

SUMMARY OF ORGANIC REACTIONS

SECTION 1 - ALIPHATIC

Aldehydes and ketones

Type of reaction	Mechanism
<p>1. oxidation (aldehydes only): aldehyde \rightarrow carboxylic acid</p> <p>reagents: potassium dichromate ($\text{K}_2\text{Cr}_2\text{O}_7$) in sulphuric acid ($\text{H}_2\text{SO}_4$) conditions: warm under reflux equation: $\text{R-CHO} + [\text{O}] \rightarrow \text{R-COOH}$ observation: orange to green</p> <p>to distinguish between aldehydes and ketones: either: add Fehling's solution and heat observation: blue solution to brick red precipitate equation: $\text{R-CHO} + 4\text{OH}^- + 2\text{Cu}^{2+} \rightarrow \text{R-COOH} + \text{Cu}_2\text{O} + 2\text{H}_2\text{O}$ or: add Tollen's reagent and heat observation: colourless solution to silver mirror equation: $\text{R-CHO} + 2[\text{Ag}(\text{NH}_3)_2]^+ + \text{H}_2\text{O} \rightarrow \text{RCOOH} + 2\text{Ag} + 4\text{NH}_3 + 2\text{H}^+$</p>	n/a
<p>2. reduction: carbonyl \rightarrow alcohol</p> <p>reagents: $\text{NaBH}_4(\text{aq})$ conditions: room temperature equation: $\text{R}_1\text{-CO-R}_2 + 2[\text{H}] \rightarrow \text{R}_1\text{-CH(OH)-R}_2$</p>	Nucleophilic addition (required)
<p>3. addition of HCN: carbonyl \rightarrow hydroxynitrile</p> <p>reagents: NaCN and HCl(aq) conditions: room temperature equation: $\text{R}_1\text{-CO-R}_2 + \text{HCN} \rightarrow \text{R}_1\text{-C(CN)(OH)-R}_2$</p>	Nucleophilic addition (required)

Carboxylic acids and their salts

Type of reaction	Mechanism
<p>1. acid-base</p> <p>a) carboxylic acids with sodium hydroxide reagent: NaOH conditions: room temperature equation: $\text{R-COOH(aq)} + \text{NaOH(aq)} \rightarrow \text{R-COO}^-\text{Na}^+\text{(aq)} + \text{H}_2\text{O(l)}$</p> <p>b) carboxylic acids with sodium carbonate reagent: Na_2CO_3 conditions: room temperature equation: $2\text{R-COOH(aq)} + \text{Na}_2\text{CO}_3\text{(aq)} \rightarrow 2\text{R-COO}^-\text{Na}^+\text{(aq)} + \text{CO}_2\text{(g)} + \text{H}_2\text{O(l)}$ observations: colourless gas evolved which turns limewater milky</p> <p>c) carboxylate salts with acids reagent: HCl(aq) conditions: room temperature equation: $\text{R-COO}^-\text{(aq)} + \text{H}^+\text{(aq)} \rightarrow \text{R-COOH(aq)}$</p>	n/a
<p>2. esterification</p> <p>reagents: any alcohol, concentrated sulphuric acid catalyst conditions: heat and reflux equation: $\text{R}_1\text{-COOH} + \text{R}_2\text{OH} \rightleftharpoons \text{R}_1\text{-COOR}_2 + \text{H}_2\text{O}$</p>	Nucleophilic addition/ Elimination (not required)

Esters

Type of reaction	Mechanism
<p>hydrolysis</p> <p>a) acid hydrolysis reagent: concentrated H_2SO_4 conditions: heat under reflux equation: $\text{R}_1\text{-COOR}_2 + \text{H}_2\text{O} \rightleftharpoons \text{R}_1\text{-COOH} + \text{R}_2\text{OH}$</p> <p>b) alkaline hydrolysis (saponification) reagent: NaOH(aq) conditions: heat under reflux equation: $\text{R}_1\text{-COOR}_2 + \text{NaOH} \rightleftharpoons \text{R}_1\text{-COO}^-\text{Na}^+ + \text{R}_2\text{OH}$</p>	n/a

