Chemistry
IGCSE

1. The Particulate Nature of Matter

States of Matter

Solid
- Fixed shape & volume
- Can't flow (not fluid)

freezes
melts

Liquid
- Fixed volume but shape of container
- Can flow

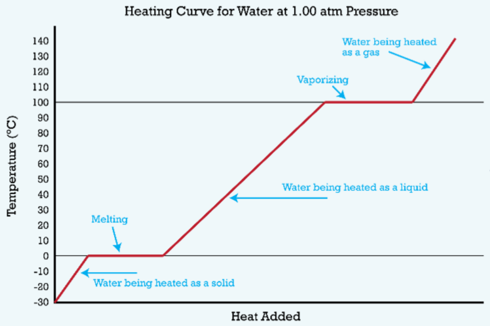
sublimation

condenses
boils

Gas
- No fixed shape nor volume
- Fills any contained
- Much lighter than the other two

Every substance has a boiling & melting point — Test for purity

Heating Curve


Heating Curve for Water at 1.00 atm Pressure

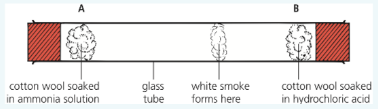
Particles

- Particles = very tiny pieces
- Pollen movement
- **Brownian Motion** — Random Movement of Particles
- **Diffusion** — Mix and spread of fluid particles
- Evidence

- **Atoms** — Smallest particles that can't be broken by chemistry
- **Molecules** — Two or more atoms bonded
- **Ions** — Atoms that carry a charge

Diffusion

- Particles collide with each other



- HCl more Massive than NH3 — 1 + 35.5 > 14 + 3×(1)
- **Mass slows down travel** — Lower relative atomic mass = faster diffusion
- Temperature (Heat energy) speeds up diffusion — More energy to collide --> bounce further

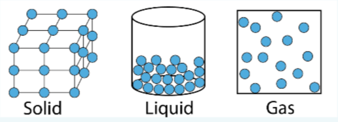
Gas Pressure

- Pressure - Dependent on Temperature & Volume
- **pV = nRT** — pressure × volume = num.moles × gas.constant × temperature
- Heating a Gas
  - Particles move faster
  - Hit the wall more often & with more force
- Squeeze Gas
  - Compressed gas occupy smaller volume
  - Hit the wall more often

Particles in Each State

Particles don't change - their arrangements change

	Particles	Force
Solid	Lattice - fixed regular pattern	Strong bond
Liquid	Move about & slide past each other	Weak Inter-Molecular Force
Gas	Far apart; move quickly	Negligible



Changing State
- **Melting** — Heated --> More Energy --> Vibrate & Expand --> Break Away From Fixed Positions
- **Boiling** — Heated --> More Energy --> Move Faster --> Overcome the Force
- **Evaporation** — Some Particles Have More Energy Than Others

2. Experimental Technique

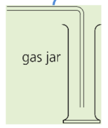
ECM
- Element
- Compound
- Mixture

Element, Compound → Pure
- Pure
  - Only 1 type of molecule

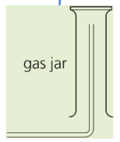
Solutions
- Solute (solid) + Solvent (liquid) = Solution (aq mixture)
- **Aqueous solution** — *containing water*
- **Solubility**
  - *How much dissolves?*
  - Rises with temperature
  - Saturated = full solubility reached
- **Volatile** — Easy to evaporate

Purity
- Why it matters
  - Baby food
  - Vaccines
- How do we know
  - Pure ==> Sharp Boiling point & Melting point
  - Impurities ==> ↓ mtp & ↑ bp (Bigger range)

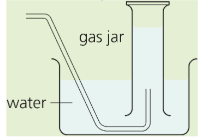
Collecting Gas



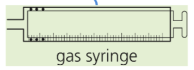
Upward Displacement (gas denser than air)



Download displacement of air (gas less dense than air)



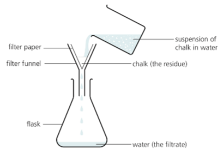
Over water (insoluble in water)



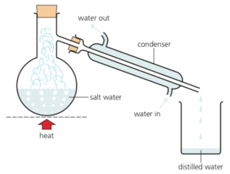
Syringe

Experimental Design
- Independent Variables — Factors that's manipulated
- Dependent Variables — Resulting data that's measured

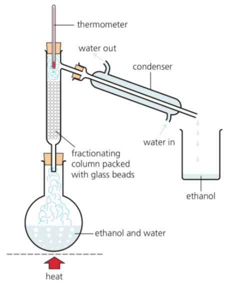
Methods of Separation



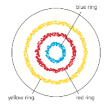
- **Filtration**
  - Solid from liquid
  - Alt. Separate two solids by a solvent that dissolves only one of them
- **Crystallization**
  - Dissolved particle
  - Heat to evaporate --> Glass rod test for saturation --> Cool --> Filter
- **Evaporation**
  - Substance from water
  - Keep heating & evaporate all the water until dry
  - If solubility inelastic



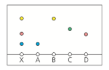
- **Simple Distillation**
  - Solvent from Solution



- **Fractional Distillation**
  - Two solutions with similar bp.
  - Boiling ethanol + Evaporating water --> Vapors condense on column
- **Paper Chromatography**
  - Two substances of different solubility



  - Chromatogram

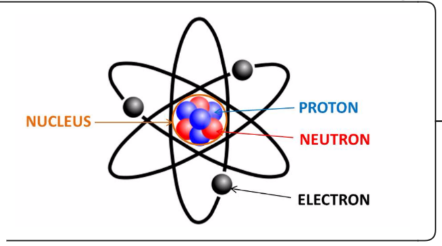


  - Identifying Substances
  - Chromatogram, Identifying Substances — Varying solubilities & attraction to paper
    - *Mixture* — Mobile phase moves
    - *Filter paper* — Stationary phase stays
  - **Locating Agent** — Dyes colorless substances
  - Rf Value — $\text{Rf Value}=\frac{\text{Distance moved by solute}}{\text{Distance moved by solvent}}$

3. Atoms and Elements

Basic Concepts

- **Atom**
  - Smallest particle of matter - can't be broken down further chemically

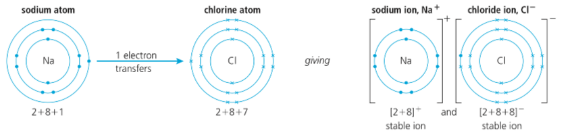


Periodic Table

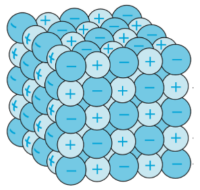
- **Symbols**
  - A representation, often a shorthand of the name
- GROUP
  PERIOD
- Looking at the Group & Period of the element
- Inferring Chemical Properties

Electrons

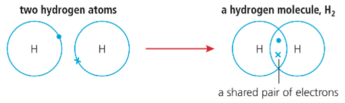
- Electron Shells
  - 2, 8, 8
- Period Number = # of shells
- Group Number = # of Valence Electrons
  - Full Valency (Group 8) == V. Stable ==> Unreactive
- Dictates the reactions
  - Atoms try to gain a full outer shell



Bonding



- Ionic Bonds
  - Metals & Nonmetals lose & gain electrons
  - Held in a lattice by strong forces
    - High melting p.



