

Alkene Rxns

Hydrohalogenation	
Hydration	
Hydration (with rearrangement)	
Addition of Alcohol	
Bromination	
Bromination in H2O	
Bromination in Alcohol	
Oxymercuration-Demercuration	
Alkoxymercuration-Demercuration	
Hydroboration-Oxidation	
Catalytic Hydrogenation (Catalytic Reduction)	
Hydrobromination with Peroxide	
Epoxidation	
Anti-Hydroxylation	
Syn-Hydroxylation	
Syn-Hydroxylation	
Ozonolysis under Reducing Conditions	

Ozonolysis under Oxidizing Conditions	
Oxidative Cleavage	

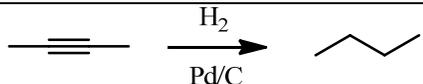
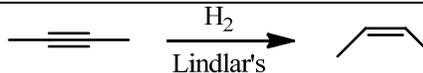
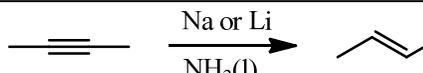
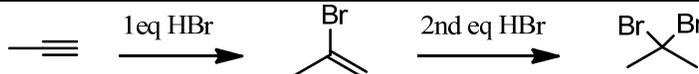
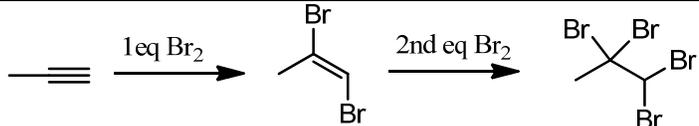
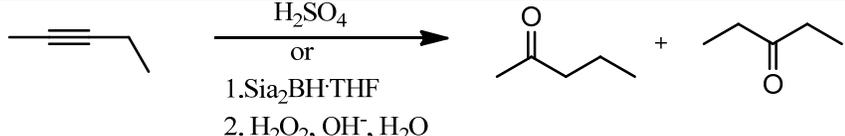
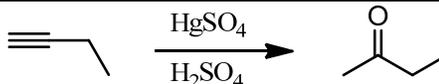
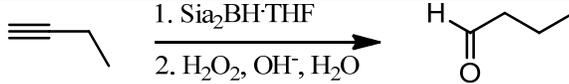
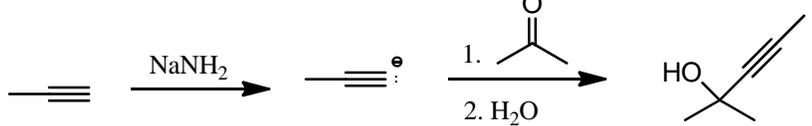
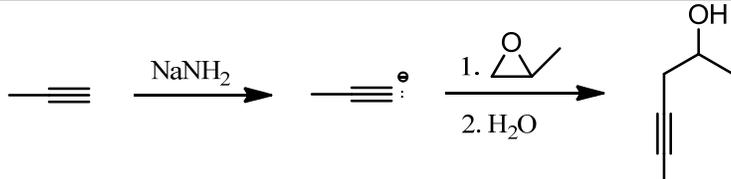
Free Radical Halogenation

Free Radical Bromination (high selectivity)	
Free Radical Chlorination (low selectivity)	
Allylic/Benzylic Bromination	

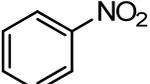
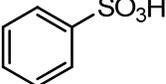
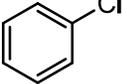
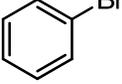
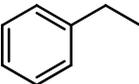
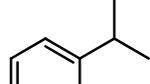
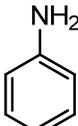
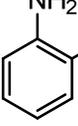
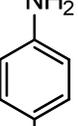
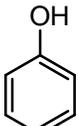
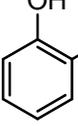
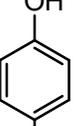
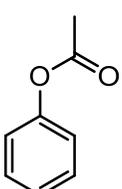
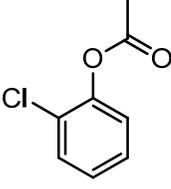
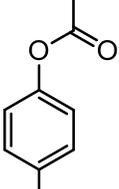
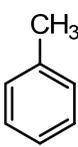
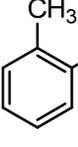
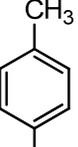
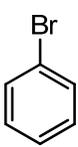
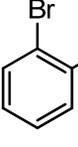
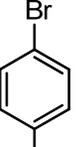
Grignard Rxns

