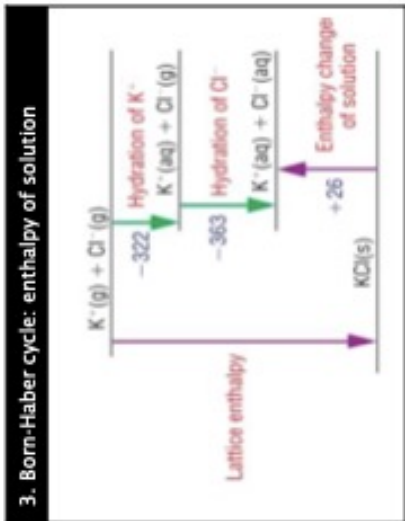
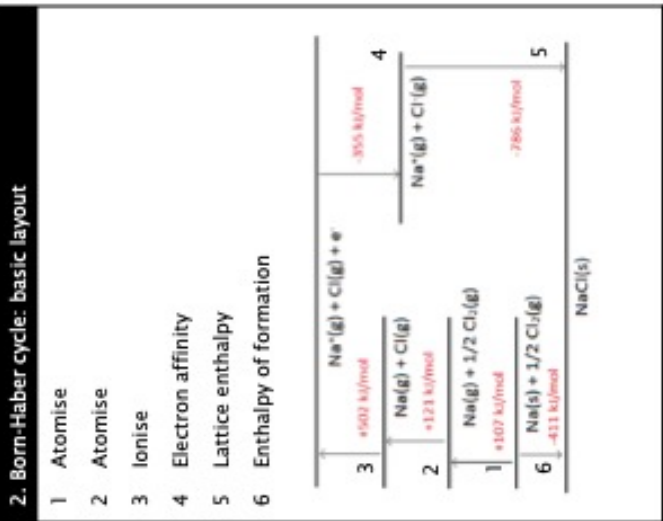




Knowledge Organiser: A-Level – Unit 8: Thermodynamics

Unit 8: Thermodynamics

1. Keywords	
Standard enthalpy change of atomisation $\Delta_{at}H^\circ$	The enthalpy change when one mole of gaseous atoms are formed from a substance at its standard states
Ionisation enthalpy $\Delta_e H^{1st}$	The enthalpy change when one mole of ions are formed from one moles of gaseous atoms under standard conditions
Electron affinity ΔH_{ea}^{1st}	The enthalpy change when one mole of gaseous atoms gain one mole of electrons under standard conditions
Lattice association enthalpy $\Delta_{li}H$	The enthalpy change when one mole of ionic lattice is <i>formed</i> from its gaseous ions under standard conditions
Lattice dissociation enthalpy $\Delta_{di}H^\circ$	The enthalpy change when one mole of an ionic lattice dissociates into isolated gaseous ions under standard conditions
Hydration enthalpy $\Delta_{hy}H^\circ$	The enthalpy change when one moles of gaseous ions are completely surrounded by water
Enthalpy of solution $\Delta_{so}H^\circ$	The enthalpy change when 1 mole of solute is completely dissolved in solvent so that the ions are infinitely diluted, under standard conditions.
Entropy	The measure of disorder within a system measured in $J\ mol^{-1}$
Entropy change ΔS	$\Sigma\ entropy\ products - \Sigma\ entropy\ reactants$
Gibbs free energy ΔG	A measure of the feasibility of a reaction. For a reaction to be feasible $\Delta G\ must\ \leq\ 0$



4. Gibbs free energy

$\Delta G = \Delta H - T\Delta S$	
ΔG	Gibbs free energy / KJ
ΔH	Enthalpy change / KJ mol^{-1}
T	Temperature / K
ΔS	Entropy change / $J\ mol^{-1}$

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Knowledge Organiser: A-Level – Unit 9: Rate Equations

Unit 9: Rate equations

1. Rate equation

$$Rate = k[A]^m[B]^n$$

Rate	The rate of reaction	Mol dm ⁻³ s ⁻¹
k	The rate constant (temperature dependent)	variable
[A]	Concentration of A	Mol dm ⁻³
m	Order of reaction with respect to A	
[B]	Concentration of B	Mol dm ⁻³
n	Order of reaction with respect to B	

2. Arrhenius equation

$$k = Ae^{-Ea/RT}$$

k	The rate constant (temperature dependent)	variable
A	Arrhenius constant	S ⁻¹
e	Euler's number (magic number e)	2.71
Ea	Activation energy	KJ mol ⁻¹
R	Boyles gas constant	8.31 J/mol K
T	Temperature	K

3. Determining order of reaction graphically

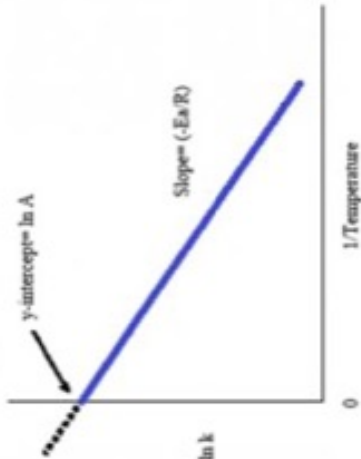


4. Determining the activation energy graphically

$$k = -\frac{Ea}{RT} + \ln A$$

$$y = mx + c$$

Y axis	k	Rate constant
X axis	$\frac{1}{T}$	Reciprocal of temperature
m	$-\frac{Ea}{R}$	Multiply by -R to determine Ea



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Knowledge Organiser: A-Level – Unit 10: Equilibria Kp

Unit 10: Equilibria Kp

1. Keywords

Mole fraction	<u>The number of moles of a species</u> The total number of moles
Partial pressure	The mole fraction of a species x total pressure

2. Kp Expression

$$K_p = \frac{(P_C)^c (P_D)^d}{(P_A)^a (P_B)^b}$$

Kp	Equilibrium constant	Variable units
(P _C) ^c	Partial pressure of C Order with respect to C	Pascals
(P _D) ^d	Partial pressure of D Order with respect to D	Pascals
(P _A) ^a	Partial pressure of A Order with respect to A	Pascals
(P _B) ^b	Partial pressure of B Order with respect to B	Pascals

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Knowledge Organiser: A-Level – Unit 11: Electrode Potentials

Unit 11: Electrode potentials and electrochemical cells

1. Keywords	
Potential difference	The difference in voltage between two points.
Electrode potential E^{\ominus}	The is the potential difference of a cell built of two electrodes: on the left-hand side of the cell diagram is the standard hydrogen electrode (SHE), and, on the right-hand side is the electrode in question under standard conditions (1 mol dm ⁻³ , 100kpa, 298K)
Standard hydrogen electrode (SHE)	The electrode given the electrode potential of 0.00v to establish all other electrode potentials
Platinum electrode	Unreactive electrode used in half cells when neither species is a solid metal
Electrochemical cell	A cell produced when 2 half cells of different electrode potentials are linked by a salt bridge
Salt bridge	A medium connecting two half cells. Contains inert ions to allow charge to flow without interfering with the electrochemistry
EMF	Electro motive force. The potential difference of a cell when no current flows
Feasible reaction	A spontaneous redox reaction which generates a positive E^{\ominus} for the cell
Anode	The electrode where oxidation happens. In an electrochemical cell this is the negative terminal
Cathode	The electrode where reduction happens. In an electrochemical cell this is the positive terminal. Often on the right
Non-rechargeable cell	A cell with a spontaneous reaction which cannot be reverse
Rechargeable cell	A cell with a spontaneous reaction which can be reversed by applying an electric current
Fuel cell	A cell which generates an EMF providing a continuous flow of chemicals are provided
Hydrogen fuel cell	A fuel cell which uses hydrogen and oxygen to generate an EMF. Water is the only waste product

2. Standard hydrogen electrode	
Half cell equation:	$2\text{H}^{+}(\text{aq}) + 2\text{e}^{-} \rightleftharpoons \text{H}_2(\text{g})$ $E^{\ominus} = +0.00\text{ V}$
Cell notation:	$\text{Pt(s)} \text{H}_2(\text{g}) \text{H}^{+}(\text{aq})$

3. How to write conventional cell notation	
left hand half cell	right hand half cell
$\text{Pt(s)} \text{H}_2(\text{g}) \text{H}^{+}(\text{aq})$	$\text{Cu}^{2+}(\text{aq}) \text{Cu(s)}$
phase boundaries	phase boundary
	salt bridge
$\text{Pt(s)} \text{H}_2(\text{g}) \text{H}^{+}(\text{aq}) \text{Cu}^{2+}(\text{aq}) \text{Cu(s)}$	
Highest oxidation state is nearest the salt bridge If platinum electrode is present it goes on the far edges	

4. Calculating the EMF of a cell	
$EMF = E_{\text{cell}} = E_{\text{right}} - E_{\text{left}}$	
Note: SHE always goes on the left	

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Knowledge Organiser: A-Level – Unit 12: Acids and Bases

