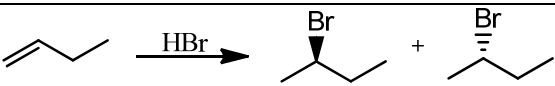
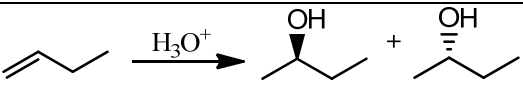
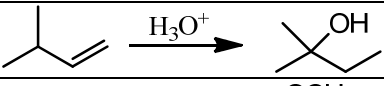
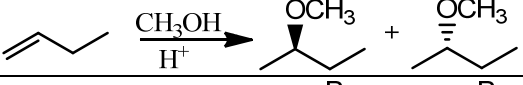
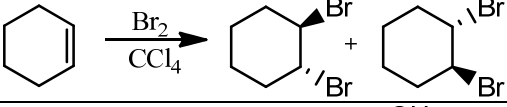
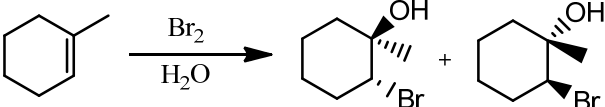
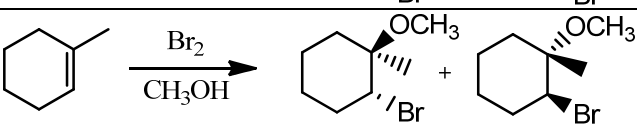
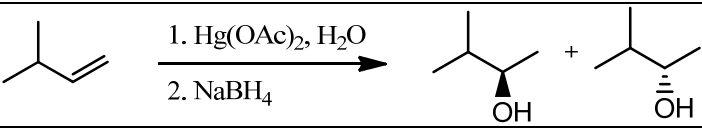
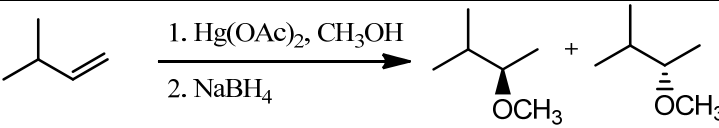
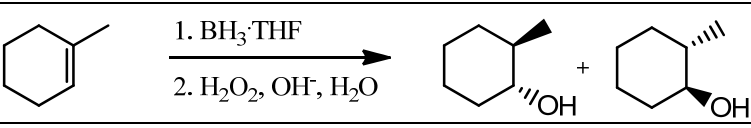
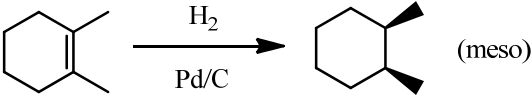
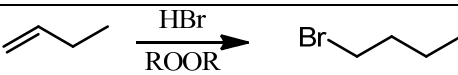
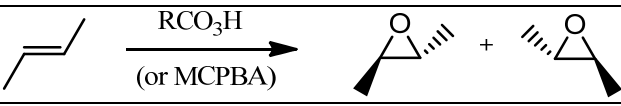
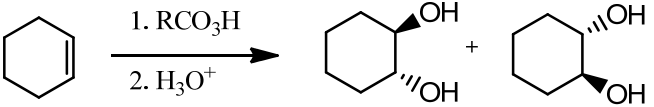
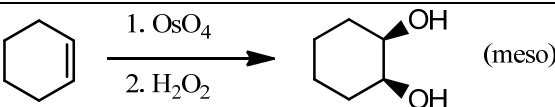
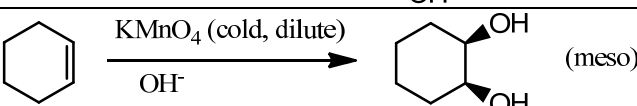
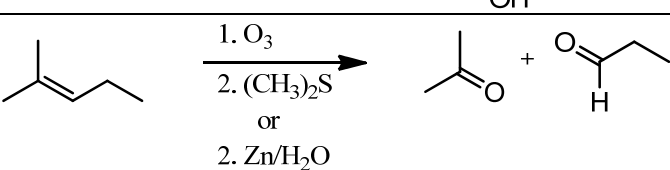