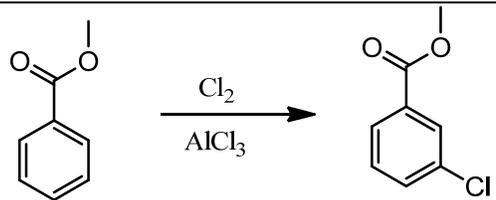
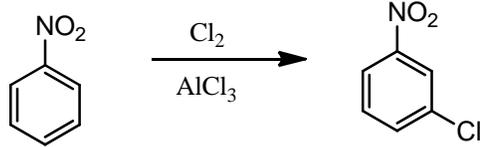
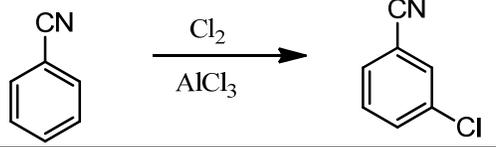
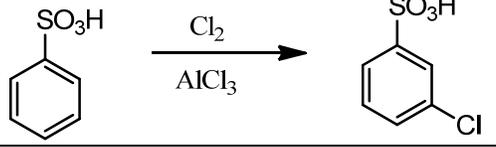
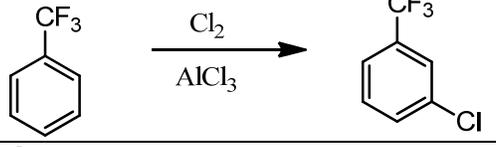
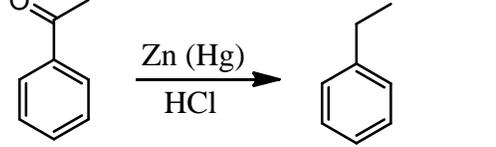
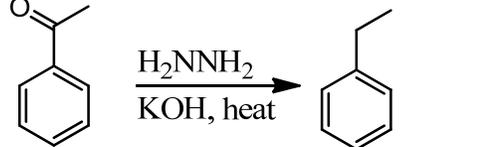
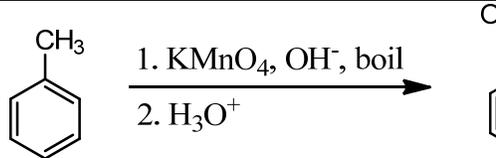
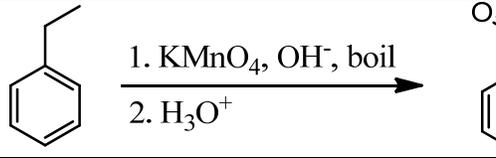
Nucleophilic Addition of a Grignard Reagent to a Ketone	
Nucleophilic Addition of a Grignard Reagent to an Epoxide (attacks less substituted side)	
Nucleophilic Addition of a Grignard Reagent to CO ₂	
Protonation of a Grignard Reagent (Grignards are protonated in protic solutions)	

Alkyne Rxns

Catalytic Hydrogenation (Catalytic Reduction)	
Reduction to cis-alkene	
Reduction to trans-alkene	
Hydrohalogenation	
	
Hydration of an Internal Alkyne	
Hydration (Markovnikov)	
Hydration (Anti-Markovnikov)	
S _N 2 Addition of an Acetylide Ion	
Addition of an Acetylide Ion to a Ketone	
Addition of an Acetylide Ion to an Epoxide	