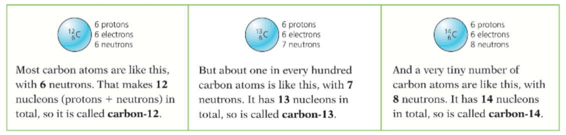
- Molecular
  - Sharing electrons between two nonmetals
  - Weak Inter-Molecular Forces
- Metal
  - Metal ions attract delocalized electrons
    - High melting p.
    - Malleable & Ductile
    - Good conductor

The Atom

- Components
  - Electron -
  - Proton +
  - Neutron 0
  - *Nucleus* (Proton, Neutron)
- The Numbers

	What is it?	What's it equal to?
Atomic (Proton) Number	Identification of atom	Electron Number
Electron Number	Dictates Chemical Properties	Atomic Number
Nucleon Number	Relative Atomic Mass	Proton + Neutron

- **Isotopes**
  - Same proton #, but different neutron #
  - Therefore different nucleon number



Most carbon atoms are like this, with **6** neutrons. That makes **12** nucleons (protons + neutrons) in total, so it is called **carbon-12**.

But about one in every hundred carbon atoms is like this, with **7** neutrons. It has **13** nucleons in total, so is called **carbon-13**.

And a very tiny number of carbon atoms are like this, with **8** neutrons. It has **14** nucleons in total, so is called **carbon-14**.

- **Radioactivity**
  - Unstable Nucleus
  - Decay ==> Radiation
    - **"Half Life"** Time for half of sample to decay
  - Uses
    - Checking for Leakages
    - Treat cancer
    - Kill germs & bacteria
    - Carbon dating
  - Particles
    - **Alpha** 2p+ & 2n
    - **Beta** v. fast e-
    - Neutrons
    - **Gamma** high energy rays
- ***Radioisotopes***
  - Random
  - Can be natural
  - Only some radioactive

Metals & Nonmetals

- What's Special about Metals?
  - Good conductor of Heat & Electricity
  - High Melting Point & Boiling Point
  - Strong, not brittle
  - Malleable & Ductile
  - Shiny
  - Sonorous - ringing sound
  - Dense
  - Form Basic Oxides
- Uses of Metals
  - Aluminum alloy for planes
  - Copper wires
  - Iron as girder

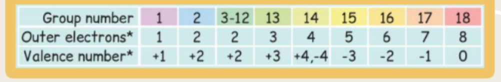
ECM

- **Elements** Only 1 kind of atom
- **Compounds** Different atoms bonded chemically
- **Mixtures** Different substances not chemically bonded

4. Stoichiometry

Writing Equations

- Chemical valency



Group number	1	2	3-12	13	14	15	16	17	18
Outer electrons*	1	2	2	3	4	5	6	7	8
Valence number*	+1	+2	+2	+3	+4,-4	-3	-2	-1	0

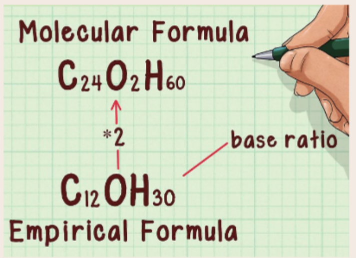
- Balancing Equations
- State Symbols
  - (s)
  - (l)
  - (g)
  - (aq)
- Relative Atomic Mass
  - Mass (g) of each mol

Calculations

- Laws
  - elements always react in the same ratio
  - total mass does not change
- % Purity
- Mass = number of moles x mass per mole (RAM)
- Gas = 24dm3 per mole
- Concentration = mol/dm3

Forming Formula

- Empirical Formula
  - The Simplest ratio of bonded atoms
- From Experiments
  - 1. Find mass of Mg (Mass of Crucible and Mg) - (Mass of Crucible)
  - 2. Heat and raise lid carefully to introduce oxygen
  - 3. when burning complete, weigh again (oxygen in Mgo)
- Molecular formula
  - Actual number of atoms combined
- From Calculations
  - Relative Molecular Mass ÷ Empirical Mass
  - x Each number in Empirical Formula



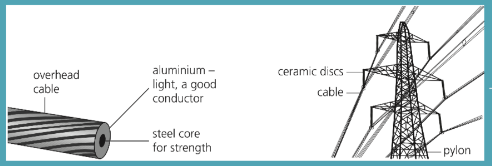
x2

Empirical Formula

5. Electricity and Chemistry

Introduction

- Electricity
  - Flow of Electrons
  - Negative terminal --> Device --> Positive terminal
- Conductors
  - Allow electrons to pass — e.g. Metals & graphite
  - Insulators — Oppo. — e.g. molecular substances & solid ionic substances

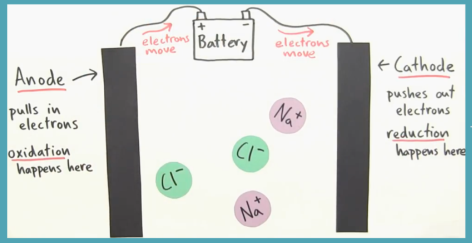


- Electrolysis
  - Breaking down an ionic compound using electricity
  - Using electricity to cause a chemical change that otherwise wouldn't happen — Reaction not spontaneous (doesn't happen on its own)

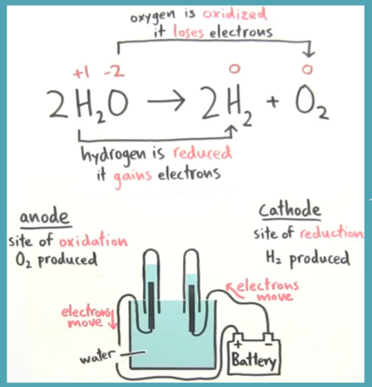
Components

- Electrolyte
  - A liquid that conducts electricity — i.e. any liquid with ions
- Anode
  - Positive Electrode
  - Attracts anions
- Cathode
  - Negative Electrode
  - Attracts cations
- PANCAKES!
  - Positive Anode
  - Negative Cathode
- Electrodes
  - Inert (C/Pt)
  - Active (for Refining/Electroplating)

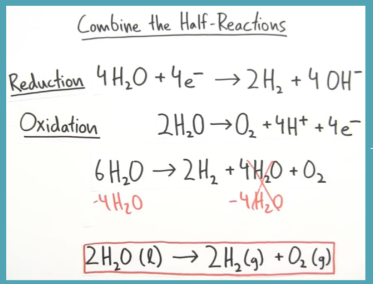
Super N: ANions = Negative = attracts ANode



Example



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



Combine the Half-Reactions

Reduction $4H_2O + 4e^- \rightarrow 2H_2 + 4OH^-$

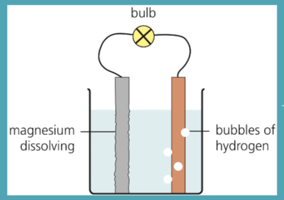
Oxidation $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$

$$6H_2O \rightarrow 2H_2 + \cancel{4H_2O} + O_2$$

$-4H_2O$ $\quad$ $-\cancel{4H_2O}$

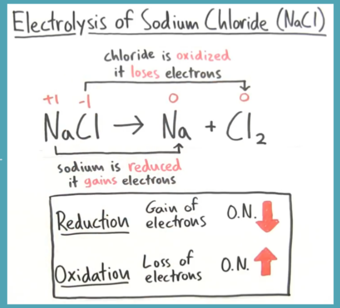
$$\boxed{2H_2O\,(l) \rightarrow 2H_2\,(g) + O_2\,(g)}$$

