

H2 CHEMISTRY

Hand-written Notes by **Kevin**

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IONIC EQUILIBRIA

Physical Chemistry.

Reaction Kinetics.

→ Terms & Definitions.

+ Rate of Reaction: Change in concentration of reactants or products over time.

$$\hookrightarrow -\frac{d[\text{reactant}]}{dt} = \frac{d[\text{product}]}{dt}$$

$$\hookrightarrow \text{Eq. } A \rightarrow B : -\frac{d[A]}{dt} = \frac{d[B]}{dt}$$

+ Rate Eqn: Eqn that relates rate of reaction to the concentrations of reactants at any given time; determined experimentally.

+ Order of Reaction: Power of concentration terms in the experimentally determined Rate eqn.

+ Rate Constant, k: A proportionality constant relating rate of reaction to concentrations of reactants in the rate eqn. Constant at given temperature.

→ Order of reaction & features.

+ Zero Order

↳ Rate of reaction = Rate constant, k (in $\text{mol dm}^{-3} \text{s}^{-1}$)

↳ Rate of reaction independent of concentration; only affected by temperature.

↳ Usually the case of decomposition of a single compound.

+ First Order

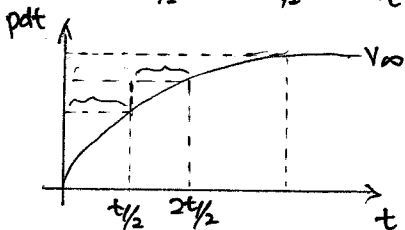
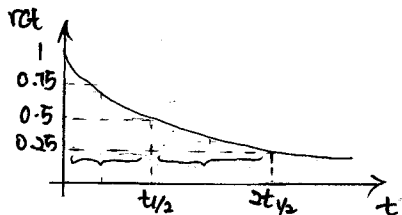
↳ Rate of reaction = $k[\text{reactant}]$; (k in s^{-1})

↳ Rate of reaction directly proportional to concentration of reactant.

↳ Constant half-life: $t_{1/2} = \frac{\ln 2}{k}$

↳ Proving of constant half-life: for reactant-time; take starting concentration as 100% (Just find any pt then half it and take the time lapse between).

for product-time; take V_{∞} as 100%
(find time lapse from 100% \rightarrow 0.5 V_{∞} and
0.5 V_{∞} \rightarrow 0.75 V_{∞})



* Note Product-Reactant Changes over time
(Half-life is for reactants)

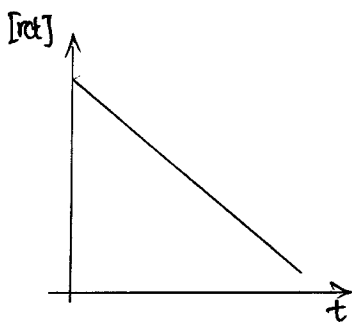
Product	0	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{7}{8}$
Reactant	1	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{8}$
Time	0	$t_{1/2}$	$2t_{1/2}$	$3t_{1/2}$

+ Second Order

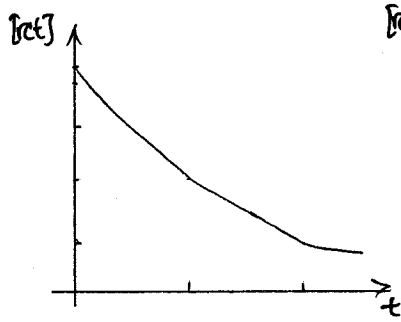
↳ Rate of reaction = $k[\text{reactant}]^2$ (k in $\text{mol}^{-1}\text{dm}^3\text{s}^{-1}$)

↳ Rate of reaction proportional to square of the concentration of reactant

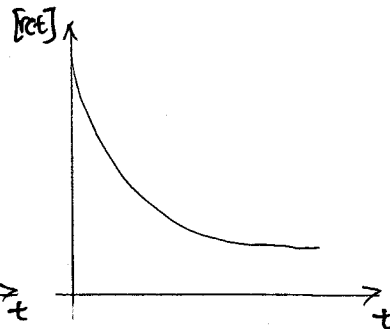
↳ Half-life not constant.



Zero order
(straight)



First order
(constant half-life
curve)



Second order
(curve with no
constant $t_{1/2}$)

→ Finding Rate of Reaction

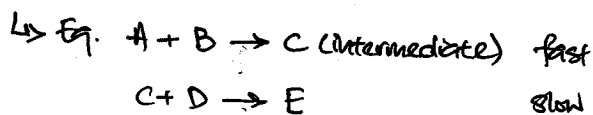
+ $\frac{\text{rate}_1}{\text{rate}_2} = \left(\frac{[\text{react}]_1}{[\text{react}]_2}\right)^x$, where x is the order of reaction & the [] of other reactants is constant.

+ $\frac{\text{rate}_1}{\text{rate}_2} = \left(\frac{[\text{react}]_1}{[\text{react}]_2}\right)^x \times \left(\frac{[\text{oth}]_1}{[\text{oth}]_2}\right)^y$, where y has been found.

→ Reaction Mechanism

+ Rate eqn only has the concentration terms of reactant in the rate-determining step (slowest), also known as RDS

+ If intermediates are in RDS, substitute them with earlier eqns:



Rate eqn should be $k[C][D]$, but since C is an intermediate and from the first eqn: $k' = \frac{[C]}{[A][B]} \Rightarrow [C] = k'[A][B]$

Hence, rate of reaction = $k'[A][B][D]$.

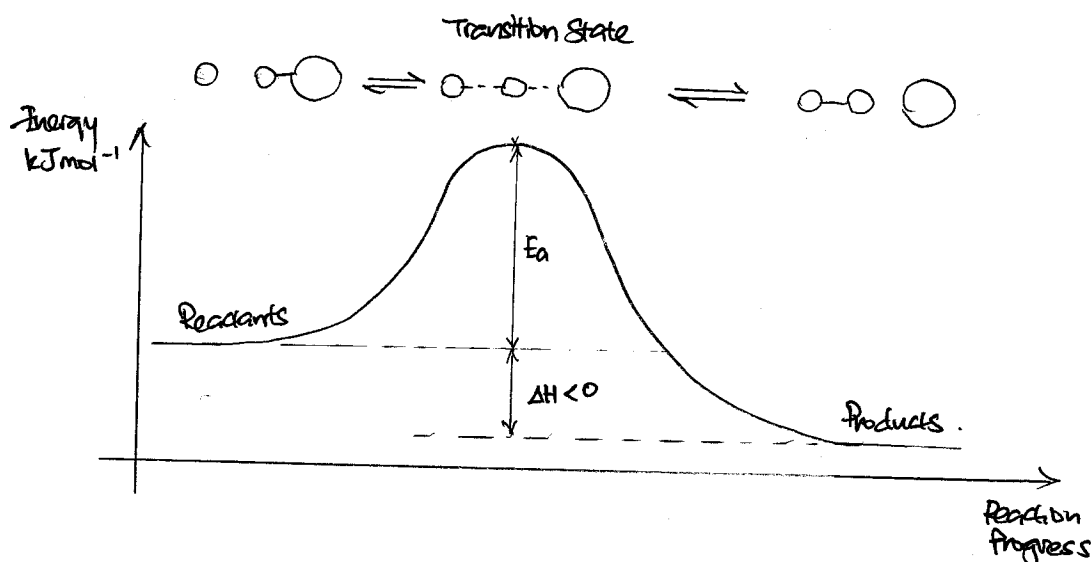
→ Factors Influencing Rates

+ Collision

- ↳ High frequency of colliding
- ↳ Correct Orientation in Collision
- ↳ Sufficient kinetic Energy during collision. (Must be able to cross energy barrier).

+ Energy Profile.

- ↳ Activation Energy: Minimum energy reacting particles must possess to overcome energy barrier before formation of the products.



+ Condition / Environmental Factors.

- ↳ Increased Concentration: more frequent collision. (Pressure for gases).
- ↳ Smaller particle size: higher exposed area.
- ↳ Increased temperature: more particles with energy above E_a (illustrated by Maxwell-Boltzmann Distribution).

Increased temperature also raise rate constant's value via $k = A e^{-\frac{E_a}{RT}}$

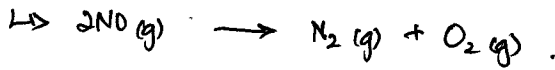
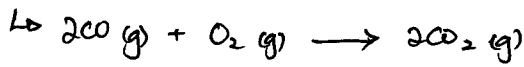
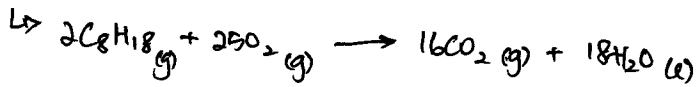
- ↳ Including Catalyst: E_a lowered by alternative energy pathways.

Lower E_a thus raise value of rate constant via Arrhenius equation (above).

- Homogeneous catalyst appears in rate eqn and thus may affect rate of reaction.
- Heterogeneous catalyst will be such that in small concentrations of reactants, increasing [reactants] help but at high [reactants], the catalysis is restricted by exposed surface area.

→ Catalysis

+ Catalytic Converter



+ Haber Process Iron Catalyst.

↳ Reactant molecules adsorb on catalyst surface: weak bonds between catalyst & reactant molecules

↳ N≡N & H-H bonds are weakened and molecule concentration is increased on the catalyst surface.

+ Autocatalysis

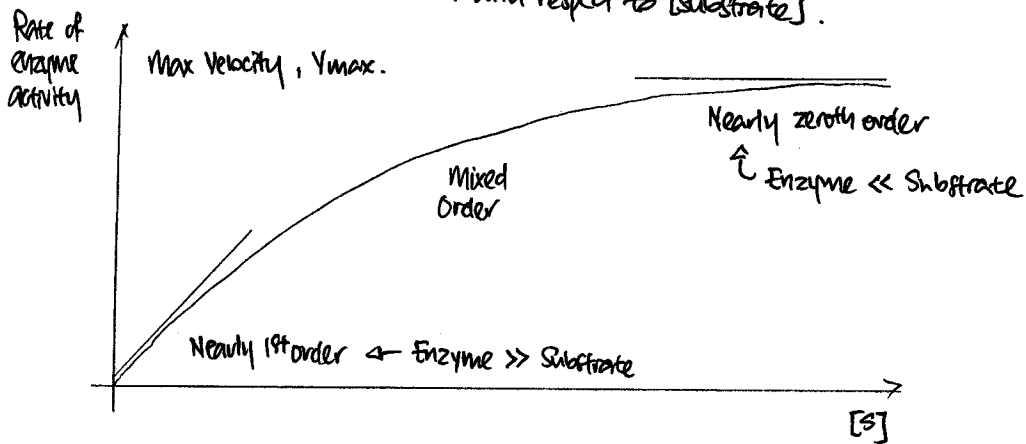
↳ A reaction with a product that catalyses the reaction itself.

