxide
 2. Zinc oxide is reduced to zinc and carbon monoxide by using coke in the furnace [more reactive metals like aluminum and magnesium can also be used]
 3. As zinc is volatile, the gaseous metal is distilled leaving less-volatile impurities behind.
 4. Zinc is condensed in a tray and collected

10.10. Uses of Metal

- Aluminum
 - Airplane/Cars (Strong/Low density/resistant to corrosion)
 - Cans/Foil (Resistant to corrosion/malleable)
 - Overhead cable (Good conductor of electricity/ductile)
- Zinc
 - Galvanizes Iron = coats it to stop it rusting
 - Alloys – brass/bronze
 - Batteries
 - Sacrificial Protection
- Copper
 - Electrical Wiring (Good conductor of electricity/Ductile)
 - Cooking utensils (Malleable/good conductor of heat)
 - Roofs (hard wearing against weather)

11. Air and Water

11.1. Tests for Water

| Test | Type of test | Positive result |
|-------------------------------|--------------|--------------------------|
| Cobalt(II) Chloride Paper | Chemical | Turns from blue to pink |
| Anhydrous copper (II) sulfate | Chemical | Turns from white to blue |

| Test | Type of test | Positive result |
|--------------------------------|--------------|-----------------------------|
| Test melting and boiling point | Physical | M.P at 0°C and B.P at 100°C |

11.2. Purification of Water

1. Water is pumped into screens to remove solid insoluble impurities
2. Aluminum sulfate is added to make small clay pieces stick together and are then removed
3. The water is then filtered through layers of sand and gravel to remove larger, insoluble debris.
4. Water encounters more flocculants (chemicals that make particles sink to the bottom) and is filtered again through coarse sand.
5. Chlorine gas is bubbled into the water to kill bacteria; the acidic effect on the water is reversed by adding an alkali, sodium hydroxide
6. Some countries add fluoride

11.3. Uses of Water

| Home | Industry |
|--|--------------------------------------|
| Drinking, cooking and washing | Water jet cutting and water blasting |
| In car radiators, for gardens and plants | As a solvent in refining ores |
| | Generating hydroelectricity |

11.4. Air

Components of clean air:

- Primary- Nitrogen (78%), Oxygen (21%)
- Secondary- Noble gases and carbon dioxide

11.5. Pollutants in Air

| Pollutant | Source | Negative impact |
|------------------------------------|---|--|
| Carbon monoxide (CO) | Incomplete combustion of carbon-containing substances (ex. Internal combustion engines) | Binds with haemoglobin, constricting oxygen supply in cells; leads to fatigue/ death |
| Sulfur Dioxide (SO ₂) | Hydrocarbons burned with sulfur impurities/compounds (ex. Fossil fuels) | Causes acid rain and bronchospasm in asthmatics |
| Nitrogen Oxides (NO _x) | High temperatures that trigger a reaction between N ₂ and O ₂ (ex. Car engines) | Causes respiratory problems, photochemical smog; contributes to acid rain |

| Pollutant | Source | Negative impact |
|----------------|----------------------------|---|
| Lead Compounds | Combustion of leaded fuels | Damages brain and nerve cells in young children |

11.6. Fractional Distillation of Air

- Air is filtered for dust
 - Cooled to -80°C to remove CO_2 and water vapour (because they would freeze and block the pipes) using absorbent filters.
 - Remaining air is cooled to liquify at -200°C . The Noble gases are still in the gaseous state and are removed.
 - The (liquid) air, consisting of NO_2 and O_2 , is pumped into the fractional column where it is slowly warmed. The remaining components rise and condense in different fractions due to different boiling points and are collected.
- Sources of methane: oil and natural gas, decomposition of vegetation, and waste gases from digestion in animals