Acyl chlorides and acid anhydrides

Type of reaction	Mechanism
<p>1. acylation using acyl chlorides</p> <p>a) with water (to make carboxylic acids) conditions: room temperature equation: $\text{R-COCl} + \text{H}_2\text{O} \rightarrow \text{R-COOH} + \text{HCl}$ observation: white misty fumes</p> <p>b) with ammonia (to make amides) conditions: room temperature equation: $\text{R-COCl} + \text{NH}_3 \rightarrow \text{R-CONH}_2 + \text{HCl}$ observation: white misty fumes</p> <p>c) with alcohols (to make esters) conditions: room temperature equation: $\text{R}_1\text{-COCl} + \text{R}_2\text{-OH} \rightarrow \text{R}_1\text{-COOR}_2 + \text{HCl}$ observation: white misty fumes</p> <p>d) with primary amines (to make N-substituted amides) conditions: room temperature equation: $\text{R}_1\text{-COCl} + \text{R}_2\text{-NH}_2 \rightarrow \text{R}_1\text{-CONHR}_2 + \text{HCl}$ observation: white misty fumes</p>	<p>Nucleophilic addition-elimination (required)</p>
<p>2. acylation using acid anhydrides</p> <p>a) with water (to make carboxylic acids) conditions: room temperature equation: $\text{R}_1\text{-COOCO-R}_2 + \text{H}_2\text{O} \rightarrow \text{R}_1\text{-COOH} + \text{R}_2\text{-COOH}$</p> <p>b) with ammonia (to make amides) conditions: room temperature equation: $\text{R}_1\text{-COOCO-R}_2 + \text{NH}_3 \rightarrow \text{R}_1\text{-CONH}_2 + \text{R}_2\text{-COOH}$</p> <p>c) with alcohols (to make esters) conditions: room temperature equation: $\text{R}_1\text{-COOCO-R}_2 + \text{R}_3\text{-OH} \rightarrow \text{R}_1\text{-COO-R}_3 + \text{R}_2\text{-COOH}$</p> <p>d) with primary amines (to make N-substituted amides) conditions: room temperature equation: $\text{R}_1\text{-COOCO-R}_2 + \text{R}_3\text{-NH}_2 \rightarrow \text{R}_1\text{-CONH-R}_3 + \text{R}_2\text{-COOH}$</p>	<p>Nucleophilic addition-elimination (not required)</p>

Amines

Type of reaction	Mechanism
<p>1. haloalkane → primary amine</p> <p>reagents: haloalkane and excess ammonia conditions: heat equation: $R-X + 2NH_3 \rightarrow R-NH_2 + NH_4X$ or reagent: haloalkane and ammonia (1:1 ratio) conditions: heat equation: $R-X + NH_3 \rightarrow R-NH_2 + HX$</p> <p>2. haloalkane → secondary amine</p> <p>reagents: haloalkane and ammonia (2:1 ratio) conditions: heat equation: $2R-X + NH_3 \rightarrow R-NH-R + HX$ or reagents: haloalkane and primary amine conditions: heat equation: $R_1-X + R_2-NH_2 \rightarrow R_1-NH-R_2 + HX$</p> <p>3. haloalkane → tertiary amine</p> <p>reagents: haloalkane and ammonia (3:1 ratio) conditions: heat equation: $3R-X + NH_3 \rightarrow R_3N + HX$ or reagents: haloalkane and secondary amine conditions: heat equation: $R_1-X + R_2-NH-R_3 \rightarrow R_1R_2R_3N + HX$</p> <p>4. haloalkane → quaternary ammonium salt</p> <p>reagents: haloalkane and ammonia (4:1 ratio) conditions: heat equation: $4R-X + NH_3 \rightarrow [R_4N]^+X^-$ or reagents: haloalkane and secondary amine conditions: heat equation: $R_1-X + R_2R_3R_4N \rightarrow [R_1R_2R_3R_4N]^+X^-$</p>	Nucleophilic substitution (required)
<p>2. reduction: nitrile → primary amine</p> <p>reagents: $LiAlH_4$ in dry ether conditions: room temperature equation: $R-CN + 4[H] \rightarrow R-CH_2NH_2$</p>	n/a
<p>3. acid-base:</p> <p>a) amines with acids equations: $R_1-NH_2 + HCl \rightarrow R_1-NH_3Cl$ $R_1R_2-NH + HCl \rightarrow R_1R_2-NH_2Cl$ $R_1R_2R_3-N + HCl \rightarrow R_1R_2R_3-NHCl$</p> <p>b) alkyl ammonium salts with alkalis equations: $R_1-NH_3Cl + NaOH \rightarrow R_1-NH_2 + NaCl + H_2O$ $R_1R_2-NH_2Cl + NaOH \rightarrow R_1R_2-NH + NaCl + H_2O$ $R_1R_2R_3-NHCl + NaOH \rightarrow R_1R_2R_3-N + NaCl + H_2O$</p>	n/a