Unit 12: Acids and Bases

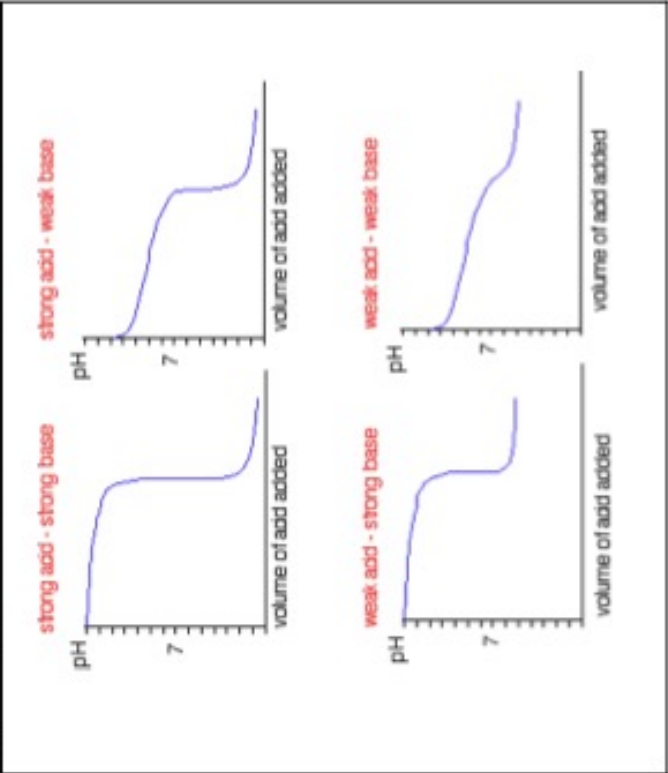
1. Keyword

Bronsted-Lowry acid	Proton donor
Bronsted-Lowry base	Proton acceptor
Conjugate base	An acid that has donated its hydrogen
Conjugate acid	A base with a hydrogen ion added to it.
Strong	Fully ionises/dissociates in solution
Weak	Partially ionises/dissociates in solution
pH	$-\text{Log}_{10} [\text{H}^+]$
K _w	Ionic product of water = $[\text{H}^+][\text{OH}^-] = 1 \times 10^{-14}$ At 298k
K _a	Acid dissociation constant. A measure of dissociation of a weak acid. Units = mol dm^{-3}
Half equivalence point	Half the volume required to neutralise and acid or base = pK _a
Indicator	A compound or compounds that change colour when pH changes. Should fall in the vertical rise on a pH curve
10 ^x	Inverse log button on your calculator duh!
Buffer	Solution which resists small changes in pH. Made from a weak acids and its salt.

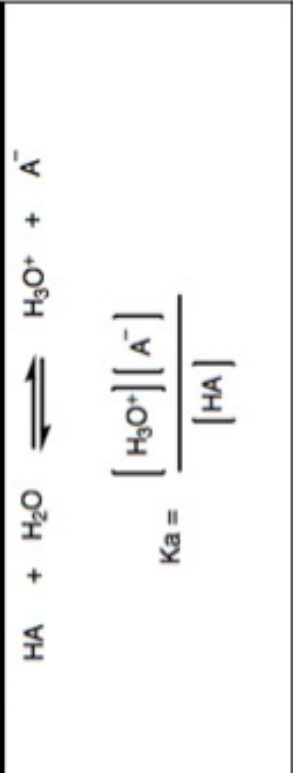
2. Useful acids

Name	Formula	Strength	Protic
Hydrochloric	HCl	Strong	Mono
Sulphuric	H ₂ SO ₄	Strong	Di
Nitric	HNO ₃	Strong	Mono
Phosphoric	H ₃ PO ₄	Strong	Tri
Ethanoic	CH ₃ COOH	Weak	Mono
Ethanedioic	HOOC ₂ COOH	Weak	Di

3. pH curves



4. K_a Expression



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Knowledge Organiser: A-Level – Unit 7: The Carbonyl Group

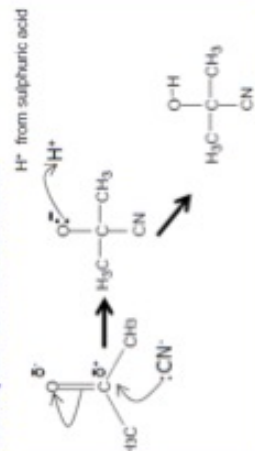
Unit 7: The carbonyl group

1. Keywords

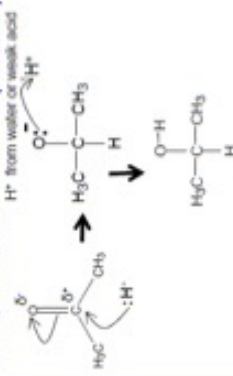
Dipole-dipole forces :	attractive forces between the positive end of one polar molecule and the negative end of another polar molecule
Electronegativity:	is a measure of an atom's ability to attract shared electrons to itself
Racemic mixture (racemate)	Mixture that has equal amounts of left- and right-handed enantiomers of a chiral molecule.



Nucleophilic Addition Mechanism



Nucleophilic Addition Mechanism (Reduction)



2. Nomenclature

The carbonyl group is present in aldehydes (RCHO) and ketones (RCOR'). They are both represented by the general formula $C_nH_{2n}O$.

- Aldehydes (-al suffix) can only be at the end of a molecule so there is no need to provide numbering their functional group.
- No ketone (-one suffix) can have less than 3 carbons. So you don't need to number the carboxyl group in propanone or butanone

3. Physical properties

The big difference in **electronegativity** between carbon and oxygen, makes the C=O bond strongly polar. There are permanent **dipole-dipole** forces between the molecules.

Shorter chains carbonyl compounds are readily soluble in water since they form hydrogen bonds with water. As the aryl/alkyl chain lengthens solubility decreases.

Methanal is a gas at room temperature. Short carbonyl compounds are liquids.

4. Reactivity

Most reactions involve the C=O bond because it is strongly polar.

Nucleophilic addition reaction:

- The reaction with NaCN and dilute HCl is very important since it increases the length of the carbon chain by one carbon.
- This reaction will produce a **racemic mixture (racemate)** of hydroxynitriles.
- If performed on ethanol and followed by and hydrolysis with HCl it will produce a racemate of lactic acid.

Oxidation:

Aldehydes can be oxidised to carboxylic acids.

Reduction (another nucleophilic addition reaction) :

Many reducing agent will reduce carbonyl groups to alcohols. Once reducing agent is sodium tetrahydridoborate(III) ($NaBH_4$) which provides a source of hydrogen to act as a nucleophile creating the H^- (hydride ion).

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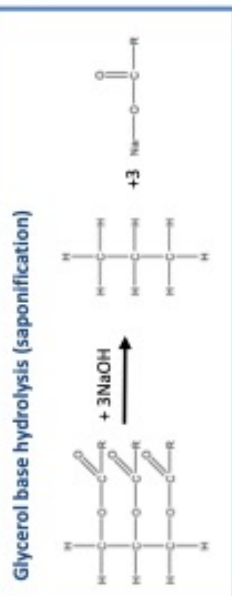
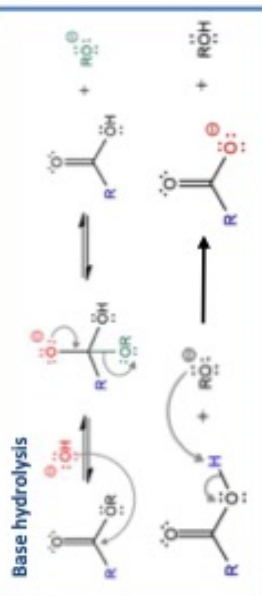
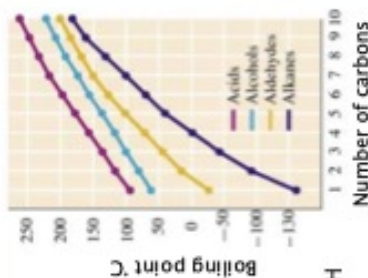
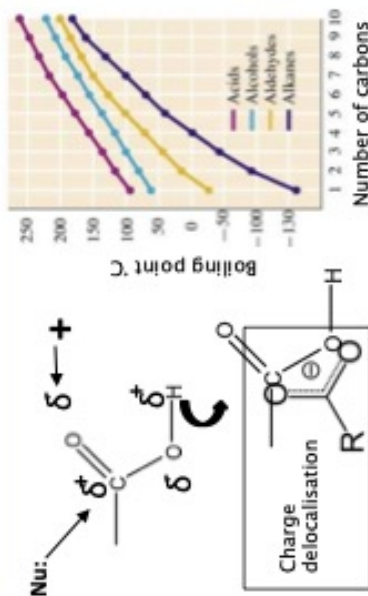


Knowledge Organiser: A-Level – Unit 8: The Carboxyl Group

Unit 8: The carboxyl group

1. Keywords

Delocalisation: when electrons in a molecule, ion or solid metal that are not associated with a single atom or a covalent bond.



2. Carboxylic acids

Carboxylic acids (RCOOH) have two functional groups:

Carboxyl group

Hydroxy group

Nomenclature:

- Suffix: -oic acid
- The functional group always ends the chain and is included in carbon chain of the root name if the acid is not attached to a benzene ring.
- Numbering starts from the carboxyl -COOH carbon.

Physical properties:

- Acids are able to form hydrogen bonds also in their solid states that's why they have higher boiling points than the respective alkanes.

Reactivity:

- Due to electronegativity the -OH group in acids is more acidic than alcohols, carboxylic acids are weak acids, so they form an equilibrium when they dissociate.
- They undergo the same chemical reactions as any inorganic acid acting as proton donors, the carboxylate ion is stabilised by charge **delocalisation**.

3. Esters

Nomenclature:

- Esters (RCOOR') are derived from the reaction between carboxylic acids and alcohols in the presence of a strong acid acting as a catalyst.
- The name of the esters are based on that of the parent acid but the name always begins with the alkyl or aryl group that has replaced the hydrogen of the acid;
i.e. methanol + ethanoic acid \square methyl ethanoate

Physical properties:

- Short esters are volatile and have pleasant fruity smells and are used in perfumes or as flavourings.
- They are also use as solvent and plasticisers.
- Fats and oils are esters with longer carbon chains.

Reactivity:

- Formation see above.
- Hydrolysis to acid and alcohol:
- Acidic: can occur at room temperature with a strong acid as a catalyst, the reaction does not go to completion.
- Base: in the presence of a base the salt of the acid is produced and the reaction goes to completion

Triglycerides (animal fats and vegetable oils):

- Triglycerides are esters of the alcohol propane-1,2,3-triol (glycerol) and the so called "fatty acids" which are long chained (12-18) carboxylic acids.
- Fats are solid unsaturated and solid, vegetable oil are saturated and liquids.
- Fats and oils can be hydrolysed by boiling in NaOH - making glycerol and a mixture of sodium salts. The salts are called soap and are used as cleaning agents.