## Alkene Rxns

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	<chem>CC(C)=CC &gt;&gt; CC(=O)C + CC(=O)O</chem>
Oxidative Cleavage	<chem>CC(C)=CC &gt;&gt; CC(=O)C + CC(=O)O</chem>

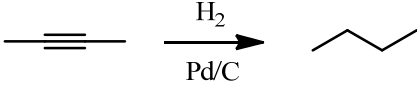
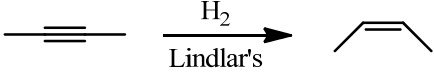
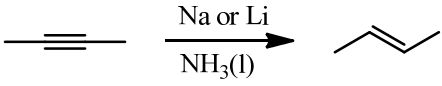
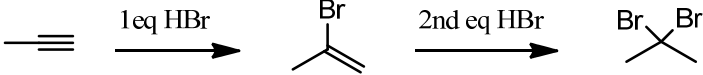
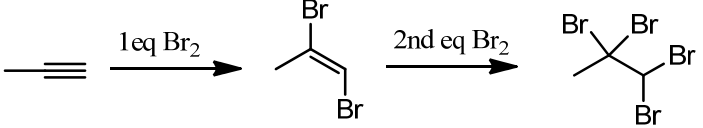
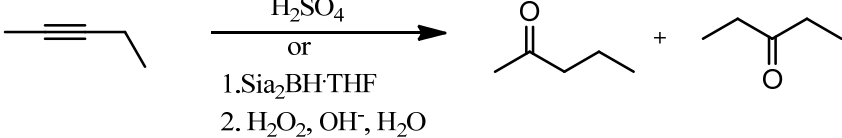
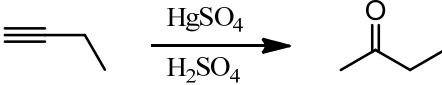
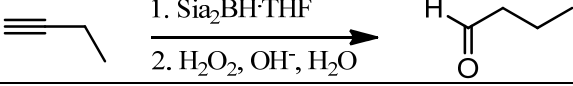
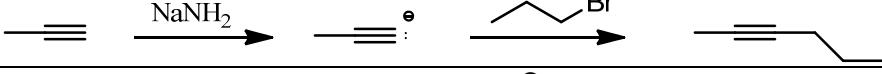
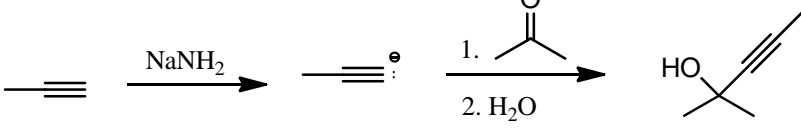
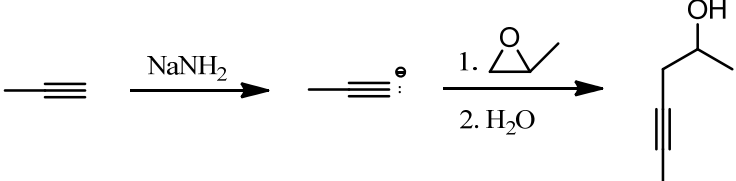
## Free Radical Halogenation

Free Radical Bromination (high selectivity)	<chem>CC1CCCCC1 &gt;&gt; CC1(Br)CCCCC1</chem>
Free Radical Chlorination (low selectivity)	<chem>CCC &gt;&gt; CCCl + CC(Cl)C</chem>
Allylic/Benzylic Bromination	<chem>C=CC &gt;&gt; C=CCBr</chem> <chem>CCc1ccccc1 &gt;&gt; C(Br)(C)c1ccccc1</chem>