Benzene Rxns

Nitration (EAS)	 $\xrightarrow[\text{H}_2\text{SO}_4]{\text{HNO}_3}$ 
Sulfonation (EAS)	 $\xrightarrow[\text{H}_2\text{SO}_4]{\text{SO}_3}$ 
Chlorination (EAS)	 $\xrightarrow[\text{AlCl}_3]{\text{Cl}_2}$ 
Bromination (EAS)	 $\xrightarrow[\text{FeBr}_3]{\text{Br}_2}$ 
Friedel-Crafts Alkylation (EAS)	 $\xrightarrow[\text{AlCl}_3]{\text{Cl}-\text{CH}_2\text{CH}_3}$ 
Friedel-Crafts Alkylation (EAS) (with rearrangement)	 $\xrightarrow[\text{AlCl}_3]{\text{Cl}-\text{CH}_2\text{CH}_2\text{CH}_3}$ 
Friedel-Crafts Acylation (EAS)	 $\xrightarrow[\text{AlCl}_3]{\text{Cl}-\text{C}(=\text{O})\text{CH}_3}$ 
Bromination (EAS) -NH ₂ is an ortho/para director and doesn't require a catalyst like FeBr ₃	 $\xrightarrow{\text{Br}_2}$  + 
Chlorination (EAS) -OH is an ortho/para director	 $\xrightarrow[\text{AlCl}_3]{\text{Cl}_2}$  + 
Chlorination (EAS) -OR is an ortho/para director	 $\xrightarrow[\text{AlCl}_3]{\text{Cl}_2}$  + 
Chlorination (EAS) -CH ₃ is an ortho/para director	 $\xrightarrow[\text{AlCl}_3]{\text{Cl}_2}$  + 
Chlorination (EAS) -Br is an ortho/para director	 $\xrightarrow[\text{AlCl}_3]{\text{Cl}_2}$  + 

Chlorination (EAS) Carbonyl is a meta director	 <p>Reaction: Methyl benzoate + Cl₂ / AlCl₃ → 3-chloro methyl benzoate</p>
Chlorination (EAS) -NO ₂ is a meta director	 <p>Reaction: Nitrobenzene + Cl₂ / AlCl₃ → 3-chloro nitrobenzene</p>
Chlorination (EAS) -CN is a meta director	 <p>Reaction: Benzonitrile + Cl₂ / AlCl₃ → 3-chloro benzonitrile</p>
Chlorination (EAS) -SO ₃ H is a meta director	 <p>Reaction: Benzenesulfonic acid + Cl₂ / AlCl₃ → 3-chloro benzenesulfonic acid</p>
Chlorination (EAS) -CF ₃ is a meta director	 <p>Reaction: Trifluoromethylbenzene + Cl₂ / AlCl₃ → 3-chloro trifluoromethylbenzene</p>
Clemmensen Reduction	 <p>Reaction: Acetophenone + Zn(Hg) / HCl → Ethylbenzene</p>
Wolff-Kishner Reduction	 <p>Reaction: Acetophenone + H₂NNH₂ / KOH, heat → Ethylbenzene</p>
Side-chain Oxidation (Benzylic Oxidation)	 <p>Reaction: Toluene + 1. KMnO₄, OH⁻, boil / 2. H₃O⁺ → Benzoic acid</p>
Side-chain Oxidation (Benzylic Oxidation)	 <p>Reaction: Ethylbenzene + 1. KMnO₄, OH⁻, boil / 2. H₃O⁺ → Benzoic acid</p>

Alcohol Rxns

Conversion to an alkyl iodide	
Conversion to an alkyl bromide	
Conversion to an alkyl chloride	
Conversion to an alkyl chloride with thionyl chloride (only for 1° and 2°)	
Conversion to an alkyl bromide (only for 1° and 2°)	
Conversion to a tosylate ester	
Acid-catalyzed Dehydration	
Chromic Acid Oxidation of a 1° Alcohol (Chromic Acid can also be written as H ₂ CrO ₄ or CrO ₃ /H ₂ SO ₄)	
PCC Oxidation of a 1° Alcohol	
Chromic Acid Oxidation of an Aldehyde	
Chromic Acid Oxidation of a 2° Alcohol	
PCC Oxidation of a 2° Alcohol	