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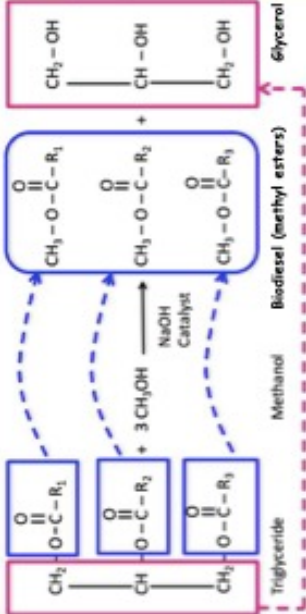


Knowledge Organiser: A-Level – Unit 8b: The Carboxyl Group

Unit 8b: The carboxyl group

1. Keywords

Delocalisation: when electrons in a molecule, ion or solid metal that are not associated with a single atom or a covalent bond.



		Increasing reactivity of nucleophile		Increasing reactivity	
	Ammonia NH_3	Acyl chloride $\text{R}-\text{C}(=\text{O})-\text{Cl}$	Acid anhydride $\text{R}-\text{C}(=\text{O})-\text{O}-\text{C}(=\text{O})-\text{R}$	Amide $\text{R}-\text{C}(=\text{O})-\text{NH}_2$	Amide $\text{R}-\text{C}(=\text{O})-\text{NH}_2$
	Amine $\text{R}'-\text{NH}_2$			N-substituted amide $\text{R}-\text{C}(=\text{O})-\text{NHR}'$	N-substituted amide $\text{R}-\text{C}(=\text{O})-\text{NHR}'$
	Alcohol $\text{R}'-\text{OH}$			ester $\text{R}-\text{C}(=\text{O})-\text{OR}'$	ester $\text{R}-\text{C}(=\text{O})-\text{OR}'$
	Water H_2O			carboxylic acid $\text{R}-\text{C}(=\text{O})-\text{OH}$	carboxylic acid $\text{R}-\text{C}(=\text{O})-\text{OH}$

1. Biodiesel

Biodiesel is a renewable fuel obtained from oils, mainly rape seed oil.

- Triglycerides are reacted with methanol in the presence of a strong alkali as a catalyst to form methyl esters and glycerol.

Uses of Glycerol

Glycerol is able to form many hydrogen bonds and it is very soluble in water so it has extensive applications:

- Used in creams and ointments to prevent their drying
- Solvent in the food industry, medicines and toothpastes
- Plasticiser.

2. Acylation (Addition-elimination reaction)

- Acylation is the addition of the acyl group ($-\text{COR}$) into another molecule.
- Acid derivatives all have the acyl group as part of their structure.
- The acid derivative is polarized and its carbonyl group can be attacked by a nucleophile, the nucleophile gets acylated.

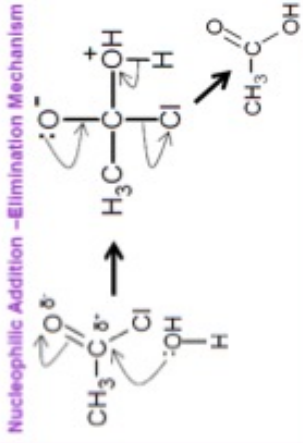
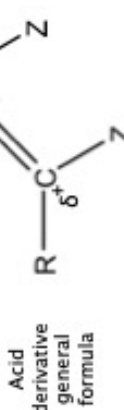
Z	Name of acid derivative	General formula	Example
$-\text{OR}$	ester	RCOOR'	Ethyl ethanoate $\text{CH}_3\text{COOC}_2\text{H}_5$
$-\text{Cl}$	acyl chloride	RCOCl	Ethanoyl chloride, CH_3COCl
$-\text{OCOR}'$	acid anhydride	$\text{RCOOCOR}'$	Ethanoic anhydride, $\text{CH}_3\text{COOCOCH}_3$

Addition-elimination reaction depends from:

- The polarization of the acid derivative depends on the electron-releasing or attracting power of Z.
- How good Z is leaving group
- How good the nucleophile is.

Ethanoic anhydride is used as an acylating agent over ethanoyl chloride because:

- It is cheaper
- It is less corrosive
- It is safer as the by-product is ethanoic acid rather than hydrogen chloride.



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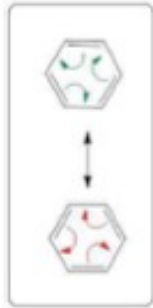
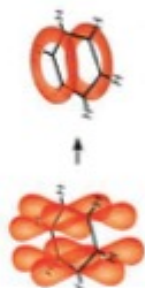
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Knowledge Organiser: A-Level – Unit 9: Aromatic Compounds

Unit 9: Aromatic compounds

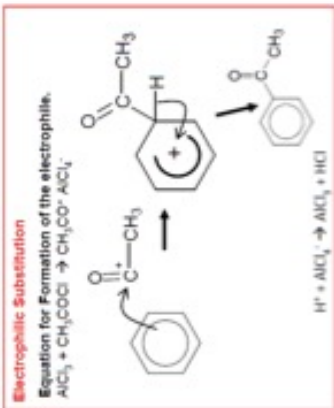
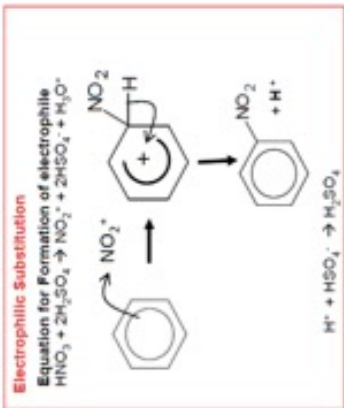
Bond	Length/nm
C-C	0.154
C-C (in benzene)	0.140
C=C	0.134



Benzene 2 Resonance Forms



Hybrid Forms



2. Benzene – Physical properties

Benzene was first isolated by Michael Faraday in 1825 and is now a major feedstock used in many industries:

- Polymers
 - Pharmaceuticals
 - Dyes
 - Explosives.
- Benzene itself is highly carcinogenic.
It is the simplest arene with an empirical formula of CH and a molecular formula of C_6H_6

- The C-C bond length in benzene is an intermediate between and C-C single bond and a C=C double bond.
- Benzene is more stable than the hypothetical cyclohexa-1,3,5-triene because of electron delocalisation.
- Each C atom has three covalent bonds – one to a H atom and the other two to C atoms. The fourth electron of each C atom is in a p-orbital. The p-orbitals overlap and the electrons in them are delocalised. This forms an area of electron density above and below the ring to form a π cloud.
- Benzene is planar and the C-C bonds are equal in length.

2. Benzene – Reactivity

- Benzene combusts like other hydrocarbons and tends to produce very smoky flames. This is due to the high carbon:hydrogen ratio, this leaves a lot of carbon unburnt.
- Benzene has electrophilic substitution reactions in preference to addition reactions.
- Benzene does not discolour bromine water.

- Electrophilic substitution – Nitration
The electrophile (NO_2^+) is made in the reaction mixture of concentrated nitric acid and concentrated sulfuric acid. The overall equation for the formation of the electrophile is:
 $\text{H}_2\text{SO}_4 + \text{HNO}_3 \rightleftharpoons \text{NO}_2^+ + \text{HSO}_4^- + \text{H}_2\text{O}$
The H^+ then reacts with the HSO_4^- to regenerate H_2SO_4 – the sulfuric acid is a catalyst.

- Electrophilic substitution – Friedel-Crafts acylation
It uses aluminium chloride as a catalyst
RCO substitutes for a hydrogen on the aromatic ring.
Acyl chlorides provide the RCO group, reacting with AlCl_3
 $\text{RCOCl} + \text{AlCl}_3 \rightleftharpoons \text{RCO}^+ + \text{AlCl}_4^-$
The aluminium chloride is then reformed by reacting with H^+ from the benzene ring:
 $\text{AlCl}_4^- + \text{H}^+ \rightleftharpoons \text{AlCl}_3 + \text{HCl}$

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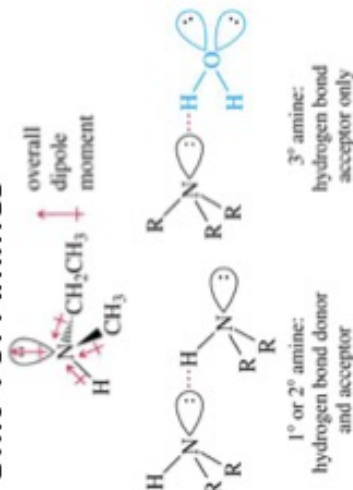
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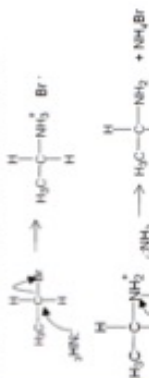


Knowledge Organiser: A-Level – Unit 10: Amines

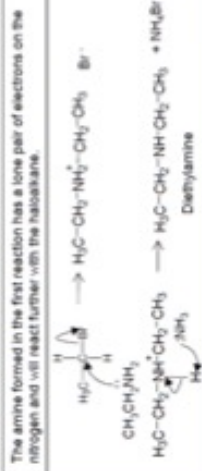
Unit 10: Amines



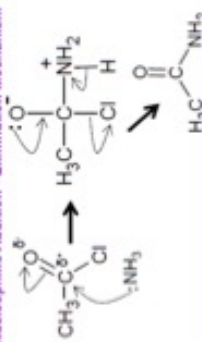
Reaction 1 with ammonia forming primary amine



Reaction 2 forming secondary amine



Nucleophilic Addition - Elimination Mechanism



1. Physical properties

- Amines are derivatives of ammonia, where one or more hydrogen atoms are replaced by alkyl or aryl groups.
- They are very reactive compounds

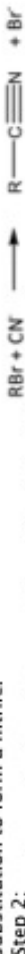
Nomenclature

- Amines are classified into primary secondary and tertiary based on the number of substituents bonded to the nitrogen.
- If there are more than one group attached to the amine we use N-R putting substituent in alphabetical order
- For secondary or tertiary amines each group from the amine group is named separately, the longest has the suffix -amine
- Amines are pyramidal molecules have all angles of approximately 107 degrees
- Short Amines are gases, longer ones are volatile liquids and have fishy smells.

