Chemistry notes

Unit 1: Matter Matters
States and properties of matter
Particle/Kinetic theory
Diffusion
Pure and impure substances
Types of mixtures (solutions, oils, alloys, emulsions)
Separation techniques (filtration, distillation, chromatography)

Matter is anything that takes up space and that has mass, it is denoted by “m” and its unit is “g or grams”.

Everything is made up of particles, and every single element, compound, or mixture has atoms.

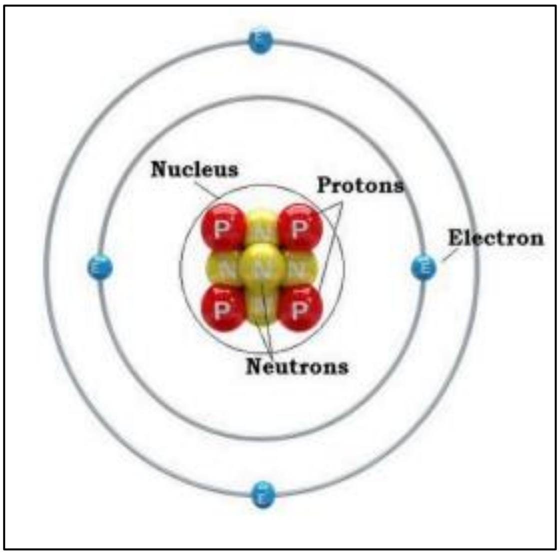
An atom is the smallest particle in the universe, and it is contained in every element.

- Elements are substances that are made from one kind of atom, a common example of it would be Oxygen.
- Compounds are made from 2 or more elements that are chemically combined.

There are a few parts of an atom (subatomic particles) that should be noted:

- **Nucleus**: Positively charged central region of an atom, it is composed of protons and neutrons.
- **Protons** are the positively charged part of an atom that is located at the centre of an atom in the nucleus, if you increase the amount protons, the atomic number will also increase.
- **Neutrons** are located in the nucleus with 0 charge or no charge. The number of neutrons can impact the stability of the element. Too many or too few neutrons can make the atom unstable. More neutrons = increase in mass number, which makes it heavier.

  to calculate the number of neutrons in an element, you must do Mass Number – Atomic Number (A-Z)
- **Electrons**: This is a subatomic particle that has a negative charge, and these are always located on the shells of an atom.

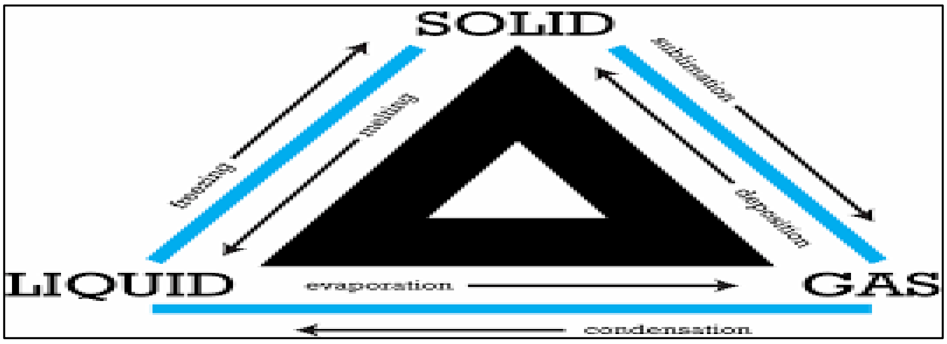


The first shell will have 2 electrons in an atom, and the others can have 8 electrons.

Valence electrons are the electrons on the outermost shell of an atom.

There are 3 states of matter
- Solid
- Liquid
- Gas

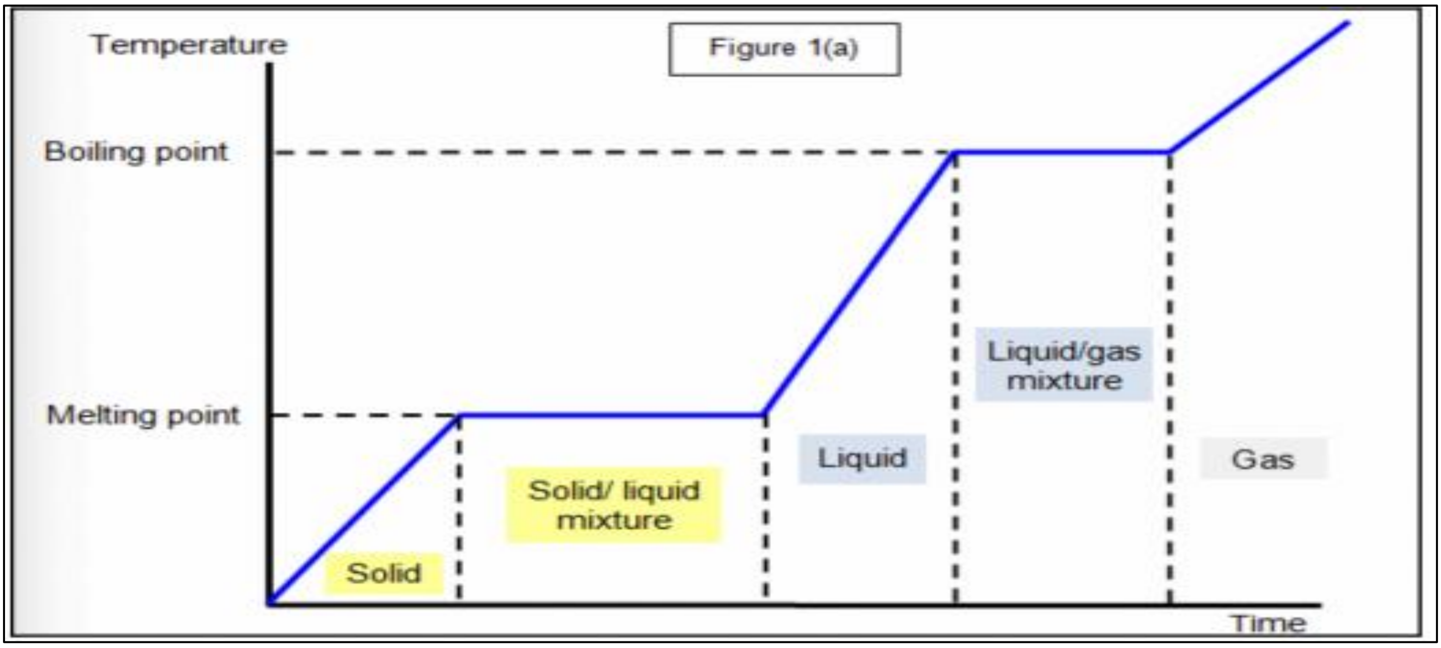
A solid has a fixed volume and a shape. The particles within the solid do not move much
A liquid has a fixed volume but not a fixed shape. The particles within a liquid experience random movement or in other words the particles move SOMEWHAT freely It takes the shape of the container you pour it into.
A gas does not have a fixed volume or shape. The particles within the gas experience very random movement. It will expand to take shape and volume of the container. It is lighter than a solid and liquid of the same volume.



Freezing: Liquid → Solid
Melting: Solid → Liquid

Evaporation: Liquid → Gas
Condensation: Gas → Liquid

Deposition: Gas → Solid
Sublimation: Solid → Gas



When a substance is heated up, its molecules move faster with greater energy. The resulting increase in collisions causes the substance to move farther away from one another, becoming less dense.

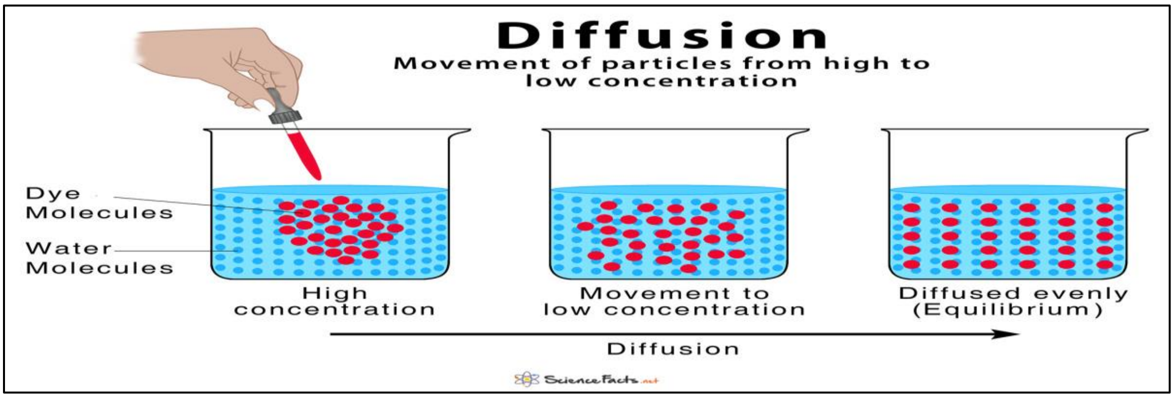
Kinetic Theory of Particles:

The kinetic particle theory is a collection of three ideas:

- A substance can be a solid, liquid or gas. And can change from state to state.
- Each state will have different characteristics.
- Each state is different in the way the particles are arranged and move.

The temperature of a substance increases when the average kinetic energy of the particles increases.
Basically, a greater number of particles moving = more collisions between particles = higher temperature.

Diffusion is when particles flow from area of more concentration to an area of less contractions until all the particles are evenly distributed.



Factors affecting diffusion:

- Temperature: An increase in temperature increases the rate of diffusion as it increases the energy of the particles, enabling them to move faster.
- Concentration Difference: A higher concentration difference will result in a faster rate of diffusion, as a lot more diffusion needs to take place.
- Diffusion Distance: The shorter distance the particles have to move, the faster they will be able to diffuse.
- Mass of the molecule: The more mass a molecule has, the rate of diffusion will decrease, as a greater mass means that more energy is required to move it.

Pure and Impure Substances:

A pure substance is a substance that is only made up of one type of molecule, for example oxygen or water.

An impure substance is a substance that is made up of different type of molecules, for example Air or Salt Water.

A mixture is a material that is made up of two or more different substances that are physically combined and that can be physically separated, never chemically combined.