11.7. Catalytic Convertor

- Present in car exhausts; contains transition metal catalysts of platinum and rhodium
- Aids redox reactions to neutralize toxic pollutants formed as a result of incomplete fuel combustion (a) Carbon monoxide (b) Nitrogen oxides (c) Unburned hydrocarbons
- Reaction equations: (a) $2\text{CO} + \text{O}_2 \rightarrow \text{CO}_2$
(b) $2\text{NO} + 2\text{CO} \rightarrow \text{N}_2 + 2\text{CO}_2$
(c) $\text{C}_8\text{H}_{18} + 12\frac{1}{2}\text{O}_2 \rightarrow 8\text{CO}_2 + 9\text{H}_2\text{O}$

11.8. Rust Prevention

- Conditions for rusting:** Presence of Oxygen and Water (Sodium Chloride catalysis rust reaction)
Iron + Water + Oxygen \rightarrow Hydrated Iron (III) Oxide

Preventing oxidation

- Coating iron with barriers that prevent contact with air or H_2O
 - Plastic, paint and grease
 - Electroplating with tin or chromium
 - Galvanizing: dipping in molten zinc
 - Sacrificial protection- attaching a block of more reactive metal, normally zinc or magnesium, to the iron body which corrodes in its place.

11.9. Fertilizer

Artificial fertilizers contain NPK:

- Nitrogen for chlorophyll and other proteins.
- Phosphorus for root growth and crop ripening

- Potassium for making proteins and to resist diseases.

Reaction with any alkali substance (except ammonia) displaces ammonia from its compound, for example:
Calcium hydroxide + ammonium chloride \rightarrow Calcium chloride + Ammonia + Water

11.10. Greenhouse Gases

- Greenhouse gases: Methane and Carbon Dioxide
- Trap heat inside Earth's atmosphere, increasing its average temperature. Leads to climate change
- Causes global warming, melting of polar-caps, rising sea levels, floods and droughts

11.11. Formation of Carbon Dioxide

- Respiration
- Reaction between an acid and a carbonate
- Complete combustion of a carbon containing substance
- Thermal decomposition of limestone

11.12. Haber Process

Materials-

N_2 : fractional distillation of liquid air

H_2 : Electrolysis of Brine (H_2 formed at the cathode)

Conditions-

Temperature: 450°C

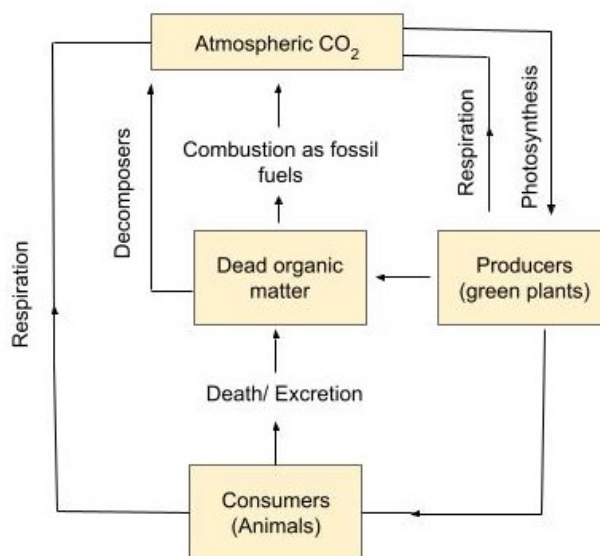
Pressure: 200 atm

Catalyst: Iron

Industrial manufacture of ammonia NH_3 :



11.13. Carbon Cycle



12. Sulfur

12.1. Sources

- By-product of petroleum and natural gas refining
- Occurs in sulphide ores e.g. lead sulphide
- Underground sulfur beds
- Volcano rims

12.2. Uses

| Sulfur | Sulfur Dioxide |
|---|---|
| Rubber vulcanization | As a bleach for wood pulp in the manufacture of paper |
| In car batteries as an electrolyte | Food preservative; kills bacteria |
| Manufacture of sulphuric acid (Contact Process) | Metal and ore refining (reducing agent) |

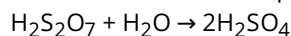
12.3. Contact Process

Essential conditions:

- Catalyst- Vanadium (V) oxide
- Temperature- 450°C
- Pressure- 2atm

Procedure:

1. Oxidation of sulfur (heated in air) to form sulfur dioxide : $S + O_2 \rightarrow SO_2$
2. It is then further oxidized to form sulfur trioxide using the catalyst, Vanadium (V) oxide under the specified essential conditions : $2SO_2 + O_2 \rightleftharpoons 2SO_3$
3. SO_3 is then dissolved in concentrated sulphuric acid to form the liquid compound Oleum : $SO_3 + H_2SO_4 \rightarrow H_2S_2O_7$
4. The compound is mixed with water to form concentrated sulphuric acid:



12.4. Properties of Sulfuric Acid

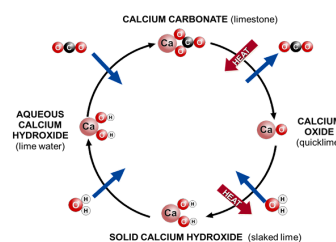
Properties:

- Concentrated H_2SO_4 is a strong oxidizing and dehydrating agent
- Corrosive when concentrated
- Low pH (turns blue litmus red)
- High electrical conductivity

Uses:

| Concentrated | Diluted |
|-------------------------------|-------------------------------|
| Used in phosphate fertilizers | Cleaning metal surfaces |
| Production of paints and dyes | Catalyst in organic reactions |

13. Carbonates

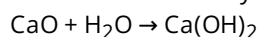


• Manufacture of lime (Calcium oxide)

1. Obtained from the thermal decomposition of limestone in a lime kiln



3. Slaked lime (Calcium Hydroxide): small amounts of water is slowly added to lime



• Uses:

| Lime | Slaked lime |
|--|-------------------------------------|
| Neutralizing acidic industrial waste products, e.g. flue gas desulfurization | Neutralizing soil acidity levels |
| Manufacture of steel | Production of sugar from sugar cane |

Uses of Limestone:

1. Making cement: strongly heat powdered limestone with clay in a kiln; add gypsum (calcium sulphate).
2. Making iron from iron ore: limestone reacts with sand, forming slag (calcium silicate). Used for road building.

14. Organic Chemistry

14.1. Organic formulae

| Suffix | Compound type |
|------------|-----------------|
| ane | Alkane |
| ene | Alkene |
| anol | Alcohol |
| anoic acid | Carboxylic acid |
| yl /anoate | Ester |

Homologous series are a group of organic compounds that have similar chemical properties due to being part of the same **functional group** [have same general formula]. The molecular formula of each following member in each series differs by CH_2

14.2. Fuels

Common fossil fuels include: coal, natural gas [main constituent: methane] and petroleum

Petroleum is a mixture of hydrocarbons which can be separated into useful fractions by fractional distillation

Properties of molecules in fractions

- Melting/boiling point increases for larger molecules
- Increasing carbon chain length, liquid is darker and thicker
- Low volatility for larger molecules

| Petroleum fraction | Use |
|-----------------------------|--|
| Refinery gas | heating and cooking |
| Gasoline fraction | petrol for cars |
| Naphtha fraction | making chemicals |
| Kerosene/paraffin fraction | jet fuel, lamps |
| Diesel oil/gas oil fraction | fuel in diesel engines |
| Fuel oil fraction | fuel in ships and home heating systems |
| Lubricating fraction | waxes and polishes |
| Bitumen | making roads |

14.3. Alkanes

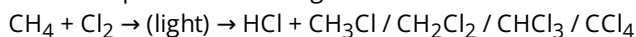
Alkanes are saturated hydrocarbons [single carbon bonds] that are generally unreactive however they do undergo combustion reactions

General formula = C_nH_{2n+2}

| | |
|---|--|
| <p>Methane: CH_4 (n=1)</p> $\begin{array}{c} H \\ \\ H-C-H \\ \\ H \end{array}$ | <p>Ethane: C_2H_6 (n=2)</p> $\begin{array}{c} H & H \\ & \\ H-C & -C-H \\ & \\ H & H \end{array}$ |
| <p>Propane: C_3H_8 (n=3)</p> $\begin{array}{c} H & H & H \\ & & \\ H-C & -C & -C-H \\ & & \\ H & H & H \end{array}$ | <p>Butane: C_4H_{10} (n=4)</p> $\begin{array}{c} H & H & H & H \\ & & & \\ H-C & -C & -C & -C-H \\ & & & \\ H & H & H & H \end{array}$ |