Fuel Cell



- Mg more reactive --> Forms ions
- Electrons flow through the bulb
- H+ in the solution forms H2
- e.g. Hydrogen Fuel Cell
  - No pollution
  - Renewable
  - Plentiful Energy

Example



Electrolysis of Sodium Chloride (NaCl)

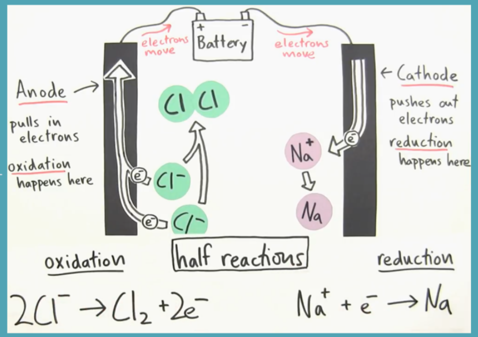
chloride is oxidized
it loses electrons

$$\overset{+1}{Na}\overset{-1}{Cl} \rightarrow \overset{0}{Na} + \overset{0}{Cl_2}$$

sodium is reduced
it gains electrons

Reduction	Gain of electrons	O.N. ↓
Oxidation	Loss of electrons	O.N. ↑

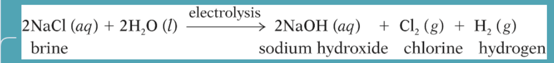
- OIL RIG
  - Oxidation is Loss (of electrons)
  - Reduction is Gain (of electrons)



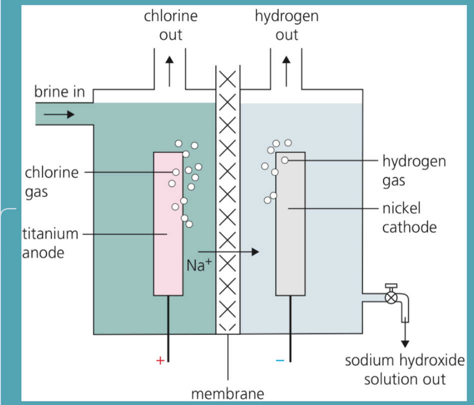
$2Cl^- \rightarrow Cl_2 + 2e^-$ $\qquad$ $Na^+ + e^- \rightarrow Na$

Electrolysis of Brine

- Brine — Concentrated NaCl-H20



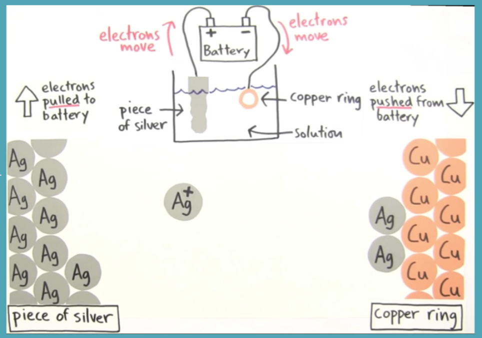
$$\underset{\text{brine}}{2NaCl\,(aq) + 2H_2O\,(l)} \xrightarrow{\text{electrolysis}} \underset{\text{sodium hydroxide}}{2NaOH\,(aq)} + \underset{\text{chlorine}}{Cl_2\,(g)} + \underset{\text{hydrogen}}{H_2\,(g)}$$



- Products
  - Cl2
    - medical drugs
    - pesticides
    - bleaches
  - NaOH
    - soap
    - detergents
    - paper
  - H2
    - Fuel
    - Nylon
    - Margarine

Electroplating

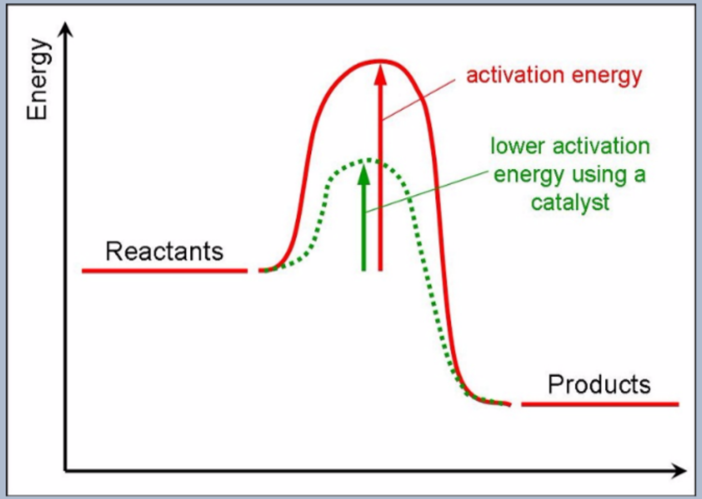
- Coating an object with another deposited metal



6. Chemical Energetics

Energy Change

- Endothermic: Taking in Heat
- Exothermic: Giving Out Heat
- *always an energy change*



- Energy Given Out (Bond Energy Decreases) in Energy Diagram

Why

- Bond Energy
  - Breaking bonds takes energy; Making bonds releases energy
  - Energy-in - Energy-out = ΔH

Fuels

- *Any substance that provides energy*
- Criteria of Good Fuel
  - Energy given out per ton of fuel
  - Pollution
  - Accessibility
  - Storage & Transport
  - Cost
- **Ethanol (C_2H_5OH)**
  - 🟢 Obtained from plants
- **Hydrogen Fuel Cell**
  - 🟢 Clean
  - 🟢 Sustainable
  - 🔴 Flammable
- **Nuclear Fuels**
  - 🟢 Lots of energy
  - 🟢 No emissions
  - 🔴 Waste material hard to dispose
  - 🔴 Radioactive leakages if accident

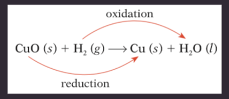
7. CHEMICAL REACTIONS

Signs of Chemical Reactions

- New substances formed
- Energy change
- Difficult to reverse

Types of Chemical Reactions

- Neutralization Reactions
- Precipitation Reactions
- Redox Reactions
  - Oxidation
    - e- lost
    - Chemical combination w/ O
    - Facilitated by oxidizing agent (which is itself reduced)
  - Reduction
    - e- gained
    - Chemical combination w/ H
    - Facilitated by reducing agent (which is itself oxidized)
  - e.g.



$$CuO\ (s) + H_2\ (g) \longrightarrow Cu\ (s) + H_2O\ (l)$$

Oxidation State

- # of atoms an element gains, loses, or shares to form a compound
- 0 Not combined with another atom
- Must add up to 0 in a compound
- e.g.
  - Potassium Manganate (KMnO4)
    - Mn - transition element (∴ different oxidation state)
    - $\underset{\text{manganate(VII) ion (purple)}}{MnO_4^-\ (aq)} \xrightarrow{\text{reduction}} \underset{\text{manganese(II) ion (colourless)}}{Mn^{2+}\ (aq)}$
    - Suitable as test for reducing agent
  - Potassium Iodide (KI)
    - $\underset{\text{dichromate(VI) ion (orange)}}{Cr_2O_7^{2-}\ (aq)} \xrightarrow{\text{reduction}} \underset{\text{chromium(III) ion (green)}}{2Cr^{3+}\ (aq)}$

Reversible Reactions

- *Goes either directions* ⇌
- Forward and Backward: One Endo and One Exo — Law of Conservation of Energy
- Dynamic Equilibrium — *Eventually the molecules forward:backward unchanged*

