

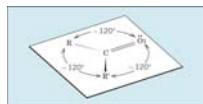
Aldehydes and Ketones

Carbonyl Compounds

- Several functional groups contain the carbonyl group
 - Carbonyl groups can be converted into alcohols by various reactions



- Structure of the Carbonyl Group
 - The carbonyl carbon is sp^2 hybridized and is trigonal planar
 - All three atoms attached to the carbonyl group lie in one plane



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1

Carbonyl Compounds

TABLE 18-1 Some Common Classes of Carbonyl Compounds

Class	General Formula	Class	General Formula
ketones	$R-C(=O)-R'$	aldehydes	$R-C(=O)-H$
carboxylic acids	$R-C(=O)-OH$	acid chlorides	$R-C(=O)-Cl$
esters	$R-C(=O)-O-R'$	amides	$R-C(=O)-NH_2$

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2

Carbonyl Structure

- Carbon is sp^2 hybridized.
- $C=O$ bond is shorter, stronger, and more polar than $C=C$ bond in alkenes.

	length	energy
ketone $C=O$ bond	1.23 Å	178 kcal/mol (745 kJ/mol)
alkene $C=C$ bond	1.34 Å	146 kcal/mol (611 kJ/mol)

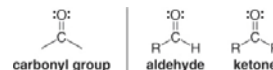
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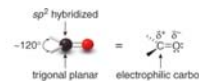
Aldehydes and Ketones

Introduction

Aldehydes and ketones contain a carbonyl group. An aldehyde contains at least one H atom bonded to the carbonyl carbon, whereas the ketone has two alkyl or aryl groups bonded to it.



Two structural features determine the chemistry and properties of aldehydes and ketones.



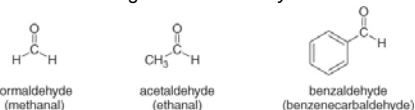
- The carbonyl group is sp^2 hybridized and trigonal planar, making it relatively uncrowded.
- The electronegative oxygen atom polarizes the carbonyl group, making the carbonyl carbon electrophilic.

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4

Nomenclature of Aldehydes

- Like carboxylic acids, many simple aldehydes have common names that are widely used.
- A common name for an aldehyde is formed by taking the common parent name and adding the suffix *-aldehyde*.



(IUPAC names are in parentheses.)

- Greek letters are used to designate the location of substituents in common names.



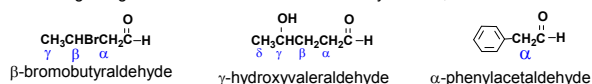
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Common Names of Aldehydes

- In the common system, **aldehydes** are named from the common names of the corresponding carboxylic acid.
- The *'ic acid'* ending is replaced with *'aldehyde'*.

Structure	IUPAC name	Common name	Structure	IUPAC name	Common name
HCO_2H	methanoic acid	formic acid	$HCHO$	methanal	formaldehyde
CH_3CO_2H	ethanoic acid	acetic acid	CH_3CHO	ethanal	acetaldehyde
$CH_3CH_2CO_2H$	propanoic acid	propionic acid	CH_3CH_2CHO	propanal	propionaldehyde
$CH_3(CH_2)_2CO_2H$	butanoic acid	butyric acid	$CH_3(CH_2)_2CHO$	butanal	butyraldehyde
$CH_3(CH_2)_3CO_2H$	pentanoic acid	valeric acid	$CH_3(CH_2)_3CHO$	pentanal	valeraldehyde
$CH_3(CH_2)_4CO_2H$	hexanoic acid	caproic acid	$CH_3(CH_2)_4CHO$	hexanal	caproaldehyde

- Substituents locations are given using Greek letters (α , β , γ , δ , ϵ , ω) beginning with the carbon *next* to the carbonyl carbon, the α -carbon.