Types of mixtures:

- Homogenous mixture is a type of mixture that has a uniform composition
- Heterogenous mixture is a type of mixture that does not have a uniform composition

It is possible to separate components in a heterogenous mixture but not in a homogenous mixture.

Mixture	Homogeneous or Heterogeneous
Air	Homogeneous
Bronze (an alloy)	Homogeneous
Concrete	Heterogeneous
Orange juice with pulp	Heterogeneous

Alloy: A substance formed from the combination of two or more metals
Emulsion: A mixture of two substances that originally don't mix but can bind together with the aid of a chemical agent (emulsifier)
Colloid: A state in which smaller particles are dispersed throughout a fluid.

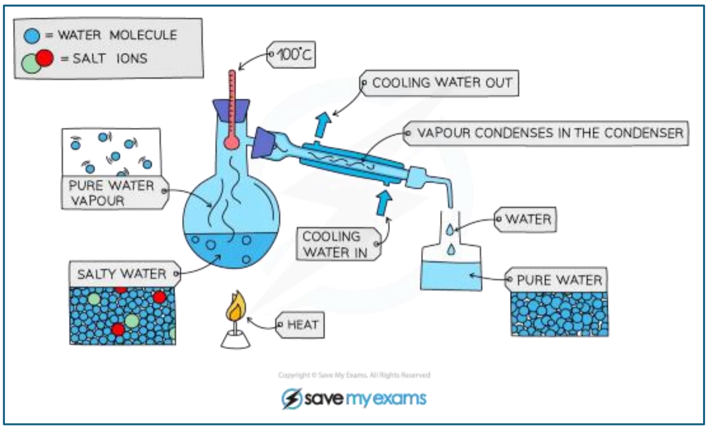
Types of separation techniques:

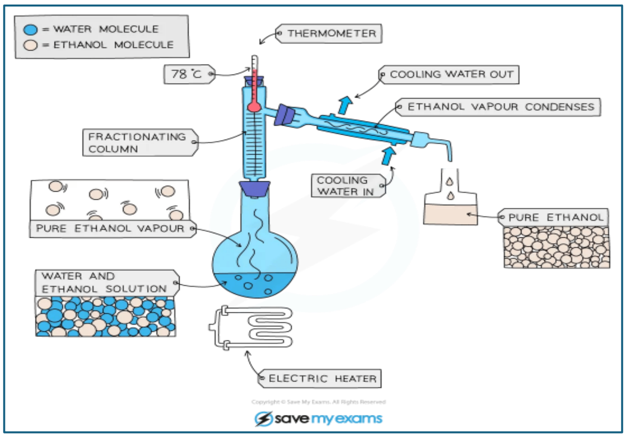
Solution – Mixture of two or more substances
Solute – Substance that is dissolved in a solution
Solvent – A substance that has the ability to dissolve a solute (normally a liquid)
soluble – able to be dissolved

Filtrate: Product of filtration
Residue: the substance that remains in the filter paper
Filtration: Used to separate an undissolved solid from a mixture of the solid and a liquid solution (eg: sand and water)
It enables the separation of insoluble solids from mixtures.
Example: Hot water with coffee being filtered to provide liquid coffee filtrate.

Crystallization: Used to separate a dissolved solid from a solution, when the solid is more soluble in a hot solvent than in cold.
This process is carried out slowly by using gentle heating or just leaving a saturated solution to evaporate so that larger crystals are formed which are easier to separate.

Simple distillation: Used to separate a liquid and a soluble solid from a solution





Fractional Distillation: Used to separate two or more liquids that are miscible with one another

Chromatography: This technique is used to separate substances that have different solubilities in a given solvent (e.g. different coloured inks that have been mixed to make black ink)

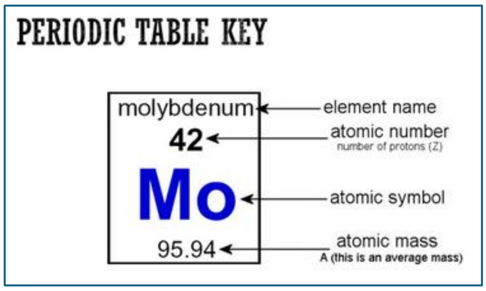
Unit 2: Small Matters?

Atomic structure (including isotopes)
Electron configuration and valency
The periodic table (metals, non-metals, transition metals, noble gases)
Periodic trends (groups and periods)
Bonding (structure and bonding, properties)

Atomic Structure

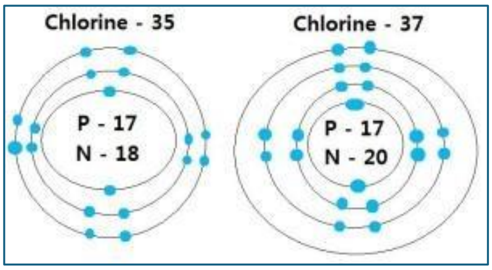
Atom is the smallest particle in the universe, it has 3 subatomic particles: electron, proton, neutron.

Electron: negative charge, Outer Shells
Neutron: No Charge, In Nucleus
Proton: Positive Charge, In Nucleus



Atomic Number = Number of Protons / Number of electrons
Mass Number = Number of Neutrons
To calculate number of neutrons do

- Mass Number (A) – Atomic Number (Z)



Isotopes are atoms of the same element with same number of protons (same atomic number) but different number of neutrons (different atomic mass). A common example of this is the Chlorine-35 and the Chlorine-37 Isotope. The '-35' or '-37' in these names indicate the mass number, and as evident from what we have seen above, we can see that the mass number/ number of neutrons has changed.

Electronic Configuration is present in every element, it is the amount of shells an element has, and the amount of electrons present in those shells. The shells are denoted by K,L,M and so on. Lets look at Oxygen for example, its atomic number is 8, so its electronic configuration would be "2,8". The first shell always has 2 electrons, then the rest have 8 electrons present. In the periodic table there are different groups (columns), there are a total of 8 columns (excluding transition metals) and these 8 columns determine the valency of the elements present, suppose for Magnesium, it is in group 2 so its valency will be 2+, which means it is able to GIVE AWAY the electrons in its outer most shell to become stable, Chlorine is in Group 7 so its valency will be 1-, which means it will TAKE 1 electron to become stable. Elements in Group 4, will be neutral, they can either GIVE AWAY electrons or TAKE electrons to become stable.

The periodic table:

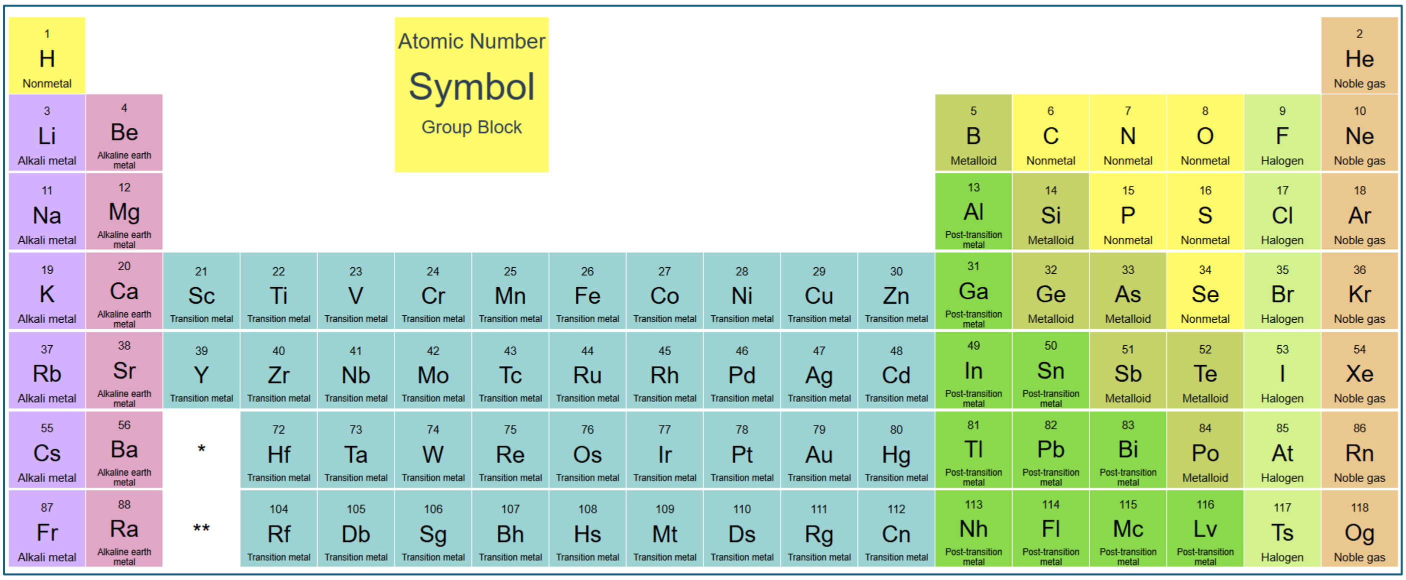
The periodic table is a table full of chemical elements, all these elements are organized by atomic number. As we go down the rows, the number of outer shells increases for each element, as we go through the columns (left to right) the atomic number increases.

Vertical Columns = Groups, symbolizes no. of electrons, elements in the same group will have the same valency.

Horizontal Rows = Periods, number of shells an element has.

Atomic number = no of protons OR no of electrons

Periodic table based on the group block.



Properties:

Group 1 (Alkali Metals): Good conductor of electricity, malleable.

Group 7 (Halogens): Highly reactive with metals, Different states at room temperature.

Group 8 (Noble Gases): No Reaction, gas at room temperature.

