Knowledge Organiser: A-Level – Unit 1: Atomic Structure

Unit 1: Atomic Structure

1. Keywords

Mass Number:	Total number of protons and neutrons (bigger no.)
Atomic number:	number of protons (smaller no.) also the number of electrons in an atom.
Isotope:	An atom that has the same number of protons but a different number of neutrons
Ionisation:	Removal of one or more electrons (endothermic)
First Ionisation Energy:	The energy needed to remove 1 electron from each atom in 1 mole of **gaseous** atoms. $M(g) \rightarrow M^+(g) + e^-$
Second ionisation energy:	The energy needed to remove 1 electron from each atom in 1 mole of **gaseous** +1 ions. $M^+(g) \rightarrow M^{2+}(g) + e^-$
Successive ionisation energies:	Removing each electron in turn from a mole of gaseous atoms. Provides evidence of energy levels and orbitals
Mass spectrometry	Technique used to calculate the mass of atoms and molecules

Key

relative atomic mass
symbol
name
atomic (proton) number

1.0
H
hydrogen
1

2. Time of Flight Mass Spec.

1	Ionisation	Sample dissolved and pushed through nozzle at high pressure and 4000v. As solvent evaporates particles gain a H+ ion
2	Acceleration	+ ions accelerated by -5000v electric field. Have a fixed kinetic energy
3	Ion drift	Region of no electric field, so drift (lighter move faster, heavier ions slower.)
4	Detection	+ ions discharge creating a flow of electrons in the detector which registers the current and plots the mass spectrum.

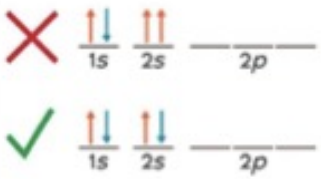
3. Rules for electron configuration

1	Aufbau "building up" principle	Electrons always fill the lowest energy level first
2	Hund's rule of maximum multiplicity (bus rule)	Electrons will fill the empty orbital of an energy level before pairing
3	Pauli's exclusion principle	When electrons pair in an orbital they have opposite spin

4. Energy levels

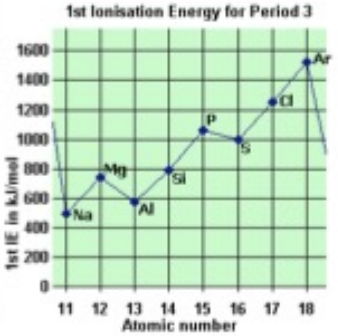
Energy level	Sub levels	Orbitals	Electrons
1	s	1	2
2	s,p	1,3	8
3	s,p,d	1,3,5	18
4	s,p,d	1,3,5	18

REMEMBER the 4s fills before the 3d (use you periodic table to remind you)



5. Drops in 1st ionisation energies across period 3

Ar	symbol	Electron config	Reason for drop?
13	Al	$3s^2\ 3p^1$	Electron is in p orbital further from nucleus to easier to remove
16	S	$3s^2\ 3p^4$	Electron is paired in 3p orbital so easier to remove



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Unit 2: Amount of substance

1. Keywords

Relative Atomic Mass: (Ar)	Average mass of an atom / $^{1}/_{12}$ th Carbon 12
Relative Molecular Mass: (Mr)	Average mass of a molecule / $^{1}/_{12}$ th Carbon 12
Relative Isotopic Mass:	Average mass of an isotope / $^{1}/_{12}$ th Carbon 12
Avogadro's constant	The number of particles that make up 1 mole of a substance.
Mole	The unit the amount of a substance is measured in. The number of particles need to make 12.00g of Carbon-12
Concentration	The amount of particles in a fixed volume. Measured in moles per litre (Mol dm^{-3})
Ideal gas	Idea gases are any gas which behaves in accordance with the ideal gas equation. It does not matter what substances are in the gas.
Empirical formula	Simplest whole number ratio of the elements in a compound
Molecular formula	The actual ratio of elements in a specific compound. Should add up to the Mr.
Balanced full equation	A balanced chemical equation showing all atoms and their relative amounts and states
Ionic equation	An equation which only shows the species which change during a chemical reaction
Spectator ions	The ions omitted from an ionic equations because they are not involved
Atom economy	Mr desired product / Mr of all reactants x100

2. Calculating moles

$$Mass = Mr \times moles$$

Mass	g
Mr	g $mole^{-1}$
moles	moles

3. Calculating concentration

$$Concentration = \frac{moles}{Volume}$$

Concentration	Mol dm^{-3}
moles	moles
Volume	dm^3

4. Ideal gas equation

$$pV = nRT$$

p	Pressure	Pa (pascals)	1 atm = 1×10^5 pa
V	Volume	m^3	$1 m^3 = 1 \times 10^6 cm^3$
n	No. of moles	Moles	
R	Boyles gas const.	J/mol K.	8.314
T	Temperature	K (kelvin)	T °C + 273

5. Ratio method for titration calculations

$$m_2 C_1 V_1 = m_1 C_2 V_2$$

m	Mole co-efficient (ratio)	
C	Concentration	Mol dm^{-3}
V	Volume	cm^3

Knowledge Organiser: A-Level – Unit 2: Amount of Substance

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Unit 3: Bonding

1. Keywords

Ionic bond	Bond formed by the transfer of electrons from a metal to a non-metal. Strong attraction between oppositely charged ions.
Covalent bond	Bond between non-metals. A shared pair of electrons
Metallic bond	Positive metal ions in a 'sea' of delocalised electrons
Macromolecular (Giant covalent)	Large covalently bonded molecule. Eg diamond, graphite, silicon dioxide
Molecular covalent molecule	Small covalently bonded molecules that are held together by intermolecular forces. Eg Iodine, water, carbon dioxide.
Co-ordinate bond	A type of covalent bond where both electrons are donated by one atom.
Bonding pair	A pair of electrons in a covalent bond
Lone pair	A pair of un-bonded electrons. Repel more than bonding pairs
Electronegativity	The power of an atom to attract the electrons in a covalent bond
Polar covalent bond	A bond with a unequal distribution of electrons due to a difference in electronegativity of the bonding atoms
Intermolecular forces	The forces between molecules. They are responsible for the trends in melting and boiling points of substances

2. Common anions

Sufate	SO_4^{2-}	Hydroxide	OH^-
Carbonate	CO_3^{2-}	Ammonium	NH_4^+
Nitrate	NO_3^-		

3. Intermolecular forces

Increasing strength

Van der Waals	Temporary dipoles induce complimentary dipoles in neighbours	Happens in all molecules	Eg. Alkanes
Permanent dipole- dipole	Attraction between slightly positive and negative ends of bond	Happens in any asymmetric bond with different electronegativity	Eg. Hydrogen chloride
Hydrogen bonding	Attraction between slightly positive and negative ends of bond	Happens when H bonded to O, N, F only	Eg. Water, Ammonia, Alcohol

4. VSEPR molecular shapes

Electron pairs	Geometry	Bonding pairs	Lone pairs	Shape	Angle	Example
2	Linear	2	0	Linear	180	$BeCl_2$
3	Trigonal planar	3	0	Trigonal planar	120	SO_3
4	Tetrahedral	4	0	Tetrahedral	109.5	CH_4
		3	1	Trigonal pyramidal	107	NH_3
		2	2	V-shape	104.5	H_2O
5	Trigonal bipyramidal	5	0	Trigonal bipyramidal	120, 90	PCl_5
		4	1	See-saw	120, 90	$TeCl_4$
		3	2	T-shape	87.5	ClF_3
6	Octahedral	6	0	Octahedral	90	SF_6
		4	2	Square planar	90	ICl_4^-