Shifting the Equilibrium

- Le Chatelier's Principle — **"When a reversible reaction is in equilibrium and you make a change, the system acts to oppose the change, and restore equilibrium. A new equilibrium mixture forms."**
- **Compromise Temperature**
  - For some reactions, low temp = higher yield
  - But too low = slow reaction
- **Changing Pressure** — Fewer particles favored
- **Remove a side** — Equilibrium will restore
- **Add catalyst**
  - Speeds up both directions equally
  - *Equilibrium does not change*

OIL RIG

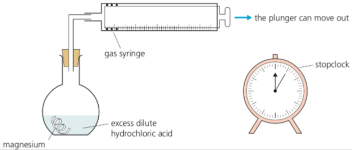
- Oxidation is Loss of electron
- Reduction is Gain of Electrons

Photochemical Reactions

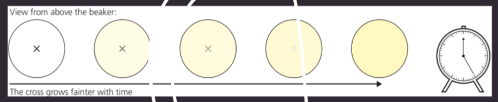
- Some reactions obtain energy from light
- e.g. Photosynthesis
  - $\underset{\text{carbon dioxide}}{6CO_2\ (g)} + \underset{\text{water}}{6H_2O\ (l)} \xrightarrow[\text{chlorophyll}]{\text{light}} \underset{\text{glucose}}{C_6H_{12}O_6\ (aq)} + \underset{\text{oxygen}}{6O_2\ (g)}$
- e.g. Film photography
  - $2AgBr\ (s) \longrightarrow 2Ag\ (s) + Br_2\ (l)$
  - $2Ag^+ + 2e^- \longrightarrow 2Ag$
  - $2Br^- \longrightarrow Br_2 + 2e^-$

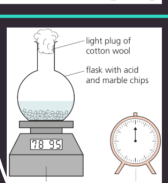
Rate of Reaction

- Measure of change per unit of time (e.g. s)
- Measured by
  - Amount of solid/liquid used up
  - Amount of gas produced



- Changing Rates of Reaction
  - Concentration
  - Temperature
  - Surface Area — e.g. Flour mills explosion (tiny particles) / coal mines (CH4 gas)





Collision Theory

- Particles collide w/ each other
- Certain energy needed to be successful (to break bonds)

Catalyst

- Substance that speeds up a reaction
- By lowering the min. energy required
- Remains chemically unchanged itself
- often transition elements / their oxides — e.g. Fe for NH3
- e.g. enzymes (proteins that are biological catalysts) — need specific temp. & pH

8. Acids, Bases and Salts

Basic Characteristics

- Acids
  - Corrosive
  - Weak Acids — Not corrosive, even concentrated
  - H+ ions

Strong vs. Weak Acids

- Strong Acids
  - High conductivity
  - Lower pH
- Weak Acids
  - Low conductivity
  - Higher pH

Common Acids

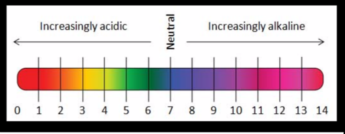
HCl	Hydrochloric Acid	
H2SO4	Sulfuric Acid	
HNO3	Nitric Acid	
CH3COOH	Ethanoic Acid	Acetic Acid (vinegar)

Indicator

Identification

	Acid	Alkalis
Litmus	Acid	Alkalis
Methyl Orange	Acid	Alkalis
Phenolphthalein	~~Color~~	Pink

Universal Indicator



- Alkalis
  - Also burn skins
  - Pure alkalis = solid (exc. ammonia)
  - = A Soluble Base
  - OH- ions

Common Alkalis

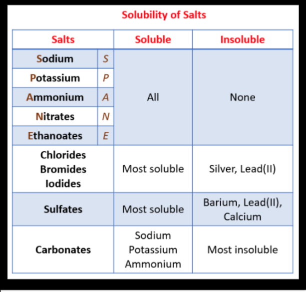
NaOH	Sodium Hydroxide
KOH	Potassium Hydroxide
Ca(OH)2	Calcium Hydroxide
NH3	Ammonia

Strong vs. Weak Alkalis

- Strong Alkalis
  - High conductivity
  - High pH
- Weak Alkalis
  - Low conductivity
  - Low pH

Making Salts

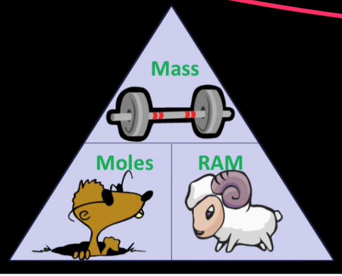
- Metal
  - 1. Excess Metal + Acid
  - 2. Filter Unused Metal
  - 3. Evaporate & Cool
  - "EFE" — But: some X react; some react too vigorously
- Insoluble Base
  - Same Method
- Soluble Base (Alkali)
  - **Titration** — Adding reactant w/ indicator
  - "PIBUE"
  - 1. Pipette (accuracy) to add x ml of R1
  - 2. Indicator added
  - 3. Burette to add R2 slowly until Ind. changes color
  - 4. Using amount obtained, repeat steps 1&3 wo/ Ind.
  - 5. Evaporate & cool
- Solubility Table



Solubility of Salts

Salts		Soluble	Insoluble
Sodium	S	All	None
Potassium	P		
Ammonium	A		
Nitrates	N		
Ethanoates	E		
Chlorides Bromides Iodides		Most soluble	Silver, Lead(II)
Sulfates		Most soluble	Barium, Lead(II), Calcium
Carbonates		Sodium Potassium Ammonium	Most insoluble

- Precipitation
  - 1. Select two appropriate solutions
  - 2. Mix
  - 3. Filter the Precipitate
  - 4. Rinse the Precipitate
  - 5. Warm to dry
  - Sad Mozart Felt Really Worried
- Applications of Precipitation
  - Colored pigments for print
  - Cleaning waste water
  - Make photographic film
- Applications of Titration
  - **Goal: Identify the Concentration**
  - 1. Calculate no. of Moles (acid)
  - 2. Infer the Mole Ratio (using the equation)
  - 3. Calculate no. of Moles (base)
  - 4. Calculate concentration of Base
  - Vice Versa
  - Equation



Reactions

Neutralization

- Reaction produces H2O
- e.g. Acidic Soil + CaCO3 / CaO / CaOH

Acid + Metal	-->	Salt + H2
Acid + Base	-->	Salt + H20
Acid + Carbonate	-->	Salt + H20 + CO2

Neutralization = Acids donates protons (H+)

e.g.

$$\mathrm{HCl}\ (aq) + \mathrm{NaOH}\ (aq) \longrightarrow \mathrm{NaCl}\ (aq) + \mathrm{H_2O}\ (l)$$

all ions

$$\mathrm{H^+}\ (aq) + \mathrm{Cl^-}\ (aq) + \mathrm{Na^+}\ (aq) + \mathrm{OH^-}\ (aq) \longrightarrow \mathrm{Cl^-}\ (aq) + \mathrm{Na^+}\ (aq) + \mathrm{H_2O}\ (l)$$

- spectator ions

$$\mathrm{H^+}\ (aq) + \cancel{\mathrm{Cl^-}\ (aq)} + \cancel{\mathrm{Na^+}\ (aq)} + \mathrm{OH^+}\ (aq) \longrightarrow \cancel{\mathrm{Cl^-}\ (aq)} + \cancel{\mathrm{Na^+}\ (aq)} + \mathrm{H_2O}\ (l)$$

$$\mathrm{H^+}\ (aq) + \mathrm{OH^-}\ (aq) \longrightarrow \mathrm{H_2O}\ (l)$$

Identifying Ions & Gases

Testing for Anions

Halide Ions + Silver	White = Cl Cream = Br Yellow = I	
SO4 + Barium	Insoluble BaSO4 (white)	
SO3 + H (from HCl)	H2O + SO2	
NO3 + NaOH + Al	Ammonia gas produced	
CO3 + HCl	CO2 produced	