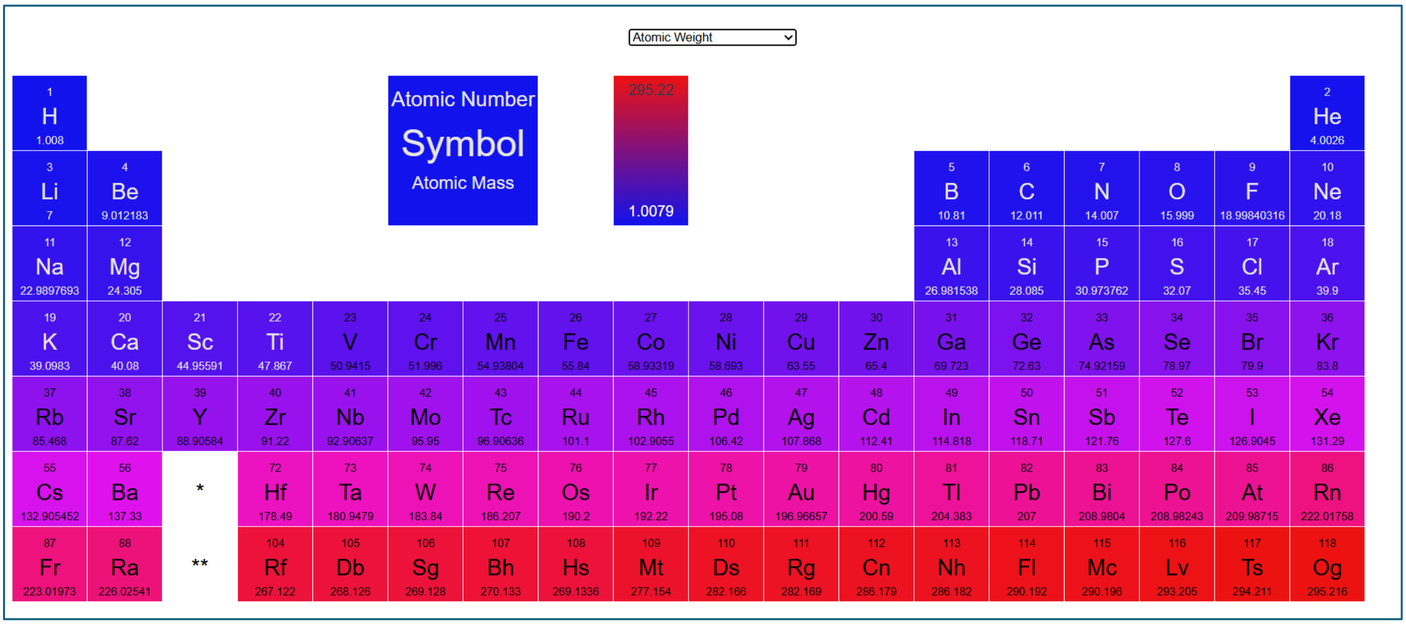
Trends:

Group 1 (Alkali Metals): MP and BP go down as you go down the group, More reactive as you go down the group

Group 7 (Halogens): MP and BP go up as you go down the group, Less reactive as you go down the group

Group 8 (Noble Gases): MP and BP go up as you go down the group, not reactive

Periodic table based on atomic mass:



Groups 1,2,3:
Form +1, +2, +3 ions. This means that for the element to become stable it will lose these electrons.

Groups 5,6,7:
Form -3,-2,-1 ions. This means that for the element to become stable, it will gain electrons.

Group 4:
Form either +4 or -4 ions, this means that for the element to become stable, it will either lose or gain the electrons.

Transition metals:
The charges always vary,
For example, it can have +2 or +3 charge, iron (ii) or iron(iii)
Generally stronger with a high melting point

Polyatomic ions:
ions made of 2 or more ions,

Formula	Polyatomic Name	Charge
SO_4	Sulphate	-2
CO_3	Carbonate	-2
CrO_4	Cromate	-2
NO_3	Nitrate	-1
OH	Hydroxide	-1
CN	Cyanide	-1
ClO_3	Chlorate	-1
HCO_3	Hydrogen carbonate	-1
PO_4	Phosphate	+3
NH_4	Ammonium	+1

Metals and non-metals:

Metals lose electrons to form cations with positive charge, Nonmetals gain electrons to form anions with negative charge. Reactivity increases down the group in groups 1 and 2

Group 1 = Alkalis:
All alkalis are bases.
Alkalis are basic substances that can be dissolved in water.
Group 1 elements are soft and are also called soft metals. They have 1 electron in their valent shell. (+1 charge)
they are highly reactive and very shiny when cut
They form oxides when they react with O2 or H2O
Density increases, boiling point and melting point decreases

Group 7 = Halogens:
They have 7 electrons in their valent shell
Melting and boiling point increases down the group
Fluorine is pale yellow and is a gas, Chlorine is yellow green and is a gas and is a gas, Bromine is red brown and is a liquid. Iodine is shiny purple and is solid, Astatine is black and is solid.
Ready to gain 1 electron (-1 charge)
Toxic as elements, but less toxic when they form ions.

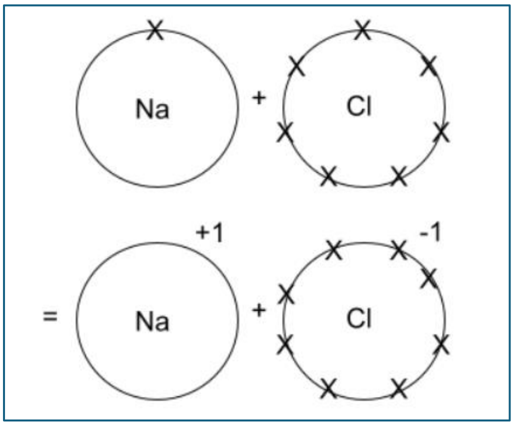
Group 8 = Noble gases
Full valence shells
completely stable
Doesn’t react
He, Ne, Ar, Kr, Xe, Rn
Colourless
Exist as atoms in nature (monoatomic)
Boiling point and density increases down the group

Transition Metals:
High melting points
Have low reactivity
Hard and have more strength
Form ions with different charges and a range of colors
Similar to each other
Some have magnetic properties
Malleable and ductile

Metals	Non-metals
Lustrous	Dull
Malleable	Non-malleable
Ductile	Non-ductile
Good conductor of heat/electricity	Bad conductor of heat/ electricity
Solid room temp (except mercury and gallium)	Solid / liquid / gas at room temp
High-density	Low-density
Positive ions (Cations)	Negative ions (Anions)
Hard	Brittle
Sonorous	(metalloids have properties from both columns)

Ionic bonding:
Ions are atoms that are positively charged or negatively charged. When electron transfer happens, atoms have more or less electrons that protons, making them ions.

- Monatomic Ion: a single ion (Helium He)
- Polyatomic ion: formed from groups of ions (Oxygen O2)



Electrostatic attraction between two oppositely charged ions

Between metals and non-metals, metal loses an electron, non-metal gains an electron

Regular repeating arrangement called an ionic lattice

All atoms want to have a full outer shell. So ionic bonding occurs when atoms exchange electrons with each other to fulfil this. Both atoms have a full valence shell.

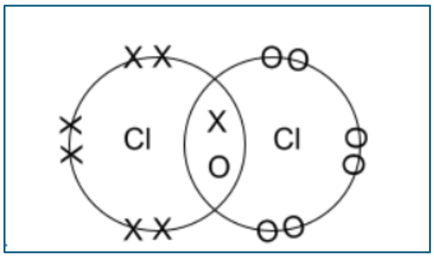
When naming an ionic compound, the metal comes first.

Atom loses electron = positively charged (vice versa)

Properties:
High MP and BPs
Ions with higher charge have higher melting point (because they have stronger electrostatic forces to overcome)
Can conduct electricity in liquid or aqueous solution
Dissolves in water
Does not dissolve in organic compounds

Covalent bonding:
Occurs between two non-metals
Share electrons with another atom instead of gaining or losing
No conductivity
Single bonds occur when there is a single pair of electrons shared (2 electrons) (weak forces, easy to break)
Double bonds occur when there is a double pair of electrons shared (4 electrons)
Triple bonds occur when there is a triple pair of electrons shared (6 electrons) (very strong, hard to break)

Properties:
Low MP and BP
Weak intermolecular forces
Do not conduct electricity
Bonds are strong
Need lots of energy needed to break them
Exist in nature as gases

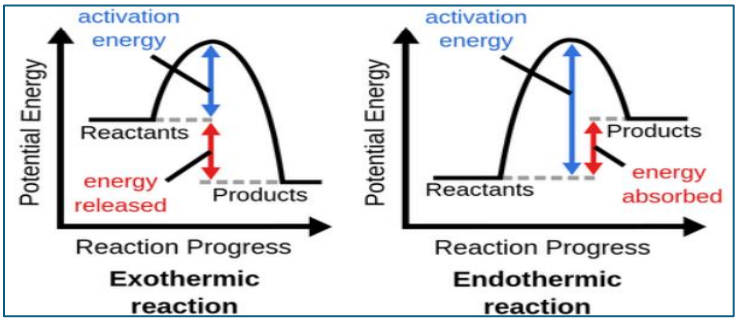


Unit 3: Energy and Development
Energy changes in reactions
Endothermic and exothermic reactions
Combustion of fuels

Exothermic reaction is a reaction that releases heat energy as the reaction happens. The solution becomes warmer.
Endothermic reaction is a reaction that absorbs heat energy as the reaction happens. The solution becomes colder.

Example: Men are warming themselves by the fire. Explain why wood releases energy.

- Burning wood releases energy as combustion is an exothermic reaction, it releases heat, increasing the temperature, allowing people in the image to warm themselves up.



Exothermic	Endothermic
Combustion Respiration Neutralization Dissolving acids Dissolving alkalis Rusting Oxidation of metals Nuclear reaction	Thermal Decomposition Dissolving some ionic salts in water, like ammonium chloride, potassium nitrate and copper (II) sulphate etc. Photosynthesis Action of light on a silver bromide

Red arrow in the diagram is ΔH
Enthalpy change is the name given to the amount of heat evolved or absorbed in a reaction.

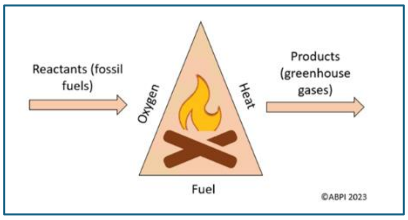
Negative value is energy released (exothermic)
Positive value is energy absorbed (endothermic)

Activation energy is the required amount of energy needed for the reaction to occur

A catalyst may work by lowering the activation energy for a reaction.