Knowledge Organiser: A-Level – Unit 3: Bonding

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Unit 4: Enthalpy

1. Keywords

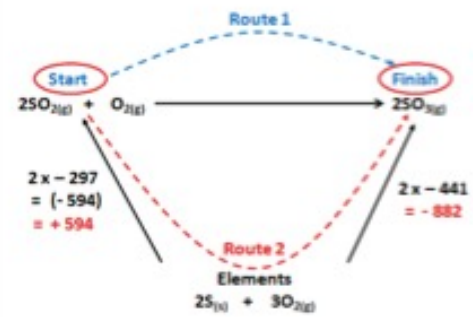
Enthalpy change ΔH	Heat energy change at constant pressure
Standard enthalpy change ΔH_{298}°	Enthalpy change under standard conditions eg 100Kpa and 298K
Standard enthalpy change of formation $\Delta_f H^{\circ}$	The enthalpy change when one mole of substance is formed from it's elements under standard conditions
Standard enthalpy change of combustion $\Delta_c H^{\circ}$	The enthalpy change when one mole of substance is completely burnt in oxygen. Reactants and products in their standard states under standard conditions.
Calorimetry	The process of measuring the heat from a chemical reaction
Hess' law	The enthalpy change of a reaction is independent of the route taken
Mean bond enthalpy	The average enthalpy change when one mole of a specific bond is broken in a range of different **gaseous** compounds

2. Calorimetry

$$q = mc\Delta T$$

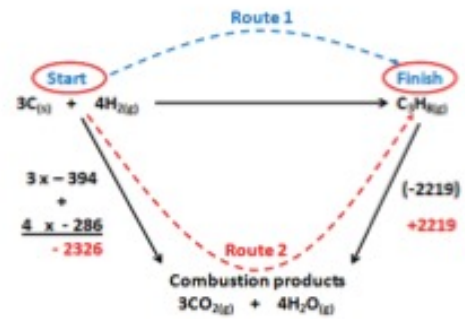
q	Energy / J	c	Specific heat capacity / J/Kg°C
m	mass / g	ΔT	Temperature change / °C

3. Enthalpy of formation cycle



Formation: Arrows go up

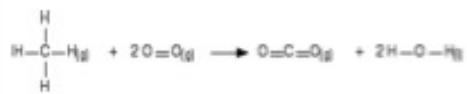
4. Enthalpy of combustion cycle



Combustion: Arrows go down

5. Bond enthalpies

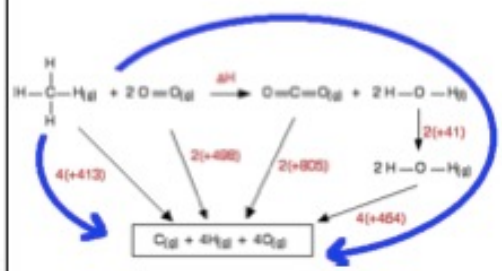
Shopping list approach



C-H	4x (+413)	C=O	2x (+805)
O=O	2x (+498)	O-H	4x (+464)
	= +2348		= +3466

= +2348 - +3466 = -1118kJmol^{-1}

Cycle approach



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Knowledge Organiser: A-Level – Unit 4: Enthalpy

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Unit 5: Kinetics

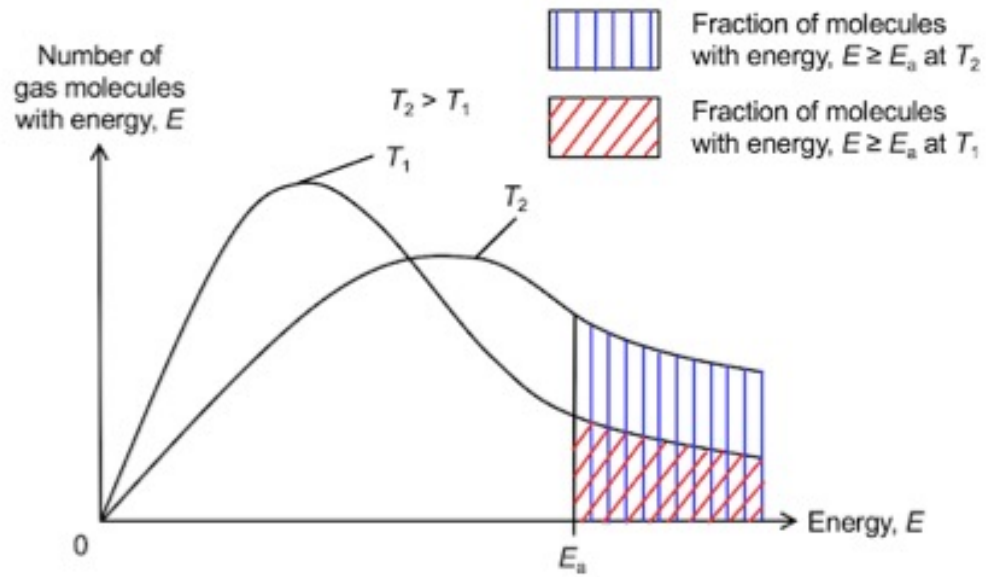
1. Keywords

Collision theory	For a reaction to occur the reactants have to collide with sufficient energy and in the correct orientation
Activation energy	The minimum energy needed for a collision to create a successful reaction
Rate of reaction	The amount of product made or reactant used up in a given time

2. Factors the increase the rate of reaction

concentration	More particles in a given spec so more collisions and increased rate
Pressure	More particles in a given spec so more collisions and increased rate
Surface area	High surface area increases the number of particles available to collide so increases rate
Temperature	Increases the kinetic store of the particles so they collide more frequently and with a greater proportion above the activation energy
Catalyst	Speed up reaction by providing an alternative route with a lower activation energy

3. Maxwell-Boltzmann distribution



Line starts at origin	No particles have no energy
Asymptotic	some particles have infinite energy
Area under the curve	Number of particles
Height of curve	Most probable energy

Knowledge Organiser: A-Level – Unit 5: Kinetics

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Unit 6: Equilibria Kc

1. Keywords

Equilibrium	When a reversible reaction has the same rate in both directions and the concentrations do not change. Happens in a closed system
Le Charteliers principle	If a change is made to a system at equilibrium then the equilibrium will shift to oppose that change

3. Kc

$$aA + bB \rightleftharpoons cC + dD$$

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

[ ]	Concentration / mol dm^{-3}
Kc >1	In favour of products
Kc<1	In favour of reactants

2. Le Charteliers principle

Factor	Effect on equilibrium	Reason	Example
Pressure Increase	Shifts to side with least moles	To decrease the pressure to reach the equilibrium pressure again	It will shift to the right as it has the least moles
Pressure Decrease	Shifts to side with most moles	To increase the pressure	It will shift to the left as it has the most moles
Concentration Increase	Shifts to other side	To decrease the concentration of what was increased	If the concentration of A is increased it will shift to the right
Concentration Decrease	Shifts to the same side	To increase the concentration of what was decreased	If the concentration of A is decreased it will shift to the left
Temperature Increase	Shifts in the endothermic direction	To cool down the reaction	It will shift to the left as this is the endothermic direction
Temperature Decrease	Shifts in the exothermic direction	To heat up the reaction	It will shift to the right as it is the exothermic direction

4. Units of Kc

$$2A + B \rightleftharpoons C$$

$$\downarrow$$

$$\frac{mol\,dm^{-3}}{(mol\,dm^{-3})^2(mol\,dm^{-3})}$$

$$\frac{\cancel{mol\,dm^{-3}}}{(mol\,dm^{-3})^2(\cancel{mol\,dm^{-3}})}$$

$$= \frac{1}{(mol\,dm^{-3})^2}$$

$$= mol^{-2}dm^{6}$$

Knowledge Organiser: A-Level – Unit 6: Equilibria Kc

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Unit 7: Redox

1. Keywords

Oxidation	The loss of electrons, gain of oxygen, increase in oxidation number
Reduction	The gain of electrons, loss of oxygen, decrease in oxidation number
Disproportionation	When one species is both oxidised and reduced simultaneously
Half equation	A balanced equation which only shows either the oxidation or reduction during a redox reaction
Oxidising agent	A substance which oxidises another substance and in doing so becomes reduced
Reducing agent	A substance which reduces another substance and in doing so becomes oxidised

2. Rules to assign oxidation numbers

Element	0
Mono atomic ion	Charge on the ion
Hydrogen	+1 (unless hydride = -1)
Oxygen	-2 (unless peroxide = -1)
Fluorine	-1
Group 1	+1
Group 2	+2
Group 7	-1 mostly

3. Steps to balance half equations

1. Balance the existing atoms
2. Determine the oxidation state before and after the reaction
3. Add electrons to balance the change in oxidation state
4. If it is a complex ion add H^+ ions to produce 1 water for every oxygen
5. Check the atoms and charge balance both sides