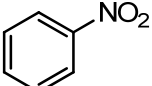

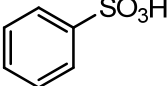

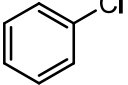

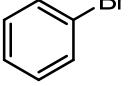

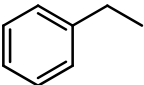

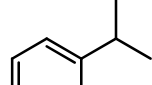

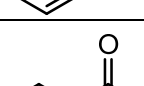
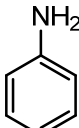
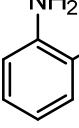
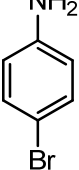
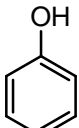
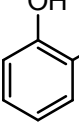
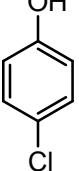
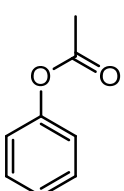
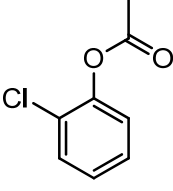
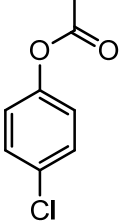
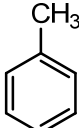
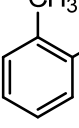
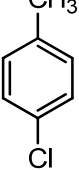
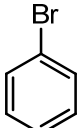
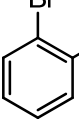
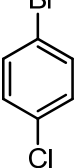
## Grignard Rxns

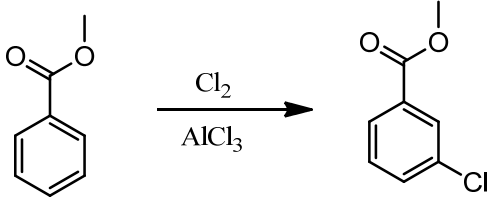
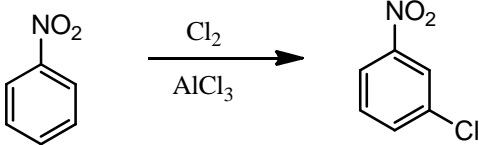
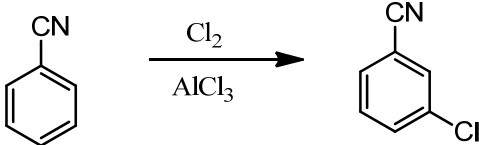
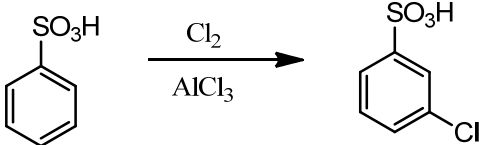
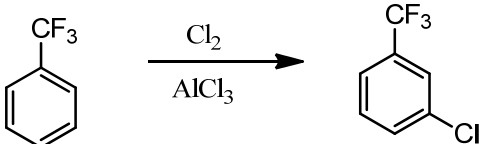
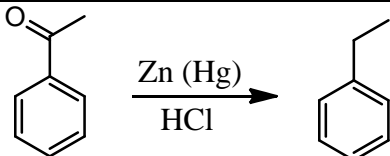
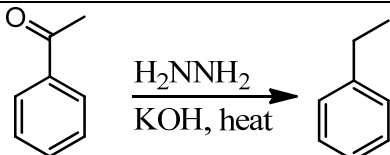
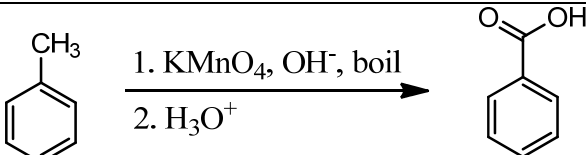
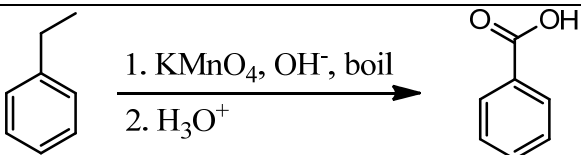
Nucleophilic Addition of a Grignard Reagent to a Ketone	<chem>c1ccccc1Br &gt;&gt; c1ccccc1C(C)(O)CC</chem>
Nucleophilic Addition of a Grignard Reagent to an Epoxide (attacks less substituted side)	<chem>c1ccccc1Br &gt;&gt; c1ccccc1CC(O)C</chem>
Nucleophilic Addition of a Grignard Reagent to CO <sub>2</sub>	<chem>c1ccccc1Br &gt;&gt; c1ccccc1C(=O)O</chem>
Protonation of a Grignard Reagent (Grignards are protonated in protic solutions)	<chem>c1ccccc1Br &gt;&gt; c1ccccc1</chem>