Combustion, otherwise known as burning, involves the reaction of a hydrocarbon and oxygen to produce carbon dioxide and water.

If there is sufficient oxygen, carbon dioxide is produced, this is known as complete combustion.
If there is not enough oxygen, carbon monoxide is produced. This is known as incomplete combustion.



Complete: $CxHy + O_2 \rightarrow CO_2 + H_2O$
Incomplete: $CxHy + O_2 \rightarrow CO + H_2O$

Unit 4: Let's Count
Chemical formulas
Chemical reactions and the conservation of mass
Balancing equations
The mole concept and chemical calculations

Diatomic elements: (Elements that always come as 2 atoms together)
HOBrINCl
Hydrogen (H_2), Oxygen (O_2), Bromine (Br_2), Iodine (I_2), Nitrogen (N_2), Chlorine (Cl_2)

Relative atomic mass is calculated using the equation:

$$A_r = \frac{(\% \text{ of isotope } 1 * \text{mass of isotope } 1) + (\% \text{ of isotope } n * \text{mass of isotope } n}{100}$$

So in the case of chlorine (Chlorine-35, 75% and Chlroine-37, 25%)

$$A_r = \frac{(75*35)+(25*37)}{100} = 35.5$$

Atom economy of a reaction is a measure of the amount of starting materials that end up as useful products.

The percentage yield shows much product is obtained compared to the maximum possible mass. Atom economy of a reaction gives the percentage of atoms in reactants that form a desired product.

$$\text{Percentage yield} = \frac{\text{actual mass of product obtained}}{\text{max theoretical mass of product}} \; x\ 100$$

$$\text{Atom Economy} = \frac{\text{mass of useful product}}{\text{total mass of reactants or products}} \; x\ 100$$

Concentration is the amount of solute / volume of solute
(mass / volume)
OR
Concentration = moles / volume
Conversions: $1000cm^3 = 1\ dm^3 = 1$ litre
22.4 L of gas = 1 mole

Emprical formula:

Example

1. A compound contains 75% carbon and 25% hydrogen. What is its empirical formula?

Elements	Carbon	Hydrogen
Amount in question (% or mass)	75	25
Atomic mass (periodic table)	12	1
Number of moles = Amount in question / Atomic mass	75/12 =6.25	25/1 =25
Mole ratio (divide each number of moles by the smallest number of moles)	6.25/6.25 =1	25/6.25 = 4
Empirical formula	C	H_4

Empirical formula CH_4

2. An oxide of carbon contains 27% carbon.
What is its empirical formula?

Elements	Carbon	Oxygen
Amount in question (% or mass)	27	73
Atomic mass (periodic table)	12	16
Number of moles = Amount in question / Atomic mass	27/12 = 2.25	73/16 4.5625
Mole ratio (divide each number of moles by the smallest number of moles)	=2.25/2.25 =1	4.5625/2.25 =2
Empirical formula		CO_2

6. Saltpetre is a potassium salt. It is 13.9% nitrogen ,38.6% potassium and 47.5% oxygen. What is its empirical formula? (Hint- the table needs an extra column but you work out everything else in the same way)

Elements	Nitrogen	Pottassium	Oxygen
Amount in question (% or mass)	13.9	38.6	47.5
Atomic mass (periodic table)	14.007	39.0983	15.999
Number of moles = Amount in question / Atomic mass	13.9/14.007 = 1	38.6/39.0983 = 1	47.5/15.999 = 3
Mole ratio (divide each number of moles by the smallest number of moles)	= 1	=1	3/1 = 3
Empirical formula		KNO3	

Extension- This one has an extra twist to it!.
7.A hydrocarbon has 80% carbon and 20 %hydrogen.
a) Calculate its empirical formula.
b) When the mass of a single molecule of this compound was analysed, it was found to have a mass of 30g. What must the true (molecular) formula of this substance be?

a)

Elements	Carbon	Hydrogen
Amount in question (% or mass)	80	20
Atomic mass (periodic table)	12	1
Number of moles = Amount in question / Atomic mass	80/12 = 6.67	20/1 = 20
Mole ratio (divide each number of moles by the smallest number of moles)	6.67/6.67 = 1	20/6.67 = 3
Empirical formula		CH3

b) True molecular formula = C = 12, H3 = 3 = 12 + (3x1) = 15
(n = mass / molecular mass) = 30 / 15 = 2
CH3 x 2
C2H6

Empirical formula of a compound shows the relative numbers of atoms of each element present, using the smallest whole numbers of the atoms.
example: hydrogen peroxide's empricial formula is HO, with the ratio being 1:1

Molecular formula is the ACTUAL number of atoms of each element in a molecule
Hydrogen peroxide's actual molecular formula is H2O2, with the ratio still being 1:1.

Molecular formula: Molar Mass / Empirical Mass

Moles = grams / atomic mass

1 mole / avogradors number = 6.022×10^{23} atoms or molecules

Atoms: to convert from moles to atoms, multiple the molar amount by avogadros number. To convert from atoms to moles divide the atom amount by avogadros number.

Molecules: moles x avogadro's number

Mass = number of moles x molar mass
molar mass = mass / n
n = mass / molar mass

Unit 5: How Fast?	Unit 6: How Far?
Rates of reaction	Reversible reactions
Factors affecting rates of reaction	Dynamic equilibrium
Collision theory	Factors affecting the position of dynamic equilibrium

Different reactions take place at different rates, there are several indicators that show whether a chemical reaction has taken place:

- Colour change
- Effervescence: escape of gas from an aqueous solution and the foaming or fizzing that results from that release.
- Precipitation
- Energy change (temperature)

Reactions with oxygen can be fast (burning) or slow (rusting)

Collision theory is used to predict rates of chemical reaction, particularly for gases. The more particles in a container, the more the chances of collision between those particles. This theory helps us understand whats happening at the atomic level when reacting particles collide. For a reaction to occur:

- The reacting particles must collide with each other
- The colliding particles must have the correct orientation at the time of collision
- The particles must have the minimum kinetic energy required to initiate a reaction (activation energy)

Particles will collide more frequently if:

- There is a higher concentration
- Particles are reacting faster

Factors affect rate of reaction:

- Surface area: When a solid is powdered, the particles are exposed so there is a more chance of a collision
- Concentration: More numbers of particles result in a higher chance of collision
- Temperature: When temperature increases, the particles gain kinetic energy, so more collisions take place.

Equilibrium: a state in which opposing forces or influences are balanced
Dynamic Equilibrium: A system in a steady state since forward reaction and backward reaction occur at the same time. No overall change in the amount of products and reactants, even though the reactions are ongoing. Takes place in a closed system otherwise the products would escape

Reversible reactions are reactions that can be reversed by changing the conditions. The products formed react together to form the reactant again. Reversible reactions that happen in a closed system eventually reach dynamic equilibrium.

The position of equilibrium is said to shift to the **right** when the **forward** reaction is favoured

- This means that there is an increase in the amount of **products** formed

The position of equilibrium is said to shift to the **left** when the **reverse** reaction is favoured

- So, there is an increase in the amount of **reactants** formed

Le Chatelier's Principle can be used to predict the effect of changes in temperature on systems in equilibrium

- To make this prediction it is necessary to know whether the reaction is **exothermic** or **endothermic**
- If the temperature of the reaction **increases:**
  - The equilibrium will shift in the direction of the endothermic reaction
- If the temperature of a reaction **decreases:**
  - The equilibrium will shift in the direction of the exothermic reaction

Nitrogen dioxide molecules can dimerise and form dinitrogen tetroxide in the following equilibrium reaction:

$$2NO_2(g) \rightleftharpoons N_2O_4(g)$$

dark brown colourless

What will the colour change be if the pressure is increased? Explain your answer.

Answer:

- The number of gas molecules produced by the forward reaction = 1
- The number of gas molecules produced by the reverse reaction = 2
- An increase in the pressure will favour the reaction that produces the least number of molecules
  - This is the forward reaction
- So, the **equilibrium shifts to the right**
  - This means that the mixture will appear increasingly colourless as the concentration of N_2O_4 increases

An increase in pressure will favour the reaction that produces the least number of molecules
A decrease in pressure will favour the reaction that produces the greatest number of molecules

The haber process is the industrial process for the manufacture of ammonia from hydrogen and nitrogen. Hydrogen is obtained from the reaction of methane and steam, producing carbon monoxide as a byproduct. The hydrogen produced from this reaction also reacts with oxygen from the air, producing water and leaving nitrogen behind. The air is 77% nitrogen. These gases are then compressed and delivered to the reactor where ammonia is produced. These gases are then cooled off and ammonia is liquified, ready to be tapped off. The unused hydrogen and nitrogen are recycled back to the reactor.

Unit 7: pHun Meeting @ Endpoint
Acids and bases
Reactions of acids and bases
Salt preparation methods
Oxides
Acid rain and its treatment

An acid is a solution that has an excess of hydrogen (H+ ions). The more (H+ ions) the more acidic the solution.

Properties of an acid:

- Tastes sour
- Conducts electricity
- Corrosive
- Some acids react strongly with metals, releasing H2 (g)
- Reactions with carbonates releasing CO2 (g)
- Turns blue litmus paper red

Uses of acids:

- Acetic acid = vinegar
- Citric acid = lemons, limes and oragnes
- Ascorbic acid = vitamin C
- Car batters

Common Acids

Sulfuric Acid	H_2SO_4	Battery acid
Nitric Acid	HNO_3	Used to make fertilizers and explosives
Phosphoric Acid	H_3PO_4	Food flavoring
Hydrochloric Acid	HCl	Stomach acid
Acetic Acid	CH_3COOH	Vinegar
Carbonic Acid	H_2CO_3	Carbonated water

A base is a solution that has an excess of OH- ions or it accepts H+ ions. Forms aqueos solutions

It is also called Alkali

H+ + OH- → H2O

Properties:

- Feel Slippery
- Taste Bitter
- Corrosive- Destroy body tissue/ dissolve fatty (lipid) material
- Can conduct electricity. (Think alkaline batteries.)
- Do not react with metals.
- Neutralise solutions containing hydrogen ions (H +)
- Turns red litmus paper blue.