Tests for Cations

NH4	add NaOH	Produces NH4
Cu	NaOH or NH3	Pale Blue precipitate
Fe (II)	NaOH or NH3	Pale Green precipitate
Fe (III)	NaOH or NH3	Red Brown precipitate
Al	NaOH or NH3	White Precipitate
Zn	NaOH or NH3	White Precipitate
Ca	NaOH	White Precipitate
	NH3	No Precipitate

Flame Tests

Li	Red
Na	Yellow
K	Lilac
Ca	Red
Ba	Green

Red Light; Yellow Nanny; Lilac Kite; Red Cat; Green Bag

Tests for Gas

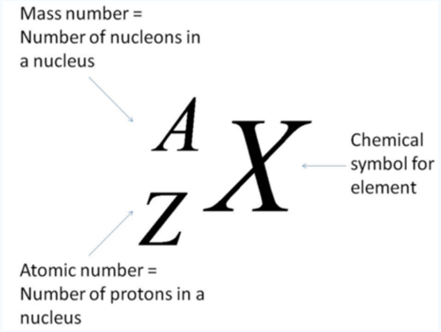
NH3	Damp red litmus paper (1) turns blue (1)
CO2	Bubble through limewater (1) turns milky (1)
Cl2	Damp indicator (1) bleached/turns white (1)
H2	Lighted splint (1) goes out with a squeaky pop (1)
O2	Glowing splint (1) relights (1)
SO2	Filter paper with K2MnO4 (1) turns colorless (1)

Oxides

- Compounds of Oxygen and something else
- Acidic Oxides — Non-metal + O2
- Basic Oxides — Metals + O2
- Amphoteric Oxides
  - React w/ both acids & alkalis
  - e.g. ZnO
- Neutral Oxides
  - React w/ neither acids nor alkalis
  - e.g. CO

9. The Periodic Table

- Overview
  - 

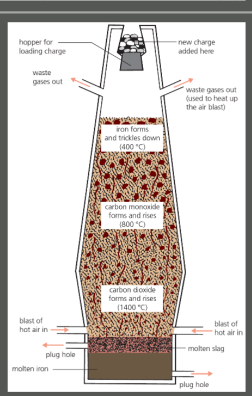
  - Group Number = no. of outer shell electrons
    - Valency electrons v. important (dictate how an element behaves)
  - Period Number = no. of electron shells
  - 

- Periodic Trends
  - More reactive down Group I
  - Less reactive down Group VII
    - Positive Nucleus attracts electrons, which is harder if there are more shells
  - Metals form basic oxides
    - "Milk Boy"
  - Non-metals form acidic oxides
    - "Not Available"
- Group Properties
  - Group I (Alkali Metals)
    - v. Soft
    - Low Density
    - Down the Group I
      - Softer
      - Denser
      - M.t.p. lower
    - Reaction with water
      - Test of reactivity
        - Violent
      - H2 & hydroxide (alkali) produced
    - Form white compounds
      - NaCl
  - Transition Metals
    - High Density
    - High m.t.p.
    - Form Colored Compounds
      - coins
    - Variable Charges
      - Conveyed by roman numerals
        - eg. Fe (II)
    - Used for
      - Calalysts
      - Alloys
  - Group VII (Halogens)
    - Colored gas/vapor
    - Diatomic (i.e. two atoms, Cl2)
    - Down the Group VII
      - Color darker
      - Denser
      - B.p. higher
  - Group VIII (Noble Gases)
    - Monoatomic (exists as single atoms)
    - Unreactive -- full valency
    - B.p. higher down the group

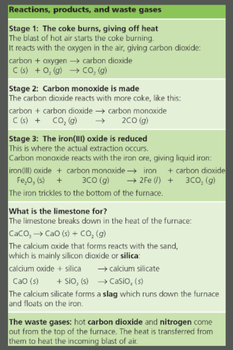
10. Metals

Iron Ore

$Fe_2O_3\,(s) + 3CO\,(g) \longrightarrow 2Fe\,(l) + 3CO_2\,(g)$



- "charge" = Iron Ore (Hematite, Fe2O3) + Limestone (CaCO3) + Coke (C)
  - Pig Iron (impure w/ C & sand)
    - poss. Cast Iron: Hard but Brittle



Reactions, products, and waste gases

Stage 1: The coke burns, giving off heat
The blast of hot air starts the coke burning.
It reacts with the oxygen in the air, giving carbon dioxide:

carbon + oxygen → carbon dioxide
$C\,(s) + O_2\,(g) \longrightarrow CO_2\,(g)$

Stage 2: Carbon monoxide is made
The carbon dioxide reacts with more coke, like this:

carbon + carbon dioxide → carbon monoxide
$C\,(s) + CO_2\,(g) \longrightarrow 2CO\,(g)$

Stage 3: The iron(III) oxide is reduced
This is where the actual extraction occurs.
Carbon monoxide reacts with the iron ore, giving liquid iron:

iron(III) oxide + carbon monoxide → iron + carbon dioxide
$Fe_2O_3\,(s) + 3CO\,(g) \longrightarrow 2Fe\,(l) + 3CO_2\,(g)$
The iron trickles to the bottom of the furnace.

What is the limestone for?
The limestone breaks down in the heat of the furnace:

$CaCO_3 \longrightarrow CaO\,(s) + CO_2\,(g)$

The calcium oxide that forms reacts with the sand, which is mainly silicon dioxide or **silica**:

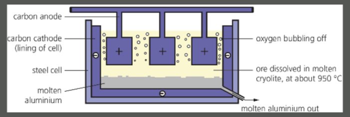
calcium oxide + silica → calcium silicate
$CaO\,(s) + SiO_2\,(s) \longrightarrow CaSiO_3\,(s)$

The calcium silicate forms a **slag** which runs down the furnace and floats on the iron.

The waste gases: hot **carbon dioxide** and **nitrogen** come out from the top of the furnace. The heat is transferred from them to heat the incoming blast of air.

Aluminum Ore

- $2Al_2O_3\,(l) \longrightarrow 4Al\,(l) + 3O_2\,(g)$
- Main ore: Bauxite (impur. Sand & Fe2O3)
- Impurities removed = Alumina (Al2O3)
- Electrolysis = Al
- Carbon Cathodes & Anodes
- M.t.p. 2045°C (incredibly expensive)
  - Dissolved in molten cryolite



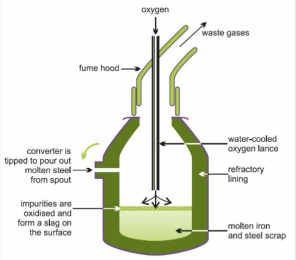
- Cathode (-)
  - $4Al^{3+}\,(l) + 12e^- \longrightarrow 4Al\,(l)$
- Anode (+)
  - $6O^{2-}\,(l) \longrightarrow 3O_2\,(g) + 12e^-$
  - $C\,(s) + O_2\,(g) \longrightarrow CO_2\,(g)$