## Alkyne Rxns

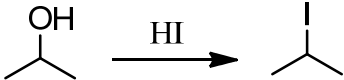

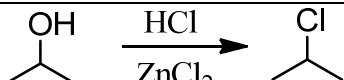
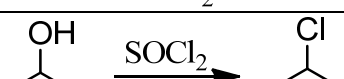
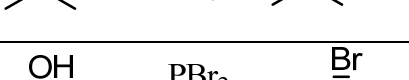
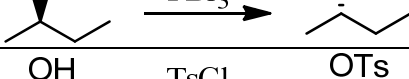
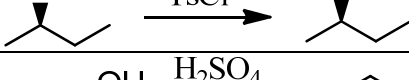
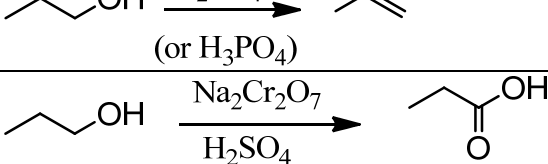
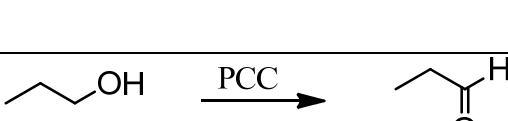
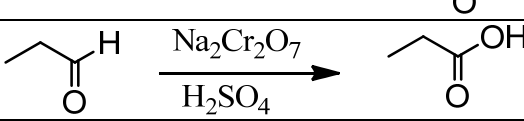
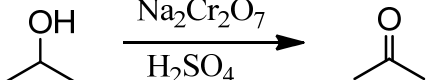

Catalytic Hydrogenation (Catalytic Reduction)	
Reduction to cis-alkene	
Reduction to trans-alkene	
Hydrohalogenation	
	
Hydration of an Internal Alkyne	
Hydration (Markovnikov)	
Hydration (Anti-Markovnikov)	
S <sub>N</sub> 2 Addition of an Acetylide Ion	
Addition of an Acetylide Ion to a Ketone	
Addition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

## Benzene Rxns

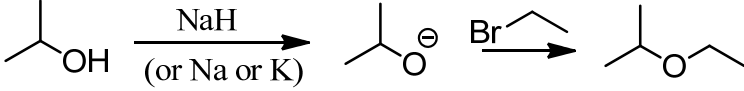
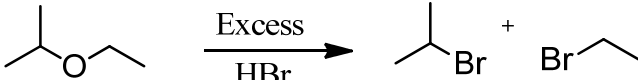
Nitration (EAS)	 $\xrightarrow[\text{H}_2\text{SO}_4]{\text{HNO}_3}$ 
Sulfonation (EAS)	 $\xrightarrow[\text{H}_2\text{SO}_4]{\text{SO}_3}$ 
Chlorination (EAS)	 $\xrightarrow[\text{AlCl}_3]{\text{Cl}_2}$ 
Bromination (EAS)	 $\xrightarrow[\text{FeBr}_3]{\text{Br}_2}$ 
Friedel-Crafts Alkylation (EAS)	 $\xrightarrow[\text{AlCl}_3]{\text{Cl}-\text{CH}_2\text{CH}_3}$ 
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 <sub>2</sub> is an ortho/para director and doesn't require a catalyst like FeBr <sub>3</sub>	 $\xrightarrow{\text{Br}_2}$  + 
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 <sub>3</sub> 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	
Chlorination (EAS) -NO <sub>2</sub> is a meta director	
Chlorination (EAS) -CN is a meta director	
Chlorination (EAS) -SO <sub>3</sub> H is a meta director	
Chlorination (EAS) -CF <sub>3</sub> is a meta director	
Clemmensen Reduction	
Wolff-Kishner Reduction	
Side-chain Oxidation (Benzylic Oxidation)	
Side-chain Oxidation (Benzylic Oxidation)	

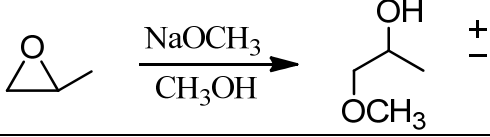
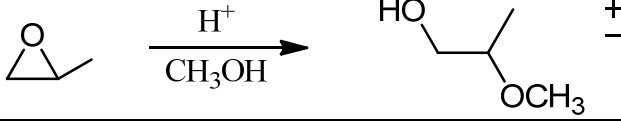
## Alcohol Rxns