Amino Acids

Type of reaction	Mechanism
<p>1. acid-base reactions of amino acids</p> <p>a) with acids reagents: HCl conditions: room temperature equation: $\text{R-CH(NH}_2\text{)-COOH} + \text{HCl} \rightarrow \text{R-CH(NH}_3^+\text{Cl}^-)\text{-COOH}$</p> <p>b) with alkalis reagents: NaOH conditions: room temperature equation: $\text{R-CH(NH}_2\text{)-COOH} + \text{NaOH} \rightarrow \text{R-CH(NH}_2\text{)-COO}^-\text{Na}^+ + \text{H}_2\text{O}$</p> <p>2. condensation reactions of amino acids</p> <p>conditions: DNA equation: $n \text{ R-CH(NH}_2\text{)-COOH} \rightarrow \text{H-(NHCRHCO)}_n\text{-OH} + (n-1) \text{ H}_2\text{O}$</p> <p>3. hydrolysis of proteins</p> <p>reagents: $6 \text{ mol dm}^{-3} \text{ HCl}$ conditions: heat, reflux equation: $\text{H-(NHCRHCO)}_n\text{-OH} + (n-1) \text{ H}_2\text{O} + n \text{ HCl} \rightarrow n \text{ R-CH(NH}_3^+\text{Cl}^-)\text{-COOH}$</p>	<p>Nucleophilic addition-elimination (not required)</p>

Polymers

Type of reaction	Mechanism
<p>1. Addition polymerisation (alkenes → polyalkenes)</p> <p>conditions: high temperature, Ziegler-Natta catalyst equation:</p> $n \begin{array}{c} \diagup \quad \diagdown \\ \text{C}=\text{C} \\ \diagdown \quad \diagup \end{array} \longrightarrow \left[\begin{array}{cc} & \\ -\text{C} & -\text{C}- \\ & \end{array} \right]_n$	Free radical addition (not required)
<p>2. Condensation polymerisation</p> <p>a) polyesters dicarboxylic acid + diol → polyester conditions: H₂SO₄, heat under reflux equation:</p> $n \begin{array}{c} \text{O} & & \text{O} \\ & & \\ \text{HO}-\text{C} & -\text{R}_1- & \text{C}-\text{OH} \end{array} + n \text{HO}-\text{R}_2-\text{OH} \rightleftharpoons \text{HO}-\left[\begin{array}{c} \text{O} & & \text{O} \\ & & \\ -\text{C} & -\text{R}_1- & \text{C}-\text{O}-\text{R}_2-\text{O}- \end{array} \right]_n \text{H} + (2n-1) \text{H}_2\text{O}$ <p>or diacyl chloride + diol → polyester conditions: room temperature equation:</p> $n \begin{array}{c} \text{O} & & \text{O} \\ & & \\ \text{Cl}-\text{C} & -\text{R}_1- & \text{C}-\text{Cl} \end{array} + n \text{HO}-\text{R}_2-\text{OH} \longrightarrow \text{Cl}-\left[\begin{array}{c} \text{O} & & \text{O} \\ & & \\ -\text{C} & -\text{R}_1- & \text{C}-\text{O}-\text{R}_2-\text{O}- \end{array} \right]_n \text{H} + (2n-1) \text{HCl}$ <p>b) polyamides dicarboxylic acid + diamine → polyamide conditions: warm, reflux equation:</p> $n \begin{array}{c} \text{O} & & \text{O} \\ & & \\ \text{HO}-\text{C} & -\text{R}_1- & \text{C}-\text{OH} \end{array} + n \begin{array}{c} \text{H} & & \text{H} \\ \diagdown & & / \\ \text{N} & -\text{R}_2- & \text{N} \\ / & & \diagdown \\ \text{H} & & \text{H} \end{array} \rightleftharpoons \text{HO}-\left[\begin{array}{c} \text{O} & & \text{O} \\ & & \\ -\text{C} & -\text{R}_1- & \text{C}-\text{N}-\text{R}_2-\text{N}- \end{array} \right]_n \text{H} + (2n-1) \text{H}_2\text{O}$ <p>or diacyl chloride + diamine → polyamide conditions: room temperature equation:</p> $n \begin{array}{c} \text{O} & & \text{O} \\ & & \\ \text{Cl}-\text{C} & -\text{R}_1- & \text{C}-\text{Cl} \end{array} + n \begin{array}{c} \text{H} & & \text{H} \\ \diagdown & & / \\ \text{N} & -\text{R}_2- & \text{N} \\ / & & \diagdown \\ \text{H} & & \text{H} \end{array} \longrightarrow \text{Cl}-\left[\begin{array}{c} \text{O} & & \text{O} \\ & & \\ -\text{C} & -\text{R}_1- & \text{C}-\text{N}-\text{R}_2-\text{N}- \end{array} \right]_n \text{H} + (2n-1) \text{HCl}$	Nucleophilic addition-elimination (not required)