Ether Rxns

Williamson Ether Synthesis (2 nd step is S _N 2)	
Acid-Catalyzed cleavage of Ethers (also works with HI and HCl)	

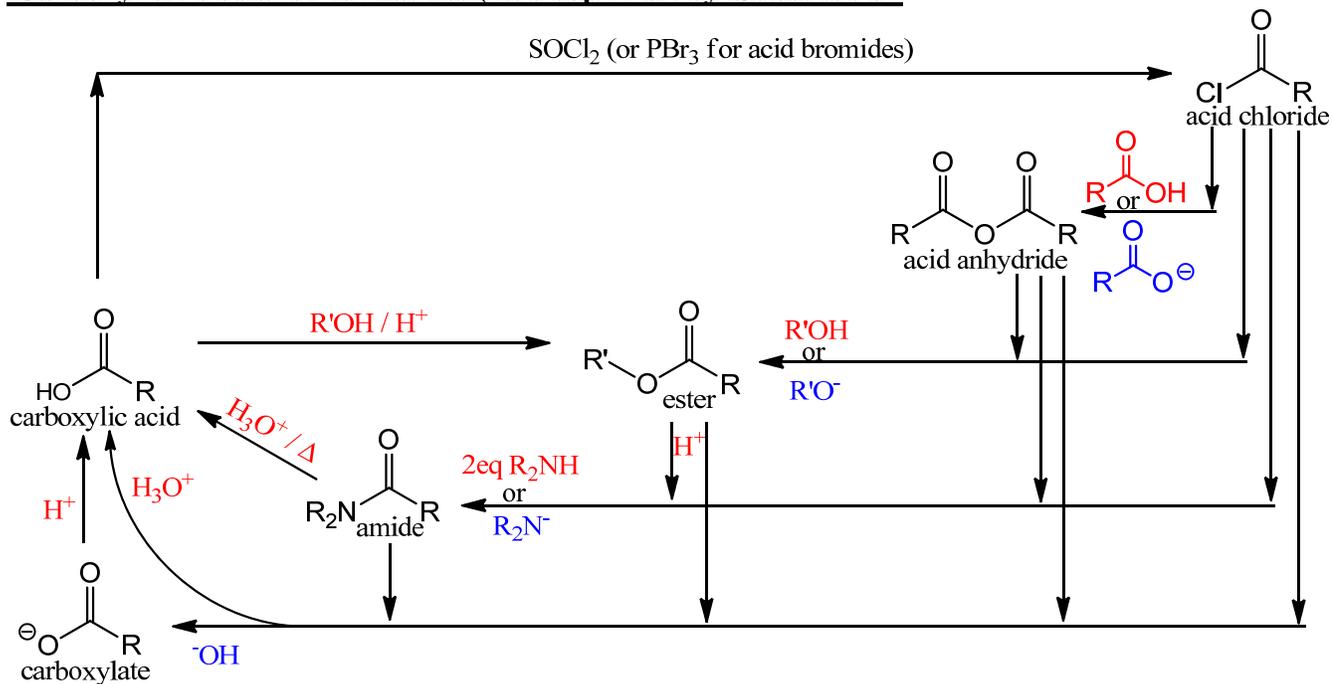
Epoxide Rxns

Base-Catalyzed Ring Opening of an Epoxide (Attacks less-substituted side)	
Acid-Catalyzed Ring Opening of an Epoxide (Attacks more-substituted side)	