Substitutional reactions [photochemical]

Alkanes go through substitutional reactions, where the hydrogen atom is replaced by the atom of another element, under the presence of UV light



Compounds = chloromethane / di/tri/tetrachloromethane

14.4. Alkenes

Alkenes are unsaturated hydrocarbons [at least 1 double bond between 2 carbon atoms]

Have isomers: same molecular formula but different structural formula (placement of double bond shifts) eg. but-1ene and but-2ene

General formula = C_nH_{2n}

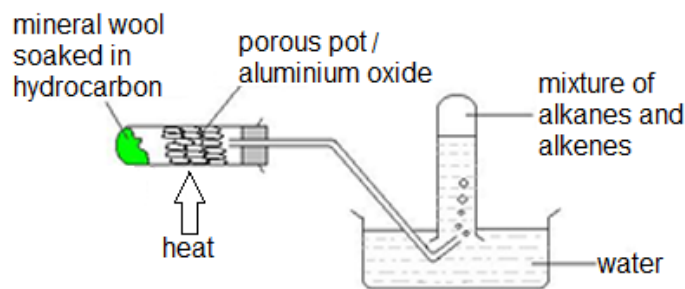
Functional group: C=C bond

| | |
|-------|------------------------|
| (n=1) | Ethene: C_2H_4 (n=2) |
|-------|------------------------|

| | |
|--|---|
| (n=1) | Ethene: C_2H_4 (n=2) |
| N/A | $\begin{array}{c} H & & H \\ & \backslash & / \\ & C=C \\ & / & \backslash \\ H & & H \end{array}$ |
| Propene: C_3H_6 (n=3) | But-1-ene: C_4H_8 (n=4) |
| $\begin{array}{c} H & H & H \\ & & \\ H-C & -C & =C \\ & & \\ H & & H \end{array}$ | $\begin{array}{c} H & H & H & H \\ & & & \\ H-C & =C & -C & -C-H \\ & & & \\ H & & H & H \end{array}$ |

Catalytic Cracking:

- Thermal decomposition reaction, in which an alkene (and sometimes hydrogen) are produced from an alkane.
- Hydrocarbon heated and vapors passed over catalyst (alumina or silica)
- Cracking always produces short chain compound with a C=C bond
e.g. Cracking of ethane will give ethene and hydrogen



- Butane → Ethane + Ethene ; $C_4H_{10} \rightarrow C_2H_6 + C_2H_4$

Distinguish between saturated and unsaturated hydrocarbons

Bromine water (orange)

Saturated: remains orange (unreactive)

Unsaturated: turns colourless

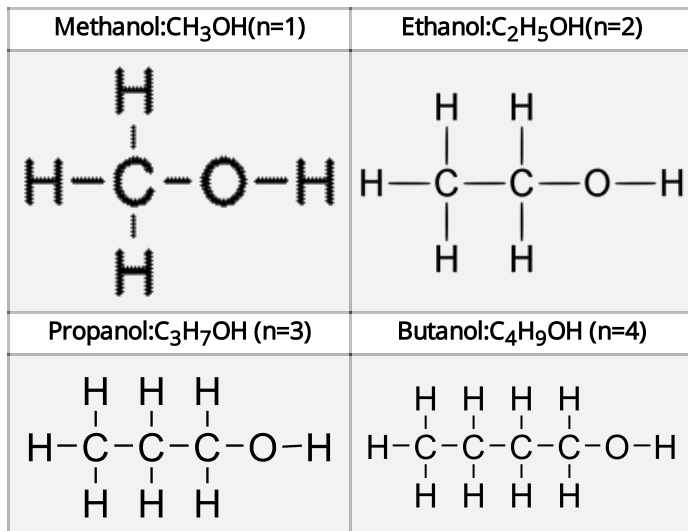
14.5. Alkenes' Addition Reactions

1. **With bromine:** (the test for saturation)
e.g. ethene (g) + bromine (aq) → 1,2-dibromoethane (l)
2. **With steam [hydration]:** forms alcohols with heat, pressure and a catalyst (phosphoric acid)
e.g. ethene (g) + steam (g) ⇌ ethanol (l)
3. **With hydrogen [hydrogenation]:** double bond breaks down to form an alkane with heat, pressure (60 atm) and a catalyst (nickel)
e.g. ethene (g) + hydrogen (g) → ethane (g)