4. Steps to combine half equations

1. Determine which is being oxidised and which is being reduced
2. Write out the balanced half equations
3. Factor up the half equations until the number of electrons balance
4. Combine the half equations
5. Cancel any redundant species

Knowledge Organiser: A-Level – Unit 7: Redox

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Unit 1a: Intro - Nomenclature

1. Keywords

Functional group:	An atom or group of atoms, such as a carboxyl group, that replaces hydrogen in an organic compound and that defines the structure of a family of compounds and determines the properties of the family.
General formula:	a chemical *formula* applicable to a series of compounds (as ROH for alcohols, CnH2n + 2 for alkanes where n is an integer)
Homologous series	A series of related chemical compounds that have the same functional group(s) but differ in formula by a fixed group of atoms.
Isomer	two or more compounds with the same formula but a different arrangement of atoms in the molecule and different properties

2. Functional groups.

Homologous series	Prefix or suffix	Functional group
Alkanes	-ane	C—C
Alkenes	-ene	C=C
Alcohols	hydroxy-/-ol	-OH
Carboxylic acid	-oic acid	
Haloalkane	Chloro- Bromo- Iodo-	-Cl -Br -I
Aldehydes	-ale	
Ketones	-one	
Amines	Amino-/-ine	-NH
Nitril	Cyano-/-nitrile	-CN
Amides	-amide	

3. International Union of Pure and Applied Chemistry (IUPAC) rules

1. Identification of the longest "parent" hydrocarbon chain.
2. Identification of the parent functional group, if any, with the highest order of precedence.
3. Identification of the side-chains branching off the parent one.
4. Identification of the remaining functional groups, if any, and naming them by their ionic prefixes (such as hydroxy for -OH, oxy for =O, oxyalkane for O-R, etc.).Different side-chains and functional groups will be grouped together in alphabetical order. (The prefixes di-, tri-, etc. are not taken into consideration for grouping alphabetically.
5. Identification of double/triple bonds.
6. Numbering of the chain. So that the functional group with the highest precedence has the lowest possible number.
7. Numbering of the various substituents and bonds with their functional group. If there is more than one of the same type of substituent/double bond, a prefix is added showing how many there are (di – 2 tri – 3 tetra – 4 then as for the number of carbons below with 'a' added).

Adding of punctuation:

- Commas are put between numbers (#)
- Hyphens are put between a number(#) and a letter
- Successive words are merged into one word

The finalized name should look like this: #,#-di<side chain>-#-<secondary functional group>-#-<side-chain>-#,#,#-tri<secondary functional group><parent chain prefix>

Order of precedence of groups:

Cations> Carboxylic acids>Esters>Amide>Nitrile>Aldehyde>Ketone>Alcohol>Amines

3. Chain nomenclature

Number of C atoms	1C	2C	3C	4C	5C	6C	7C	8C	9C	10C
prefix	Meth-	Eth-	Prop-	But-	Pent-	Hex-	Hept-	Oct-	Non-	Dec-

4. Cahn-Ingold-Prelog (CIP) rules

These rules help with naming geometric isomers E/Z:

1. Compare the atomic number of the atoms directly attached to the double bond; the group having the atom of higher atomic number receives higher priority.
2. If there is a tie, we must consider the atoms at distance 2 from the double bond—as a list is made for each group of the atoms bonded to the one directly attached to the double bond. Each list is arranged in order of decreasing atomic number. Then the lists are compared atom by atom; at the earliest difference, the group containing the atom of higher atomic number receives higher priority.
3. If there is still a tie step 2 is repeated for the atoms at distance 3 from the double bond.
4. If two groups differ only in isotopes, then the larger atomic mass is used to set the priority.

This process is repeated recursively, each time with atoms one bond farther from the double bond, until the tie is broken.

E: the higher priority groups are on opposite sides of the double bond.
Z : the higher priority groups are on the same side of the double bond.

Knowledge Organiser: A-Level – Unit 1a: Intro to Organic Chemistry

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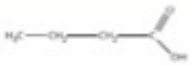
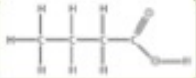
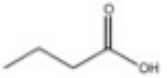
Knowledge Organiser: A-Level – Unit 1b: Spacial Representation

Unit 1b:Intro- Spacial representation

1. Type of chemical reactions

Reaction Type	Explanation
Addition:	reaction where two or more molecules combine to form a single product with 100% atom economy. $C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$
Combustion:	is a high-temperature exothermic redox chemical reaction between a fuel and an oxidant, usually atmospheric oxygen, that produces oxidized, often gaseous products, in a mixture termed as smoke. $CH_4 + 2O_2 \rightarrow 2H_2O + CO_2$
Condensation:	reaction in which two or more molecules combine to form a larger molecule, with the simultaneous loss of a small molecule such as water or methanol. $CH_3NH_2 + CH_3COOH \rightarrow CH_3NHCOCH_3 + H_2O$
Decomposition:	is the process or effect of simplifying a single chemical entity into two or more fragments. $2H_2O_2 \rightarrow 2H_2O + O_2$
Dehydration:	is a reaction that involves the loss of water from the reacting molecule or ion. $CH_5Cl + NaOH \rightarrow C_2H_4 + NaCl + H_2O$
Displacement	when an element or ion moves out of one compound and into another. It is a type of substitution reaction. $Mg + 2H_2O \rightarrow Mg(OH)_2 + H_2$
Elimination:	produces an unsaturated product by loss of atoms or groups from adjacent carbon atoms. $CH_5Cl + NaOH \rightarrow C_2H_4 + NaCl + H_2O$
Hydrolysis:	reaction in which a molecule of water is added to a substance= a compound splits apart in a reaction involving water. Sometimes this addition causes both substance and water molecule to split into two parts. $H_2SO_4 + H_2O \rightarrow H_3O^+ + HSO_4^-$
Neutralisation	reaction in which an acid and a base react quantitatively with each other. $NaOH + HCl \rightarrow NaCl + H_2O$
Redox:	redox is a type of chemical reaction in which the oxidation states of atoms are changed. $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$
Substitution	reaction during which one functional group in a chemical compound is replaced by another functional group. $CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$

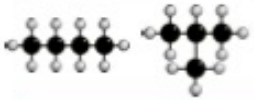
2. Types of chemical formulas

Chemical Formula	Definition	Example
Molecular Formula (written)	shows the actual number of atoms of each element in a molecule.	$C_4H_8O_2$
Empirical Formula (written)	shows the simplest whole number ratio of atoms of in a compound.	C_2H_4O
Structural Formula (drawn)	shows the minimal detail that shows the arrangement of atoms in a molecule.	
Displayed Formula (drawn)	shows the relative positioning of atoms and the bonds between them, all bonds shown	
Skeletal Formula (drawn)	shows only the bonds of the carbon skeleton and any functional groups. C atoms not shown, nor H atoms bonded to C atoms.	

STRUCTURAL ISOMERISM

Same molecular formula but different structural formulae

CHAIN ISOMERISM



POSITION ISOMERISM

FUNCTIONAL GROUP ISOMERISM

STEREOISOMERISM

Same molecular formula but atoms occupy different positions in space.

GEOMETRICAL ISOMERISM

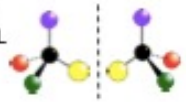
Occurs due to the restricted rotation of C=C double bonds (E/Z or trans/cis)

E-trans Z-cis

OPTICAL ISOMERISM

Occurs when molecules have a chiral centre. Get two non-superimposable mirror images.

Two options R/L



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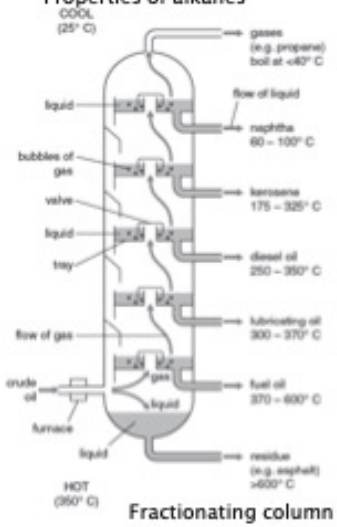
Knowledge Organiser: A-Level – Unit 2: Alkanes

Unit 2: Alkanes

Size chain	Short	Long
Boiling point	Low	High
Flammability	High - Ignites easily	Low -Hard to ignite
Viscosity	High - Flows easily	Low - Doesn't flow well

Properties of alkanes



Fractionating column

Zeolite - structure

1. Properties

General formula: CnH2n+2
Properties of the alkanes, summarised to the left, are linked to the length of their chains. Between these simple molecules there are weak intermolecular forces of attraction which increase with the chain length. Alkanes are fairly unreactive but good combustibles.