Hydride Reduction Rxns

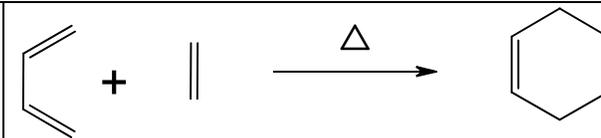
Reduction of a ketone to a 2° alcohol	<p> <chem>CCC(=O)C</chem> $\xrightarrow[\text{EtOH}]{\text{NaBH}_4}$ <chem>CCC(O)C</chem> <chem>CCC(=O)C</chem> $\xrightarrow[2. \text{H}_3\text{O}^+]{1. \text{LiAlH}_4}$ <chem>CCC(O)C</chem> </p>
Reduction of an aldehyde to a 1° alcohol	<p> <chem>CCCC=O</chem> $\xrightarrow[\text{EtOH}]{\text{NaBH}_4}$ <chem>CCCCO</chem> <chem>CCCC=O</chem> $\xrightarrow[2. \text{H}_3\text{O}^+]{1. \text{LiAlH}_4}$ <chem>CCCCO</chem> </p>
Reduction of an acid chloride to a 1° alcohol	<p> <chem>CCC(=O)Cl</chem> $\xrightarrow[\text{EtOH}]{\text{NaBH}_4}$ <chem>CCCO</chem> <chem>CCC(=O)Cl</chem> $\xrightarrow[2. \text{H}_3\text{O}^+]{1. \text{LiAlH}_4}$ <chem>CCCO</chem> </p>
Reduction of an ester to two alcohols	<p> <chem>CCC(=O)OCC</chem> $\xrightarrow[2. \text{H}_3\text{O}^+]{1. \text{LiAlH}_4}$ <chem>CCCO</chem> + <chem>CCO</chem> </p>
Reduction of a carboxylic acid to a 1° alcohol	<p> <chem>CCC(=O)O</chem> $\xrightarrow[2. \text{H}_3\text{O}^+]{1. \text{LiAlH}_4}$ <chem>CCCO</chem> </p>
Reduction of an amide to an amine	<p> <chem>CCC(=O)N</chem> $\xrightarrow[2. \text{H}_3\text{O}^+]{1. \text{LiAlH}_4}$ <chem>CCCN</chem> </p>
Reduction of an ester to an aldehyde using DIBALH (also called DIBAH) DIBALH is diisobutylaluminum hydride (shown below)	<p> <chem>CCC(=O)OCC</chem> $\xrightarrow[2. \text{H}_2\text{O}]{1. \text{DIBALH } -78^\circ\text{C}}$ <chem>CCC=O</chem> </p> <p> </p>
Reduction of an acid chloride to an aldehyde using tri- <i>t</i> -butoxyaluminum hydride	<p> <chem>CCC(=O)Cl</chem> $\xrightarrow[-78^\circ\text{C}]{\text{LiAl}[\text{OC}(\text{CH}_3)_3]_3\text{H}}$ <chem>CCC=O</chem> </p>
Hoffman Rearrangment Converts an amide to an amine with the loss of a carbon (note the difference with reduction of an amide with LiAlH ₄ where there is no loss of carbon)	<p> <chem>CCC(=O)N</chem> $\xrightarrow[\text{OH}^-]{\text{Br}_2}$ <chem>CCN</chem> </p>

Carboxylic Acids and Derivatives (Nucleophilic Acyl Substitution)