+ Biological Catalyst: Enzyme.

↳ Substrate-specific

↳ Has optimal pH & temperature.

↳ Changing order of reaction with respect to [Substrate].



Chemical Energetics.

→ Definitions + Terms

- + Enthalpy change, ΔH : Change in total enthalpy/heat content of substances in a reaction. (kJ mol^{-1})
- + Entropy Change, ΔS : Change in total disorder (randomness) of a system (J mol^{-1})
- + Heat Capacity: Amount of heat required to raise its temperature by 1K. (J K^{-1})
- + Specific Heat Capacity: Heat Capacity per unit mass of substance. ($\text{J K}^{-1} \text{g}^{-1}$)
- + Hess Law: Enthalpy change in a reaction is determined only by initial + final states of system (Independent of pathway).

→ Calculating Enthalpy Change

$$+ q = mc\Delta T \quad \text{OR} \quad C\Delta T$$

$$= mc(T_f - T_i)$$

$$+ \Delta H = \frac{q}{n_{\text{react}}} \quad \leftarrow \text{Add (-) if exothermic, add (+) if endothermic.}$$

$$+ \Delta H_{\text{neq}} = - \frac{q}{n_{\text{H}_2\text{O}}}$$

$$+ \Delta H_{\text{atom}} (\text{diatomic gas}) = \frac{1}{2} \text{BDE}$$

$$+ \Delta H_{\text{hyd}} \propto \left| \frac{q^+}{r^+} \right| \quad \text{OR} \quad \left| \frac{q^-}{r^-} \right|$$

$$+ \text{L.E.} \propto \left| \frac{q^+ q^-}{r^+ r^-} \right|$$

$$+ \Delta H_{\text{sol}} = \Delta H_{\text{hyd}} (\text{cation}) + \Delta H_{\text{hyd}} (\text{anion}) - \text{L.E.}$$

$$+ \Delta H_{\text{rxn}} = \sum \Delta H_f^\circ (\text{products}) - \sum \Delta H_f^\circ (\text{reactants})$$

$$\Delta H_f^\circ = \sum \Delta H_c (\text{reactants}) - \sum \Delta H_c (\text{products}).$$

→ Thermodynamics Formula

+ All spontaneous change must cause entropy of the universe to increase where

$$\Delta S_{\text{univ}} = \Delta S_{\text{sys}} + \Delta S_{\text{surr}} \quad \text{AND} \quad \Delta S_{\text{surr}} = \frac{-\Delta H}{T}$$

↳ Factors for Entropy to increase

- Δn must be positive.
- Phase change: Solid \rightarrow Liquid OR Liquid \rightarrow Gas.
- Lower Pressure: more movement \rightarrow more disorder.

↳ Examples

- Expansion of Gas
- More molecules after reaction
- Mixing of particles.
- Increase in temperature
- Phase Change.

+ Gibbs free energy: $\Delta G = \Delta H - T\Delta S$.

↳ Positive ΔG : Reaction won't occur spontaneously.

↳ Negative ΔG : Reaction occurs spontaneously; more vigorously the more negative.

↳ $\Delta G = 0$: During a phase change.

↳ ΔG^\ominus , standard Gibbs free energy change can approximate ΔG @ other temperatures if there's no phase change involved.

+ Reaction Feasibility.

↳ $\Delta H^\ominus > 0$, $\Delta S^\ominus > 0$; ΔG can be (-) at high temperatures

↳ $\Delta H^\ominus < 0$, $\Delta S^\ominus < 0$; ΔG can be (-) at low temperatures.

↳ $\Delta H^\ominus > 0$, $\Delta S^\ominus < 0$; ΔG always (+) and have to be driven (by energy source like sunlight or a potential difference).

↳ $\Delta H^\ominus < 0$, $\Delta S^\ominus > 0$; ΔG always (-) and spontaneous all the time.

↳ When $\Delta G = 0$ @ phase changes,

$$\Delta S_{\text{fus}}^\ominus = \frac{\Delta H_{\text{fus}}^\ominus}{T_{\text{fus}}} \quad \text{or} \quad \Delta S_{\text{vap}}^\ominus = \frac{\Delta H_{\text{vap}}^\ominus}{T_{\text{vap}}}$$

Chemical Equilibrium.

→ Terms & Definition

- + Equilibrium position: Where rate of forward reaction equals to backward reaction
- + Reversible Reaction: Reaction that do not go to completion but stop at the equilibrium position where both products & reactants are detectable in quantity
- + Dynamic Equilibrium: Equilibrium whereby macroscopic properties like concentrations of species are constant as the forward reaction = backward reaction. but identity of individual molecules are changing.
- + Equilibrium Constant: Temperature dependent constant that shows quantitatively the relationship that exists at equilibrium between [products] & [reactants].
* Bigger K implies more tendency to form products.

→ Factors Changing Equilibrium & Rate of Reaction.

- + Temperature: \uparrow Rate & Equilibrium Position (depends on ΔH).
- + Concentration: \uparrow Rate & Equilibrium Position
- + Pressure: \uparrow Rate (if all gas) & Equilibrium Position (if $\Delta n \neq 0$) ^{Gas only.}
- + Catalyst: \uparrow Rate Only.

\uparrow Rate: R_f & R_b
 \uparrow Rate: R only.

→ Equilibrium Expressions.

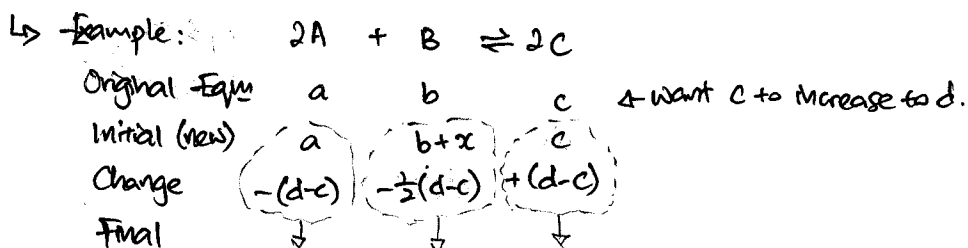
$$K_c = \frac{K_p}{K_b} = \frac{[C]^c [D]^d}{[A]^a [B]^b} \quad \text{if } aA + bB \rightleftharpoons cC + dD$$

+ Rule for K_c / K_p

- ↳ K_c : Include gas & liquid but not solid
- ↳ K_p : Include gas but not liquid or solid.
- ↳ Note to follow stoichiometric Ratio of reaction

→ Problem Solving.

- + When asked how much of one particular reactant to add so as to increase the yield of products, set 'x' as the addition in the new initial.



+ On Degree of Dissociation given to find K_p / K_c .

↳ Example: $A \rightleftharpoons bB$, has a degree of dissociation α @ γ atm

Initial γ -

Change $-x$ $+bx$

Final $\gamma-x$ bx Total mol: $\gamma + (b-1)x$, $P_T = \gamma$ atm

$$K_p = \frac{(P_B)^b}{P_A} = \frac{\left[\frac{bx}{\gamma + (b-1)x} \times \gamma\right]^b}{\left(\frac{\gamma-x}{\gamma + (b-1)x} \times \gamma\right)}$$

+ On K_p / K_c given to find degree of dissociation ($\alpha = \frac{\text{moles dissociated}}{\text{Initial moles}}$)

↳ Example: Refer to top, with P_T value changed.

* Industrial Conditions for Ammonia Production (Haber Process).

+ P : 200 atm → Expensive to raise P too high

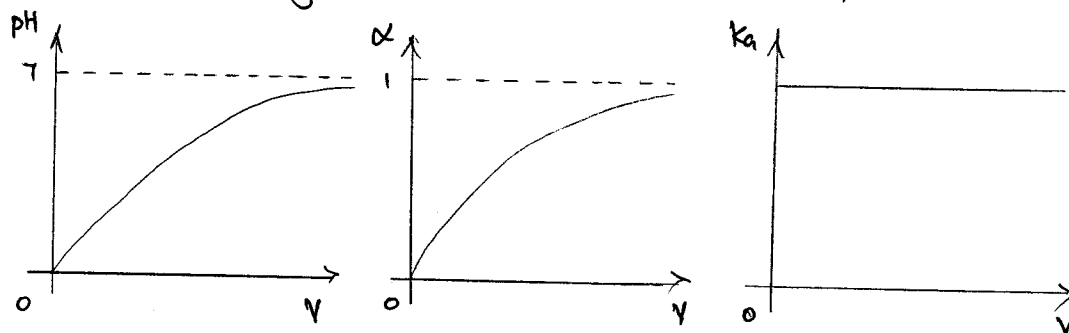
+ T : 450°C or 670K - 770K → Rate slows with low temperature.

+ Catalyst: finely divided Iron metal.

Ionic Equilibria.

→ Acid strength & Comparison

- + Strength of acid is its ability to donate protons.
- + Strong Acids: HCl , HNO_3 , HBr , HI , HClO_3 , HClO_4 , H_2SO_4
- + Weak Acids: H_2SO_3 , H_2CO_3 , Organic Acids.
- + Measures of strength: As a weak acid is diluted with water,



↳ Since K_a & K_b does not vary with concentration, it is the best measure of acid strength.

↳ $\text{pH} = -\log [\text{H}^+]$ and $\alpha = \frac{\text{Concentration of acid dissociated}}{\text{Initial concentration}}$, both varies with concentration of the acid.

+ Calculation of Acid strength.

↳ For acid HA , $K_a = \frac{[\text{H}^+][\text{A}^-]}{[\text{HA}]}$. At 25°C , with only the acid in water, $[\text{H}^+] = [\text{A}^-]$. Hence $K_a = \frac{[\text{H}^+]^2}{[\text{HA}]}$

↳ For base B , $K_b = \frac{[\text{BH}^+][\text{OH}^-]}{[\text{B}]}$. At 25°C , with only the base in water, $[\text{BH}^+] = [\text{OH}^-]$. Hence $K_b = \frac{[\text{BH}^+]^2}{[\text{B}]}$

* At any time when $[\text{H}^+]$ is less than 10^{-6} , autoprotolysis must be accounted.

→ Indicators

+ $K_{in} = \frac{[\text{H}^+][\text{In}^-]}{[\text{HIn}]}$ ⇒ Working range of Indicator: $\text{p}K_{in} \pm 1$

+ Methyl Orange: Red $\xrightarrow{\text{pH } 4}$ Yellow

+ Litmus: Red $\xrightarrow{\text{pH } 7}$ Blue

+ Phenolphthalein: Colorless $\xrightarrow{\text{pH } 8}$ Red (Pink).