2. Reactivity

Preparation :

- by reaction of ammonia with halogenoalkanes (Nucleophilic substitution)
The 1° amine can then act as a nucleophile and react with the halogenoalkane to produce a 2° amine, which can react to give a 3° amine, which in turn will react to make a 4° ammonium salt. This is not efficient.
- Preparation by reduction of nitriles
Halogenoalkanes react with a cyanide ion in aqueous ethanol. The ion replaces the halide ion by nucleophilic substitution to form a nitrile.



Step 2:
Nitriles can be reduced to primary amines with a nickel/hydrogen catalyst.



- Electrophilic substitution (nitration) of benzene. Nitrobenzene is then reduced to phenylamine using tin and HCl as the reducing agent:

Amines can act as bases

- Amines can accept a proton so they are weak Bronsted-Lowry bases:
- Alkyl groups release electrons towards the nitrogen atom, this is called inductive effect. The nitrogen is a stronger electron pair donor and so more attractive to protons.
- 1° alkylamines are stronger bases than ammonia because the inductive effect of the alkyl group increases the electron density on the N atom and makes it a better electron pair donor.
- 2° alkylamines have two inductive effects = stronger bases.
- 3° alkylamines = not strong because they are poorly soluble in water.
- Aryl groups withdraw electrons from the nitrogen atom. The nitrogen is a weaker electron pair donor and so less attractive to protons, so aryl amines are weaker bases than ammonia.

Amines can act as nucleophiles

- Ammonia and primary amines undergo addition-elimination reactions with acyl chlorides and acid anhydrides.

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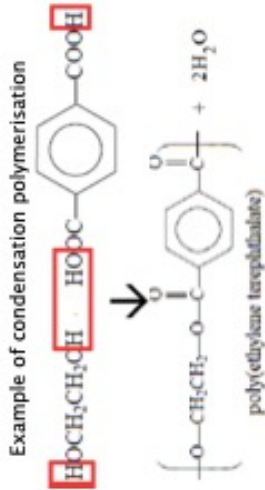
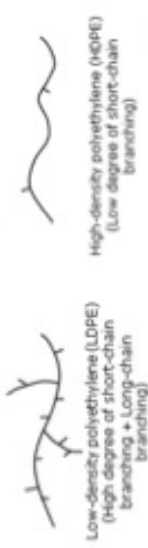
Knowledge Organiser: A-Level – Unit 11: Polymers

Unit 11: Polymers

1. Keywords

Plasticiser	a substance added to a synthetic material to produce or promote plasticity and flexibility and to reduce brittleness.
Atomic number:	number of protons (smaller no.) also the number of electrons in an atom.

Polymers	Addition	Condensation
Monomer	Alkene	With 2 functional groups
Synthesis	No by product	HCl or H ₂ O
Repeating unit	Symmetrical	Asymmetrical
Disposal	Some are recyclable	Biodegradable

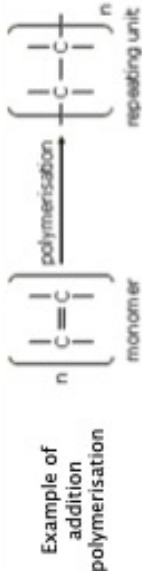


2. Types of polymers.

- Addition polymers.
- Alkenes can be used to make polymers such as poly(ethene) and poly(propene) by addition polymerisation.
 - Addition polymers are very unreactive and inert because all the non-polar single C-C bonds.
 - Polythene chains only have van der Waals forces between chains so are not good for forming fibres or weaving.
 - Polyethene is very useful though as it has no branches so the chains can pack closely and hence is a strong, rigid material.
 - LDPE is made at high temperatures and high pressures via free radical mechanism, hence it is highly branched and less packed than HDPE so it is stretchier. HDPE is made in the presence of the Ziegler-Natta catalyst at temperatures and pressures little higher than room conditions.
 - PVC (Poly(chloroethene)) contains polar C-Cl bonds. This makes PVC a hard but brittle material.
 - The properties of PVC can be modified using a plasticiser which makes the material softer and bendier. The plasticiser pushes the chains apart and the chains can slide making them more flexible. Plasticised PVC is used to make electrical cable insulation, flooring tiles and clothing.
- Condensation polymerisation
- Condensation polymerisation involves monomers with two functional groups (COOH and OH groups or COOH and NH₂ groups). During the condensation water or HCl is eliminated...
 - Condensation polymers can be hydrolysed so they are biodegradable.
 - Common condensation polymers:
 - Polyesters (-COO- linkage), like Terylene.
 - Polyamides (-CONH- linkage), like Nylon and Kevlar.
 - Polypeptides (-CONH- linkage), comprising all proteins.

3. Disposal of polymers.

- The options for disposal are either burying in landfill, burning or reusing/recycling.
- Advantages: reduces the amount of waste going to landfill, saving raw materials and producing less CO₂ than burning the plastic.
 - Disadvantages are that it is difficult to recycle; collecting, sorting and processing is expensive and the plastic can be easily the recycling process. Contaminated.
- Types of recycling:
- Mechanical recycling: types of plastics are separated, washed and ground to pellets that can be melted and remoulded.
 - Feedstock recycling: plastics are heated to produce the monomers that can be reused to make new plastic. This can be only done a limited amount of times.



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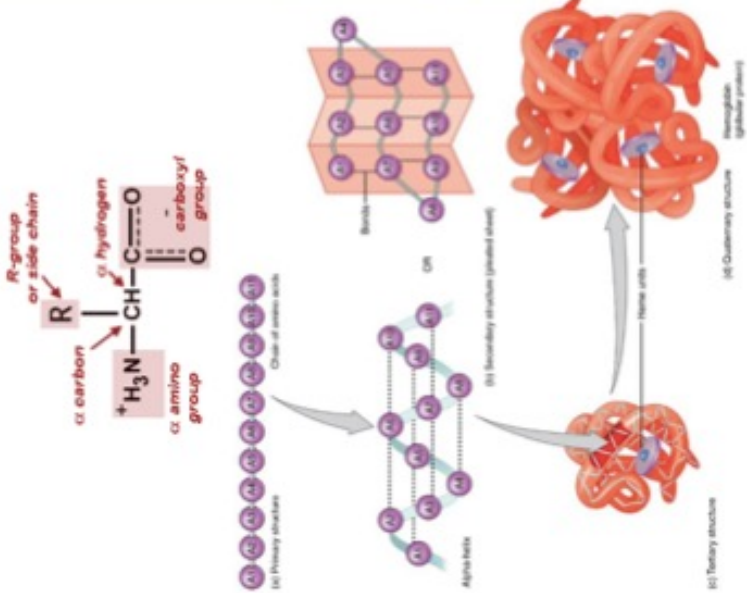


Knowledge Organiser: A-Level –

Unit 12: Peptides

Unit 12:Peptides

1. Keywords	destroy the characteristic properties of a biological macromolecule by heat, acidity, or other effect which disrupts its molecular conformation.
Stereospecific	preferentially interacting a particular stereoisomeric form of the substrate.
Zwitterions	molecule or ion having separate positively and negatively charged groups.



2. Aminoacids

- There are 20 essential amino acids that make up proteins in the human body.
- Amino acids contain both amine (NH_2) and carboxyl ($COOH$) functional groups.
- The molecule is chiral (not glycine) because it has a carbon bonded to four different groups.
- Most naturally occurring amino acids are the (-) enantiomer.
- Amino acids exist as **zwitterions** – ions that have both a permanent positive charge and a permanent negative charge, but are neutral overall.
- They can act both as acids and as bases
- α - amino acids have the amine group on the carbon next to the $-COOH$ group

Proteins are sequences of amino acids joined by peptide links $-CONH-$. (condensation reaction). Proteins can have 4 structures:

- Primary structure:** the sequence of amino acids along a protein chain. The structure is held together by strong covalent bonds (peptide bonds) and is therefore stable.
- Secondary structure:** Either an α -helix or a β -pleated sheet. Held together by hydrogen bonds which are much weaker than covalent bonds.
- Tertiary structure:** The secondary structure can be folded into a 3-D shape. This is held together by hydrogen bonding, ionic interactions and sulphur-sulphur bonds.
- Quaternary structure:** arrangement of two or more folded polypeptide chains that bond together with several types of bonds.

Sulfur-sulfur bonds.

- The amino acid cysteine has a side chain with a $-CH_2SH$ group.
- When oxidised, two cysteine molecules can form a sulfur-sulfur bond that makes a bridge between the two molecules; this is called a disulfide bridge.
- A double amino acid called cystine is formed.

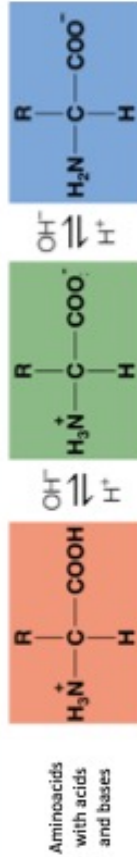


2. Denaturation

- The primary structure can be hydrolyzed: by boiling a protein or a peptide in HCl . The structure breaks down into a mixture of all the constituent amino acids. Hydrolysis requires 24 hours and $6 \text{ mol dm}^{-3} HCl$ since the covalent bond is a strong bond.
- Secondary structure can be disrupted by changes in pH or gentle heating (**denaturing**).

3. Enzymes

- Enzymes are biological catalysts
- Stereospecificity:** The active site of an enzyme can be so specific that many enzymes will only catalyse reactions of one enantiomeric form of a substrate.