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 <sub>2</sub> CrO <sub>4</sub> or CrO <sub>3</sub> /H <sub>2</sub> SO <sub>4</sub> )	
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	

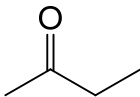
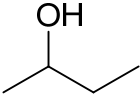
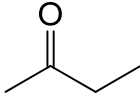
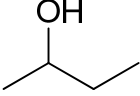
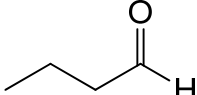
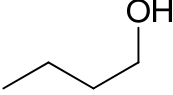
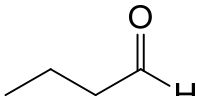
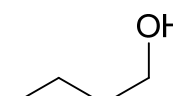
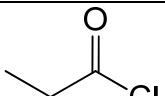
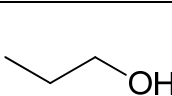
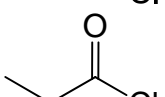
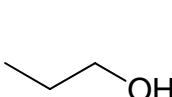
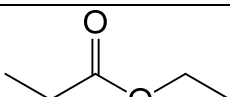
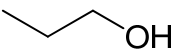
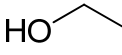
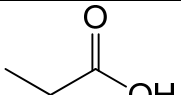
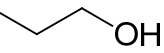
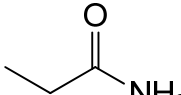
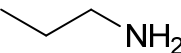
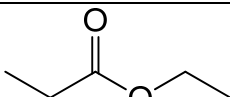
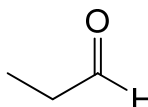
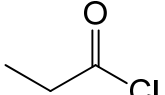
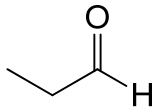
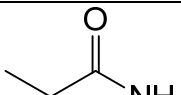
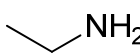
## Ether Rxns

Williamson Ether Synthesis (2 <sup>nd</sup> step is S <sub>N</sub> 2)	
Acid-Catalyzed cleavage of Ethers (also works with HI and HCl)	