2. Fractional distillation

In fractional distillation:

- crude oil heated to about 370°C and fed into the bottom of a fractionating column, hottest at bottom, coolest at top.
- the vapours pass up the tower via a series of rays containing caps until they reach a tray that is cold enough to allow their condensation depending on boiling point.
- at each level the fraction is piped of.
- lighter smaller chains rise, cool and condense at the top
- heavier longer chain fractions are collected at the bottom

Large chain fractions are cracked producing smaller more useful fuels.

3. Cracking

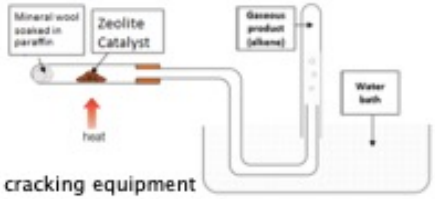
Cracking – breaks long chain hydrocarbons into shorter chain hydrocarbons

Thermal cracking
Conditions high temperature (700-1200°K) and high pressure 7000Pa.
C-C bonds break forming 2 radicals that form a variety of shorter chains molecules. High proportions of alkanes are produced.

Catalytic cracking
Conditions 720°K, pressure just above atmospheric and Zeolite catalyst. Makes branched alkanes, cycloalkanes and aromatic compounds.

4. Combustion

- Complete combustion (plenty of oxygen) of alkanes produces carbon dioxide and water only, releasing large amounts of energy.
- Incomplete combustion (limited supply of oxygen) of alkanes produces carbon monoxide and water ,with even less oxygen carbon (soot) is produced. This often happens with long hydrocarbons that need a lot of oxygen. Less energy is released.



Laboratory catalytic cracking equipment

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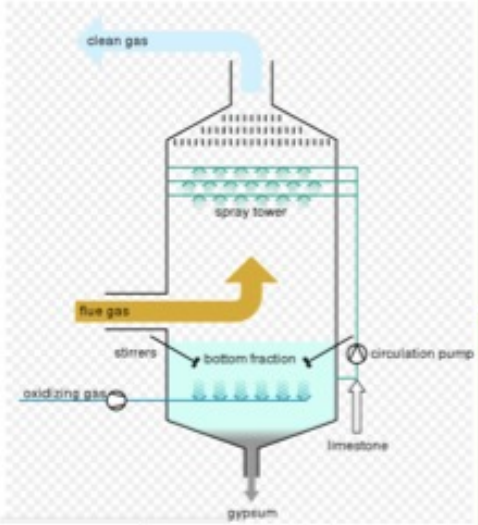
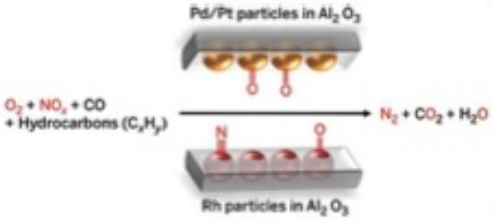
Unit 3: Pollution



Flue gas desulfurisation



Catalytic converter

1. Pollution

Combustion of all hydrocarbons may produce polluting products when burnt such as:

- Carbon monoxide (CO): a poison
- Nitrogen oxides (NOx): formed in the engine thanks to the high temperatures. These gasses can react with water to form nitric acid arising acid rain and photochemical smog.

$$N_2(g) + O_2(g) \rightarrow 2NO(g)$$

- Sulphur dioxide (SO_2): produced by sulphur impurities in fuel. This gas can react with water to form sulphuric acid arising acid rain.

$$S(s) + O_2(g) \rightarrow SO_2(g)$$
$$SO_2(s) + 0.5O_2(g) + H_2O(l) \rightarrow H_2SO_4(l)$$

- Carbon particles, called particulates, which can cause cancer and asthma.
- Unburnt hydrocarbons may enter the atmosphere that contribute to photochemical smog and are green house gasses.
- Carbon dioxide (CO_2):a green house gas.
- Water vapour (H_2O): a green house gas.

2. Desulfurisation

The gas given out by power stations are called flue gases so the process of removing sulphur dioxide is called flue gas desulfurisation.

- In one method a slurry of calcium oxide (lime) and water is sprayed into the flue gas to form gypsum (calcium sulphate) that can be used to make plaster and plasterboards:

$$CaO(s) + SO_2(s) + 0.5O_2(g) + 2H_2O(l) \rightarrow CaSO_4 \cdot 2H_2O(s)$$

- In an alternative process calcium carbonate (limestone) is used instead of calcium oxide:

$$CaCO_3(s) + SO_2(s) + 0.5O_2(g) \rightarrow CaSO_4 + CO_2(g)$$

3. Catalytic converter

The catalytic converters is a honeycomb made of ceramic coated with platinum and rhodium metals that work as catalysts. The structure allows for a high surface area to catalyse:

$$CO(g) + NO(g)) \rightarrow CO_2(g) + 2CO_2(g)$$

And this reaction with unburned hydrocarbons (this reaction can be adapted to any hydrocarbon):

$$C_8H_{18} + 25NO \rightarrow 12.5N_2 + 9H_2O + 8CO_2$$

4. CFCs

Chlorofluorocarbons (CFCs) can be damaging for the Ozone layer due to a free radical mechanism reaction where chlorine acts as a catalyst to the breakdown of ozone into oxygen. (more details about free radicals in section 4)

$$CCl_2F_2 \rightarrow {}^{\bullet}CClF_2 + Cl^{\bullet}$$
$$Cl^{\bullet} + O_3 \rightarrow ClO^{\bullet} + O_2$$
$$ClO^{\bullet} + O_3 \rightarrow Cl^{\bullet} + 2O_2$$

Knowledge Organiser: A-Level – Unit 3: Pollution

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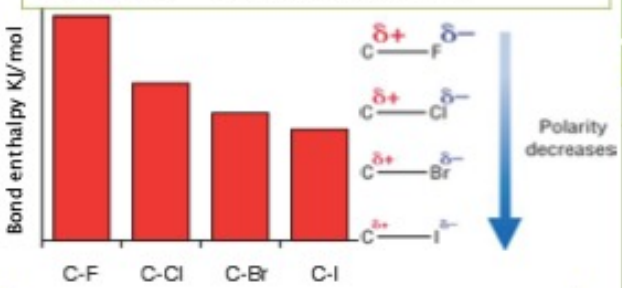
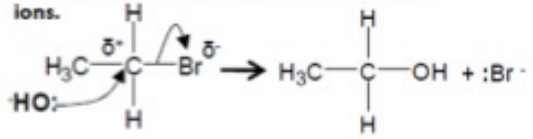
Unit 4: Halogenoalkanes

1. Keywords

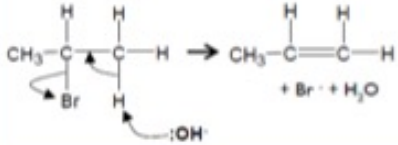
Anhydrous	In the absence of water
Initiation:	Radical forming step.
Nucleophile:	Electron pair donor.
Propagation:	Spreading of the radicals.
Radical:	Free radicals are reactive species with an unpaired electron and are drawn using a dot.
Termination:	All radicals are removed.



Nucleophilic Substitution of Halogenoalkanes with aqueous hydroxide ions.



Elimination of Halogenoalkanes with ethanolic hydroxide ions



2. Properties

General formula $C_nH_{2n+1}X$ where X is the halogen

Halogenolakanes can be classified into:
- Primary have one R group attached to the carbon linked to the halogen.
- Secondary have two R groups attached to the carbon linked to the halogen.
- Tertiary have three R groups attached to the carbon linked to the halogen.

Physical properties of halogenoalkanes mainly depend on the polarity of the C-X bond.

- Solubility: the polarity of the bond is not enough to make halogenoalkanes soluble in water, the main intermolecular forces are Van der Walls and dipole-dipole attractions.
- Boiling point: - increases with increased chain length.
  - increases going down the halogen group.

Chemical properties depend on the C-X bond strength and polarity. Reactivity increases going down the halogen group even though C-I is the least polar bond, this is due to atom size.