Zinc Blend

- $ZnO\,(s) + CO\,(g) \longrightarrow Zn\,(s) + CO_2\,(g)$
  - zinc + slag of impurities
  - separated via fractional distillation
  - less pure than electrolysis
- $Zn^{2+}\,(aq) + 2e^- \longrightarrow Zn\,(s)$ (reduction)
  - electrolysis
  - Melted @ 1975°C
  - Dissolved in H2SO4
    - insoluble in water
    - ZnO basic, so neutralized to ZnSO4

Steel

- Mild Steel
  - Iron + Tiny amount of C
  - Hard & Strong
    - Buildings, ships, cars, machinery
- Stainless Steel
  - Hard & Rustproof
    - Cutlery
- Oxygen Converter



  - Molten Iron + Oxygen
  - Waste gas: CO2 & SO2 (Oxidized impurities)
  - Slag: CaO react w/ P2O5 (Skimmed off)

Alloys

- Mixture of Metals
  - Mixed when Molten
  - Properties altered

General Metallic Properties

- *Physical*
  - **Strong**
  - **Malleable** Hammered into shape
  - **Ductile** Drawn into wires
  - **Sonorous** Making a ringing sound
  - **Dense** Mass / Volume
- *Chemical*
  - Form Salts w/ Acids
  - Form Oxides w/ O2
  - Positive ions

Reactivity Principles

- Test by reaction with carbon / water / acid
- More reactive is ...
  - Reacting to Displace a less reactive metal
  - Competing to form Oxides
  - More inclined to form Ions

Reactivity Series

- Potassium
- Sodium
- Calcium
- Magnesium
- Aluminum
- Carbon
- Zinc
- Iron
- Lead
- Hydrogen
- Copper
- Silver
- Gold

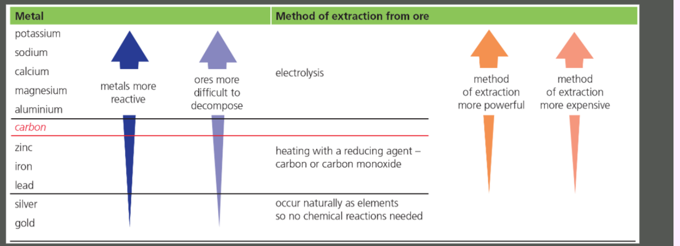
Please Stop Calling Me A Cute Zebra -- I Like Her Call Smart Goat

Applications

- **Thermite Process**
  - Repair / Join rail lines
  - $Fe_2O_3(s) + 2Al\,(s) \longrightarrow 2Fe\,(l) + Al_2O_3\,(s)$
- **Making Simple Cells** Higher voltage if larger difference in reactivity
- **Sacrificial Protection** e.g. Zn more reactive than Fe, so used in boats to prevent Fe rusting
- **Galvanizing** Coating another metal thro. electrolysis to prevent air/moisture

Extracting Metal from Metal Ores

- Unreactive metals -- occur naturally (separate physically)
- Metal Compound -- reduction --> Metal
- Reactive metals = stable compounds = electrolysis needed Expensive ∵ electricity used
- Less Reactive metals = less stable compounds = displacement react.

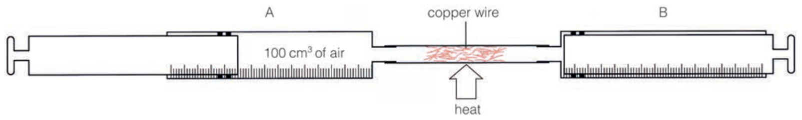


Metal	Method of extraction from ore
potassium sodium calcium magnesium aluminium	electrolysis
carbon	
zinc iron lead	heating with a reducing agent – carbon or carbon monoxide
silver gold	occur naturally as elements so no chemical reactions needed

11. Air and Water

Air

- Composition
  - 78% N
  - 21% O
  - A little bit of everything else (CO2, noble gas, ...)
  - Not always dry — Usually water vapor: H2O (g)
  - Not always clean — Pollutants like CO, SO2 — from power stations, factories, traffic, etc.
- We Need O2
  - Respiration — glucose + oxygen --> carbon dioxide + water (+ energy)



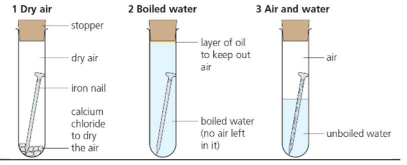
  - Measured by
    - 1. Heat (CuO produced)
    - 2. Alternate pushing A and B
    - 3. Stop heating & read volume
    - 4. Repeat until volume same
- Utilizing Air
  - Fractional Distillation = air into different columns
  - Oxygen
    - Hospitals: oxygen masks
    - Steel Work: Impure iron -- blast furnace --> Steel
    - + C2H2 (acetylene) ===> Fuel for welding/cutting metal
  - Nitrogen
    - Freeze liquid in cracked pipes to fix them
    - Food packaging since it is unreactive
  - Noble Gas
    - Neon: advertising signs
    - Helium: fill balloons (light & safe)

Pollutants

- Source
  - Burning Fossil Fuels (coal, petroleum, crude oil) — Most are hydrocarbons (C and H only)
- Examples
  - CO2 & CH4
  - CO
    - Incomplete combustion (C with not enough O2)
    - Reacts with hemoglobin in blood --> oxygen starvation
  - SO2
    - Burning of sulfur compounds (esp. power stations)
    - Causes respiratory problems & acid rain
  - NO and NO2
    - N and O reacts together (e.g. cars)
    - Causes respiratory problems & acid rain
- Solution
  - **Catalytic Converters for Cars**
    - *Catalysts of transition elements*
    - Redox
      - Reduction — $2NO\ (g) \longrightarrow N_2\ (g) + O_2\ (g)$
      - Oxidation — $2CO\ (g) + O_2\ (g) \longrightarrow 2CO_2\ (g)$

Rusting

- Rusting
  - Corrosion of Iron & Steel
    - $4Fe\ (s) + 3O_2\ (g) + 4H_2O\ (l) \longrightarrow 2Fe_2O_3.2H_2O\ (s)$
    - iron + oxygen + water ⟶ hydrated iron(III) oxide (rust)
- Experiment



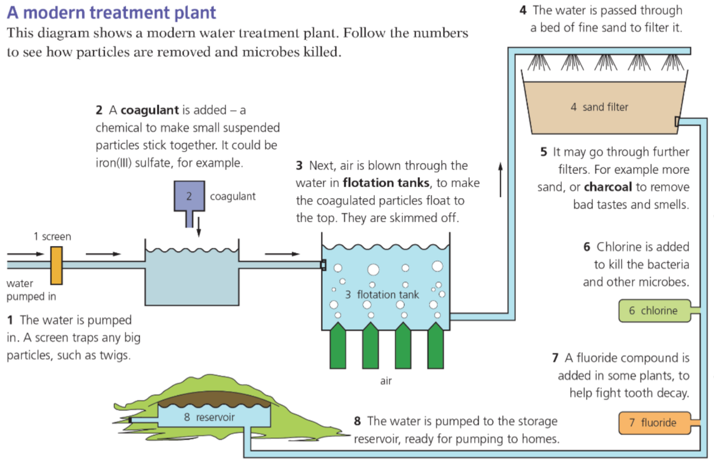
- Prevention
  - **Paint** — Bridges & Railings
  - **Grease** — Tools & Machine parts
  - **Galvanizing** — Coating w/ Zn
  - **Sacrificial Protection**
    - Let another metal corrode instead
    - Rusting = oxidation
    - More reactive metal = oxidized first
  - ***Keep air/water out***

Water

- Provision

A modern treatment plant

This diagram shows a modern water treatment plant. Follow the numbers to see how particles are removed and microbes killed.