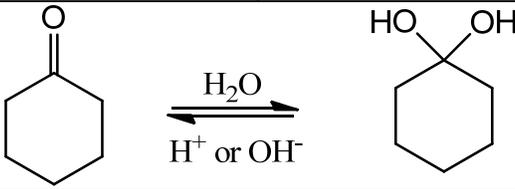
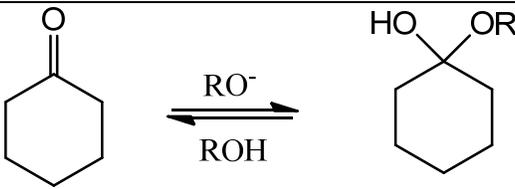
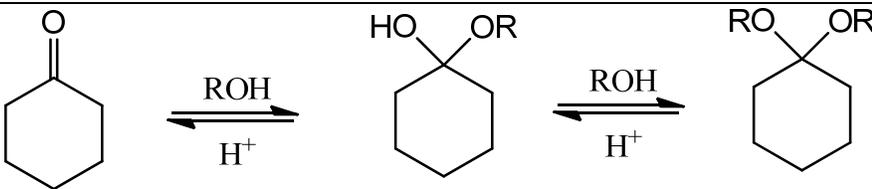
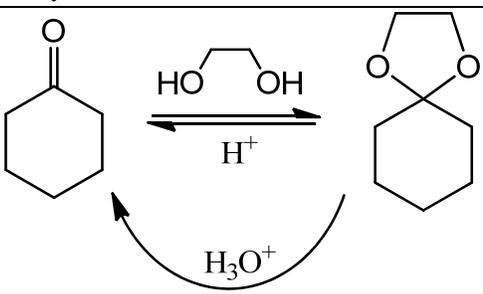
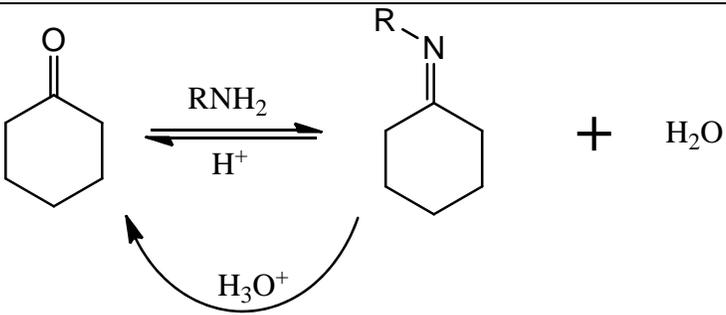
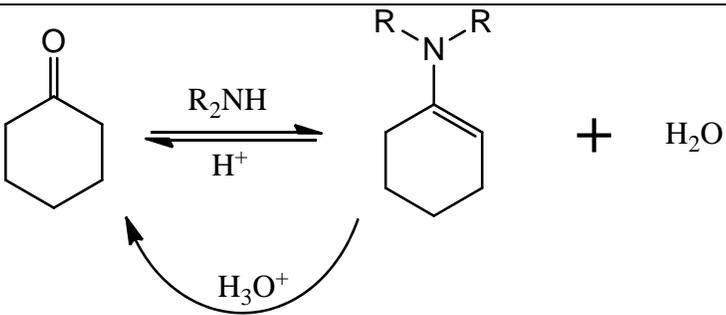


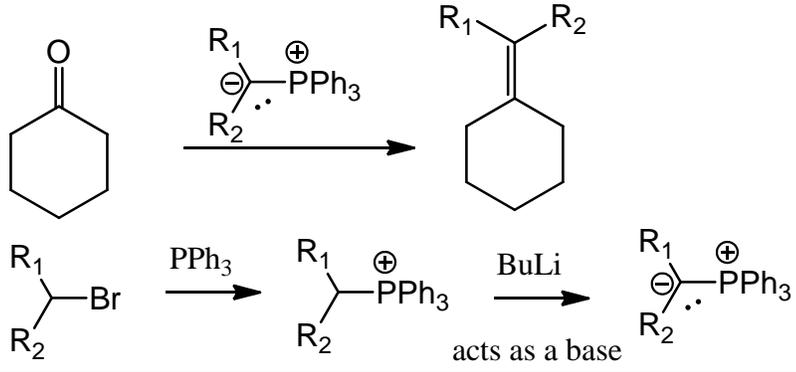
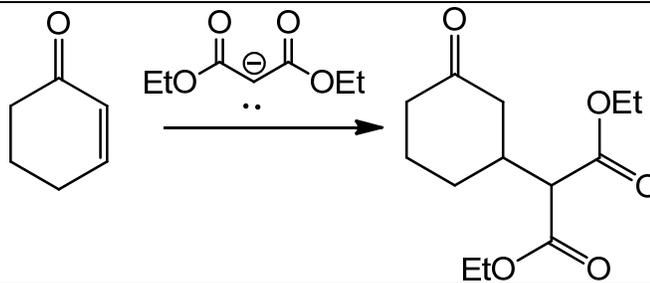
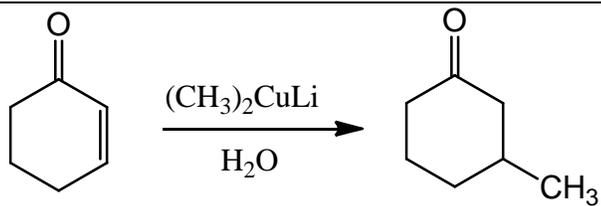
Diels-Alder Rxns