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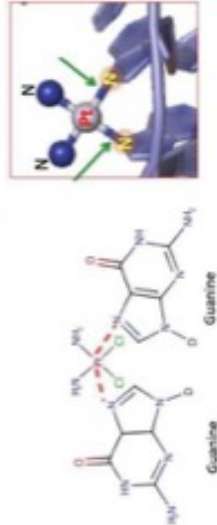
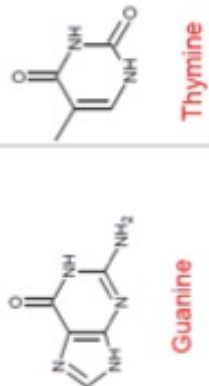
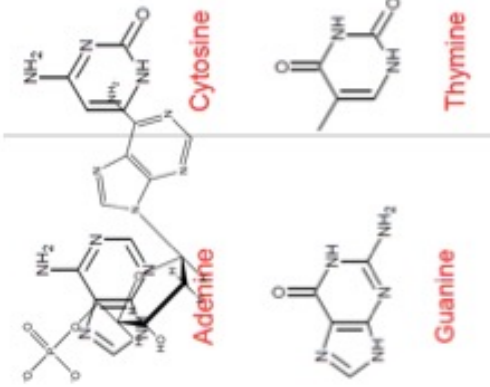
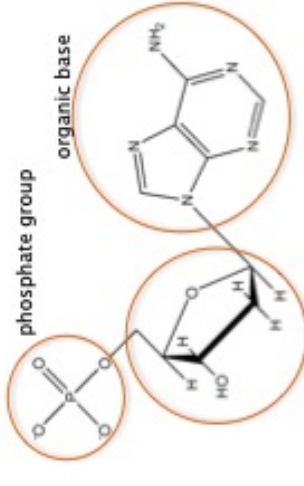
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Knowledge Organiser: A-Level – Unit 13: DNA

Unit 13: DNA



1. DNA

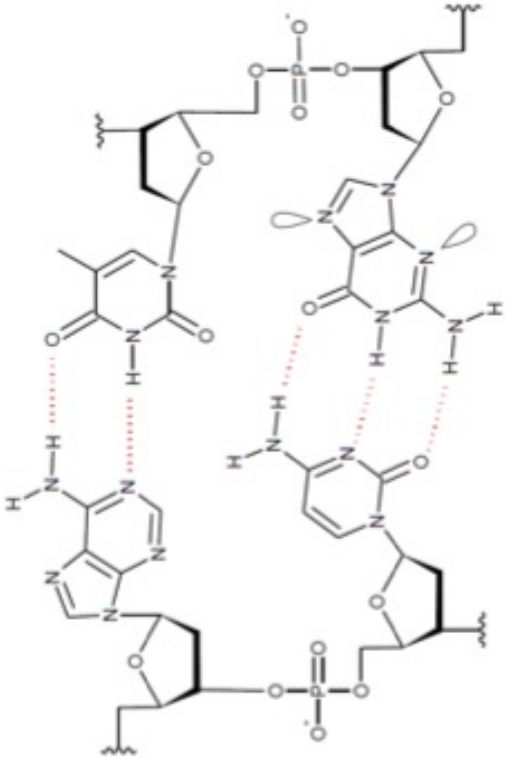
- DNA = Deoxyribonucleic acid
- A single strand of DNA is a polymer made up from four different monomers (nucleotides):
 - Cytosine (C)
 - Thymine (T)
 - Adenine (A)
 - Guanine (G)
- A nucleotide has three parts - a phosphate, a sugar and a base
- A single strand of DNA is a polymer of nucleotides linked by covalent bonds between the phosphate group of one nucleotide and the sugar of another nucleotide. Formed in a condensation reaction.
- The DNA Double helix is stabilised by hydrogen bonds between bases of complementary chain (A - T, C-G)

2. Anticancer drug

- Cisplatin is an anticancer drug
- works by bonding to strands of DNA (Ligand replacement reaction), distorting their shape and preventing the replication of the cells.
- The molecule bonds to the lone pair of nitrogen atoms on two adjacent guanine bases on a strand of DNA forming a dative covalent bonds with the platinum, displacing the Cl^- ions.

Side effects:

- It will bond to DNA in healthy cells as well as cancerous ones.



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Knowledge Organiser: A-Level –

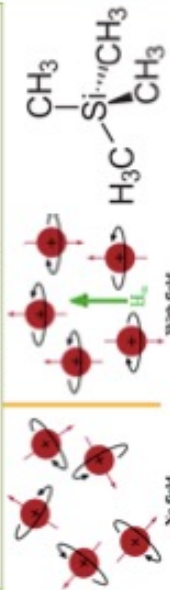
Unit 16: NMR

Unit 16: NMR

1. Keywords

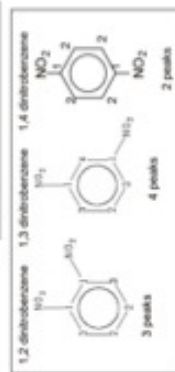
Chemical shift (δ).

the resonant frequency (signal) of a nucleus relative to a standard in a magnetic field.



¹ H NMR chemical shift data		¹³ C NMR chemical shift data	
Type of proton	δ ppm	Type of carbon	δ ppm
ROH	0.5–5.0	–C–C–	5–40
ROCH ₃	0.7–1.2	R–C–Cl or Br	10–70
RENH ₂	1.0–4.5	R–C(=O)–	20–50
R ₂ CH ₂	1.2–1.4	R–C(=O)–N	25–60
R ₂ CH	1.4–1.6	alcohols, ethers or esters	50–90
R–C(=O)–H	2.1–2.6	C=C	90–150
R–O–C(=O)–H	3.1–3.9	R–C≡N	110–125
ROCH ₂ Cl or Br	3.1–4.2	esters or acids	110–160
R–C(=O)–O–C(=O)–H	3.7–4.1	alkynes	160–185
R–C(=O)–O–R	4.5–6.0	aldehydes or ketones	190–220

¹³C NMR



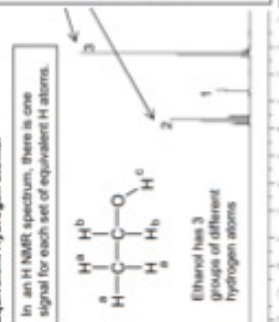
3. Interpretation

- Each ¹³C or ¹H atom of a specific functional group has its own δ .
- Tetramethylsilane, Si(CH₃)₄ (TMS) is used as a standard as all the hydrogen atoms are in identical environments. This means it produces a single peak, far away from most other absorption peaks. The single peak is given a chemical shift value of 0. It is also inert, non-toxic and volatile (easy to remove from the sample).
- The higher the electron density around the atom the higher the shielding hence the lower the δ on the NMR spectrum.
- In a NMR spectrum, there is one signal (peak) for each set of equivalent ¹³C or ¹H atoms.

¹H NMR

- The peaks can be split into multiple smaller peaks (spin-spin coupling). These split into the number of hydrogen atoms on the adjacent carbon plus one. Following the **n+1 rule**.
- The area of each peak is related to the number of H atoms producing it.
- The instrument produces a line called the integration trace. The relative heights of the steps show the relative number of each type of hydrogen.

Equivalent Hydrogen atoms.



signal	singlet	doublet	triplet	quartet
appearance				
Split number of peaks	1	2	3	4
number of neighbouring inequivalent H atoms	0	1	2	3
relative size		1:1	1:2:1	1:3:3:1

2. Nuclear Magnetic Resonance - theory

- Neutrons and protons can be found in the nucleus spinning on their own axis. In many atoms, these neutrons cancel each other out, but in those with an odd number of protons the nucleus itself will have an overall spin.
- This generates a small magnetic field around the nucleus, much like that of a bar magnet.
- If we place a bar magnet in an external magnetic field, it aligns parallel to it, much like a compass aligns with Earth's magnetic field. If we place nuclei with spin in a magnetic field, they, too, will align with it.
- If we provide the required energy, we can 'flip' the nuclei. This energy required for this can be supplied in the form of radio waves it can be recorded as a spectrum which we can then use to find information on the compound's structure.
- This flipping of the atom from one magnetic alignment to the other by the radio waves is known as the resonance condition.
- Each atom of each compound will have its specific **chemical shift (δ)**.

There are two main types of NMR:

- ¹³C NMR C-13 - Only 1% of the carbons are ¹³C (sensitivity problems).
- ¹H (proton) NMR - ¹H NMR spectra are obtained using samples dissolved in deuterated solvents or CCl₄

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Knowledge Organiser: A-Level – Unit 17: Chromatography

Unit 17: Chromatography

1. General principles

Chromatography describes a range of separation techniques where a mixture can be separated if it is dissolved in a solvent and the resulting solution moves over a solid.

- The mobile phase flows through the stationary phase and carries the components of the mixture with it. It is a liquid or a gas.
- The stationary phase is a solid, or a liquid supported on a solid. It will hold back the components in the mixture that are attracted to it.

The more affinity a component in the mixture being separated has for the stationary phase, the slower it moves with the solvent.

2. Thin layer chromatography

Advantages compared to paper chromatography:

- Faster
- Plates are harder wearing than paper
- Smaller amounts of mixtures can be separated

Detection

- Once a sample has run UV or other developing agents are used to locate the spots.
- The distance travelled relative to the solvent is called the R_f value.