→ Salt hydrolysis.

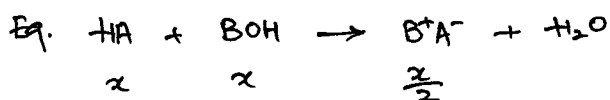
+ Strong Base - Strong Acid: Neutral Salt.

+ Strong Base - Weak Acid: Basic Salt

+ Strong Acid - Weak Base: Acid Salt

+ Weak Acid - Weak Base: Acid if $K_a > K_b$, Basic if $K_a < K_b$ & Neutral if $K_a = K_b$.

* Note always that resulting concentration of salt produced before hydrolysis is half of the concentration of acid & base if they are equal.



→ Buffer Solution

+ A solution that resist pH changes upon addition of small amount of acid or base.

+ Max Buffer Capacity : $[\text{H}^+] = K_a$ & $\text{pH} = \text{p}K_a$.

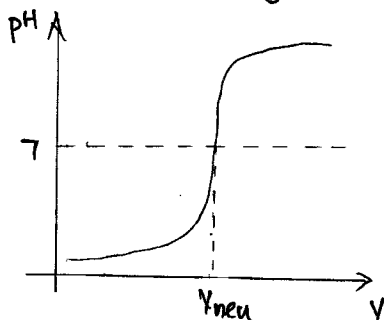
+ Effective Buffer Range : $\text{pH} = \text{p}K_a \pm 1$ OR $\text{pOH} = \text{p}K_b \pm 1$

+ pH OR pOH of Buffers : $[\text{H}^+] = \frac{K_a[\text{acid}]}{[\text{salt}]}$ OR $[\text{OH}^-] = \frac{K_b[\text{base}]}{[\text{salt}]}$

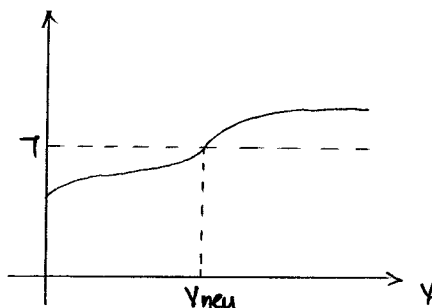
+ Blood as buffer : $\text{H}^+ + \text{HCO}_3^- \rightleftharpoons \text{H}_2\text{CO}_3(\text{aq}) \rightleftharpoons \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$.

→ Titration Curves.

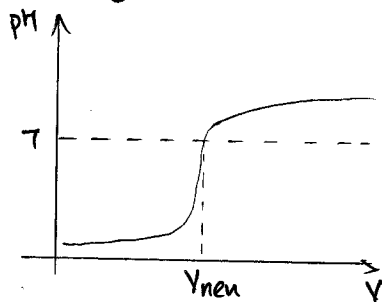
+ strong acid - strong base



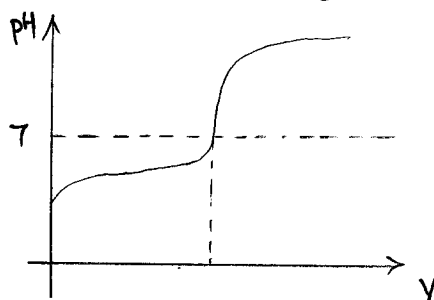
+ Weak acid - Weak Base.



+ Strong acid - Weak base



+ Weak acid - Strong base.



→ Solubility Product

+ For any $\text{M}_x\text{X}_n \rightleftharpoons x\text{M}^{n+} + n\text{X}^{m-}$, $K_{sp} = [\text{M}^{n+}]^x [\text{X}^{m-}]^n$

+ Solubility (g dm^{-3}) \div M_r = Molar Solubility (mol dm^{-3}).

+ $K_{sp} = [\text{I}]_{\text{eqm}} [\text{J}]_{\text{eqm}}$ & $\text{IP} = [\text{I}]_{\text{aftermix}} [\text{J}]_{\text{aftermix}}$

↳ $\text{IP} < K_{sp}$: No ppt ; $\text{IP} = K_{sp}$: 1st appear or just dissolve ; $\text{IP} > K_{sp}$: ppt appear.

ORGANIC CHEMISTRY

REACTION MECHANISMS & CONCEPTS COVERED

ALKANE

ALKENES

ARENES/BENZENE

HALOGEN DERIVATIVES

HYDROXY GROUP

CARBONYL

CARBOXYLIC ACID/CARBOXY GROUP

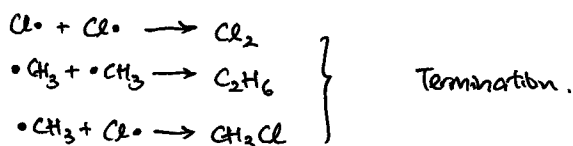
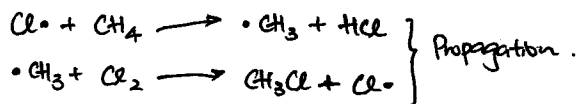
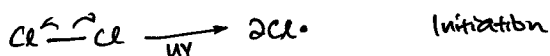
NITRILE

NITROGEN COMPOUNDS

PROTEINS

Alkane

→ Free Radical Substitution

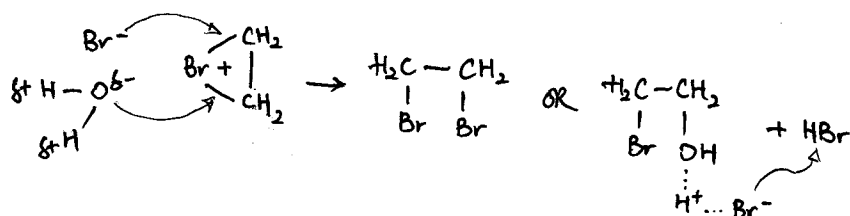
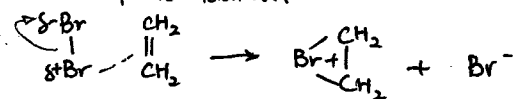


→ Cracking

+ Thermal: High temp & pressure (500°C - 800°C)

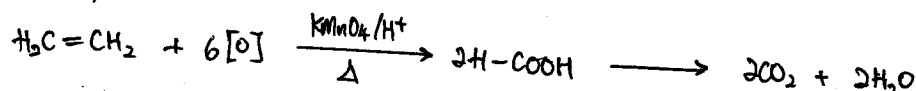
+ Catalysis: Lower temp (450°C) with Al_2O_3 & SiO_2 Alkene

→ Electrophilic Addition

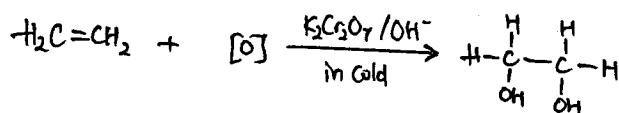


→ Oxidation

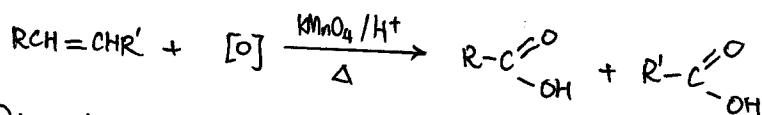
+ Cleavage:



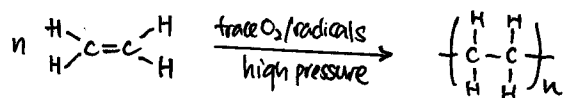
+ Mild Oxidation:



+ Long Chain Cleavage

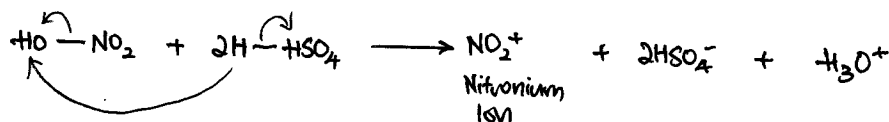


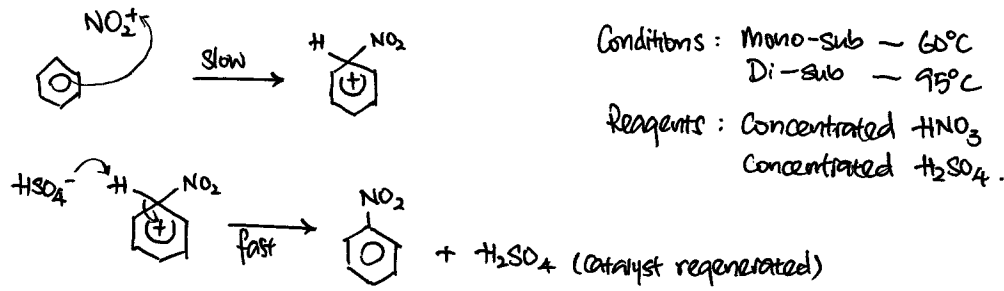
→ Polymerisation

Arenes/Benzene.

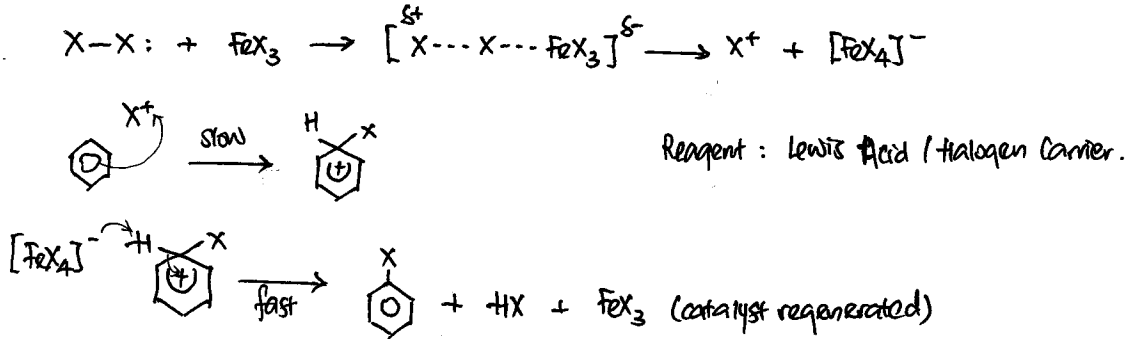
→ Electrophilic Substitution.