1 The water is pumped in. A screen traps any big particles, such as twigs.

2 A **coagulant** is added – a chemical to make small suspended particles stick together. It could be iron(III) sulfate, for example.

3 Next, air is blown through the water in **flotation tanks**, to make the coagulated particles float to the top. They are skimmed off.

4 The water is passed through a bed of fine sand to filter it.

5 It may go through further filters. For example more sand, or **charcoal** to remove bad tastes and smells.

6 Chlorine is added to kill the bacteria and other microbes.

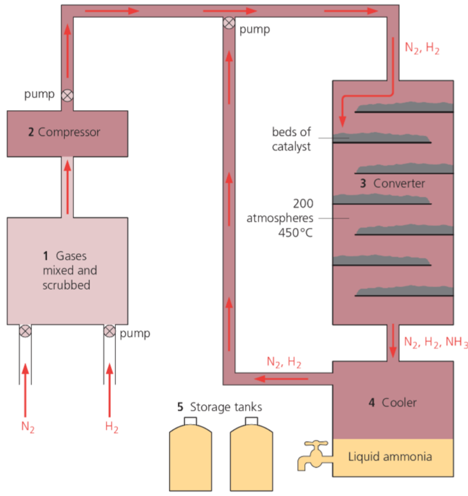
7 A fluoride compound is added in some plants, to help fight tooth decay.

8 The water is pumped to the storage reservoir, ready for pumping to homes.

- Two Tests
  - ***water present***
    - Anhydrous Cu2SO4 (white) turns blue
    - CoCl2 paper (blue) turns pink
  - ***pure water***
    - Melts at 0°C & Boils at 100°C

Nitrogen & Fertilizers

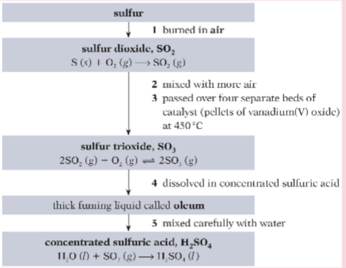
- Nitrogen
  - Colorless, odorless, unreactive gas
- Ammonia
  - $N_2\ (g) + 3H_2\ (g) \rightleftharpoons 2NH_3\ (g)$
  - Reversible Reaction
  - Used for fertilizers



- Haber Process
  - 1. N2 + H2 (from Methane + Steam)
  - 2. 200 a.t.p
  - 3. Converter of 450°C
  - ***compromise conditions***
    - lower temp = high yield but too slow
    - higher a.t.p. (>200) = expensive & unsafe
- Fertilizers
  - Substances added to soil to improve its quality
  - Plants need N, K, and P
  - e.g.
    - $NH_3\ (aq)$ ammonia + $HNO_3\ (aq)$ nitric acid $\longrightarrow$ $NH_4NO_3\ (aq)$ ammonium nitrate
    - $2NH_3\ (aq)$ ammonia + $H_2SO_4\ (aq)$ sulfuric acid $\longrightarrow$ $(NH_4)_2SO_4\ (aq)$ ammonium sulfate
  - But
    - Helps algae grow in rivers
    - N ions in drinking water bond w/ hemoglobin

12. Sulfur

- Sulfur
  - Location
    - Found near Volcanoes as S
    - PbS in metal ores
    - S-compounds in fossil fuels
  - Extraction
    - H2S = impurity in CH4
  - Properties
    - Two Allotropes
  - Uses of SO2
    - Produce H2SO4
    - Food preservative for dried fruits / jam
- Sulfuric Acid
  - Contact Process
    - Input
      - S/SO2, Air, Water
    - Process



sulfur

1 burned in **air**

sulfur dioxide, SO_2

$S(s) + O_2(g) \longrightarrow SO_2(g)$

2 mixed with more air

3 passed over four separate beds of catalyst (pellets of vanadium(V) oxide) at 450 °C

sulfur trioxide, SO_3

$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

4 dissolved in concentrated sulfuric acid

thick fuming liquid called **oleum**

5 mixed carefully with water

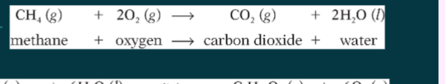
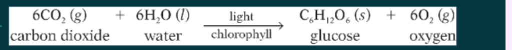
concentrated sulfuric acid, H_2SO_4

$H_2O(l) + SO_3(g) \longrightarrow H_2SO_4(l)$

- 450°C = compromise
  - Catalyst needs > 400°C
  - Exothermic Reversible Reaction (↓Yield when ↑T)
- Uses of H2SO4
  - Paints / Pigments
  - Soaps & Detergents

13. Carbonates

Carbon Cycle

- CO2 added by Respiration & Combustion
  - 
    $C_6H_{12}O_6\ (aq) + 6O_2\ (g) \longrightarrow 6CO_2\ (g) + 6H_2O\ (l)$
    glucose + oxygen ⟶ carbon dioxide + water
  - 
    $CH_4\ (g) + 2O_2\ (g) \longrightarrow CO_2\ (g) + 2H_2O\ (l)$
    methane + oxygen ⟶ carbon dioxide + water
- CO2 removed by Photosynthesis
  - 
    $6CO_2\ (g) + 6H_2O\ (l) \xrightarrow[\text{chlorophyll}]{\text{light}} C_6H_{12}O_6\ (s) + 6O_2\ (g)$
    carbon dioxide water glucose oxygen

Carbon Compounds

- CO2
  - Colorless, odorless
  - Heavier than air
- CO
  - From Combustion in insufficient oxygen
  - Deadly poisonous gas (bonds w/ hemoglobin)
- CO3
  - Carbonates, e.g. CaCO3
  - React w/ acids –> salt + H2O + CO2
- CH4
  - Natural gas (as fuel)
  - When Bacteria break down plants wo/ O2

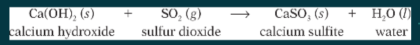
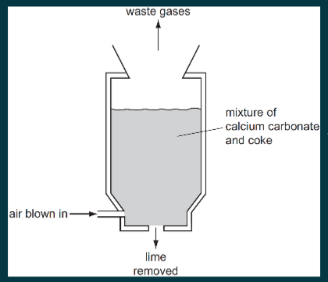
Climate Change

- Greenhouse Gases (e.g. CO2, CH4) traps heat in the atmosphere
- ↑CO2 ∵ ↑Burning of fossil fuels
  - Can't escape atmosphere
  - Only a little bit dissolved by ocean
- ↑CH4 ∵ ↑Farming(Animal & Plant)

Limestone (CaCO3)

Heat (Thermal Decomposition)

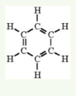
heat w/ clay

- Uses
  - CaO
    - Producing Steel from Fe
    - Neutralize acidic soil
    - Drying agent
  - *Add H2O*
  - Ca(OH)2
    - Neutralize acidic soil
    - Neutralize lakes w/ acidic rain
    - Flue gas desulfurization
      - 
        $Ca(OH)_2\ (s) + SO_2\ (g) \longrightarrow CaSO_3\ (s) + H_2O\ (l)$
        calcium hydroxide sulfur dioxide calcium sulfite water
  - Cement
    - Concrete
- Processes
  - 

14-1. Organic Chemistry (1)

Names of Compounds

- **Empirical Formula** — Simplest Ratio of atoms (from observ. or exp.) — e.g. CH
- **Molecular Formula** — Considering Chemical Bonding in a molecule — e.g. C6H6
- **Structural Formula** — Showing how atoms are arranged in a compounds — e.g.