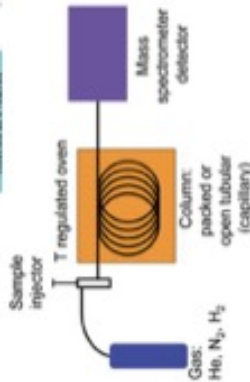
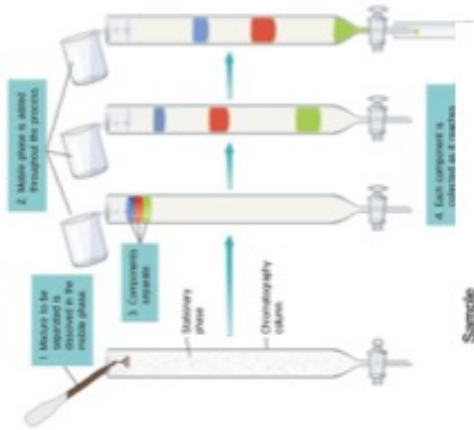
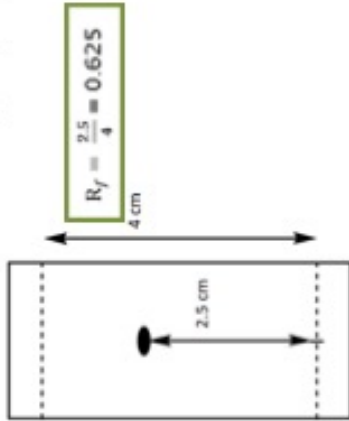
$$R_f = \frac{\text{distance travelled by the compound}}{\text{distance travelled by the solvent}}$$

3. High Pressure liquid chromatography

- HPLC is a column chromatography performed at high pressure.
- Pressure drives the elution rather than gravity.

4. Gas-liquid chromatography

- In Gas-liquid chromatography a column is packed with a solid or with a solid coated by a liquid, and a gas is passed through the column under pressure at high temperature.
- The sample is carried by the gas and the mixture separates as some of the components move along with the gas and some are retained by the oil.
- Different types of detectors are used to identify the emerging gas.
- In GCMS (Gas Chromatography-Mass Spectrometry) a mass spectrometer is used as the detector.



Chromatography	Mobile phase	Stationary phase	Support
Paper	Solvents	Paper	Paper
Thin layer	Solvents	Silica gel (SiO_2) or Alumina (Al_2O_3)	Glass or plastic
Column	Solvents	Silica gel (SiO_2) or Alumina (Al_2O_3)	Column
Gas-liquid	N_2 or He	Powder coated with oil	Capillary

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Knowledge Organiser: A-Level –

Unit 18: Test Tube Reactions

Unit 18: Test tube reactions

3. Tollens' Reagent

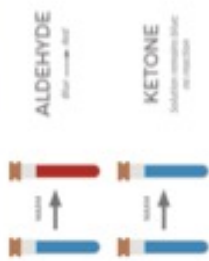
- Reagent: aqueous ammonia + silver nitrate.
 - The active substance is the complex ion of $[\text{Ag}(\text{NH}_3)_2]^+$
 - Conditions: heat gently
 - Reaction: The silver(I) ions are reduced to silver atom and aldehydes/alcohols oxidised.
 - Observation: a silver mirror forms coating the inside of the test tube. Ketones result in no change.
- $\text{CH}_3\text{CHO} + 2\text{Ag}^+ + \text{H}_2\text{O} \rightarrow \text{CH}_3\text{COOH} + 2\text{Ag} + 2\text{H}^+$

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 with Fehling's solution.
- $\text{CH}_3\text{CHO} + 2\text{Cu}^{2+} + 2\text{H}_2\text{O} \rightarrow \text{CH}_3\text{COOH} + \text{Cu}_2\text{O} + 4\text{H}^+$

FEHLING'S SOLUTION

Contains complexed Cu^{2+} ions. Aldehydes reduce these ions to red copper (I) oxide. Ketones don't react with Fehling's solution.



TOLLEN'S REAGENT

Contains the diamine silver ion, $[\text{Ag}(\text{NH}_3)_2]^+$. Aldehydes reduce this to metallic silver, forming a silver mirror on the glass surface.



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 st or 2 nd 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 $2\text{CH}_3\text{CO}_2\text{H} + \text{Na}_2\text{CO}_3 \rightarrow 2\text{CH}_3\text{CO}_2\text{Na} + \text{H}_2\text{O} + \text{CO}_2$ pH paper/indicator	Effervescence of CO_2 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)

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Knowledge Organiser: A-Level –

Unit 19: Organic Synthesis

Unit: 19 Organic synthesis

1. Keywords

Atom economy: a measure of the percentage of reactants that become useful products.

Target molecule: desired product of a synthetic process.

3. Chemical agents

Oxidising agents:

- Potassium dichromate ($K_2Cr_2O_7$) + sulphuric acid

Reducing agents:

- Sodium tetrahydridoborate (III) ($NaBH_4$), will reduce C=O but not C=C
- Hydrogen with a nickel catalyst (H_2/Ni) will reduce C=C but not C=O
- Tin and hydrochloric acid (Sn/H^+) will reduce nitrates to amines.

Dehydrating agents:

- Heated aluminium oxide
- H^+ (elimination reactions)

2. Reaction schemes

Using organic reactions you can work out a reaction scheme to convert a starting material into a **target molecule**.

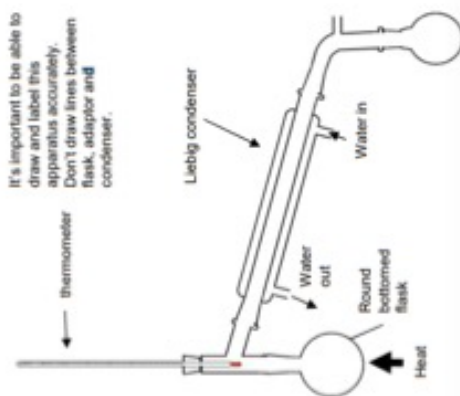
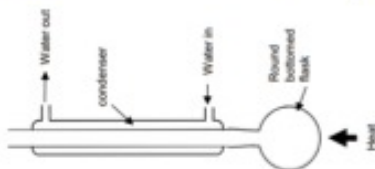
- Start by writing down the formula of the starting molecule and the target molecule.
- Write down all the compounds which can be made from the starting molecule and all the ways that the target molecule can be made.
- It is important to keep the number of steps in a reaction as small as possible and the **atom economy** high – this increases profit and reduces waste
- Chemists aim to design processes that do not require a solvent and use non-hazardous starting materials as this is more sustainable and has less environmental impact.

4. Reflux

Never seal the end of the condenser as the build up of gas pressure could cause the apparatus to explode.

Anti-bumping granules are added to the flask in both distillation and reflux to prevent vigorous, uneven boiling

- Don't draw lines between flask and condenser.
 - Don't have top of condenser sealed
 - Condenser must have outer tube for water that is sealed at top and bottom
 - Condenser must have two openings for water in and out that are open
- Electric heaters are often used to heat organic chemicals.



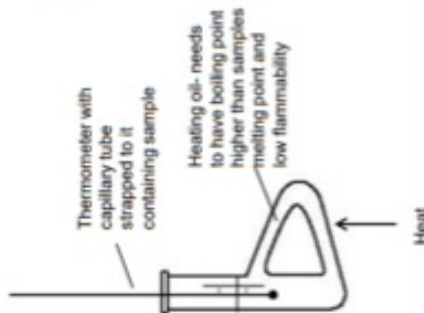
6. Distillation

- In general used as separation technique to separate an organic product from its reacting mixture.
- The distillate will be collected at the approximate boiling point range of the desired liquid.

5. Thiele tube

A Thiele tube is used to measure melting points.

- If impurities are present the melting point will be lowered and the sample will melt over a range of several degrees Celsius.
- The capillary tube is strapped to a thermometer immersed in some heating oil.
- Melting point can also be measured in an electronic melting point machine
- In both cases a small amount of the sample is put into a capillary tube.
- The tube is heated up and is heated slowly near the melting point



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Knowledge Organiser: A-Level – Unit 4: Period 3

Unit 4: Period 3

1. Keywords

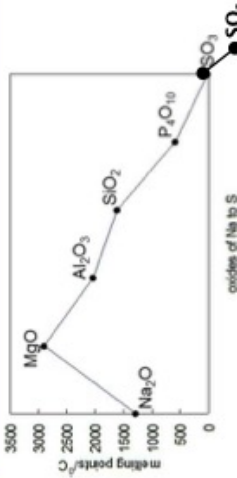
Amphoteric: able to react both as a base and as an acid.

4. Reactivity of Period 3 oxides with acids/bases

Na ₂ O	Na ₂ O(s) + 2HCl(aq) → 2NaCl(aq) + H ₂ O(l)	Alkali
MgO	MgO(s) + 2HCl(aq) → MgCl ₂ (aq) + H ₂ O(l)	Alkali
Al ₂ O ₃	Al ₂ O ₃ (s) + 6HCl(aq) → 2AlCl ₃ (aq) + 3H ₂ O(l) Al ₂ O ₃ (s) + 2NaOH(aq) + 3H ₂ O(l) → 2NaAl(OH) ₄ (aq)	Amphoteric
SiO ₂	SiO ₂ (s) + 2NaOH(aq) → 2Na ₂ SiO ₃ (aq) + H ₂ O(l)	Weak acid
P ₄ O ₁₀	P ₄ O ₁₀ (s) + 12NaOH(aq) → 4Na ₃ PO ₄ (aq) + 6H ₂ O(l)	Acid
SO ₂	SO ₂ (g) + 2NaOH(aq) → Na ₂ SO ₃ (aq) + H ₂ O(l)	Acid

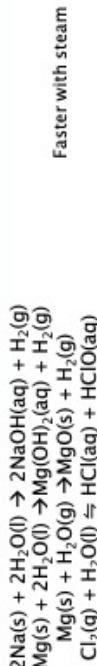
5. Reactivity of Period 3 oxides with water

Na ₂ O	Na ₂ O(s) + H ₂ O(l) → 2NaOH(aq)	pH = 14
MgO	MgO(s) + H ₂ O(l) → Mg(OH) ₂ (aq)	pH = 9
Al ₂ O ₃	Insoluble no reaction	pH = 7
SiO ₂	Insoluble	pH = 7
P ₄ O ₁₀	P ₄ O ₁₀ (s) + 6H ₂ O(l) → 4H ₃ PO ₄ (aq)	pH = 1-2
SO ₂	SO ₂ (g) + H ₂ O(l) → H ₂ SO ₃ (aq)	pH = 2-3
SO ₃	SO ₃ (g) + H ₂ O(l) → H ₂ SO ₄ (aq)	pH = 0-1