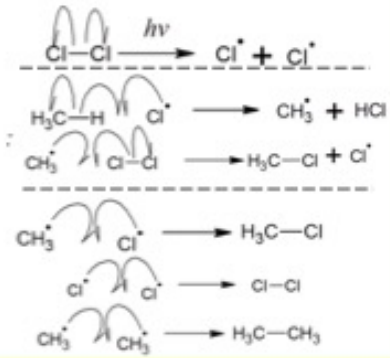
3 Formation

Halogenoalkanes are formed via different mechanisms.

Free radical substitution reaction starting from an alkane and an halogen, this reaction occurs only in the presence of UV light.

CH_4 (g) + Cl_2 (g) □ CH_3Cl(g) + HCl (g) this reaction occurs in 3 steps:

1. Initiation: breaking of the covalent bond of the halogen. Highly reactive free radicals are formed.
2. Propagation: the free radical takes the hydrogen on the alkane to form an acid and a new alkyl radical is formed. The new radical reacts with another halogen producing an halogenoalkane and another halogen radical.
3. Termination: in this step free radicals react with each other. All radicals are removed.



Other products are formed.

From alkenes with hydrogen halides at room temperature or from alkenes reacting with halogens.

$C_3H_6 + HBr$ □ C_3H_7Br $C_3H_6 + Br_2$ □ $C_3H_6Br_2$

4 Chemical reactions

Halogenoalkanes undergo Nucleophilic substitution in the presence of a nucleophile with the halogens as the leaving group. Or elimination reaction in hot anhydrous, usually ethanolic, conditions.

Knowledge Organiser: A-Level – Unit 4: Halogenoalkanes

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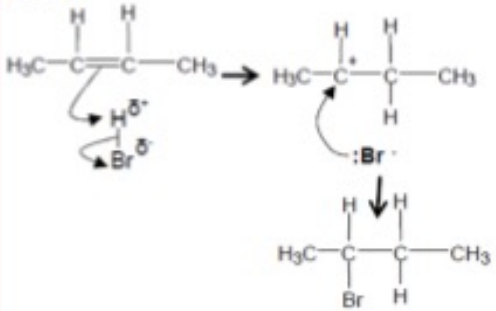
Unit 5: Alkenes

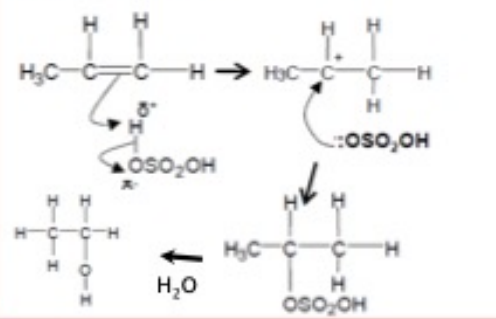
1. Keywords

Carbocation	ion with a positively charged carbon atom.
Electrophile	Electron pair accepting groups

Electrophilic Addition of Alkenes with hydrogen bromide



Electrophilic Addition of Alkenes with sulphuric acid



2. Properties

General formula C_nH_{2n}

Alkene's functional group is the C=C double bonds which consists of a sigma bond and a pi bond.

- The pi bond lies above and below the sigma bond.
- There is no rotation around a double bond – resulting in geometric isomers (cis/trans E/Z)
- The double bond sits on a plane and the angles between each bond is roughly 120°

Physical properties are very similar to those of the alkanes.

Chemical properties are influenced by the double bond that had an enthalpy of 612kJ/mol (a C-C bond has a bond enthalpy of 347kJ/mol) and it is an electron rich area which can easily attract electrophiles

3. Reactions

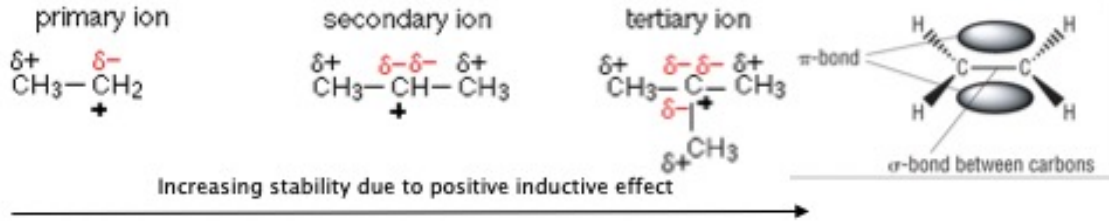
- Combustion – alkenes will burn in oxygen like alkanes.

Electrophilic additions reactions undergo via carbocation. Main products are determined by the stability of the carbocation.

- Hydrogenation - ethene reacts with hydrogen in the presence of a finely divided nickel catalyst at a temperature of about 150°C. Ethane is produced $CH_2{=}CH_2 + H_2$ □ CH_3CH_3

Uses of hydrogenation – Process used to manufacture margarine from unsaturated vegetable oils in palm and sunflower seeds. Vegetable oils = liquids, have double carbon bonds that are mostly cis-double bonds. These get converted to C-C bonds, turns liquid oils into spreadable fatty solids like margarine.

- Alkenes and steam – react in presence of phosphoric acid catalyst to produce alcohols. Generally reversible reaction. 570K, 65 atm pressure, $C_2H_4 + H_2O$ □ CH_3CH_2OH
- Alkenes and halogens – Cl_2 and Br_2 react rapidly at room temperature with alkenes to form dihalogenoalkanes via electrophilic addition reaction. Reaction with iodine is slower.
  - the reaction with bromine water is the qualitative test for alkenes. Shake alkene with bromine water, orange solution goes colourless.
- Alkenes with hydrogen halides –react readily at room temperature with alkenes, form halogenoalkanes. Unsymmetrical alkenes will react to produce a major and minor product.
- Alkenes with hydrogen halides – reacts at room temperature and it is exothermic the sulfuric acid acts as a catalyst and the product is an alcohol.



Knowledge Organiser: A-Level – Unit 5: Alkenes

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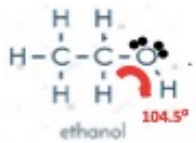
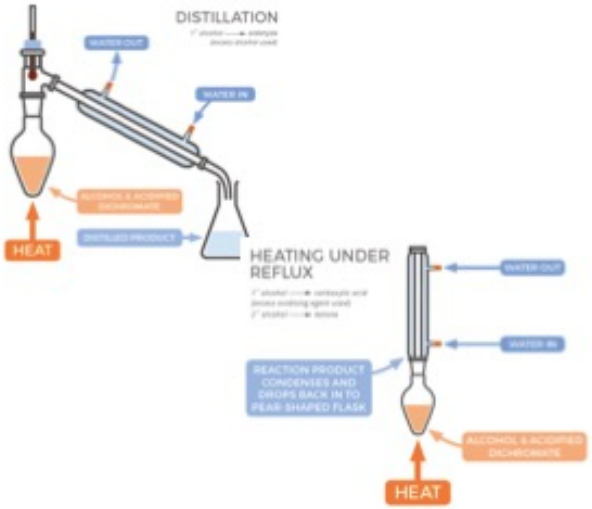
Unit 6: Alcohols



	Hydration of ethene	Fermentation of sugars
Method	Requires laboratory equipment; high level of expertise – cracking and hydration.	Can be undertaken at home – fermentation
Sustainability	Non-renewable	**Renewable**
Rate of reaction	**Fast**	Slow
Type of process	**Continuous**	Batch
Purity	Essentially pure, although any contaminants may be toxic	Low, aqueous solution of alcohol is produced; can be distilled to increase ethanol content and improve purity
Percentage yield	**90–100%**	~15%
Atom economy	**100%**	51%
By-products	None	Carbon dioxide – a greenhouse gas



1. Physical properties

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

- Alcohols are classified into primary, secondary and tertiary based on the substitution of the carbon linked to the -OH group, like the halogenoalkanes.
- The –OH group allows alcohols to form hydrogen bonds.
- Short alcohols are soluble in water

2. Production of ethanol

Ethanol is the most important alcohol in industrial chemistry since it is used as intermediate in reactions and as solvent.