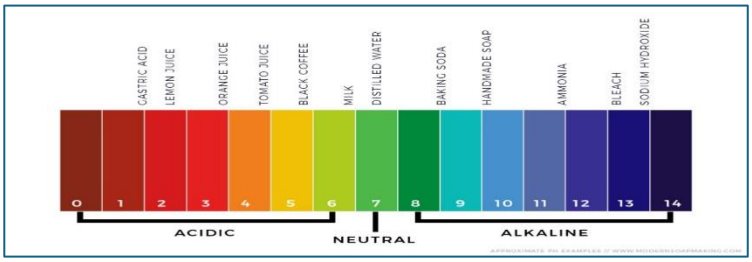
Uses of bases:

- Bases give soaps, ammonia, and many other cleaning products
- The OH- ions interact strongly with certain substances, such as dirt and grease.
- Chalk and oven cleaner are examples of familiar products that contain bases.
- Your blood is a basic solution (around pH 7.4).

The ph scale is a scale running from 0 to 14 for expressing the acidity and the alkalinity of a solution.

pH scale shows whether a substance is an acid or base or a neutral
pH scale measures the concentration of H+ ions.

pH < 7 = acid
pH > 7 = Base
pH = 7 = Neutral



Metals form oxides that are basic, but non metals form oxides that are acidic.
Sulfur and Carbon are both non metals, the react with oxygen to form sulfur dioxide and carbon dioxide, these are gases which dissolve in rain water making it acidic

PbO	Lead Oxide	Al_2O_3	Aluminum Oxide	SiO_2	Silicon Oxide
Na_2O	Sodium Oxide	B_2O_3	Boric Oxide	TiO_2	Titanium Oxide
K_2O	Potassium Oxide	Fe_2O_3	Iron Oxide	ZrO_2	Zirconium Oxide
CaO	Calcium Oxide			P_2O_5	Phosphorus Oxide
MgO	Magnesium Oxide				
BaO	Barium Oxide				
Li_2O	Lithium Oxide				
SrO	Strontium Oxide				
ZnO	Zinc Oxide				

Oxides form Metal oxides OR Nonmetal oxides
Metal oxdies can be seen as Calcium Oxide, Zinc Oxide etc.
Non metal oxides can be seen as CO2, SO2, NO2, etc

Once metal oxides react with water they form a hydroxide in the products. For example
$CaO + H_2O \rightarrow Ca(OH)_2$
In this the pH level is greater than 7 making it alkaline ($pH > 7$)

Once non metal oxides react with water they form a hydrogen. For example:

$CO_2 + H_2O \rightarrow H_2CO_3$ which makes it a carbonic acid

And in this the pH level is lower than 7 making it acidic ($pH < 7$)

Now in acids and bases there is something interesting called concentration and strength, both are not the same.

Concentration deals with the amount of hydronium ions are in the solution in the solution. Compared to the amount of water in the solution

More acid or base and less water = more concentrated

More ions and less molecules = stronger
Concentration = how much acid is there in a certain volume

Strong vs Weak Acids?
Strong acids ionize completely, all of the acid particles will dissociate (H_2SO_4, HCl, HNO_3)
Weak acid don't fully ionize (less than 5%) and not all of the acid particles dissociate completely, it is a reversible reaction. (H_3PO_4, $HC_2H_3O_2$, organic acids)

Now to identify what pH level an acid is we can use indicators.
Litmus paper (blue to red)
Phenolphthalein (colorless)
Methyl orange (orange to red)
Bromothymol Blue (Changes to yellow)

Neutralization reaction what is it?

Acid + metal oxide → Salt + water

$HCl + Na_2O \rightarrow NaCl + H_2O$

Acid + Metal Hydroxide → Salt + Water

$H_2SO_4 + KOH \rightarrow K_2SO_4 + H_2O$

Combine the negative and positive ion on the reactants side to form the salt (Cl + Na)

Acid + Metal Carbonate → Salt + Water +Carbon Dioxide

$HNO_3 + CaCO_3 \rightarrow Ca(NO_3)_2 + H_2O + CO_2$

Neutralization reaction apparatus:

1. Take a dilute acid (HCl) in a beaker
2. Heat with a Bunsen burner
3. Put insoluble base like copper oxide a little bit at a time and it will disappear.
4. Once you can see some of the insoluble copper oxide in the beaker that means it is not disappearing, and this means we have neutralized all of the acid.

Unit 8: ReDox
Oxidation
Reduction
Electrochemistry

Redox reactions are of two types: Reduction & Oxidation

1. Oxidation: gain of oxygen, loss of electron, gain of hydrogen. (GOLEGH) The atom undergoing oxidation is the reduction agent
    a. $2MgO + H_2O \rightarrow 2MgO$ (metal is oxidized)
    b. $4Al + 3O_2 \rightarrow 2Al_2O_3$ (gain of oxygen to metal)
2. Reduction: loss of oxygen, gain of electron, loss of hydrogen (LOGELH) The atom undergoing reduction is the oxidizing agent.
    a. $2MgO \rightarrow 2Mg + O_2$ (oxygen is reduced)
    b. $2Al_2O_3 \rightarrow 4Al + 3O_2$ (loss of oxygen in metal)

Oxidation
Is
Loss of Electrons

Reduction
Is
Gain of Electrons

*Most metals exist as oxides (magnesium oxide) in nature due to an abundance of oxygen, only unreactive metals exist as pure (gold)

With loss and gain of electrons, if they lose electrons we can say it has been oxidized, if it gains electrons, we can say it has been reduced.

Normally oxidation and reduction don't happen by themselves, both take place at the same time. When it happens at the same time, its called Redox reaction.

Example:

Loses electrons

Oxidized

$$Mg + 2H^+ \rightarrow Mg^{2+} + H_2$$

Reduced

Gains electrons

Displacement Reactions

A more reactive metal displacing a less reactive one.

$$- \ Ca + Fe^{2+}SO_4^{2-} \rightarrow Ca^{2+}SO_4^{2-} + Fe$$

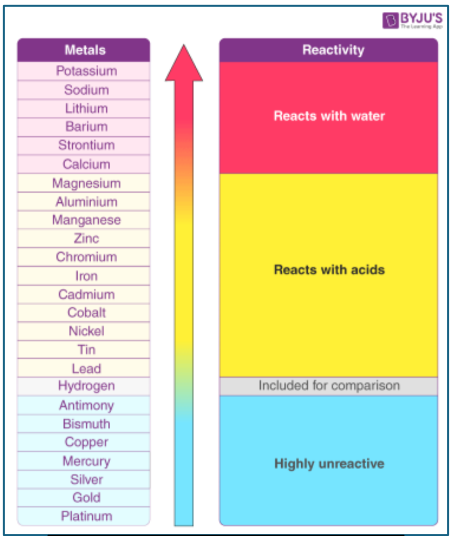
(Calcium would displace the iron to form Calcium Sulphate and the Iron will precipitate out as a solid, **CALCIUM SULPHATE ACT AS SPECTATOR IONS**)

$$- \ Ca + Fe^{2+} \rightarrow Ca^{2+} + Fe$$

(Ionic Equation, Spectator Ions got eliminated)

The second step is known as an ionic equation, which only shows the particles that take part in the reaction and changes in some way

Individual Half Equations – these show us the gain and loss of electrons
$Ca \rightarrow Ca^{2+} + 2e^-$ (loses 2 electrons, Oxidation)
$Fe + 2e^- \rightarrow Fe2^+$ (gains 2 electrons, Reduction)



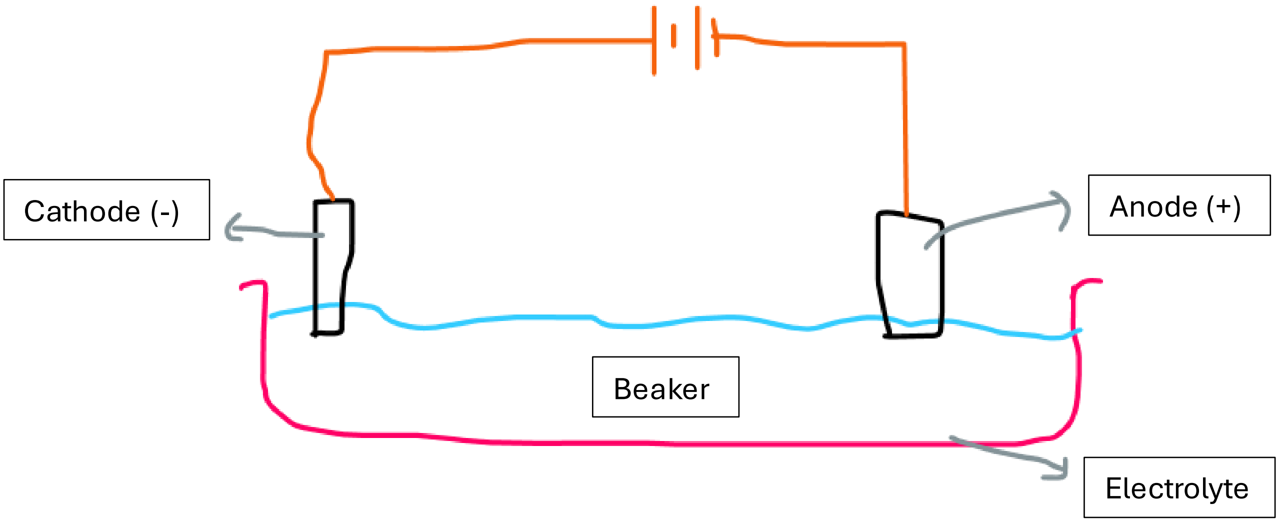
Reactivity Series Chart

Electrolysis:

It is used to separate elements in insoluble ionic compounds like Lead Bromide. Electrolysis literally means splitting up with electricity, to pass electric current through the electrolyte, like if lead bromide ($PbBr_2$) was the electrolyte then the negative bromide ions present in the beaker would be attracted to the anode and it will be discharged. It will convert from a negatively charged ion to a neutral atom, these type of atoms normally form a gas and flow up. The positive lead ions will get attracted to the cathode and get discharged and become pure lead, this will cause it to fall down and become a solid, it will form a layer of molten lead.