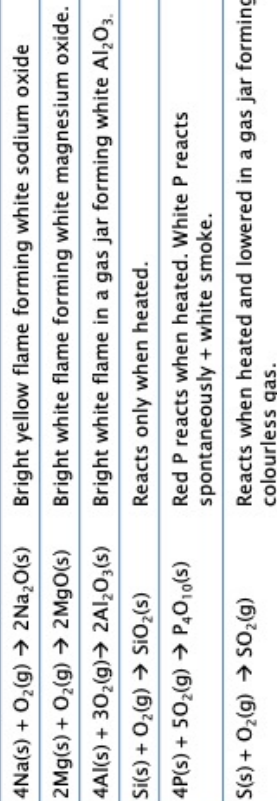


2. Reactivity

Reactivity with water (only Na, Mg, Cl₂):

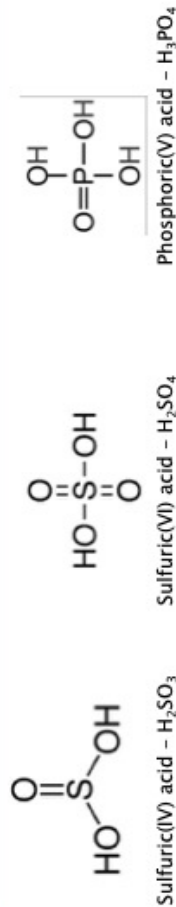


Reactivity with oxygen:



3. Period 3 oxides melting points

Na ₂ O/1548 K	Ionic structure = high melting points.
MgO/ 3125K	Ionic structure = high melting points. Smaller and more highly charged than Na giving a stronger attraction to the oxygen ions
Al ₂ O ₃ /2345K	Ionic structure with covalent character. Very high charge density on the small Al
SiO ₂ /1883K	Giant covalent structure. Strong covalent bonds Si-O.
P ₄ O ₁₀ /573K	Simple molecular compounds = low melting points.
SO ₃ /290K	Simple molecular compounds/weak intermolecular forces = low melting points
SO ₂ /200K	Simple molecular compounds/weak intermolecular forces = low melting points



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Knowledge Organiser: A-Level – Unit 5a: Transition Metals

Unit 5a: Transition metals

1. Keywords

Colorimetry:	scientific technique that is used to determine the concentration of coloured compounds using its absorbance
Complex ions:	metal ion surrounded by dative covalently bonded ligands.
Coordination number:	is the number of dative covalent bonds that are formed with central transition metal ion.

2. Classification

A transition metal is an element that forms at least one stable ion with a partially full d-shell.
<ul style="list-style-type: none">Transition metals have incomplete d subshells. When the fourth period metals form ions the 4s electrons are the first to be lost then 3d electrons.Scandium and Zinc are not considered to be transition metals. Scandium forms only a 3+ ion [Ar] 4s⁰ 3d⁰Zinc forms only a 2+ ion [Ar] 4s⁰ 3d¹⁰Copper is a transition metal because its +2 ion has an incomplete d orbital. [Ar] 4s⁰ 3d⁹

Chemical properties	Physical properties
<ul style="list-style-type: none">Form coloured ionsForm complex ionsAct as good catalystsVariable oxidation states.	<ul style="list-style-type: none">ShinyStrongHardGood conductors

3. Coloured ion formation

Ions with d¹⁰ or d⁰ are colourless, those partly filled tend to be coloured.

Energy is absorbed when an electron is promoted to a higher energy level. The frequency of light is proportional to the energy difference.

Electrons in lower 3d sublevels absorb energy from visible light which promotes them to a higher 3d sublevel. The rest of the frequencies are transmitted hence the complementary colour is observed.

Factors affecting colour

- Size & type of ligand
- Oxidation state
- Complex shape
- Coordination number
- Strength of metal-ligand bond

The size of the energy gap can be calculated if we know the frequency (v) or wavelength (λ) of the light absorbed:

$$\Delta E = h\nu = \frac{hc}{\lambda}$$

ΔE = energy absorbed (J)

$$c = \text{speed of light } (3.00 \times 10^8 \text{ m s}^{-1})$$

$$h = \text{Planck's constant } (6.63 \times 10^{-34} \text{ J s})$$

λ = wavelength of light absorbed (m)

ν = frequency of light absorbed (Hz)

Colorimetry: we can then determine the concentration by comparing our sample against known concentrations of the same metal ion / ligand.

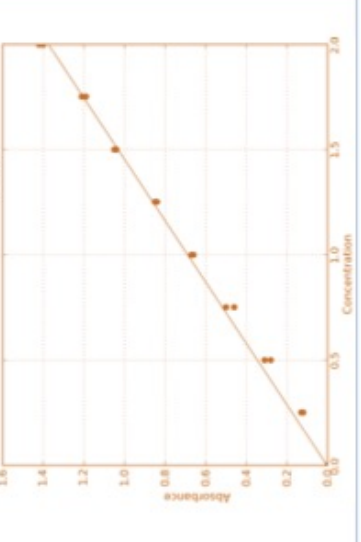
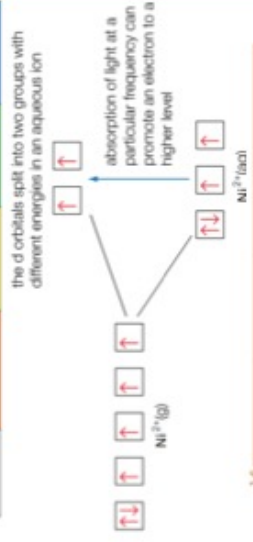
1. Make up solutions of known concentration.
2. Measure absorption of each known solution
3. Plot a graph of absorption vs concentration
4. Measure absorption of unknown and compare on the graph to give a concentration reading

Compounds of Vanadium

Aqueous ion	VO ₂ ⁺	VO ²⁺	V ³⁺	V ⁵⁺
Oxidation state	+5	+4	+3	+2
Colour	yellow	blue	green	violet

Compounds of Chromium

Aqueous ion	Cr ₂ O ₇ ²⁻ (aq)	CrO ₄ ²⁻ (aq)	Cr ³⁺	Cr ⁶⁺
Oxidation state	+6	+6	+3	+2
Colour	Orange	Yellow	Green	Blue



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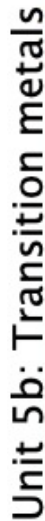
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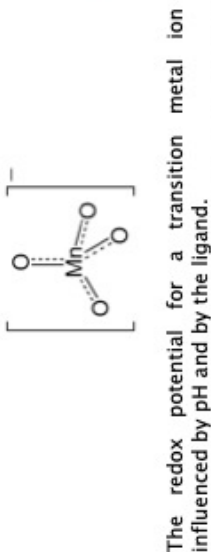
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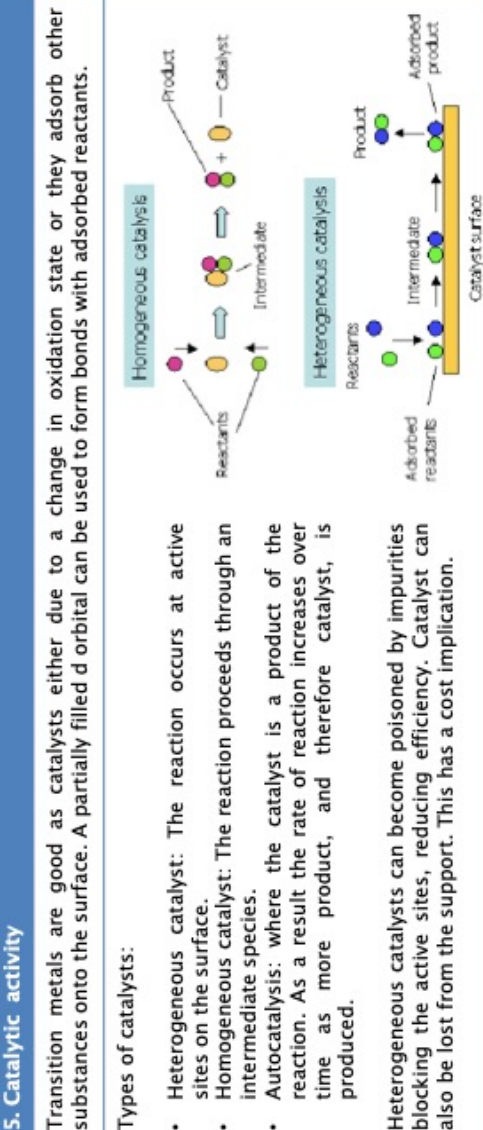


1. Keywords

The table shows the oxidation states of the transition metals. (red indicates the most common oxidation states found for that element). Not all of them are stable, only the lower oxidation states exist as stable ions (i.e. Mn 7+ exists only when in a covalent bond).

[illegible]

Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
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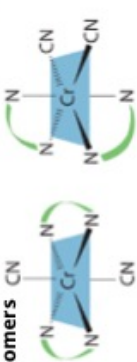
Knowledge Organiser: A-Level – Unit 6: Complex Ions

Unit 6: Complex ions

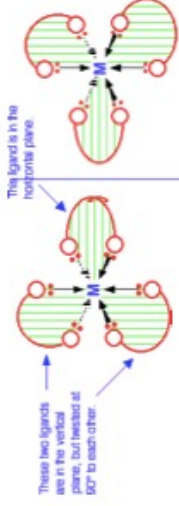
1. Keywords

Chelate:	compound containing a ligand bonded to a central metal atom at two or more points.
Coordinate (dative) bond ;	a covalent bond where both electrons in the shared pair come from the same atom
Coordination number:	is the number of dative covalent bonds that are formed with central transition metal ion.
Ligand:	is an atom, ion or molecule that donates a pair of electrons to a central transition metal .
Optical isomerism:	when two or more forms of a compound with the same structure are mirror images of each other and typically differ in optical activity.