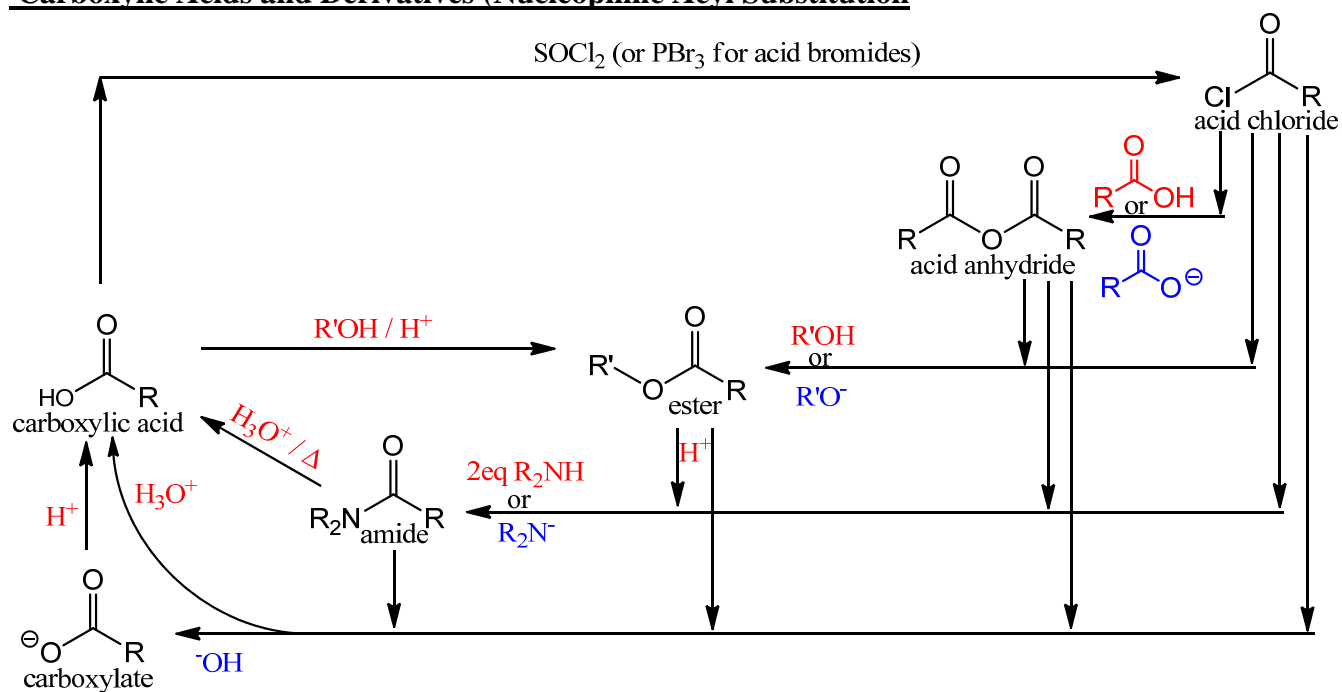
## Epoxide Rxns

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

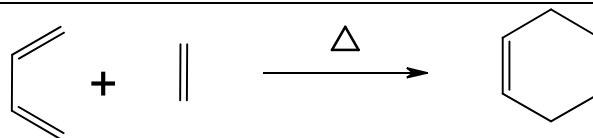
Reduction of a ketone to a 2° alcohol	 $\xrightarrow[\text{EtOH}]{\text{NaBH}_4}$   $\xrightarrow[2. \text{H}_3\text{O}^+]{1. \text{LiAlH}_4}$ 
Reduction of an aldehyde to a 1° alcohol	 $\xrightarrow[\text{EtOH}]{\text{NaBH}_4}$   $\xrightarrow[2. \text{H}_3\text{O}^+]{1. \text{LiAlH}_4}$ 
Reduction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

## Carboxylic Acids and Derivatives (Nucleophilic Acyl Substitution)



## Diels-Alder Rxns

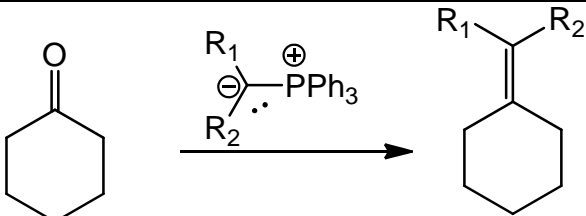
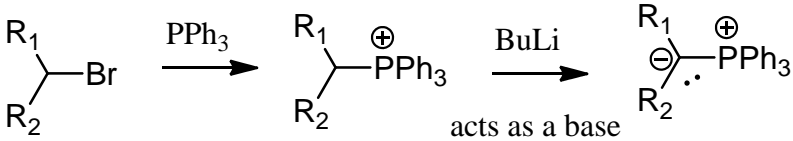
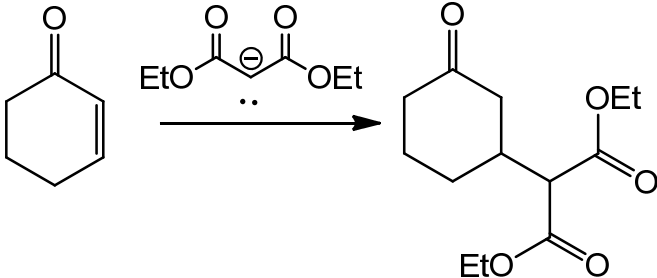
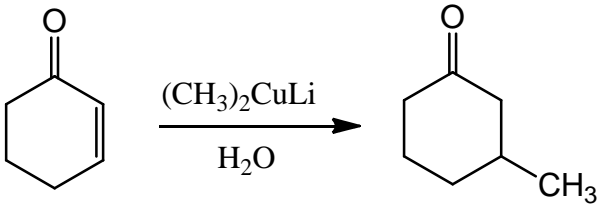
Basic Diels-Alder Rxn  
(a 4+2 cycloaddition rxn)





## Nucleophilic Addition to Ketones and Aldehydes

Addition of water to form a hydrate	
Addition of an alcohol under basic conditions to form a hemi-ketal	
Addition of 1eq of an alcohol in acid to form a hemi-ketal and then a 2 <sup>nd</sup> eq to form a ketal	
Addition of ethylene glycol to form a cyclic ketal which functions as a protecting group for ketones and aldehydes  $\text{H}_3\text{O}^+$ is used to de-protect	
Addition of a 1° amine to form an imine  (can be reversed with $\text{H}_3\text{O}^+$ )	
Addition of a 2° amine to form an enamine  Forms on less substituted side if there's a difference  (can be reversed with $\text{H}_3\text{O}^+$ )	