+ Nitration

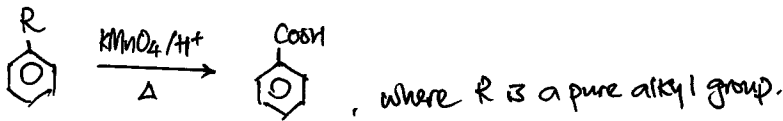




+ Halogenation



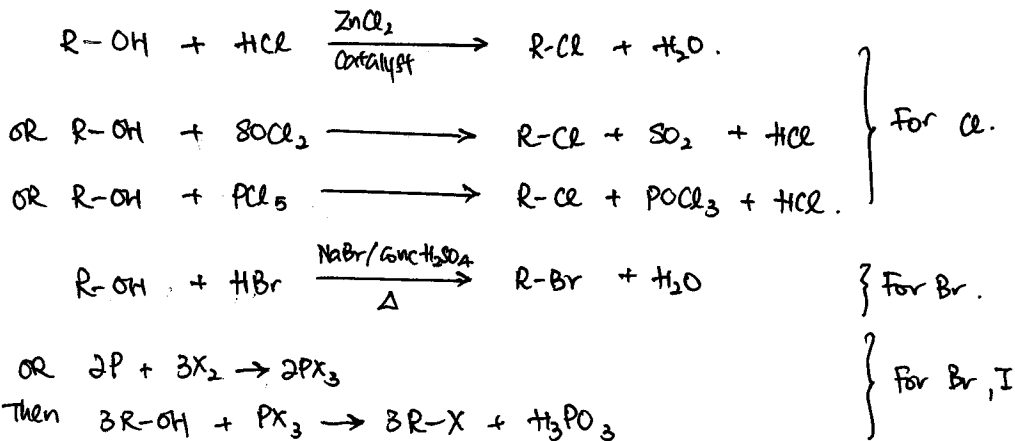
→ Side-Chain Oxidation



+ Alkaline medium would yield same product after acidification.

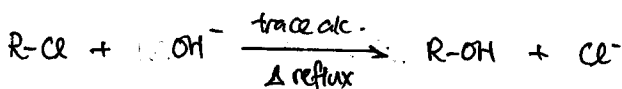
Halogen Derivatives.

→ Substitution with -OH.

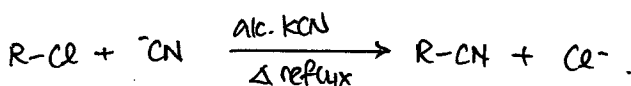


→ Nucleophilic Substitution.

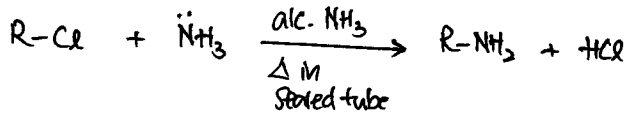
+ With NaOH.



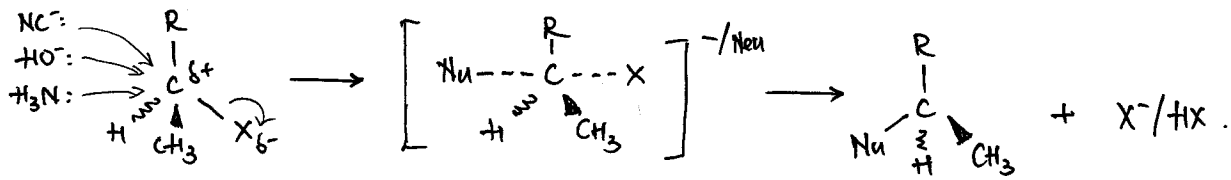
+ With KCN



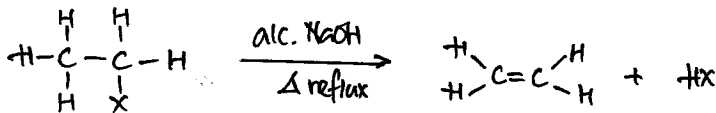
+ With NH₃



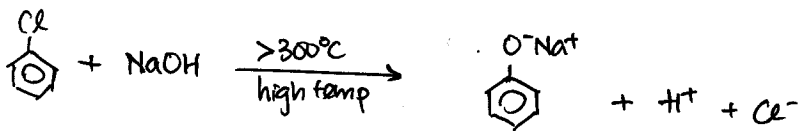
+ General Formula.



→ Elimination Reaction.

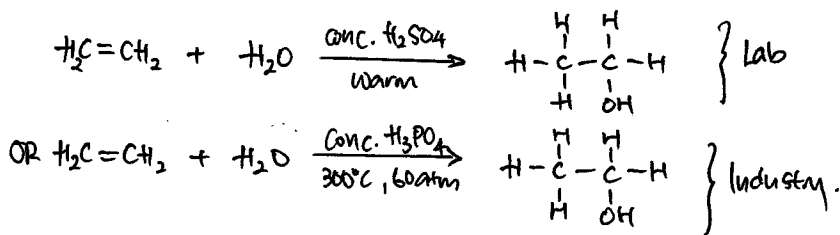


→ Chloro/Halo-benzene Substitution.

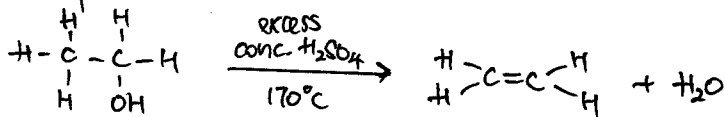


Hydroxy.

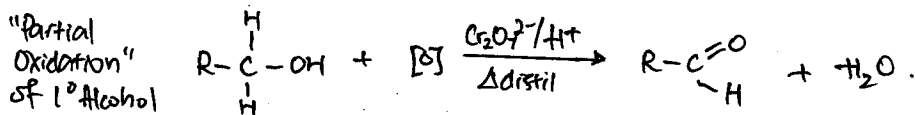
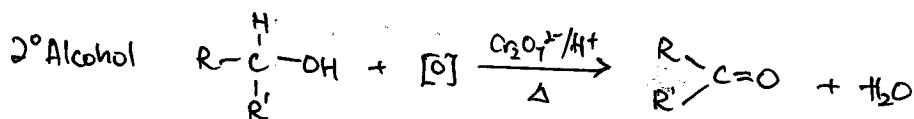
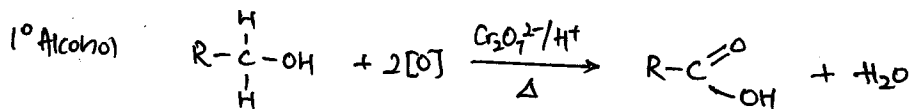
→ Hydration of Alkene



→ Dehydration Reaction.

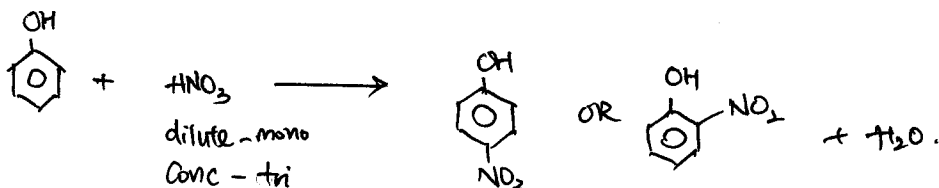
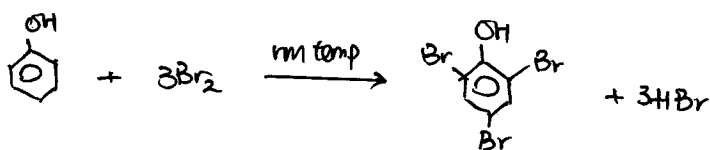


→ Oxidation Reaction.

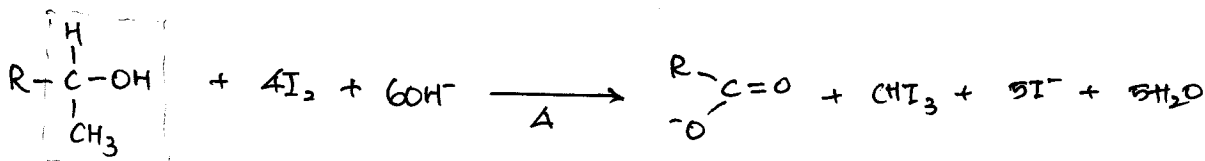


→ Phenol Reactions.

+ Trisubstitution of Bromine / Nitro.

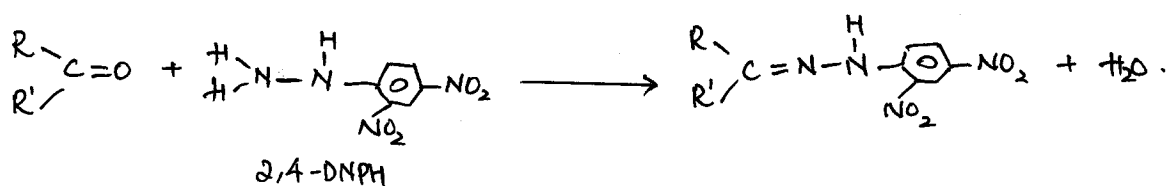


→ Iodoform Reaction



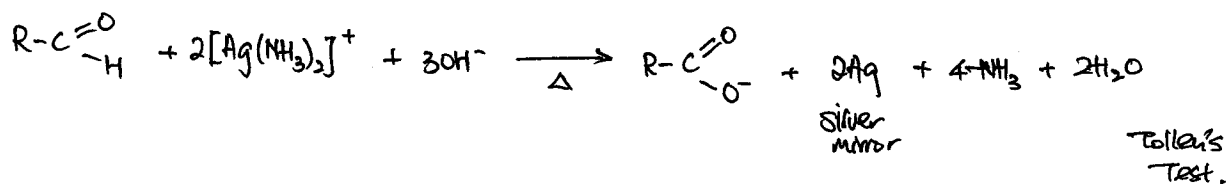
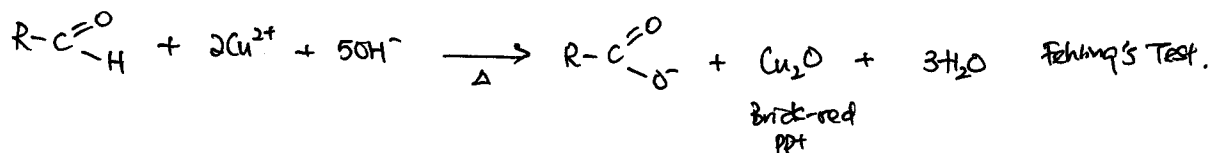
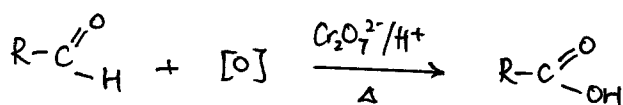
Carbonyl Compounds.

→ Condensation Reaction.