Ethanol can be made industrially in two ways:

- Hydration of ethane in the presence of phosphoric acid as catalyst (high yield, little sustainability)
  $C_2H_4 + H_2O$ □ C_2H_5OH
- Fermentation of sugars (batch production, renewable)
  $C_6H_{12}O_6$ (aq) □ $2C_2H_5OH$ (aq) + CO_2(g)

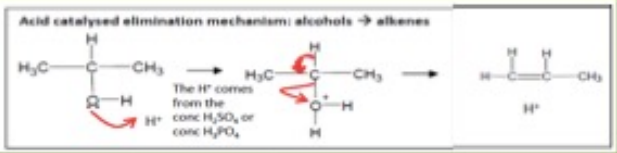
3. Reactivity

Alcohols can undergo the following reactions:

-Combustion, all alcohols are flammable and can undergo complete or incomplete combustion, like alkanes.

-Elimination: it is a dehydration reaction with conc sulphuric or phosphoric acid or by passing its vapours over heated aluminium oxide.

An alkene is formed.



-Oxidation: alcohols can be oxidised ins stages, usually potassium dichromate (VI) is used since its reduction into chromium (III) ions translates into a change of colour from orange to green.

- Partial oxidation to aldehydes (if primary alcohol) or ketones (if secondary) is done with a distillation apparatus.

  C_2H_5OH (l) + [O] □ C_2H_4O (g) + H_2O(l)

- Complete oxidation of a primary alcohol (or aldehyde) to carboxylic acid is performed in the presence of potassium dichromate (VI) under reflux.

  C_2H_5OH (l) + 2[O] □ CH_3COOH (g) + H_2O(l)

- Oxidation is also used as a test for alcohols or to distinguish primary alcohols from the others

- Substitution: alcohols undergo substitution reactions to form haloalkanes with halide ions in the presence of an acid ($NaBr/H_2SO_4$).

The order of reactivity of alcohols is 3° > 2° > 1°.
The order of reactivity of the hydrogen halides is NaI > NaBr > NaCl (NaF is generally unreactive).

Knowledge Organiser: A-Level – Unit 6: Alcohols

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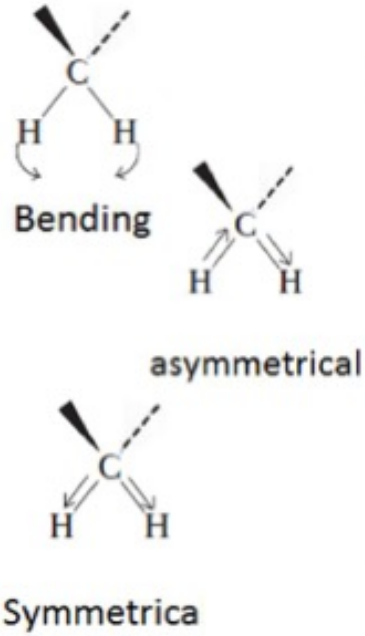
Unit 14: Infrared spectroscopy

1. Technique.

- Infrared depends on the fact that infrared radiation is absorbed by certain molecular bonds and this causes them to vibrate.
- There are three types of vibrations, symmetrical, asymmetrical and bending.
- Different bonds absorb IR radiation at different wavelengths and can be used to identify different functional groups.

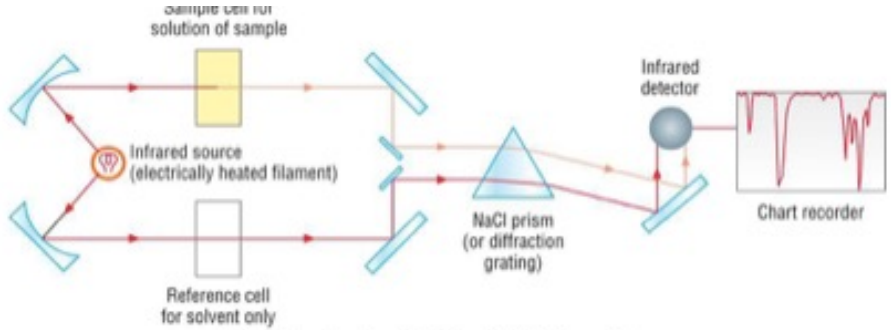
- The finger print region is in the range 1500-500cm-1 is unique for any given compound but is too complicated to analyse.
- Because the finger print region is unique, compounds can be identified by comparing it to a data base of known IR spectra.

- IR is limited as technique because it only gives information about functional groups. Other evidence is required to determine the precise structural formula.

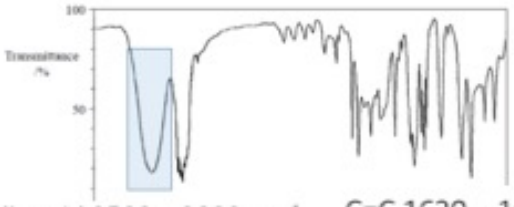


Infrared absorption data

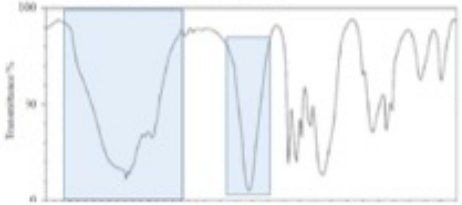
Bond	Wavenumber /cm^{-1}
N – H (amines)	3300 – 3500
O – H (alcohols)	3230 – 3550
C – H	2850 – 3300
O – H (acids)	2500 – 3000
C ≡ N	2220 – 2260
C = O	1680 – 1750
C = C	1620 – 1680
C – O	1000 – 1300
C – C	750 – 1100



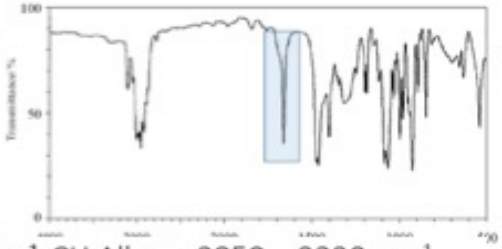
OH Alcohols 3230 – 3550 cm^{-1}



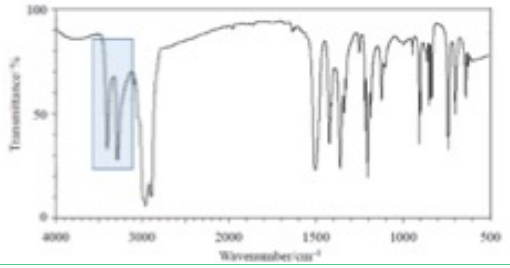
OH carboxylic acid 2500 – 3000 cm^{-1}
C=O 1680 – 1750 cm^{-1}



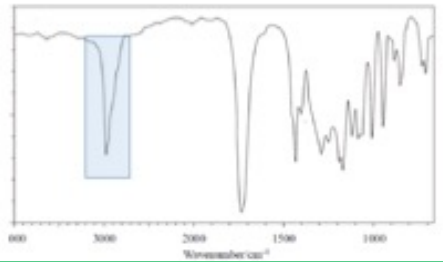
C=C 1620 – 1680 cm^{-1}



N-H amines 3300 – 3500 cm^{-1}



CH Alkane 2850 – 3330 cm^{-1}



Knowledge Organiser: A-Level – Unit 14: IR Spectroscopy

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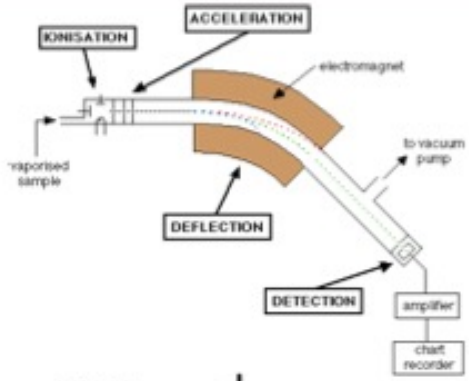
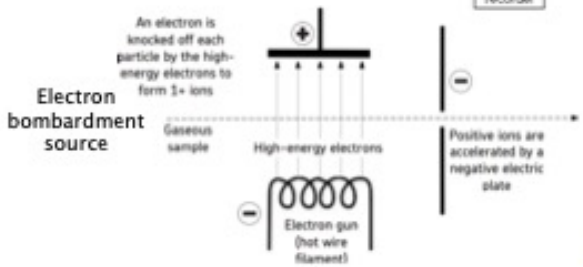
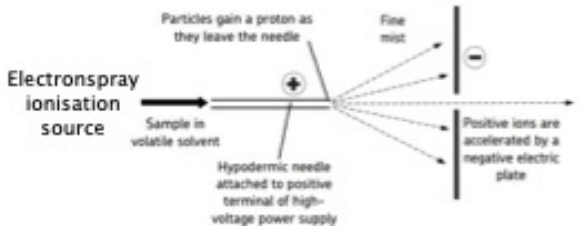
Unit 15: Mass Spectrometry

1. Keywords

Fragmentation	In MS, the process in which a molecular ion breaks into smaller ions, radicals, and/or neutral molecules. Fragments.
m/z value	Mass/charge value used in MS to identify peaks.