14.6. Alcohols

General formula = $C_nH_{2n+1}OH$

Functional group: OH



Methods of production:

| Fermentation (only for ethanol) | Hydration of Ethane |
|---|--|
| -Yeast added to dissolved glucose. Products: ethanol, carbon dioxide and heat- Temperature between 25-35 °C for optimal enzyme activity (dies after alcohol concentration increases) | The ethene reacts with steam (reversibly) to form ethanol in the following conditions: 570°C 60-70atm Catalyst- phosphoric acid [while low temp. gives better yield, high temp. is used for faster rate of reaction] |
| Slow reaction, produces dilute solution that requires processing. Can only be produced in batches | Fast reaction, produces pure ethanol. Continuous production (no batches) |
| Produces greenhouse gas (CO_2) | No greenhouse pollutants |
| Uses renewable resources | Uses non-renewable resources (crude oil) |

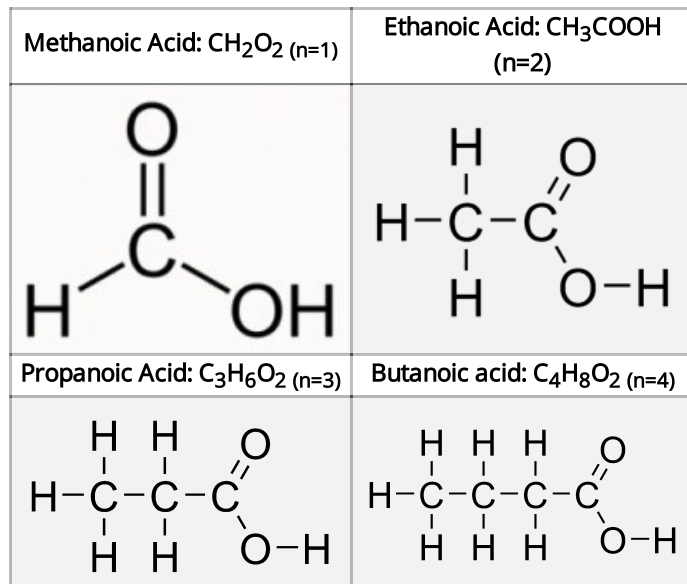
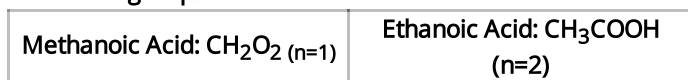
Uses of ethanol:

- Solvent in glues, printing inks & perfumes
- Fuel

14.7. Carboxylic Acids

General formula = $\text{C}_n\text{H}_{2n+1}\text{COOH}$

Functional group: COOH



Ethanoic acid:

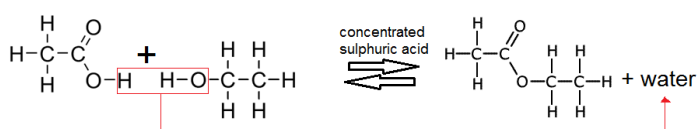
- Weak acid with high pH and low dissociation
- Formed by:
 - Oxidation of ethanol
 - With acidified potassium manganate (VII)

Carboxylic acids react with alcohols (with an acid catalyst) to give esters, in a condensation reaction, for example:

- Ethanoic acid + ethanol \rightleftharpoons ethyl ethanoate + water (alcohol = -yl & carboxylic acid = -oate)

14.8. Polymers

- Large molecules built up from small units known as monomers.