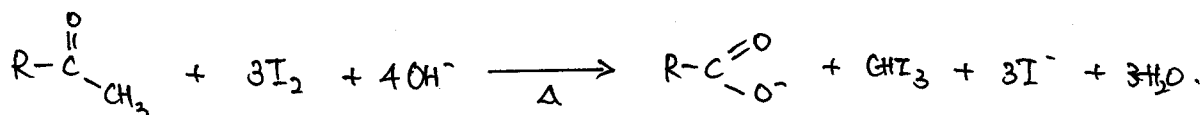


→ Oxidation

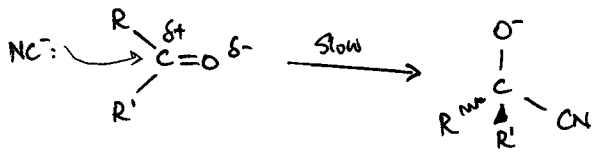
+ of Aldehyde.



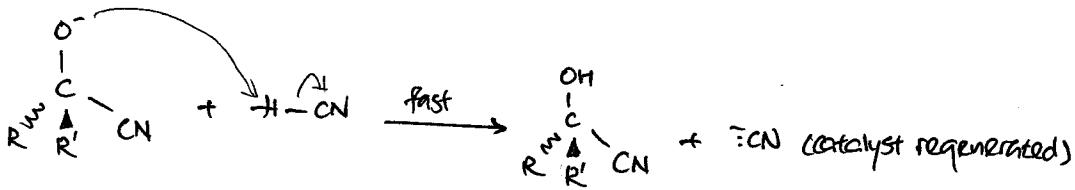
+ of ketone: Iodoform Test.



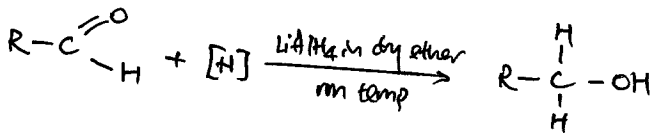
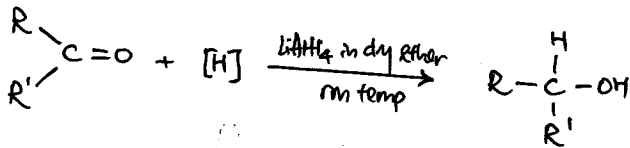
→ Nucleophilic Addition.



Conditions: pH ~ 9 or trace KCN.

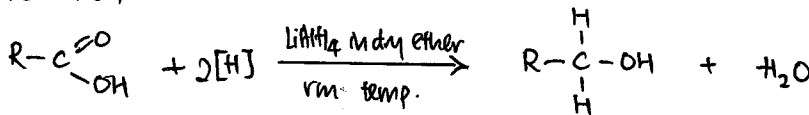


→ Reduction

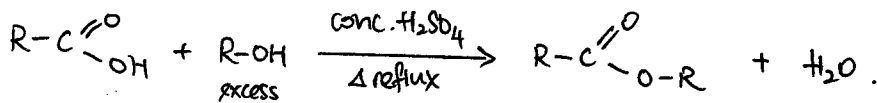


Carboxylic Acids / Carboxy.

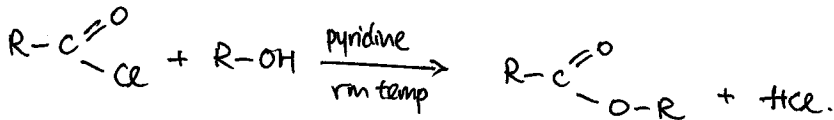
→ Reduction



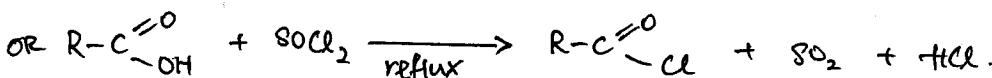
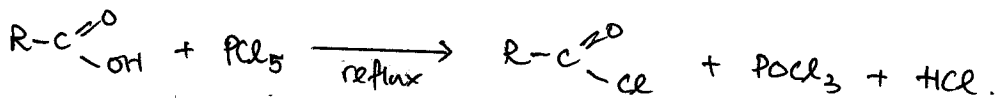
→ Esterification.



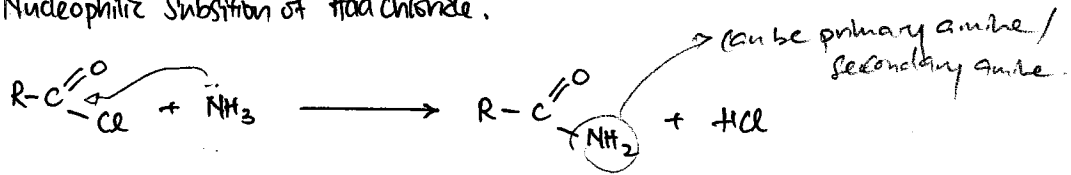
+ Note that it will not react with HO-C₆H₅, phenol this way.



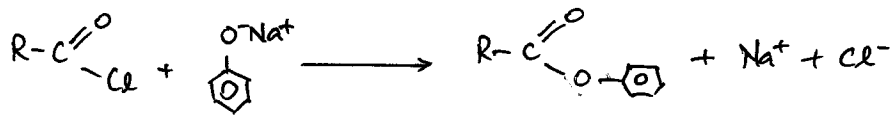
→ Acylation



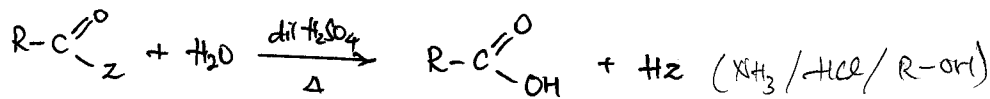
→ Nucleophilic Substitution of Acid Chloride.



+ Same applies for reaction with OH⁻ and water

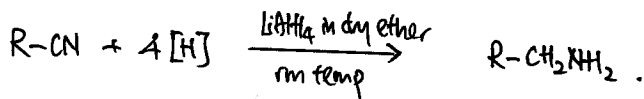


→ Hydrolysis of Carboxy Derivatives.

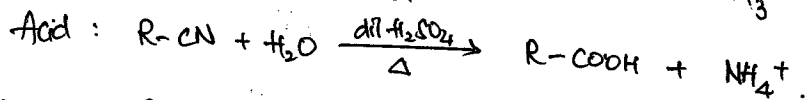
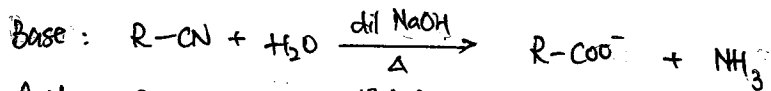


Nitrile.

→ Reduction

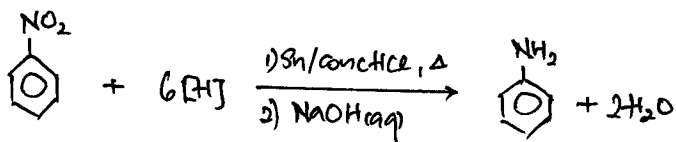


→ Hydrolysis

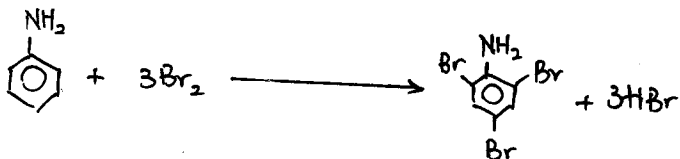


Nitrogen Compounds.

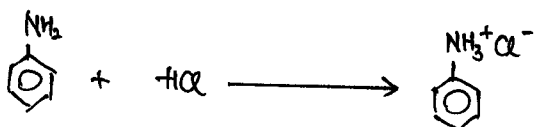
→ Preparation (Reduction of Nitrobenzene).



→ Trisubstitution of Bromine.



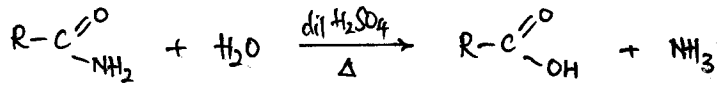
→ Neutralisation



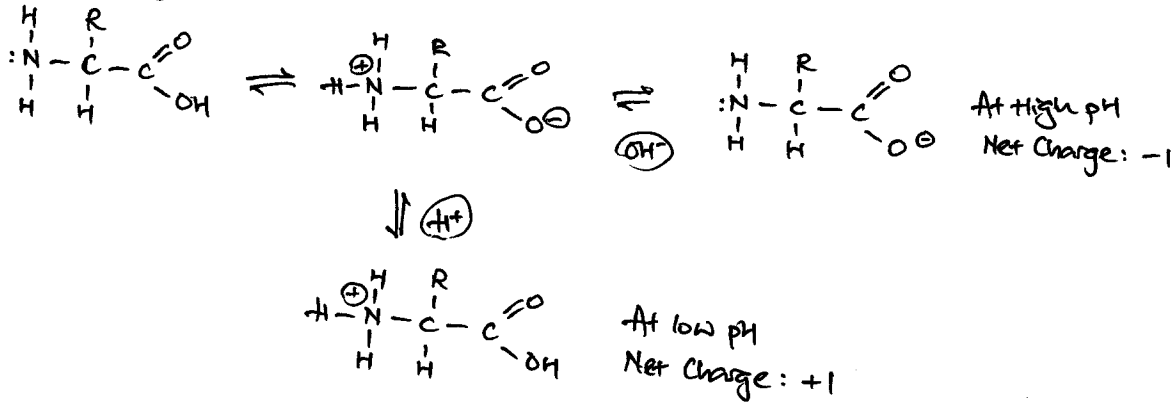
→ Nucleophilic Substitution



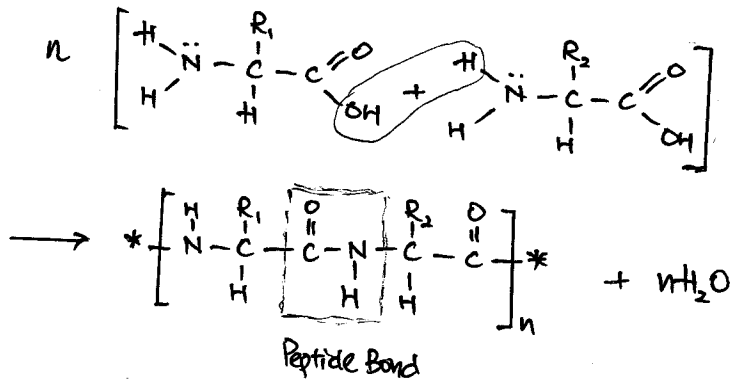
→ Hydrolysis (of Amides)



→ Formation of Zwitterions.



→ Peptide Bond Formation Between Amino Acids.



Proteins.

→ Hierarchy of Structure

+ Primary Structure: Composition + Sequence of Amino Acids.