2. Time of Flight Mass Spec.

1	Ionisation	Sample dissolved and pushed through nozzle at high pressure and 4000v. As solvent evaporates particles gain a H+ ion
2	Acceleration	+ ions accelerated by -5000v electric field. Have a fixed kinetic energy
3	Ion drift	Region of no electric field, so drift (lighter move faster, heavier ions slower.)
4	Detection	+ ions discharge creating a flow of electrons in the detector which registers the current and plots the mass spectrum.

3. Ion sources

Electron bombardment

- The sample being is vaporised and then high energy electrons are fired at it so it becomes ionised and lose and e-, giving a molecular ion M+

  $C_2H_5OH + e^-$ □ $C_2H_5OH^+ + 2e^-$ or $C_2H_5OH\ (g)$ □ $C_2H_5OH^+\ (g) + e^-$
- The mass lose of e- is negligible
- Molecular ion mass = molecular mass of compound
- Molecular ion detected and analysed

Excess energy from ionisation can be transferred to molecular ion making it vibrate, this can cause bond to weaken and can split molecular ion into fragments - Fragmentation

$C_2H_5OH^+\ (g)$ □ $CH3 + CH_2OH^+\ (g)$

- Molecular ion fragments are detected in MS

Electronspray ionisation

- The sample X is **dissolved** in a volatile solvent and **injected through** a fine hypodermic **needle** to give a fine mist (aerosol).
- The tip of the needle is attached to the positive terminal of a high-voltage power supply.
- The particles are **ionised by gaining a proton** from the solvent as they leave the needle producing XH+ ions (ions with a single positive charge and a mass of **Mr + 1**).
- The solvent evaporates away while the XH+ ions are attracted towards a negative plate where they are accelerated. $C_2H_5OH\ (g) + H^+$ □ $C_2H_6OH^+\ (g)$
- Fragmentation rarely takes place

4. Fragmentation

- If fragmentation occurs, the peak at the highest m/z on the mass spectrum is formed by the heaviest ion that passes through the spectrometer. Unless all molecules of the original substance break up, this corresponds to the molecular ion of the sample substance.
- Although the molecular ion peak for 2 isomers will be the same m/z value, fragmentation patterns will be different

Knowledge Organiser: A-Level – Unit 15: Mass Spectroscopy

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Unit 18: Test tube reactions

3. Tollens' Reagent

- Reagent: aqueous ammonia + silver nitrate.
- The active substance is the complex ion of $[Ag(NH_3)_2]^+$
- Conditions: heat gently
- Reaction:. The silver(I) ions are reduced to silver atom and aldehydes/alcohols oxidised.
- Observation: a silver mirror forms coating the inside of the test tube. Ketones result in no change.

$$CH_3CHO + 2Ag^+ + H_2O \square \quad CH_3COOH + 2Ag + 2H^+$$

4. Fehling's Solution

- Reagent: Fehling's Solution containing blue Cu^{2+}
- ions. Conditions: heat gently
- Reaction: aldehydes only are oxidised and the copper (II) ions are reduced to copper(I) oxide .
- Observation: Blue Cu^{2+} ions in solution change to a red precipitate of Cu_2O. Ketones do not react Fehling's solution.

$$CH_3CHO + 2Cu^{2+} + 2H_2O \square \quad CH_3COOH + Cu_2O + 4H^+$$

1. Reactions

Functional group	Reagent	Result
Acyl chloride	Silver nitrate	Vigorous reaction steamy fumes of HCl rapid white precipitate of AgCl
Alkene	Bromine water	Orange colour decolourises
Aminoacids	Ninhydrin.	Blue-purple spot appears
Aromatic	Combustion	Smoky flames
1 ^ry or 2^ry alcohol	Sodium dichromate and sulfuric acid	Orange to green colour change
Aldehyde	Fehling's solution	Blue solution to red precipitate
	Tollens' reagent	Silver mirror formed
	Sodium dichromate and sulfuric acid	Orange to green colour change
Carboxylic acid	Sodium carbonate $2CH_3CO_2H + Na_2CO_3 \square \quad 2CH_3CO_2Na + H_2O + CO_2$	Effervescence of CO_2 evolved
	pH paper/indicator	Mildly acidic solution
Esters		Fruity smell
Haloalkane	Warm with aqueous NaOH then cool then add nitric acid then add silver nitrate	White precipitate (chloroalkane) Cream precipitate (bromoalkane) Yellow precipitate (iodoalkane)

2. Further observations

- Is the compound solid? (possible long unbranched carbon chain or ionic bonding)
- Is the compound liquid? (hydrogen bonds, branched carbon chain)
- Is the compound soluble? (can form hydrogen bond)

Knowledge Organiser: A-Level – Unit 18: Test Tube Reactions

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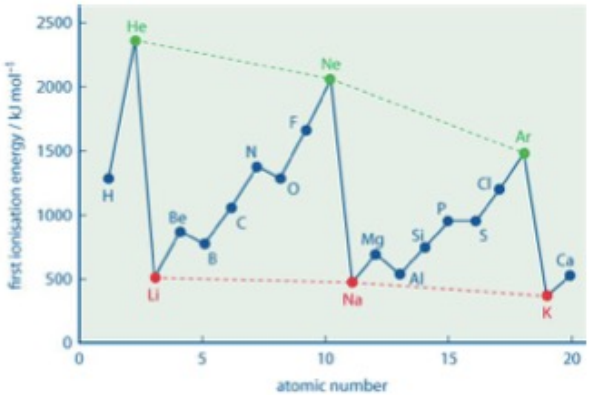
Knowledge Organiser: A-Level – Unit 1: Periodicity

Unit 1: Periodicity

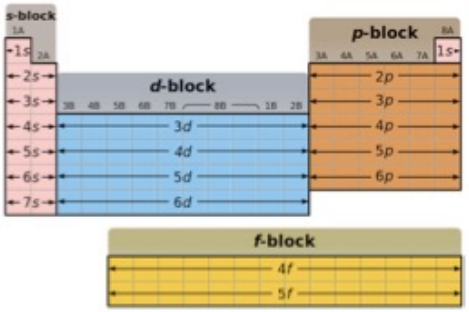
1. Keywords

Periodicity	The quality or character of being periodic; the tendency to recur at intervals.
First ionisation energy	The energy needed to remove 1 electron from each atom in 1 mole of gaseous atoms. $M(g) \rightarrow M^+(g) + e^-$
Second ionisation energy:	The energy needed to remove 1 electron from each atom in 1 mole of gaseous +1 ions. $M^+(g) \rightarrow M^{2+}(g) + e^-$
Successive ionisation energies:	Removing each electron in turn from a mole of gaseous atoms. Provides evidence of energy levels and orbitals
Atomic radius	a measure of the size of its atoms, usually the mean or typical distance from the center of the nucleus to the boundary of the surrounding shells of electrons.



2. The periodic table.

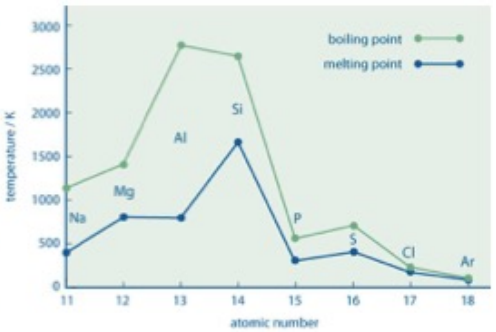
An element is classified as s, p, d or f block according to its position in the Periodic Table, which is determined by its proton number so on the nature of the orbital into which the last electron of the atom enters.



3. Melting and boiling point across period 3

Trends in melting and boiling point are explained based on the intermolecular forces between the molecules.