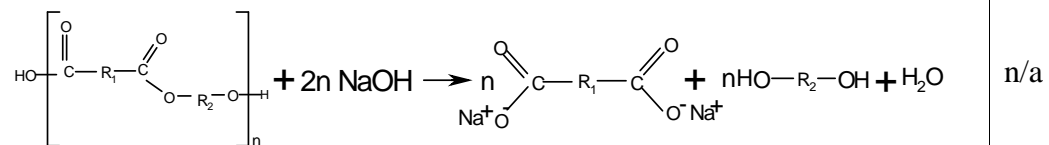
3. Hydrolysis of condensation polymers

a) polyesters

reagents: NaOH(aq)

conditions: heat

equation:

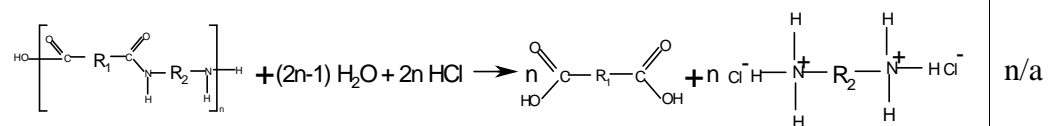


b) polyamides

reagents: HCl(aq)

conditions: heat

equation:



SECTION 2 – AROMATIC

Type of reaction	Mechanism
1. nitration (benzene → nitrobenzene) Reagent: conc HNO ₃ in conc H ₂ SO ₄ Conditions: 50-55°C under reflux Equation: $\text{C}_6\text{H}_6 + \text{HNO}_3 \rightarrow \text{C}_6\text{H}_5\text{NO}_2 + \text{H}_2\text{O}$	Electrophilic substitution (required)
2. alkylation (benzene → alkylbenzene) Reagent: R-Cl with anhydrous AlCl ₃ Conditions: 50°C under reflux Equation: $\text{C}_6\text{H}_6 + \text{R-Cl} \rightarrow \text{C}_6\text{H}_5\text{-R} + \text{HCl}$ OR Reagent: alkene with anhydrous AlCl ₃ and HCl Equation: $\text{C}_6\text{H}_6 + \text{R}_1\text{R}_2\text{C=CR}_1\text{R}_2 \rightarrow \text{C}_6\text{H}_5\text{CR}_1\text{R}_2\text{CR}_3\text{R}_4$	Electrophilic substitution (required)
3. acylation (benzene → phenylketone) Reagent: R-COCl with anhydrous AlCl ₃ Conditions: 50°C under reflux Equation: $\text{C}_6\text{H}_6 + \text{R-COCl} \rightarrow \text{C}_6\text{H}_5\text{COR} + \text{HCl}$	Electrophilic substitution (required)
4. reduction (nitrobenzene → phenylamine) Reagents: Sn in conc HCl Conditions: heat under reflux Equation: $\text{C}_6\text{H}_5\text{NO}_2 + 6[\text{H}] \rightarrow \text{C}_6\text{H}_5\text{NH}_2 + 2\text{H}_2\text{O}$	n/a