+ Secondary Structure: Regular folding of Regions of Polypeptide.

↳ α-Helix (Alpha Helix): 3.6 Amino acid per turn of helix

Side chains point outwards from the axis of helix

↳ β-pleated sheets (Beta-pleated sheets): R-group alternates & points out of the plane of the sheet.

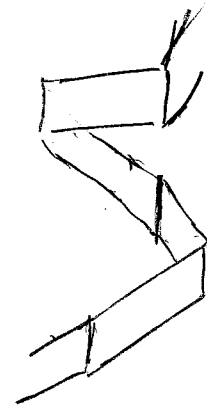
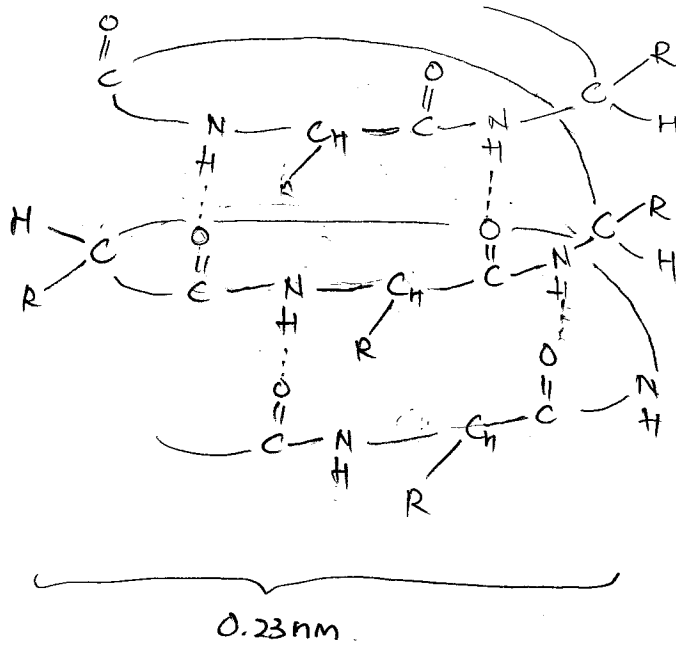
+ Tertiary Structure: Coiled & organised in 3-dimensional form

↳ Stabilised by Hydrogen Bonding, Electrostatic Attraction, Hydrophobic Interaction, Disulphide Linkages.

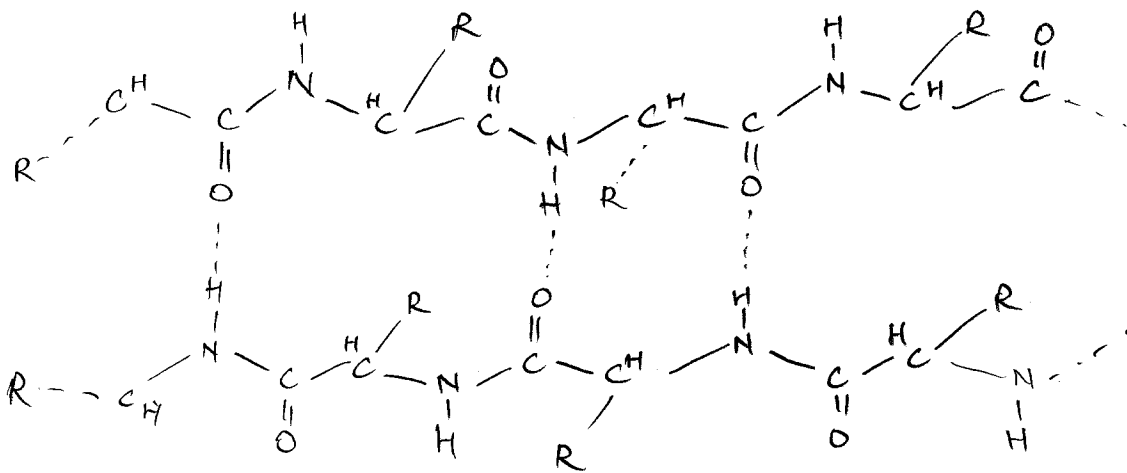
+ Quaternary Structure: More than 1 amino acid chain together.

→ Diagrams.

+ α -Helix:



+ β -pleated sheet.



→ Factors for Protein Denaturation.

- + Heat
- + Changes in pH
- + Mechanical Agitation.
- + Oxidizing & Reducing Agents.
- + Detergents
- + Heavy Metals.

INORGANIC CHEMISTRY

REACTIONS & CONCEPTS COVERED

PERIOD 3 REACTIONS

PERIODICITY

GROUP II COMPOUNDS

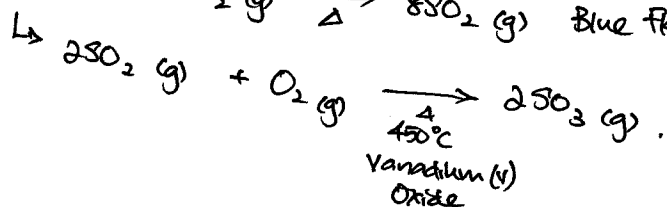
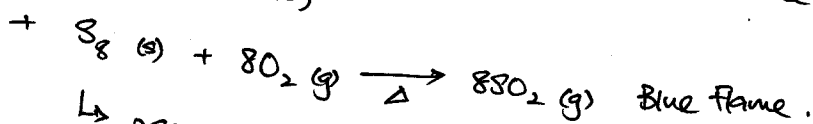
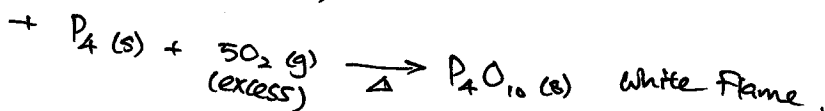
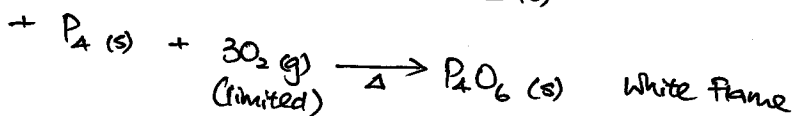
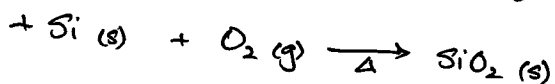
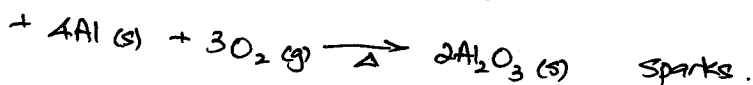
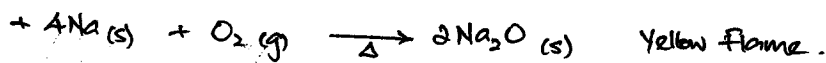
GROUP VII COMPOUNDS

TRANSITION METALS

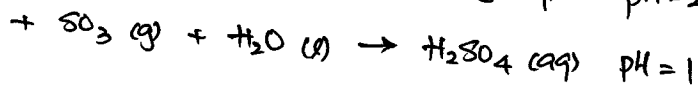
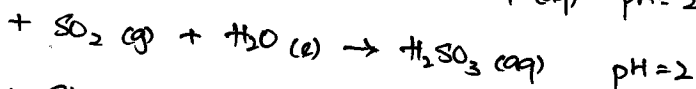
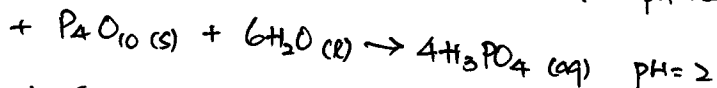
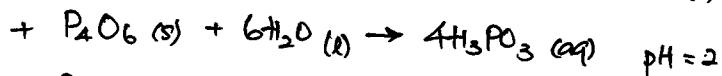
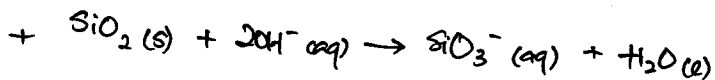
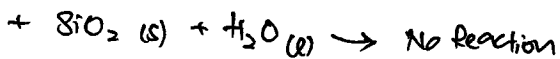
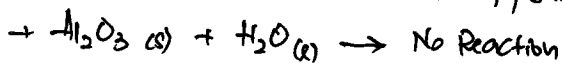
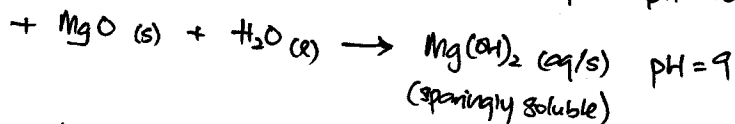
Inorganic Chemistry.

Period 3 Reactions.

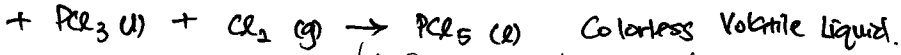
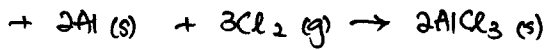
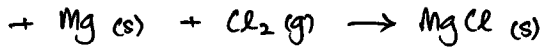
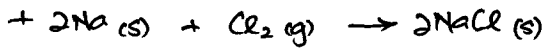
→ Formation of Oxides.



→ Oxides Reactions with Water

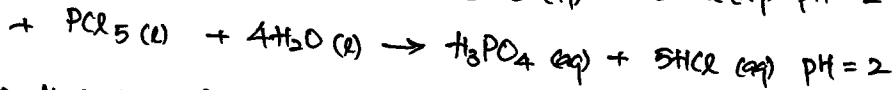
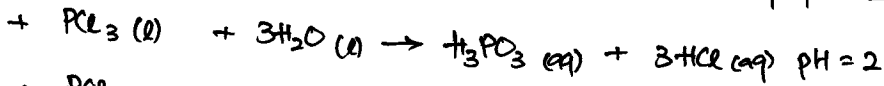
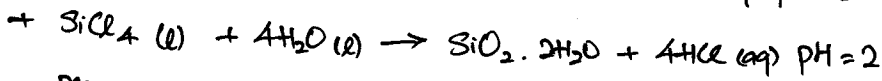
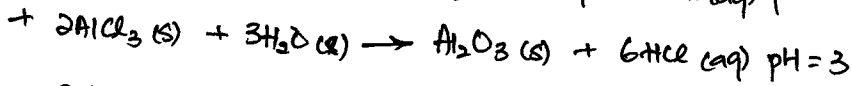
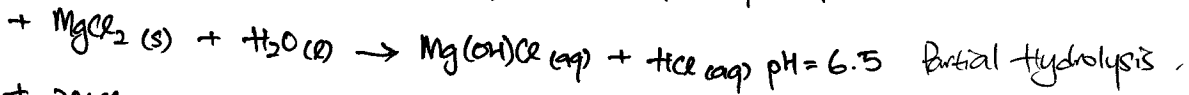


→ Formation of Chlorides.