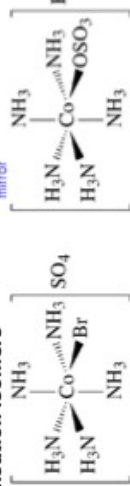
Geometrical isomers



Optical isomers



Ionisation isomers



2. Complex ion formation

All transition metals form co-ordinate bonds by accepting electron pairs from other ions or molecules generally called ligands. Different ligands form different strength bonds.

Monodentate ligands (single co-ordinate bond):	Bidentate (two co-ordinate bonds):	Multidentate (can form many co-ordinate bonds):
<ul style="list-style-type: none">H₂O (Aqua)NH₃ (Ammino)CN⁻OH⁻ (Hydroxi)Cl⁻	<ul style="list-style-type: none">H₂NCH₂CH₂NH₂ ethane 1,2 diamine (en)C₂O₄²⁻ ethanedioate (oxalate)Benzene 1,2 diol	<ul style="list-style-type: none">HaemEDTA⁴⁻ which can form 6 co-ordinate bonds

The charge of the complex ion depends on the charge of the transition metal and on the charge and number of the ligand.

3. Complex ion shapes

The coordination number dictates the shape of the complex ions.

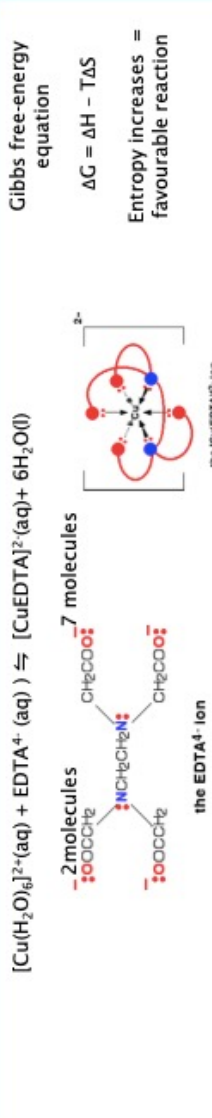
Coordination number	2	4	6
Shape	Linear	Tetrahedral or square planar	Octahedral

Types of isomerism can occur in complex ions:

- Geometrical isomerism – when two molecules have ligands in different positions in space.
- Optical isomerism – when two or more bidentate ligands are in a complex.
- Ionisation isomerism – when a ligand has exchanged places with an anion or neutral molecule that was originally outside the coordination complex.

4. Chelate effect

When bidentate or multidentate ligands take the place of monodentate, there are more products than reactants hence entropy of system increases, so products are thermodynamically more stable. The enthalpy change of these reactions is very small but the increase in entropy makes the reaction possible.



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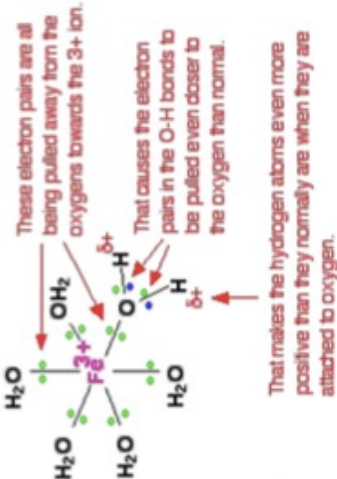
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Knowledge Organiser: A-Level – Unit 7a: Reactivity of Complex Ions

Unit 7a: Reactivity of complex ions

1. Keywords	
Amphoteric	means can behave as an acid and as a base.
Hydrolysis	the chemical breakdown of a compound due to reaction with water.



2. Acidity of aqua ion	
<ul style="list-style-type: none">In general the acidity of M^{3+} will be greater than that of M^{2+}, i.e. Fe^{3+} has a greater charge density than Fe^{2+}, there are more positive charges on the same ion and the ion is smaller. So the Fe^{3+} aqua ion (pKa 2.2) is more acidic than the Fe^{2+} (pKa 5.9) aqua ion.	
Reaction with OH^- (same with NH_3)	$[M(H_2O)_6]^{3+}(aq) + OH^-(aq) \rightarrow [M(H_2O)_5(OH)]^{2+}(aq) + H_2O(l)$
M^{3+} aqua ion	$[M(H_2O)_5(OH)]^{2+}(aq) + OH^-(aq) \rightarrow [M(H_2O)_4(OH)_2]^+(aq) + H_2O(l)$ $[M(H_2O)_4(OH)_2]^+(aq) + OH^-(aq) \rightarrow [M(H_2O)_3(OH)_3](s) + H_2O(l)$
M^{2+} aqua ion	$[M(H_2O)_6]^{2+}(aq) + OH^-(aq) \rightarrow [M(H_2O)_5(OH)]^+(aq) + H_2O(l)$ $[M(H_2O)_5(OH)]^+(aq) + OH^-(aq) \rightarrow M(H_2O)_5(OH)_2(s) + H_2O(l)$
Reaction with CO_3^{2-} M^{3+} aqua ion	$2[M(H_2O)_6]^{3+}(aq) + 3CO_3^{2-}(aq) \rightarrow 2[M(H_2O)_5(OH)_3](s) + 3H_2O(l) + 3CO_2(g)$
M^{2+} aqua ion	$[M(H_2O)_6]^{2+}(aq) + CO_3^{2-}(aq) \rightarrow MCO_3(s) + 6H_2O(l)$
CO_3^{2-} does not remove the proton from the complex, it is not a strong enough base. In general carbonates of M^{3+} do not exist, M^{2+} ones do.	
2. Aluminium	
Aluminium hydroxide is the most often quoted example of an amphoteric hydroxide.	
Acting as an acid	$[Al(H_2O)_6]^{3+}(aq) + OH^-(aq) \rightarrow [Al(H_2O)_5(OH)]^{2+}(aq) + H_2O(l)$ $[Al(H_2O)_5(OH)]^{2+}(aq) + OH^-(aq) \rightarrow [Al(H_2O)_4(OH)_2]^+(aq) + H_2O(l)$ $[Al(H_2O)_4(OH)_2]^+(aq) + OH^-(aq) \rightarrow [Al(H_2O)_3(OH)_3](s) + H_2O(l)$
This ion will dissolve. What you see occurring is the precipitation of neutral aluminium hydroxide and then the re-dissolving of it. The aluminium hydroxide has acted as an acid.	
Acting as a base.	$[Al(H_2O)_3(OH)_3](s) + OH^-(aq) \rightarrow [Al(OH)_4]^-(aq) + 3H_2O(l)$ $[Al(H_2O)_3(OH)_3](s) + 3HCl(aq) \rightarrow [Al(H_2O)_6]^{3+}(aq) + 3Cl^-(aq)$ $[Al(H_2O)_3(OH)_3](s) + H^+(aq) \rightarrow [Al(H_2O)_4(OH)_2]^+(aq)$ $[Al(H_2O)_4(OH)_2]^+(aq) + H^+(aq) \rightarrow [Al(H_2O)_5(OH)]^{2+}(aq)$ $[Al(H_2O)_5(OH)]^{2+}(aq) + H^+(aq) \rightarrow [Al(H_2O)_6]^{3+}(aq)$

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Knowledge Organiser: A-Level – Unit 7b: Reactivity of Complex Ions

Unit 7b: Reactivity of complex ions

1. Ligand exchange	
Ligands can be swapped around, this is called ligand exchange. It usually results in a colour change. This happens when: <ul style="list-style-type: none">The new ligand can form stronger bonds with the metal ionThe new ligand is more concentrated	
	Replacing water as a ligand
with a neutral ligand	$[M(H_2O)_6]^{2+} (aq) + NH_3(aq) \rightleftharpoons [M(NH_3)_6]^{2+} (aq) + 6H_2O (l)$
Complete substitution	the coordination number doesn't change and neither does the shape.
with a neutral ligand	$[Cu(H_2O)_6]^{2+} (aq) + 4NH_3(aq) \rightleftharpoons [Cu(NH_3)_4(H_2O)_2]^{2+} (aq) + 4H_2O (l)$
Partial substitution (Cu^{2+})	Ammonia first will act as a base and then as a ligand. the coordination number doesn't change and the shape is still octahedral but it is now a distorted octahedral, this is because water has longer bonds with Cu since it has less affinity.
with other charged ligands (Cu^{2+})	$[Cu(H_2O)_6]^{2+} (aq) + 4Cl^- (aq) \rightleftharpoons [CuCl_4]^{2-} (aq) + 6H_2O (l)$
with a multidentate ligand	Change in the coordination number and in the shape See chelate effect Unit 6

Change in the coordination number and in the shape forming more stable complex.

Metal aqua-ion	With OH ⁻ or NH ₃ (aq)	With excess OH ⁻ (aq)	With excess NH ₃ (aq)	With Na ₂ CO ₃ (aq)
$[Fe(H_2O)_6]^{2+}$ (aq) Yellow	$[Fe(H_2O)_4(OH)_2] (s)$ Red-Brown	No change, precipitate remains	No change, precipitate remains	$FeCO_3(s)$
$[Fe(H_2O)_6]^{3+}$ (aq)	$[Fe(H_2O)_3(OH)_3] (s)$ Red-Brown	No change, precipitate remains	No change, precipitate remains	$[Fe(H_2O)_3(OH)_3] (s)$ Red-Brown
$[Cu(H_2O)_6]^{2+}$ (aq)	$[Cu(H_2O)_4(OH)_2] (s)$	No change, precipitate remains	$[Cu(NH_3)_4(H_2O)_2]^{2+}$ (aq) Deep-blue	$CuCO_3(s)$ Blue-green
$[Al(H_2O)_6]^{3+}$ (aq) Colourless	$[Al(H_2O)_3(OH)_3] (s)$ White	$[Al(OH)_4]^-$ (aq)	No change, precipitate remains	$[Al(H_2O)_3(OH)_3] (s)$ White

Colours of Vanadium oxidation states



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