Basic Diels-Alder Rxn
(a 4+2 cycloaddition rxn)



Nucleophilic Addition to Ketones and Aldehydes

<p>Addition of water to form a hydrate</p>	
<p>Addition of an alcohol under basic conditions to form a hemi-ketal</p>	
<p>Addition of 1eq of an alcohol in acid to form a hemi-ketal and then a 2nd eq to form a ketal</p>	
<p>Addition of ethylene glycol to form a cyclic ketal which functions as a protecting group for ketones and aldehydes</p> <p>H_3O^+ is used to de-protect</p>	
<p>Addition of a 1° amine to form an imine</p> <p>(can be reversed with H_3O^+)</p>	
<p>Addition of a 2° amine to form an enamine</p> <p>Forms on less substituted side if there's a difference</p> <p>(can be reversed with H_3O^+)</p>	

<p>Wittig Rxn Addition of a phosphylide to form an alkene</p> <p>Formation of a phosphylide from an alkyl halide</p>	
<p>Michael Addition (also called β-addition or conjugate addition)</p>	
<p>Michael Addition with a lithium dialkylcuprate</p>	

Alpha Addition Rxns

Self Aldol Condensation	$2 \text{ CH}_3\text{COCH}_3 \xrightarrow{\text{OH}^-} \text{CH}_3\text{CH(OH)CH}_2\text{C(CH}_3)_2 \xrightarrow{\Delta} \text{CH}_3\text{CH=C(CH}_3)_2$
Mixed Aldol Condensation	$\text{C}_6\text{H}_5\text{CHO} + \text{CH}_3\text{COCH}_3 \xrightarrow{\text{OH}^-} \text{C}_6\text{H}_5\text{CH(OH)CH}_2\text{COCH}_3 \xrightarrow{\Delta} \text{C}_6\text{H}_5\text{CH=CHCOCH}_3$
Self Claisen Condensation	$2 \text{ CH}_3\text{CH}_2\text{CO}_2\text{Et} \xrightarrow[2. \text{H}_2\text{O}]{1. \text{NaOEt}} \text{CH}_3\text{CH}_2\text{C(O)CH(CH}_3\text{)C(O)OEt}$
Mixed Claisen Condensation	$\text{C}_6\text{H}_{11}\text{O} \xrightarrow[3. \text{H}_2\text{O}]{1. \text{LDA}, 2. \text{CH}_3\text{CH}_2\text{CO}_2\text{Et}} \text{C}_6\text{H}_{11}\text{C(O)CH}_2\text{CH}_2\text{C(O)OEt}$
Malonic Ester Synthesis	$\text{EtO}_2\text{CCH}_2\text{CO}_2\text{Et} \xrightarrow[4. \text{C}_6\text{H}_5\text{CH}_2\text{Br}]{1. \text{NaOEt}, 2. \text{CH}_3\text{CH}_2\text{Br}, 3. \text{NaOEt}} \text{EtO}_2\text{CCH(C}_6\text{H}_5\text{)C(CH}_2\text{CH}_3)_2 \xrightarrow[\Delta]{\text{H}_3\text{O}^+} \text{C}_6\text{H}_5\text{CH}_2\text{CH}_2\text{CH}_2\text{CO}_2\text{H} + \text{CO}_2$
Acetoacetic Ester Synthesis	$\text{EtO}_2\text{CCH}_2\text{COCH}_3 \xrightarrow[4. \text{C}_6\text{H}_5\text{CH}_2\text{Br}]{1. \text{NaOEt}, 2. \text{CH}_3\text{CH}_2\text{Br}, 3. \text{NaOEt}} \text{EtO}_2\text{CCH(C}_6\text{H}_5\text{)C(CH}_2\text{CH}_3)_2 \xrightarrow[\Delta]{\text{H}_3\text{O}^+} \text{C}_6\text{H}_5\text{CH}_2\text{CH}_2\text{COCH}_3 + \text{CO}_2$