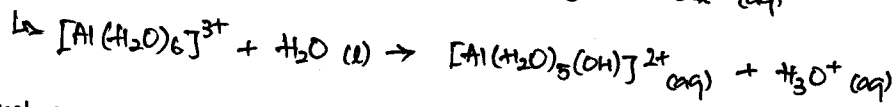
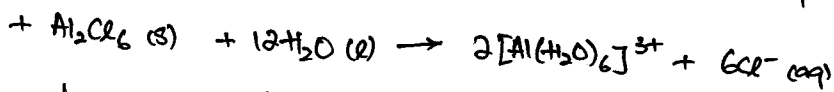
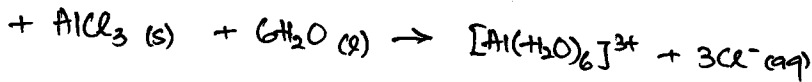


↳ Eqm: 50% dissociated under m-temp.

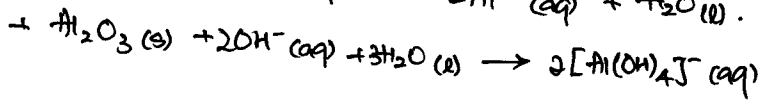
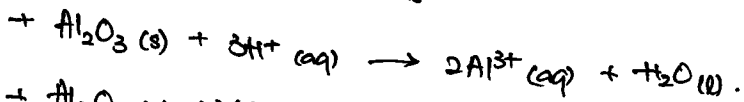
→ Chloride Reaction with Water.



→ Hydration of Al^{3+}



→ Amphoteric Acid / Base Reactions



Periodicity.

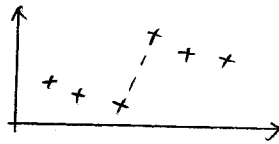
↳ Atomic Radius

- + Decrease across the period.
- + Increasing nuclear charge
- + Almost constant shielding effect (electrons adding to valence shell of same quantum no.)
- + Increase in effective nuclear charge; so outer electrons pulled closer.



↳ Ionic Radius.

- * Positive ions smaller radius than its atomic radius; Negative ions is the converse.
- + In an isoelectronic series, ionic radius decrease across the period.
 - Nuclear charge increases
 - Shielding effect constant
 - Increase in effective nuclear charge.
- + Sharp increase from cation to anion, cation has 'n' quantum shells while anion has 'n+1' quantum shell.



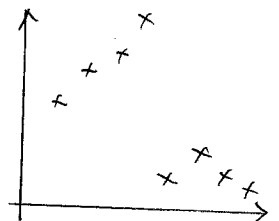
↳ First Ionisation Energy

- + Increases across the period
- + Nuclear charge increases
- + Shielding effect almost constant
- + Atomic Radius Decreases \Rightarrow stronger attraction between nucleus & electrons \Rightarrow more energy needed to overcome attraction.
- * Al lower IE than Mg: electron of Al from '3p', which is further from nucleus.
- * S lower IE than P: electron of S from paired 3p-subshell \Rightarrow interelectronic repulsion makes removal easier.



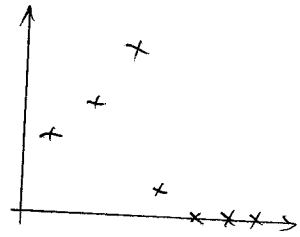
↳ Melting & Boiling point.

- + Rising temperature required until Group IV, then drop dramatically.
 - Temperatures required for non-metals dependent on their bonding.
- + Na, Mg, Al have giant metallic lattice; with electrostatic attraction, which strengthens as valence electrons increase.
- + Si has very high melting point due to its giant covalent structure with strong covalent bonds between each atoms.
- + P₄, S₈ & Cl₂ are simple covalent molecules \Rightarrow Van der Waals forces
 - S₈ has the highest no. of electrons, thus strongest.
- + Ar is atomic structure with atoms held by Van der Waals forces.



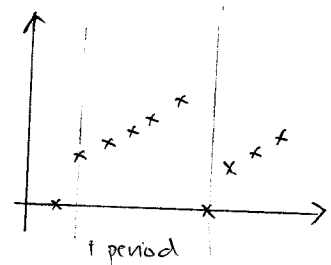
C → Electrical Conductivity.

- + Increases until one element before non-metal, then decrease at metalloid.
- Non-metals will not conduct.
- + Metals have delocalised electrons to move & carry charges.
- As no. of electrons increase, they can carry more charge
⇒ Conductivity increase
- + Silicon is a metalloid ⇒ Semiconductor.
- + Non-metals don't have delocalised electrons; electrons bound in covalent bonds ⇒ cannot carry charge.



C → Electronegativity.

- * Measure of attraction of an atom for electrons in a chemical bond (usually covalent).
- * Relation with IE: elements with high IE would have high EN.
- Increase across period from Group I to VII.
- Decreases down the group as the atomic radius increase.
⇒ electrons further from nucleus.



Inorganic Chemistry Summary

Group II: Alkaline Earth Metals

Elements	Be - Beryllium	Mg - Magnesium	Ca Sr	Ba - Barium
Combustion Flame	Colorless	White	Red Crimson	Green
Melting Boiling	Very High	Increase down the group (gen) [Mg < Ba < Sr < Ca] Increase down the group [Mg < Ca < Sr < Ba] *Both higher than respective Group I Metals		
Atomic Radius	Increases down the group			
Conductivity Thermal Electrical	*Both features follows the same trends Decreases down the group [Ba < Sr < Mg < Be < Ca] Decreases down the group [Ba < Sr < Mg < Be < Ca]			
Density Hardness	Increase down the group (gen) [Ca > Mg > Be > Sr > Ba] Harder than respective Group I but softer than Transition Metals			
Reactions Oxygen Water	Reactivity increases down the group $2M_{(s)} + O_{2(g)} \rightarrow 2MO_{(s)}$ M = Be, Mg, Ca, Sr, Ba (can form peroxide) $M_{(s)} + H_2O_{(g/l)} \rightarrow M(OH)_{2(s)} + H_{2(g)}$ M = Mg (with steam), Ca, Sr, Ba			
Ions	Be ²⁺	Mg ²⁺	Ca ²⁺ Sr ²⁺	Ba ²⁺
Ionic Radius	Increases down the group			
Reducing Strength	Increases down the group (E ⁰ values more negative down the group – higher tendency to be oxidized)			
Oxides Reaction with Water	Reactivity increases down the group $MO_{(s)} + H_2O_{(g/l)} \rightarrow M(OH)_{2(s)}$ M = Ca, Sr, Ba			
Peroxides Reaction with Water	Slow release of oxygen down the group $2MO_{2(s)} + 2H_2O_{(g/l)} \rightarrow 2M(OH)_{2(s)} + O_{2(g)}$ M = Mg, Ca, Sr, Ba			
Salt Solubility Hydroxide, OH⁻ Carbonates CO₃²⁻ Sulphate, SO₄²⁻	Insoluble Insoluble Highly Soluble	Insoluble Depends Soluble	Depends on concentration of salt	Soluble Depends Insoluble
Polarizing Power & Thermal Stability of polyanionic salts	Stability increases down the group as polarizing power decreases down the group, making the polyanions more stable			

Group VII: Halogens

Elements	F - Fluorine	Cl - Chlorine	Br - Bromine	I - Iodine
Appearance	Colorless Gas	Greenish-yellow Gas	Brown Liquid	Violet Crystals
Solution Color Water Organic	Colorless Colorless	Colorless Colorless (Pale Green)	Yellow/Orange/Red Orange/Reddish Brown	Yellow/Brown Purple/ Violet
Energy Bond Ionization Electron Affinity Electronegativity	Decreases down the group [Cl < Br < F < I] – F Small Size Decreases down the group [F < Cl < Br < I] Decreases down the group [Cl < Br < F < I] – F Interelectronic repulsion Decreases down the group [F < Cl < Br < I]			
Oxidising Power	Decreases down the group (E^\ominus values less positive down the group – higher tendency to be oxidized)			
Reaction with Water	Oxidizes Water, may form ozone	$X_2(g) + H_2O(l) \rightleftharpoons HX(aq) + HOX(aq)$ Only Chlorine: $2HOCl(aq) \rightarrow 2H^+(aq) + 2Cl^-(aq) + O_2(g)$		$I_2 + I^- \rightleftharpoons I_3^-$ Brown Complex
Reaction with Hydrogen	$X_2(g) + H_2(g) \rightarrow 2HX(g)$ Reaction less vigorous down the group (reversible for Iodine)			
Oxidation	All: SO_3^{2-} to SO_4^{2-} - $X_{2(aq)} + SO_3^{2-}(aq) + H_2O(l) \rightarrow 2X^-(aq) + SO_4^{2-}(aq) + 2H^+(aq)$ H_2S to S - $X_{2(g)} + H_2S(g) \rightarrow 2X^-(aq) + S(s) + 2H^+(aq)$ Chlorine & Bromine: $S_2O_3^{2-}$ to SO_4^{2-} - $4X_{2(aq)} + 2S_2O_3^{2-}(aq) \rightarrow 8X^-(aq) + 2SO_4^{2-}(aq) + 10H^+(aq)$ Iodine: $S_2O_3^{2-}$ to $S_4O_6^{2-}$ - $I_{2(aq)} + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$			
Reaction with Alkalis	Fluorine: $2F_2(g) + 2OH^-(aq) \rightarrow 2F^-(aq) + F_2O(aq) + H_2O(l)$ $2F_2(g) + 4OH^-(aq) \rightarrow 4F^-(aq) + O_2(g) + 2H_2O(l)$ Chlorine (15°C then 70°C), Bromine (0°C then 15°C) & Iodine (0°C): *Reactivity increases down the group $X_2(aq) + 2OH^-(aq) \rightarrow X^-(aq) + XO^-(aq) + H_2O(l)$ $3XO^-(aq) \rightarrow 2X^-(aq) + XO_3^-(aq)$ Overall: $3X_2(aq) + 6OH^-(aq) \rightarrow 5X^-(aq) + XO_3^-(aq) + 3H_2O(l)$			

Hydrogen Halide	HF	HCl	HBr	HI
Boiling Point	Boiling point increases down the group [HF > HCl > HBr > HI]			
$\Delta H_{\text{formation}}$	Increases down the group [HF < HCl < HBr < HI] with HI positive ΔH_f			
Bond Energy	Decreases down the group [HF > HCl > HBr > HI]			
K_a Value	Low	Increases down the group [HCl < HBr < HI]		
Thermal Stability (Decomposition)	Strong heating no effect	Decompose at 1500°C	Decompose at 800°C	Decompose at 500°C

