

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 ($K_2Cr_2O_7$) in sulphuric acid (H_2SO_4) conditions: warm under reflux equation: $R-CHO + [O] \rightarrow R-COOH$ 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: $R-CHO + 4OH^- + 2Cu^{2+} \rightarrow R-COOH + Cu_2O + 2H_2O$ or: add Tollen's reagent and heat observation: colourless solution to silver mirror equation: $R-CHO + 2[Ag(NH_3)_2]^+ + H_2O \rightarrow RCOOH + 2Ag + 4NH_3 + 2H^+$</p>	n/a
<p>2. reduction: carbonyl \rightarrow alcohol</p> <p>reagents: $NaBH_4(aq)$ conditions: room temperature equation: $R_1-CO-R_2 + 2[H] \rightarrow R_1-CH(OH)-R_2$</p>	Nucleophilic addition (required)
<p>3. addition of HCN: carbonyl \rightarrow hydroxynitrile</p> <p>reagents: $NaCN$ and $HCl(aq)$ conditions: room temperature equation: $R_1-CO-R_2 + HCN \rightarrow R_1-C(CN)(OH)-R_2$</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: $R-COCl + H_2O \rightarrow R-COOH + HCl$ observation: white misty fumes</p> <p>b) with ammonia (to make amides) conditions: room temperature equation: $R-COCl + NH_3 \rightarrow R-CONH_2 + HCl$ observation: white misty fumes</p> <p>c) with alcohols (to make esters) conditions: room temperature equation: $R_1-COCl + R_2-OH \rightarrow R_1-COOR_2 + HCl$ observation: white misty fumes</p> <p>d) with primary amines (to make N-substituted amides) conditions: room temperature equation: $R_1-COCl + R_2-NH_2 \rightarrow R_1-CONHR_2 + HCl$ 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: $R_1-COOCO-R_2 + H_2O \rightarrow R_1-COOH + R_2-COOH$</p> <p>b) with ammonia (to make amides) conditions: room temperature equation: $R_1-COOCO-R_2 + NH_3 \rightarrow R_1-CONH_2 + R_2-COOH$</p> <p>c) with alcohols (to make esters) conditions: room temperature equation: $R_1-COOCO-R_2 + R_3-OH \rightarrow R_1-COO-R_3 + R_2-COOH$</p> <p>d) with primary amines (to make N-substituted amides) conditions: room temperature equation: $R_1-COOCO-R_2 + R_3-NH_2 \rightarrow R_1-CONH-R_3 + R_2-COOH$</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>	<p>Nucleophilic substitution (required)</p>
<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>	<p>n/a</p>
<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>	<p>n/a</p>

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

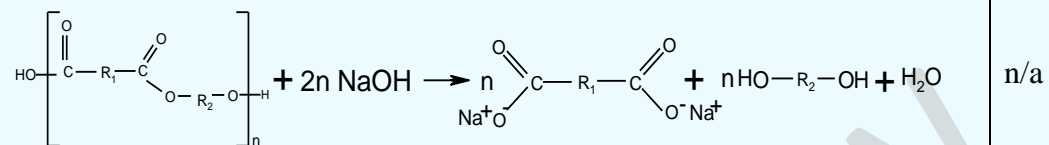
3. Hydrolysis of condensation polymers

a) polyesters

reagents: NaOH(aq)

conditions: heat

equation:

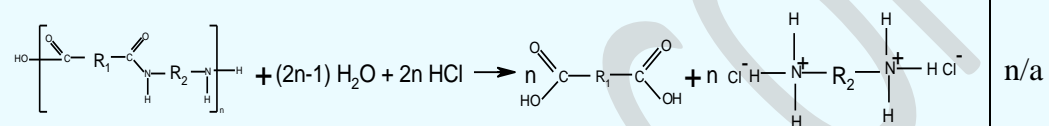


b) polyamides

reagents: HCl(aq)

conditions: heat

equation:



SECTION 2 – AROMATIC

Type of reaction	Mechanism
<p>1. nitration (benzene → nitrobenzene)</p> <p>Reagent: conc HNO₃ in conc H₂SO₄ Conditions: 50-55°C under reflux</p> <p>Equation: $C_6H_6 + HNO_3 \rightarrow C_6H_5NO_2 + H_2O$</p>	Electrophilic substitution (required)
<p>2. alkylation (benzene → alkylbenzene)</p> <p>Reagent: R-Cl with anhydrous AlCl₃ Conditions: 50°C under reflux</p> <p>Equation: $C_6H_6 + R-Cl \rightarrow C_6H_5-R + HCl$</p> <p>OR</p> <p>Reagent: alkene with anhydrous AlCl₃ and HCl</p> <p>Equation: $C_6H_6 + R_1R_2C=CR_1R_2 \rightarrow C_6H_5CR_1R_2CR_3R_4$</p>	Electrophilic substitution (required)
<p>3. acylation (benzene → phenylketone)</p> <p>Reagent: R-COCl with anhydrous AlCl₃ Conditions: 50°C under reflux</p> <p>Equation: $C_6H_6 + R-COCl \rightarrow C_6H_5COR + HCl$</p>	Electrophilic substitution (required)
<p>4. reduction (nitrobenzene → phenylamine)</p> <p>Reagents: Sn in conc HCl Conditions: heat under reflux</p> <p>Equation: $C_6H_5NO_2 + 6[H] \rightarrow C_6H_5NH_2 + 2H_2O$</p>	n/a