	Structure	MP/BP
Metal (Na,Mg,Al)	Electrostatic	Low
Semi Metal (Si)	Macromolecular	High
Non Metal (P_4,S_8,Cl_2)	Small molecules substances	Low
Noble gas (Ar)	Monoatomic	Low

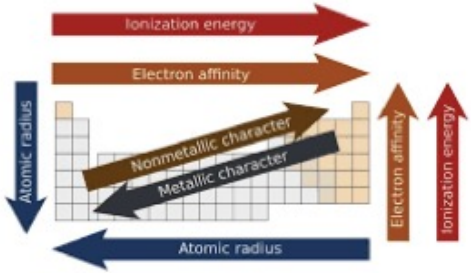


4. Atomic radius

The atomic radii are taken to be the half distance between the centres of a pair of atoms. Atomic radius decreases across each period and increases down a group

5. Ionisation energy

Ionisation energy increases across a period. Ionisation energy decreases going down a group.



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Knowledge Organiser: A-Level – Unit 2: Group 2

1. Physical properties

Trends in group II, Beryllium is not typical of the group and it is not considered here.

Symbol	Z	Atomic radius (nm)	Melting point (K)	1st ionisation energy (kJ/mol)	Density ρ
Mg	12	0.160	650	738	1.74
Ca	20	0.197	842	590	1.54
Sr	38	0.215	777	550	2.60
Ba	56	0.218	727	503	3.52

2. Reactivity with water

Reactivity with water INCREASES down the group.

Magnesium reacts slowly with liquid water, but rapidly when heated in the presence of steam.

$$\overset{0}{M(s)} + 2H_2O(l) \rightarrow \overset{+1}{M(OH)_2}(aq) + \overset{0}{H_2}(g)$$

3. Hydroxides and sulphates - solubility

Hydroxides – $M(OH)_2$

- Varying solubility in water.
- Solubility INCREASES as you descend the group.
- pH of the hydroxide in water varies.
- pH increases as you descend the group.

Sulphates – MSO_4

- Colourless solids
- Solubility DECREASES as you descend the group.
- Thermal Decompose to form MO(s) and CO_2(g).
- Thermal stability increases as you descend the group.

4. Application of group II compounds

Chemical	Common name	Applications
$Mg(OH)_2$	Milk of magnesia	Treat indigestion, heartburns and wind.
$Ca(OH)_2$	Slaked lime	Neutralise fields and polluted lakes.
$BaSO_4$	Barium meal	Contrast medium for gut X-ray.

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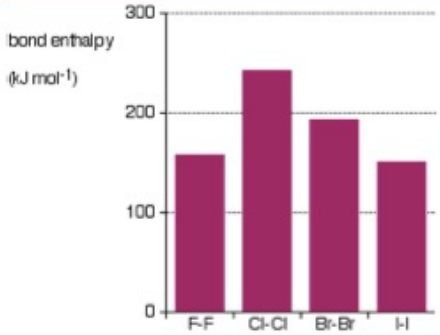
Knowledge Organiser: A-Level – Unit 3a: Group 7

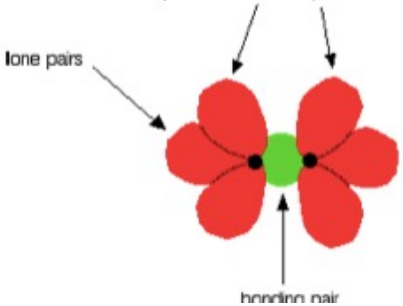
Unit 3a: Group VII

1. Keywords

Mean bond Enthalpy:	The average enthalpy change when one mole of a specific bond is broken in a range of different gaseous compounds.
Displacement:	A displacement reaction is a type of reaction in which part of one reactant is replaced by another reactant.
Electronegativity:	The power of an atom to attract the electrons in a covalent bond.



As the atoms get smaller, lone pairs on the two atoms get close enough together to experience serious repulsion.



2. Physical properties

Trends in group VII. A number of properties of Fluorine are untypical, this mainly stem from the fact that the mean bond enthalpy of the F-F bond is unexpectedly low. This is due to electron repulsion.

Symbol	Z	Electronegativity	Atomic (covalent) radius (nm)	Melting point (K)	Boiling point (K)
F	9	4.0	0.071	53	85
Cl	17	3.0	0.099	8172	238
Br	35	2.8	0.114	266	332
I	53	2.5	0.133	387	457

3. Physical states

The physical state of the halogens are summarised below.

Symbol	In pure form	In non-polar solvents	In water
F	Pale yellow gas	(Reacts with solvents)	(Reacts with water)
Cl	Pale green gas	Pale green solution	Pale green solution
Br	Dark red liquid	Orange solution	Orange solution
I	Grey solid	Purple solution	Insoluble

4. Oxidising abilities – Displacement reactions

The oxidising ability of the halogens decreases down the group.
You cannot investigate the oxidising ability of Fluorine in aqueous solution because it reacts with water.

	F^-	Cl^-	Br^-	I^-
F_2	-	yes	yes	yes
Cl_2	no	-	yes	yes
Br_2	no	no	-	yes
I_2	no	no	no	-

Leave blank to allow students to glue.

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Unit 3b: Reactivity of halide ions and chlorine.

1. Keywords

Disproportionation:	a reaction in which a substance is simultaneously oxidized and reduced, giving two different products..
Precipitate (ppt):	deposited solid formed in a solution.

2. Reducing strength

The reducing ability of the halide ions increases down the group.

Symbol	Atomic radius (nm)
F^-	0.133
Cl^-	0.180
Br^-	0.195
I^-	0.215

4. Reaction with silver ions

All metal halides (but fluoride) react with silver ion to form an insoluble precipitate. Dilute nitric acid is added before the reaction to get rid of any carbonate or hydroxide impurities.

$$Ag^+(aq) + X^-(aq) \rightarrow AgX(s)$$

Symbol	Observation	Halide salt solubility
Cl^-	White ppt	Dilute NH_3
Br^-	Cream ppt	Concentrated NH_3
I^-	Pale yellow ppt	Insoluble in NH_3

3. Reaction with concentrated sulphuric acid

Solid halides react with concentrated sulphuric acid giving different products based on their reducing powers.

Summary table

Chemical reactions.	Reaction A	Reaction B	Reaction C	Reaction D	Observations
Products	$MeHSO_4$	SO_2	S	H_2S	
Cl^-	√	×	×	×	• Steamy fumes (HCl) • Ppt ($MeHSO_4$)
Br^-	√	√	×	×	• Steamy fumes (HBr) • Brown fumes (Br_2) • Pungent gas (SO_2)
I^-	√	√	√	√	• Steamy fumes (HI) • Black ppt (I_2) • Rotten egg smell (H_2S) • Yellow ppt (S)

Reaction A	$MeX(s) + H_2SO_4(l) \rightarrow MeHSO_4(s) + HX(g)$	Types of reaction
Reaction B	$2H^+(aq) + 2X^-(aq) + H_2SO_4(l) \rightarrow SO_2(g) + 2H_2O(l) + X_2(l)$	Acid-base
Reaction C	$6H^+(aq) + 6X^-(aq) + H_2SO_4(l) \rightarrow S(s) + 4H_2O(l) + 3X_2(s)$	Acid-base and redox
Reaction D	$8H^+(aq) + 8X^-(aq) + H_2SO_4(l) \rightarrow H_2S(g) + 4H_2O(l) + 4X_2(s)$	Acid-base and redox

5. Reactivity of chlorine

Reactivity with water:	
$Cl_2(g) + H_2O(l) \leftrightharpoons HCl(aq) + HClO(aq)$ "chlorine water"	Disproportionation reaction
Reactivity with water in sunlight:	
$2Cl_2(g) + 2H_2O(l) \rightarrow 4HCl(g) + O_2(g)$	Goes from pale green to colourless
Alternative chlorination of swimming pools:	
$NaClO(s) + H_2O(l) \leftrightharpoons Na^+(aq) + OH^-(aq) + HClO(aq)$	Water is kept slightly acidic
Reactivity with alkali:	
$Cl_2(g) + 2NaOH(aq) \rightarrow Cl^-(aq) + NaClO(aq) + H_2O(l)$	Disproportionation reaction

Knowledge Organiser: A-Level – Unit 3b: Reactivity of Halide ions

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