- Polymers can have different linkages depending on the type of polymerization and monomer

Example:

| Small units (monomers) | Linkages | Macromolecules |
|--------------------------|----------|----------------|
| Glucose | Ester | Starch |
| Amino acids | Amide | Protein |
| Fatty acids and glycerol | Ester | Lipids |

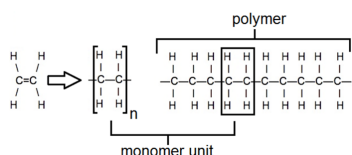
| | Use | Structure |
|-----------|--|-----------|
| Polythene | Plastic bags and gloves, clingfilm (low density), mugs, bowls, chairs, dustbins (high density) | |

| | Use | Structure |
|-------------------------------|--|---|
| Polychloroethane (PVC) | Water pipes, wellingtons, hoses, covering for electricity cables | <p>chloroethene poly(chloroethene) PVC</p> |
| Polypropene | Crates, ropes | <p>propene poly(propene)</p> |
| Polystyrene | Used as expanded polystyrene in fast-food cartons, packaging, and insulation for roofs and walls | <p>phenylethene poly(phenylethene) polystyrene</p> |
| Teflon | Coated on frying pans to make them non-stick, fabric protector, windscreen wipers, flooring | <p>tetrafluoroethene poly(tetrafluoroethene) PTFE / Teflon</p> |

14.9. Addition and Condensation Polymerization

Addition Polymerization:

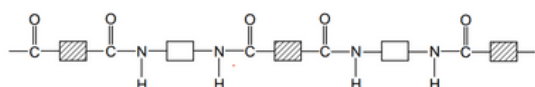
- Only occurs in monomers that contain double carbon (C=C) bonds
- Polymers produced using alkene monomers
- Forms only a polymer molecule
- Poly(ethene) / Polythene: is a polymer produced from ethene by addition polymerization



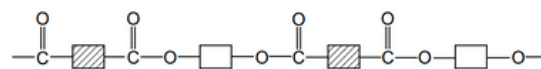
Double bond splits and polymer is formed

Condensation Polymerization:

- When 2 different monomers are linked together with the removal of a smaller molecule, usually water (forms one H₂O molecule per linkage).
 1. **Nylon** [polyamide] is made from a dicarboxylic acid monomer and an amine monomer (compound with an NH₂ functional group). Forms amide linkage.



2. **Terylene** [polyester] made from a dicarboxylic acid monomer and diols (alcohol with an -OH functional group). Forms ester linkage.



14.10. Pollution from Plastics

- Choke birds, fish and other animals that try to eat them.
- They clog up drains and sewers and cause flooding.
- They collect in rivers, and get in the way of fish. Some river beds now contain a thick layer of plastic
- When incinerated, release greenhouse gases (like carbon dioxide) that contribute to climate change.

14.11. Natural Polymers

Proteins and carbohydrates as the main constituents of food.

Proteins:

- Proteins contain the same linkages (amide links) as nylon, but with different units. Their structure is:



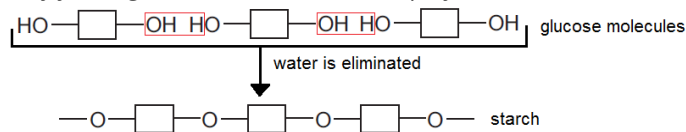
- In digestion proteins are broken down into amino acids (hydrolysis).

Carbohydrates:

- Complex carbohydrates: are a large number of joined sugar units (monosaccharide like glucose). The sugar units are represented like this:



They join together in a condensation polymerization



- The fermentation of fructose and glucose with yeast enzymes produces ethanol and carbon dioxide

In digestion, the hydrolysis (Decomposition of a chemical compound by reaction with water) of starch happens in the mouth by the enzyme amylase to make glucose

1. **Hydrolysis:**

- Starch → glucose
- Proteins → amino acids
- Fats → fatty acids and glycerol

But if hydrolysis is not complete, polymers are not completely broken down so you get a mixture of molecules of different sizes

2. **Identification:**

- Chromatography can be used to identify products & substances
- However, amino acids and sugars are colourless when dissolved in water, so a locating agent is

- used.
- Substances can be identified using Rf values or by matching them with spots which are horizontal

CAIE IGCSE

Chemistry (0620)

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