The ions are being oxidized and reduced at the electrodes. At the anode it will be *oxidized*:
$2Br^- \rightarrow Br_2 + 2e^-$

At the cathode it will be *reduced*:
$Pb \rightarrow Pb^{2+} + 2e^-$
Equipment Used:



Electroplating:

An electric current is passed through a solution that conducts electricity called an electrolyte, to create this current, two electrodes are dipped into the electrolyte solution and connected to a battery or a power supply.

Copper plating: We have a copper anode and a brass cathode, with a copper sulphate solution ($CuSO_4$). The electrolyte will have positively charged Copper Ions (Cu^{2+}) and Negatively charged Sulphate ions (SO_4^{2-}).
The Copper Ions will be attracted to the negative electrode (the Cathode), the copper ions will deposit onto to the brass cathode and form a thin copper plate.

The positively charged copper ions will GAIN electrons which is known as reduction:
$Cu^{2+} + 2e^- \rightarrow Cu\ (s)$

The negatively charged sulphate ions will get attracted to the positively charged copper anode. The current supplied to the anode causes the copper atoms to oxidize (lose electrons) and then dissolve into the electrolyte solution.

Electrons move from anode to cathode (positive to negative) along the wire.

Copper anode bar gradually dissolves to replenish the copper ions in the electrolyte solution. The solution will stay at the same concentration.

Loss of electrons – anode
gain of electrons – cathode

Factors to Consider: Stronger Current – Increases speed at which ions and electrons move through the circuit.
One way to increase current is to increase concentration of solution.

IN AN IONIC OR COVALENT COMPOUND, THE OXIDATION STATE IS ALWAYS 0.
For $MgSO_4$, the oxidation number of Mg is +2; oxygen is -2 and S is +6
Adding them up together gives 0: (+2) + (+6) + (4 x -2) = 0

Unit 9: Organic Chemistry
Alkanes and alkenes
Combustion and substitution reactions
Testing for alkenes
Alcohols (ethanol from ethene and sugars, biofuels)
Carboxylic acids and esters
Polymerization and plastics (natural and synthetic polymers)

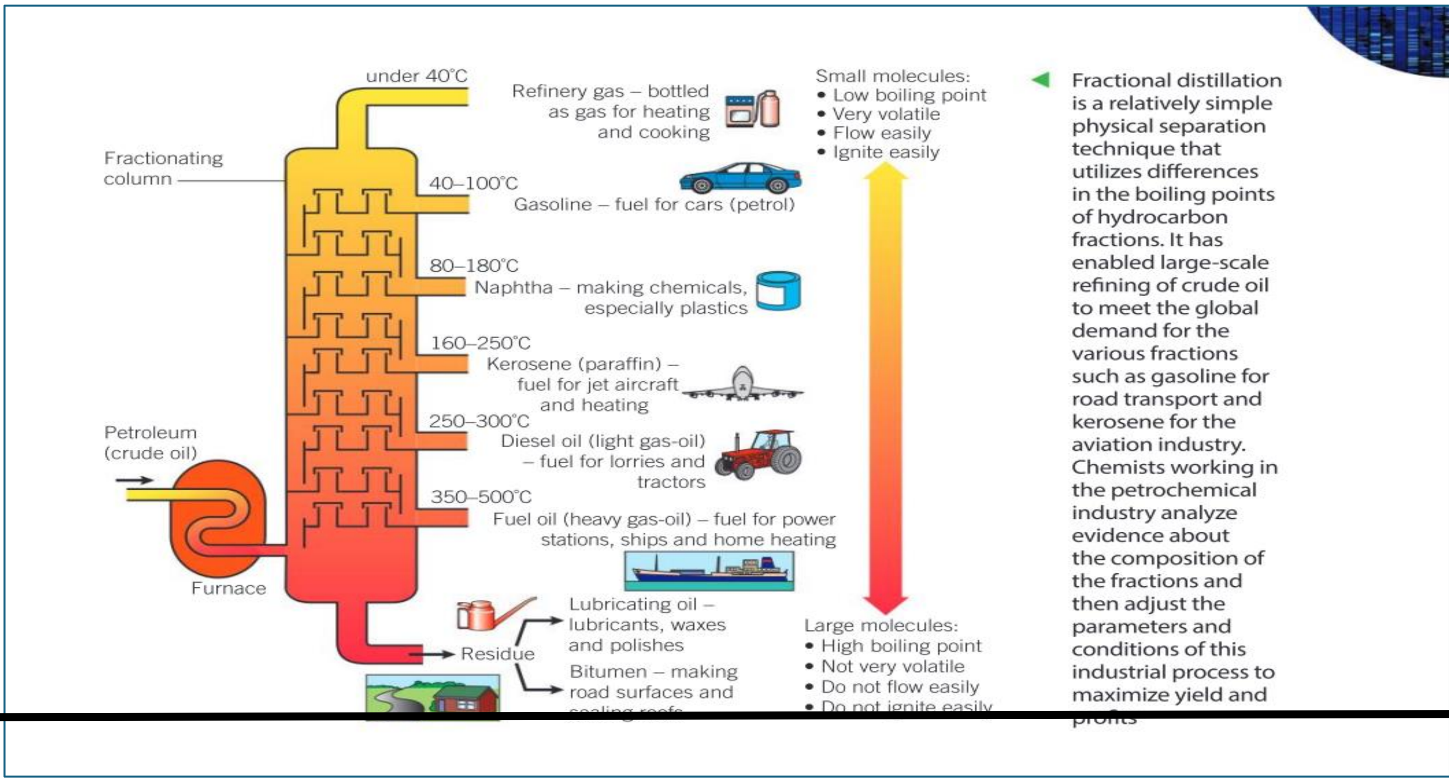
Organic Chemistry:

particularly focused in Crit A&D.

Hydrocarbon is a compound made up of **ONLY** hydrogen (H) and carbon (C).
Crude oil is unfiltered oil. It is a mixture of hundreds of hydrocarbons that need to be separated out in an oil refinery

Environmental impact of Oil Extraction: one of the main impacts would be Pollution, Oil and gas operations / drilling could release many tons of harmful pollutants in the air and therefore discharge dangerous chemicals into the water. Which will degrade the clean air of water.

Process of Crude oil extraction:



The main process used in Crude Oil mining = fractional distillation

- Mining/ Drilling
- Fractional Distillation
- Refining.

Smallest hydrocarbon chain length get collected at the top of the fractionating column
Highest hydrocarbon chain length get collected at the bottom of the fractionating column.
Carbon chain length is **directly proportional** to temperature.

---x--

<u>What is a fuel?</u> All fuels are extracted from crude oil, it is a material that is used to produce heat or power by burning/ combustion

<u>Types of fuels:</u> Liquified Petroleum Gas, Propane, Methane, CNG, Ethanol, Gasoline, etc.

<u>Method of extraction of crude oil?</u> Fractional Distillation. **Refer to separation techniques**

- Crude oil is heated, and it gets transferred to a separating column and the different components have different boiling points, the ones with lower boiling points get elevated up (in the column) and they form more gaseous states, the different components with higher boiling points gets situated at the bottom of the column and form more solid states. The reason for the elevation and the demotion is because of density and viscosity and the chain length of carbon increases, which needs more energy to overcome the forces of attraction to break the bonds.
- Viscosity & Chain length increase as they go down in the fractionating column
- Flammability decreases as the different components of crude oil go down in the fractionating column

<u>Alkanes (single covalent bonds):</u>

Methane - CH_4

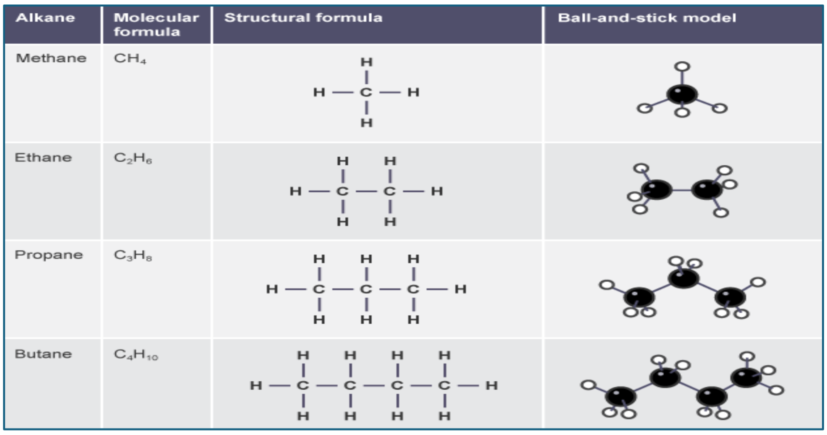
Ethane - C_2H_6

Propane – C_3H_8

Butane– C_4H_{10}

<u>Formula</u>

C_nH_{2n+2}



Pent – 5
Hex – 6
Hept – 7
Oct – 8
Non – 9
Dec – 10

<u>Physical properties:</u>

- Boiling point increases (becomes hotter) as the carbon chain length increases. (direct proportionality)
- Melting point has a general increase (becomes cooler) with the molar mass & carbon chain length increasing (direct proportionality)
- Solubility alkanes are non-polar, so these alkanes are immiscible (don't mix with) with water and they are soluble (miscible) in most organic solvents.

Alkanes usually are extracted from non-renewable fossil fuels such as unprocessed crude oil, natural gas, coal, and oil.
Alkanes undergo combustion. This is because they are reactive with the oxygen in the air (they are relatively unreactive in normal cases)
The state of matter of an Alkane can be any of the 3 but it depends on the Van Der Waal's force, all liquids come from crude oil, all solids come from coal.
As alkanes undergo combustion it is harder for the alkanes with the higher chain lengths to ignite (bigger molecules are harder to ignite).

When there is less complete combustion, we can see a yellow flame, when there is complete combustion, we can see a blue flame.
it is Saturated which means it is only carbon – carbon single bonds.

Alkenes (1 C=C double bond in the structural formula)
Only contains C and H
it is unsaturated – which means atoms can be added to the formula.
contains a C=C double bond somewhere in the structural formula.

PHYSICAL PROPERTIES ARE THE SAME.

In this case But-1-ene and But-2-ene have the same molecular formula but they have a different structural formula, this is because they are isomers.