Ions	F ⁻ - Fluoride	Cl ⁻ - Chloride	Br ⁻ - Bromide	I ⁻ - Iodide
Ionic Radius	Increases down the group [F ⁻ < Cl ⁻ < Br ⁻ < I ⁻]			
Reducing Strength	Increases down the group (E^\ominus values less positive down the group – higher tendency to be oxidized)			
Reaction with AgNO₃	$\text{Ag}^+_{(\text{aq})} + \text{X}^-_{(\text{aq})} \rightarrow \text{AgX}_{(\text{s})}$ AgCl, AgBr & AgI salts are insoluble in water			
AgX Color	No ppt	White	White/Cream	Yellow
AgX Reaction with NH₃	$\text{AgX}_{(\text{s})} \rightleftharpoons \text{Ag}^+_{(\text{aq})} + \text{X}^-_{(\text{aq})}$ $\text{Ag}^+_{(\text{aq})} + 2\text{NH}_3_{(\text{aq})} \rightleftharpoons [\text{Ag}(\text{NH}_3)_2]^+_{(\text{aq})}$			
AgX Solubility In Dilute NH ₃ In Conc NH ₃	-	Soluble Soluble	Soluble Insoluble	Insoluble Insoluble
AgX K_{sp}	-	Decreases down the group [Cl ⁻ > Br ⁻ > I ⁻]		
Reaction with PbNO₃	$\text{Pb}^{2+}_{(\text{aq})} + 2\text{X}^-_{(\text{aq})} \rightarrow \text{PbX}_2_{(\text{s})}$ All PbX ₂ salts are only soluble in hot water & solid reappears on cooling			
PbX₂ Color	White	White	White	Yellow
Reaction with conc H₂SO₄	$\text{X}^-_{(\text{s})} + \text{H}_2\text{SO}_4_{(\text{l})} \rightarrow \text{HX}_{(\text{g})} + \text{HSO}_4^-_{(\text{aq})}$ X = F ⁻ , Cl ⁻ , Br ⁻ , I ⁻ Chlorine Only: $4\text{HCl}_{(\text{g})} + \text{MnO}_2_{(\text{s})} \rightarrow \text{Cl}_2_{(\text{g})} + \text{MnCl}_2_{(\text{aq})} + 2\text{H}_2\text{O}_{(\text{l})}$ Bromine & Iodine: $2\text{HX}_{(\text{g})} + \text{H}_2\text{SO}_4_{(\text{l})} \rightarrow \text{X}_2_{(\text{aq})} + 2\text{H}_2\text{O}_{(\text{l})} + \text{SO}_2_{(\text{g})}$ X = Br ⁻ & I ⁻ Iodine Only: $6\text{HI}_{(\text{g})} + \text{H}_2\text{SO}_4_{(\text{l})} \rightarrow \text{S}_{(\text{s})} + 3\text{I}_2_{(\text{s})} + 4\text{H}_2\text{O}_{(\text{l})}$ $8\text{HI}_{(\text{g})} + \text{H}_2\text{SO}_4_{(\text{l})} \rightarrow \text{H}_2\text{S}_{(\text{g})} + 4\text{I}_2_{(\text{s})} + 4\text{H}_2\text{O}_{(\text{l})}$			

Transition Metals

→ Definition

- + Element that forms 1 or more stable ions with partially filled d-orbital.
- + Hence Zn is not a transitional metal since it doesn't produce any ions with partially filled d-orbitals. Same applies for Sc.
- + Characteristic trait of transition metals is thus the formation of colored ions; variable oxidation state is also exhibited by heavy non-transition metals (like Pb, forms Pb^{2+} & Pb^{4+}).

→ Special Electronic Configurations.

- + Both Cr and Cu enjoy half-filled 4s-orbitals in order to stabilise the d-orbitals (by half-filling or filling it).
- + This results in higher atomic radius for Cr & Cu (doesn't fit into the trend).

→ Metallic & Atomic Radius Trends

- + Increases only gradually as electrons are added to inner shells as proton number increase; thus shielding increases with nuclear charge.
- + Other elements have more significant increases because of relatively constant shielding (electrons added to outermost shell) while nuclear charge increase.
- + Same reasoning results in similar trends for 1st IE.

→ Melting, Density & Electrical Conductivity.

- + Increase with sudden decrease for Cr & Mn as a result of the extra stability of d^5 , half-filled d-orbital making the 3d electrons less available for delocalisation.
- + Fe to Zn decrease in melting & boiling because electron pairing starts to occur and paired electrons don't participate fully in metallic bonding (decrease strength of metallic bonding).
- + Increasing density due to gradual (though irregular) decrease in atomic radius coupled with increasing atomic mass.
- + Increasing conductivity for thermal & electrical due to the fact that they have more mobile electrons to aid conductivity.

→ Variable Oxidation State

- + Due to ease of removal 3d electrons.
- + Possible oxidation states increase up to Mn then decrease because electron pairing reduces orbitals for formation of covalent bonds.
- + Stability of ions dependent on whether they are filled; half-filled, empty & full d-orbital ions are more stable than the others.

ION COMPLEXES COLOURS CHEAT SHEET

Chromium

Ion	Ox. no. of metal	Colour
$\text{Cr}^{2+}(\text{aq})$	+2	blue
$\text{Cr}^{3+}(\text{aq})$, i.e., $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$	+3	green or blue-green
CrO_4^{2-} , chromate(VI)	+6	yellow
$\text{Cr}_2\text{O}_7^{2-}$, dichromate(VI)	+6	orange

Copper

Ion	Ox. no. of metal	Colour
$\text{Cu}^{2+}(\text{aq})$, i.e., $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$	+2	blue
$\text{Cu}(\text{OH})_2$	+2	pale blue solid (<i>insoluble in water</i>)
CuO	+2	black solid (<i>insoluble in water</i>)
Cu_2O	+1	reddish-brown solid (<i>insoluble in water</i>)
Cu metal	0	pink solid
$[\text{Cu}(\text{NH}_3)_4]^{2+}$	+2	dark blue
$[\text{CuCl}_4]^{2-}$	+2	yellow
$[\text{Cu}(\text{EDTA})]^{2-}$	+2	light blue
Cu_2I_2	+1	white solid (<i>insoluble in water</i>)

Iron

Ion	Ox. no. of metal	Colour
$\text{Fe}^{2+}(\text{aq})$, i.e., $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$	+2	pale green
$\text{Fe}^{3+}(\text{aq})$, i.e., $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$	+3	yellow
$\text{Fe}(\text{OH})_2$	+2	green solid (<i>insoluble in water</i>)
$\text{Fe}(\text{OH})_3$	+3	reddish-brown solid (<i>insoluble in water</i>)
$[\text{Fe}(\text{SCN})]^{2+}$, i.e., $[\text{Fe}(\text{SCN})(\text{H}_2\text{O})_5]^{2+}$	+3	blood-red

Manganese

Ion	Ox. no. of metal	Colour
$\text{Mn}^{2+}(\text{aq})$, i.e., $[\text{Mn}(\text{H}_2\text{O})_6]^{2+}$	+2	faint pink (dilute solution appears colourless)
MnO_2	+4	dark brown solid (<i>insoluble in water</i>)
MnO_4^- , manganate(VII)	+7	purple

GRAPHIC CALCULATOR TIPS

PREAMBLE

This section includes a set of instructions on how you might be able to make use of the graphic calculator to check or work out Reaction Kinetics Questions. Even if calculation is not necessary, the graphic calculator statistic plots can be used to visualize the points on the kinetics curve to deduce the order of reaction.

Using Regression Lines on Graphic Calculator

to Extrapolate + Plot Reaction Kinetics Graph.

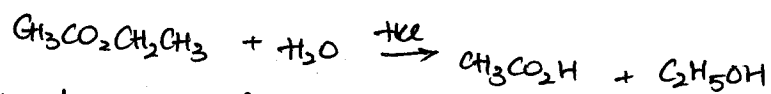
By KEVIN LOW

Intro

We understand that very often, in A levels Chem, students are made to plot rate of reaction sort of graphs for 1st order reactions in kinetics (Reaction). Using the 'ln' linear model, we can successfully utilise our graphic calculators during practice to check our plots or just to work out a more accurate version of answer to check for our own plotting precision.

An Example

A typical example would be a reaction like:



the hydrolysis of an ester.

the following table is also given*.

Time	[ester] when [HCl]=0.1	[ester] when [HCl]=0.2
0	0.2	0.2
25	0.162	0.115
50	0.115	0.067
75	0.088	0.038
100	0.067	0.022
125	0.051	0.013

* Units are omitted for simplicity.

First, we should key in the data into our GC. Note that only 1 set of data is required to test if reaction is 1st order with respect to [ester].

Key the 'time' into L1 and '[ester]' to L2. Since the model is a 'ln' model such that:

$$t = a \ln [] + b \Leftrightarrow [] = e^{\frac{t-b}{a}}$$

We have to create a L3 which is 'ln(L2)'.
①

With all these data ready, we can start plotting + drawing graphs.

To plot the linear graph using L_1 and L_3 , type the following.

$$\text{LinReg}(ax+b) \quad L_3, L_1, Y_1$$

* Note that for linear regression function, always put the y-axis variable list then the x-axis variable list followed by the function you want the graph to be input on.

For my example, typing the above yields

$$\begin{aligned} \text{LinReg} \\ y = ax + b \\ a = -91.54769509 \\ b = -147.5340103 \\ r^2 = 0.9999747083 \\ r = -0.9999873541 \end{aligned} \quad \left. \vphantom{\begin{aligned} \text{LinReg} \\ y = ax + b \\ a = -91.54769509 \\ b = -147.5340103 \\ r^2 = 0.9999747083 \\ r = -0.9999873541 \end{aligned}} \right\} \text{Indicating a very good fit}$$

When you switch to the equation screen, you'll see that Y_1 is filled:

$$Y_1 = (-91.54769508749)X + (-147.53401034585)$$

Since Y_1 here represents 't' and X represents 'ln []', we need to manipulate the equation according to the model stated to:

$$Y_1 = e^{(x + 147.53401034585) \div (-91.54769508749)}$$

To verify the accuracy of the graph by visual means (rather than the r-constant), go to STAT PLOT1 and key in L_3 for the Xlist and L_1 for the Ylist. Press [ZOOM] on your ΔC and select ZoomStat to view that Stat data points with the graph drawn.

— There you have it! ∇ The reactant-time graph of the reaction.

- * To find initial rate, use $\frac{dy}{dx}$ on the $t=0$
- * To find half-life, just select any 2 [ester] and then check the time elapsed for them to become half.
- * Using $\frac{dy}{dx}$ you can also get the rate of reaction @ every time with respect the [ester].

— END —