- Prefix
  - 1 (C) — **Meth-**
  - 2 (C) — **Eth-**
  - 3(C) — **Pent-**
  - 4 (C) — **But-**

Most Elephants Prefer Bananas

Fuels

- Fossil fuels
  - **Petroleum (Crude Oil)**
  - **Coal**
  - **Natural Gas**

Organic Compounds
- Contain C, and usu. H
- Most are Hydrocarbons (Contain C and H only)

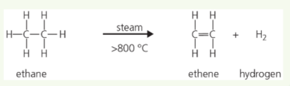
Refining Petroleum

- Refining = Grouping by molecule size
- How? — Fractional Distillation
- The Fractions
  - Refinery Gas — Bottled for Cooking & Heating
  - Gasoline — Fuel for Automobiles
  - Naphtha — Feedstock (starting point) for Many Chemicals
  - Kerosene — Jet fuel
  - Diesel (Gas) Oil — Diesel Engines
  - Fuel Oil — Power Stations & Ships
  - Lubricating Fraction — Car Engines & Machinery
  - Bitumen — Roads & Roofs
- Patterns — More Carbons (Lower in the Fraction)
  - Large molecules (long chains of C)
  - Viscous (sticky)
  - Less Volatile
  - X Combust Easily

Really Great & Noble Kings Don't Forget Lady's Birthdays

Cracking

- Why
  - Shorter chain fractions more useful (e.g. gasoline)
  - C=C double bond hydrocarbons produced (v. reactive)
- How — Thermal Decomposition
- E.g.

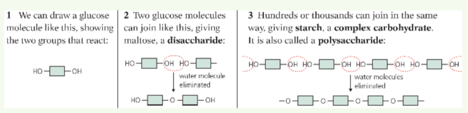


Homologous Series

- **Same Functional Group** — The part of a molecule that dictates its reactions — e.g. C=C
- Same General formula
- Similar Chemical Properties

Natural Polymers

- e.g. Starch from glucose; protein from amino acids



1 We can draw a glucose molecule like this, showing the two groups that react:

2 Two glucose molecules can join like this, giving maltose, a **disaccharide**:

3 Hundreds or thousands can join in the same way, giving **starch**, a **complex carbohydrate**. It is also called a **polysaccharide**:

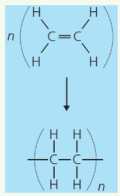
- Digesting Polymers — Polymers -- Hydrolysis --> Monomers

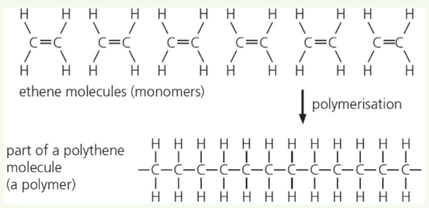
Synthetic Polymers

- Manmade
- e.g. Nylon, Terylene
- Plastic
  - Properties
    - Insulator & Unreactive
    - Light to carry
    - Strong / Not brittle
  - Problems
    - Choke birds & clog up drains
    - Blow into trees & beach
    - Non-biodegradeable
- General Uses
  - Plastic bags/gloves
  - Insulator/Food Packaging
  - Ropes/cloths

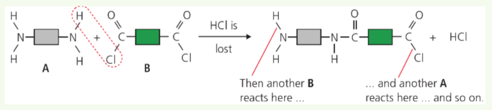
Polymers

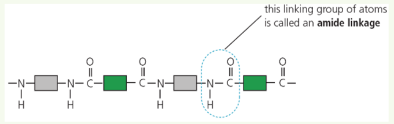
- Very large molecules, the combination of many small molecules
- **Polymerization**
  - Monomers --> Polymers — Thousands of small molecules (monomers) join to form a very large molecule (polymer)



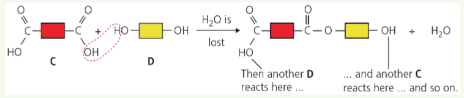


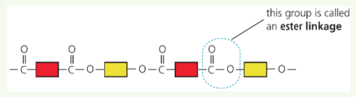
- **Addition Polymerization**
  - Molecules add on to each other
  - Monomer must have C=C double bond
- **Condensation Polymerization**
  - Two Types of Monomers, each w/ Two Functional Groups
  - Functional Groups join & a small molecule eliminated
  - e.g. Nylon





- Proteins = same amide linkage
- Nylon = Polyamide
- e.g. Terylene



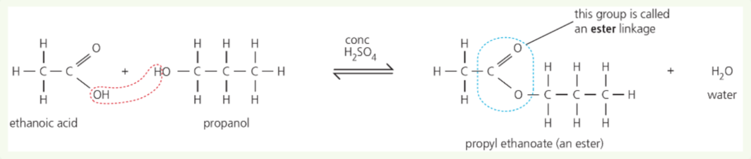


- Terylene = Polyester

14-2. Organic Chemistry (2)

Esters

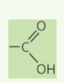
- Ethanoic Acid + Alcohols



- Condensation Reaction — Water produced
- *Alcohol part first in name (A = 1st)

Carboxylic Acids

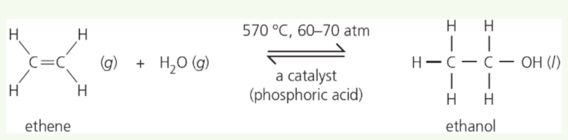
- COOH functional group



- Gen. formula: CnH2nO2
- Producing Ethanoic Acid
  - Acid Fermentation — Bacteria oxidation
  - Oxidizing Agent — Potassium Manganate(VII) KMnO4 — Purple --> Colorless

Alcohols

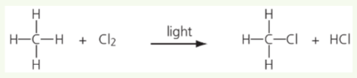
- OH functional group
- Gen. formula: CnH2n+1OH
- Ethanol — Volatile (evaporates easily) --> Good as solvent for glue/ink/perfume
- Producing Ethanol
  - $C_6H_{12}O_6\,(aq) \xrightarrow[\text{in yeast}]{\text{enzymes}} 2C_2H_5OH\,(aq) + 2CO_2\,(g)$ — Yeast (biological catalyst) stops working if temp. v. high / alcohol v. high



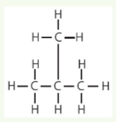
  - Hydration Reaction (water added on)
  - Reaction is fast & continuous, but oil unrenewable
- Ethanol as Fuel
  - Made cheaply (from waste plant materials)
  - Overall carbon neutral (plants counterbalances CO2 emissions)

Alkanes

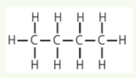
- C-C single bond — "Saturated"
- Gen. formula: CnH2n+2
- Substitution Reactions — AB + C --> A + BC
- Photochemical Reaction — (Sun)light needed to break bonds and start reaction
- example — [both substitution and photochemical]



- Isomers — Same formula but different structures
  - straight

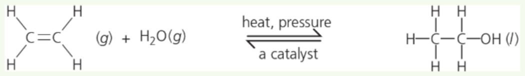


  - branched



Alkenes

- C=C double bond — "Unsaturated"
- Gen. formula: CnH2n
- Addition Reactions — A + B --> AB
- example



- Engage in Polymerization
- Testing for Saturation — If Unsaturated: Bromine water decolorizes from orange to colorless

14.Organic