Alkanes are saturated as they can't have more bonds which is why they are less reactive. Alkenes have double bonds which can be broken and replaced with another compound, making it more reactive.
Alkanes undergo substitution reactions as they are saturated.
Alkenes undergo addition reactions with something and form Alkane. Addition occurs as all hydrogen stays but the double bond turns into a single bond as it progresses to the products side, and it provides space for another element (when making it a product). This is why they undergo addition they turn into alkanes as they are fully saturated.

Combustion of propane reaction (Combustion of any type of hydrocarbons form carbon dioxide and water if its incomplete combustion and there's less oxygen it will produce carbon monoxide)

$C_3H_8 + O_2 \rightarrow CO_2 + H_2O$
$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

Ethane and bromine = $C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$ (Double bond between carbon breaks in the reactants side and it forms the product which is all single bonds.

Cracking is the process of dividing hydrocarbons into shorter chains through heat or pressure. Breaking long chain hydrocarbon molecules into shorter and more useful products like smaller alkanes, alkenes, and hydrogen using heat or catalyst. Naptha from the crude oil fractioning column is the main source for the long hydrocarbons.

The smaller alkanes (the ones that get divided by catalystic cracking) are normally used as fuels.
The smaller alkENEs are normally used as polymers in the plastic industry.

Catalyst – lowers activation energy, alters rate of reaction, does not use itself in the chemical reaction.

C-C and C-H singles covalent bonds are very strong and splitting them require a lot of energy.

Importance of cracking:
Cracking Produces:

- Smaller alkanes: better fuel, therefore in high demand
- Alkenes: starting material for plastics and other organic products.
- Hydrogen: used in the manufacture of ammonia by Haber process and as a fuel.

Higher Alkane → Smaller alkanes + alkenes + hydrogen

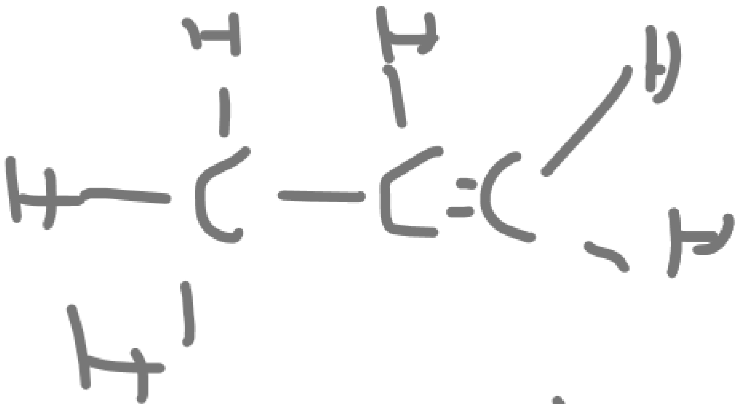
Products of cracking:

- The number of C and H atoms are conserved in cracking.
- There is no single unique reaction. Hydrocarbons break in random ways and form a mixture of shorter hydrocarbons and H2
- Any combination of alkane, alkene, and hydrogen can be made, if the numbers are balanced.

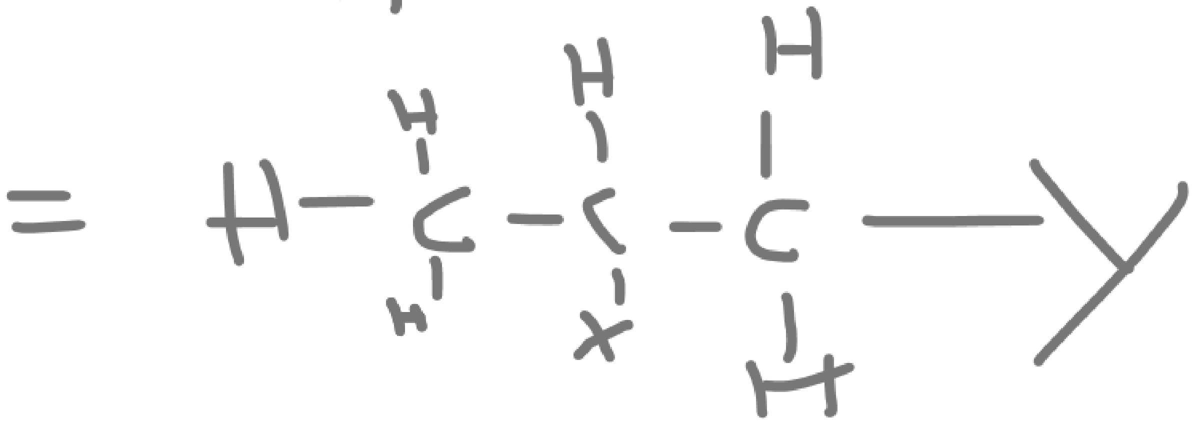
Testing for Alkenes:

Meth – 1
eth – 2
prop – 3
but – 4
pent – 5
hex – 6

Now with addition reactions for alkenes, suppose we have c3h6



C_3H_6



Carbon double bond opens up and we can **add** a new molecule to the formula.
3 types of addition reaction – water (H2O), hydrogen (H2), Halogens
Hydrogen:

$$C_3H_6 + H_2 \xrightarrow{\text{Catalyst}} C_3H_8$$

Propane (alkane)

Propene (alkene)

The double bond will break apart and the hydrogen atoms will form with the carbon atoms and it will form propane, and since the double bond broke the new compound formed is saturated

Water $C_2H_4 + H_2O \xrightarrow[\text{high temp}]{\text{Catalyst}} C_2H_5OH$

Now with this reaction, we are doing ethene + water and the product becomes an ethanol which is a type of alcohol. Now alcohols are only the ones that have the hydroxide molecule. Ethanol is a widely used type of alcohol used in industries and in day to day drinking activities in bars etc. This reaction is very common in industrial processes. Once this reaction has taken place we have to separate the ethanol from any unwanted ethene and unwanted water. The unwanted ethene is easy to separate because it has a low boiling point so we can just cool it. Once the ethene is a gas, we are left with a liquid state of ethanol and water. To separate the two we can use fractional distillation. To do this, we put the liquid state in a flask and we put a Bunsen burner underneath, then since ethanol has a low boiling point, it will evaporate up and it will then go to the fractioning column where it will condense and it will get separated into another beaker. The water will remain in the heating flask as it didn't evaporate. **ONLY FOR INDUSTRIAL PROCESSES**

Halogens:

Now if you were to take 2 tubes, one with an alkane gas and the other with an alkene gas. And if you were to add bromine water (orange colored solution of bromine) to both of them and then shake them, the alkene containing tube will become colorless while the alkane tube will remain the same.

This reaction between bromine and the alkene is called addition reaction.

$C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$

the product here is called dibromoethane. This bromine test is the main test that is used to distinguish alkenes and alkanes

Alkenes – Double bonds – more reactive
Alkanes – single bonds – less reactive compared to alkenes

Alcohols
It is another homologous series of organic compounds. In an alkane there are 2 carbon single bonds and 6 hydrogens, but in an alcohol, one of those hydrogens is a hydroxide. It will look like this.

Same prefixes as the previous homologous series. Instead of ethane we replace the final e and make it ol so it will be ethanol.

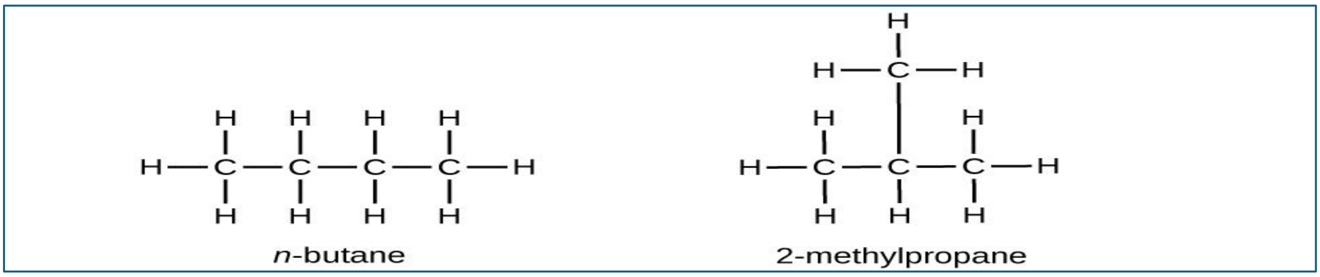
Methanol, Ethanol, Propanol, Butanol

$C_nH_{2n+1}OH$ C_2H_5OH

Properties of alcohols:
It changes as the molecules get bigger, they are flammable, soluble, and they can be oxidized to form carboxylic acids.
- They can go complete combustion in air, for example they can react with oxygen gas (O2) to form Carbon Dioxide + Water.
- Dissolve in water to form a solution, they aren't acidic, they have a neutral acid.

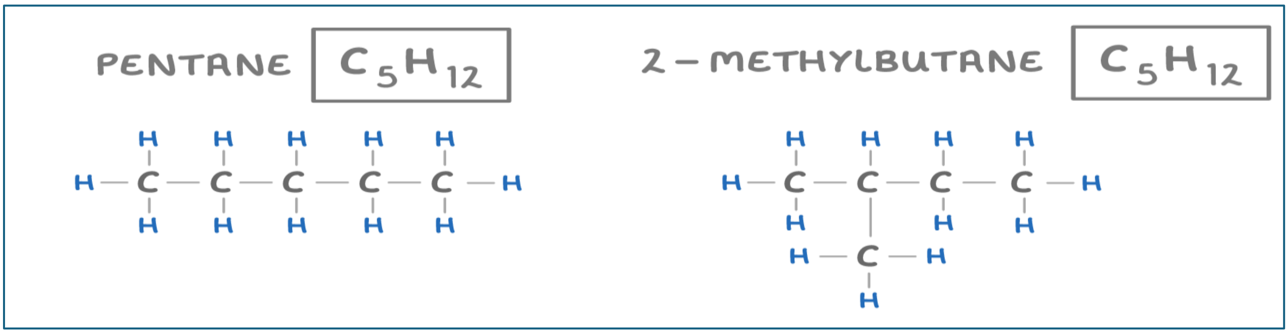
Isomerism

Isomers have the same molecular formula but different structural formula.