<p>Wittig Rxn Addition of a phosphylide to form an alkene</p>	 <p>The reaction shows cyclohexanone reacting with a phosphylide <math>\text{R}_1\text{R}_2\text{C}^-\text{P}^+\text{Ph}_3</math> to form an alkene where the carbonyl oxygen is replaced by the <math>\text{R}_1\text{R}_2\text{C}</math> group.</p>
<p>Formation of a phosphylide from an alkyl halide</p>	 <p>The reaction shows an alkyl halide <math>\text{R}_1\text{R}_2\text{CH}_2\text{Br}</math> reacting with <math>\text{PPh}_3</math> to form a phosphonium salt <math>\text{R}_1\text{R}_2\text{CH}_2\text{P}^+\text{Ph}_3</math>. This salt then reacts with <math>\text{BuLi}</math> (labeled "acts as a base") to form the phosphylide <math>\text{R}_1\text{R}_2\text{C}^-\text{P}^+\text{Ph}_3</math>.</p>
<p>Michael Addition (also called <math>\beta</math>-addition or conjugate addition)</p>	 <p>The reaction shows cyclohex-2-en-1-one reacting with the enolate of diethyl malonate, <math>\text{EtO}-\text{C}(=\text{O})-\text{CH}^--\text{C}(=\text{O})-\text{OEt}</math>, to form a 1,5-dicarbonyl product.</p>
<p>Michael Addition with a lithium dialkylcuprate</p>	 <p>The reaction shows cyclohex-2-en-1-one reacting with a lithium dialkylcuprate <math>(\text{CH}_3)_2\text{CuLi}</math> followed by <math>\text{H}_2\text{O}</math> to form 2-methylcyclohexanone.</p>

## Alpha Addition Rxns

Self Aldol Condensation	$2 \text{ CH}_3\text{COCH}_3 \xrightarrow{\text{OH}^-} \text{CH}_3\text{CH(OH)CH}_2\text{CH}_3 \xrightarrow{\Delta} \text{CH}_3\text{CH=CHCH}_3$
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	$2 \text{ CH}_3\text{CH}_2\text{CO}_2\text{Et} \xrightarrow[2. \text{H}_2\text{O}]{1. \text{NaOEt}} \text{CH}_3\text{CH}_2\text{COCH(CH}_3\text{)CO}_2\text{Et}$
Mixed Claisen Condensation	$\text{Cyclohexanone} \xrightarrow[3. \text{H}_2\text{O}]{1. \text{LDA}, 2. \text{CH}_3\text{CH}_2\text{CO}_2\text{Et}} \text{Cyclohexanone-CH}_2\text{CH}_2\text{COCH}_3$
Malonic Ester Synthesis	$\text{EtOOCCH}_2\text{COOEt} \xrightarrow[4. \text{C}_6\text{H}_5\text{CH}_2\text{Br}]{1. \text{NaOEt}, 2. \text{CH}_3\text{CH}_2\text{Br}, 3. \text{NaOEt}} \text{EtOOCCH(C}_6\text{H}_5\text{)CH}_2\text{COOEt} \xrightarrow[\Delta]{\text{H}_3\text{O}^+} \text{C}_6\text{H}_5\text{CH}_2\text{CH}_2\text{COOH} + \text{CO}_2$
Acetoacetic Ester Synthesis	$\text{EtOOCCH}_2\text{COCH}_3 \xrightarrow[4. \text{C}_6\text{H}_5\text{CH}_2\text{Br}]{1. \text{NaOEt}, 2. \text{CH}_3\text{CH}_2\text{Br}, 3. \text{NaOEt}} \text{EtOOCCH(C}_6\text{H}_5\text{)CH}_2\text{COCH}_3 \xrightarrow[\Delta]{\text{H}_3\text{O}^+} \text{C}_6\text{H}_5\text{CH}_2\text{CH}_2\text{COCH}_3 + \text{CO}_2$