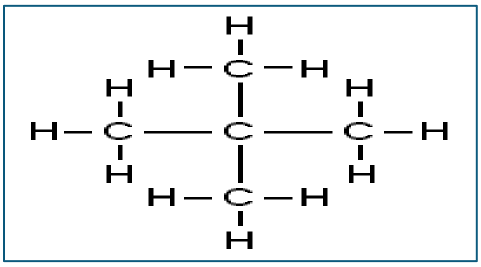


In the second chain there is a CH3 at the above part of the structural formula, this is called methyl. The entire thing with the rest of the carbons and hydrogens making it C4H10 is called a 2-methylpropane. Because the upper part of the structural formula is a CH3 so this is methyl, the below part is a propane, so we just merge the two names and it becomes 2-methylpropane. But why is there a 2? The 2 is added to the name because the methyl is connected to the second carbon in the propane.

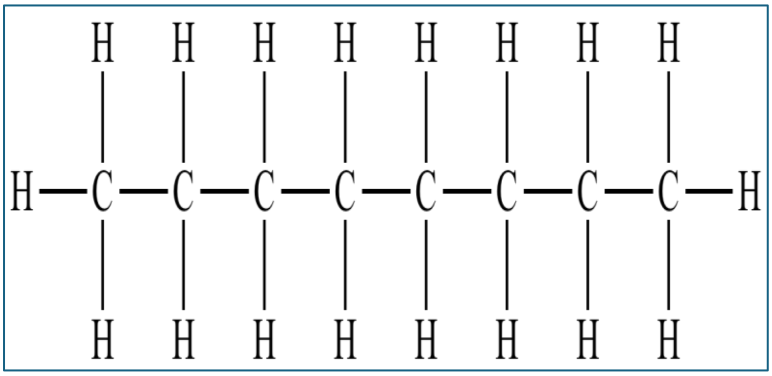
Now lets look at pentane:



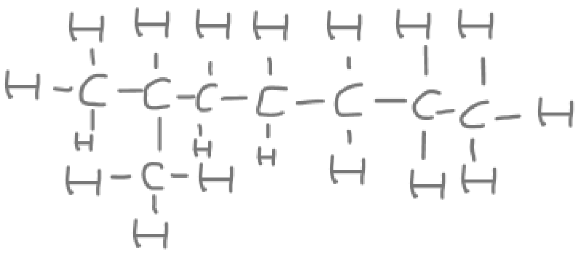
Over here you can see it is 2-methylbutane, this makes a lot of sense. But if the methyl were connected to the third carbon in the butane, it would become 3-methylbutane right? No. it would remain the same because then we would start counting from the other side (righyt hand side).



Now this structure would be 2-di-methyl propane. We add the "di" because it is a prefix for 2 (mono,di, etc). and seeing that there are 2 methyls we can do "di-methyl" and the "2" would remain the same as it is connected to the second carbon in the long chain length.



Now this is octane, the isomer for this would be 2-methylheptane



Isomer properties:

The long chain hydrocarbon molecules have more surface contact with whatever they contact with, so the BP and MP will be higher. These molecules will be more reactive because it isn't a complex structure it is a

simple structure.
Branched structures (isomeric structure) have less surface contact and the BP and MP will be lesser. The reactivity with the branched structures with these would be less reactive as it is a complex structure.

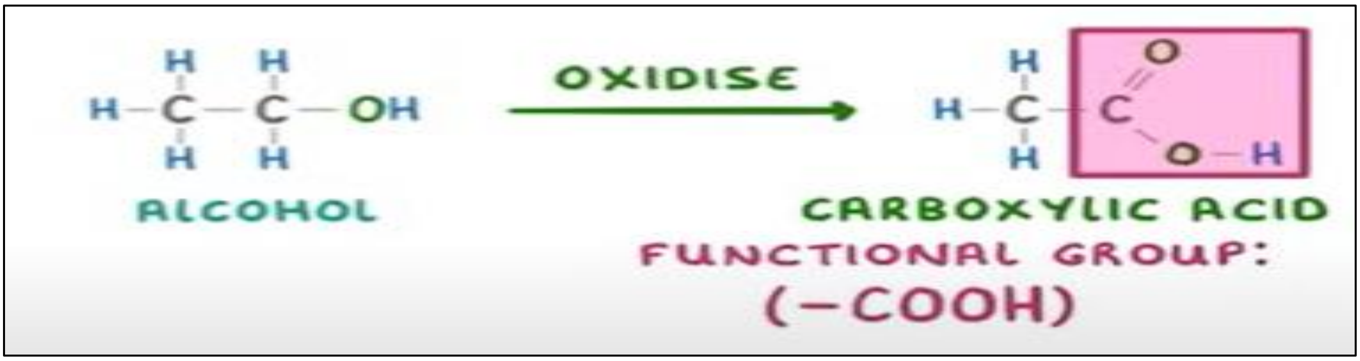
In alkenes the isomerism will be based on the different positions for the double bonds. This is called positional isomerism. The double bond closer to the end of the long chain length will be more easier to react. Compared to an isomer of an alkene that has the double bond in between the long chain length, the reactivity in this will be harder to break down and harder to react compared to the alkene with a double bond at the end of the length

HYDROCARBONS CANNOT BE AN ISOMER IF THE EXTENSION OF THE HYDROCARBON IS CONNECTED TO THE FIRST CARBON IN THE LONG CHAIN LENGTH, IT WILL REMAIN AS THE SAME NAME.
EACH CARBON SHOULD HAVE 4 BONDS IN THE CARBON CHAIN LENGTH.

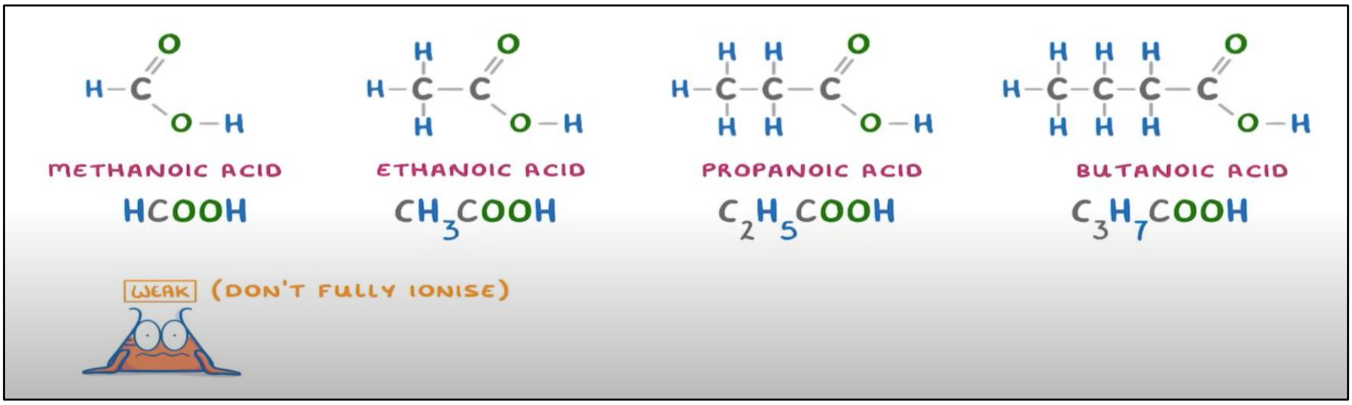
Alcohol Isomers:

Propan-1-ol: C3H7OH OR CH3CH2CH2OH

Now alcohols have 3 properties, we have previously looked at 2 of them but the 3rd one is that Alcohols can be oxidized to form carboxylic acids.



As the alcohols oxidize they form a carboxylic acid. Now carboxylic acids are a homologous series and its functional group is -COOH, this means that one oxygen is double bonded with carbon, and the other oxygen is single bonded, and the hydrogen is bonded to the single bond oxygen. The names end in 'anoic acid'.



Now linking back to the acids and bases unit, these acids are weak acids and they don't fully ionize, which means that not all Carboxylic acids release their hydrogen molecules, because of this, we show the ionization reaction like this

$$C_2H_5COOH \rightleftharpoons \underline{C_2H_5COO^-} + H^+$$

Now the underlined ion in this reaction “C2H5COO-“ is called a propanoate ion. So if a carboxylic acid looks like this, it will end with ‘anoate’.

Carboxylic acid + metal carbonate → salt +water +co2
Ethanoic Acid + Potassium carbonate → Potassium Ethanoate + Water +Co2 (example)

Carboxylic acids have several uses, for example: Vinegar contains ethanoic, Oranges and Lemons contain citric acid, Aspirin is a Carboxylic acid, Vitamin C contains ascorbic acid.

How are carboxylic acids made?
Take an alcohol and oxidize it and use an oxidizing agent and the product that is formed is carboxylic acid.

Esters have the functional group -COO- *(It is called ester link or ester group)* and they are often deemed as chemicals with pleasant smells. They are also extremely volatile which means they evaporate easily. They are commonly found in perfumes and food flavorings etc.

In order to make an ester we have to do “Carboxylic Acid + Alcohol → Ester + water”

For example in order to produce Ethyl Ethanoate (CH3COOC2H5) we would have to do Ethanoic Acid (CH3COOH) + Ethanol (C2H5OH). We would also need an acid catalyst. Now when we perform this chemical reaction the OH group in the carboxylic acid and the HYDROGEN OF THE OH GROUP in the alcohol are lost, and together these lost elements form a byproduct which is a water molecule and it gets added to the products

$CH_3COOH + C_2H_5OH \rightarrow CH_3COOC_2H_3 + H_2O$

Esterification:
Alcohols react with Carboxylic; Reaction is reversible, Esters have characteristic smells.

Polymers:

Multiple monomers combined together to form a polymer. From unsaturated monomers it forms saturated polymers.

Example:
Ethene + Ethene + ethene… → Poly(ethene)

This is called addition polymerization

Addition polymerization does not form any byproducts. To form a polymer, you can only use one type of unsaturated organic monomers like the example given above.

To name a polymer you add “poly” before the name of the monomer and then you add the monomers name in brackets after “poly”

Uses of poly(ethene) – plastic bags, plastic bottles, containers, clingfilm, plastic buckets and hoses.