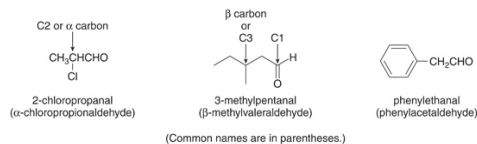
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6

Aldehydes and Ketones

Nomenclature of Aldehydes

- If the CHO is bonded to a chain of carbons, find the longest chain containing the CHO group, and change the **-e** ending of the parent alkane to the suffix **-al**. If the CHO group is bonded to a ring, name the ring and add the suffix **-carbaldehyde**.
- Number the chain or ring to put the CHO group at C1, but omit this number from the name. Apply all the other usual rules of nomenclature.



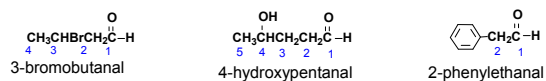
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IUPAC Names of Aldehydes

Aldehydes: in open chains:

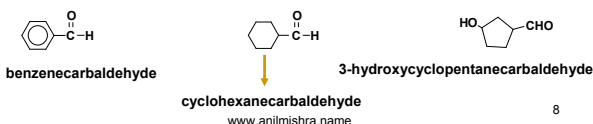
alkane+al \rightarrow "alkanal"



- The parent chain must contain the CHO- group, and this group is numbered as carbon 1 (because it is always at a chain end).

Aldehydes: attached to rings:

ring+carbaldehyde \rightarrow "ringcarbaldehyde"

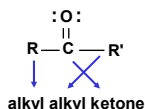


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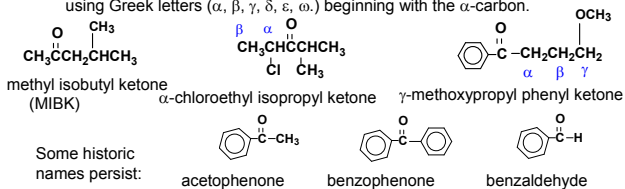
Nomenclature of Ketones

Common Names of Ketones



- The two alkyl groups attached to the carbonyl are named and the word "ketone" is added as a separate word. It is literally "alkyl alkyl ketone".
- The alkyl groups are listed alphabetically or in order of increasing size.

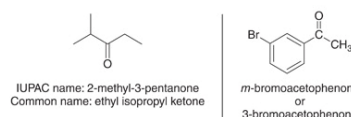
- As with aldehydes, substituents locations are given in common names using Greek letters (α , β , γ , δ , ϵ , ω .) beginning with the α -carbon.



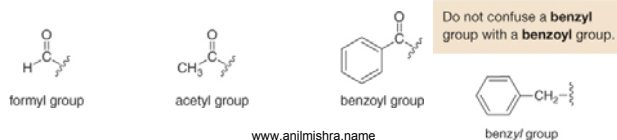
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9

Nomenclature of Ketones



- Sometimes, acyl groups must be named as substituents. The three most common acyl groups are shown below:



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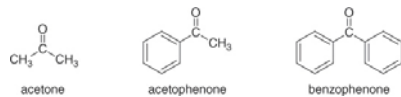
Do not confuse a benzyl group with a benzoyl group.

Nomenclature of Ketones

- Most common names for ketones are formed by naming both alkyl groups on the carbonyl carbon, arranging them alphabetically, and adding the word "ketone".



- Three widely used common names for some simple ketones do not follow this convention:



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11

Nomenclature of Ketones

- In the IUPAC system, all ketones are identified by the suffix "one".
- Find the longest continuous chain containing the carbonyl group, and change the **-e** ending of the parent alkane to the suffix **-one**.
- Number the carbon chain to give the carbonyl carbon the lowest number. Apply all of the usual rules of nomenclature.
- With cyclic ketones, numbering always begins at the carbonyl carbon, but the "1" is usually omitted from the name. The ring is then numbered clockwise or counterclockwise to give the first substituent the lower number.

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12

Nomenclature of Ketones

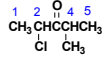
Ketones: in both open chains and rings:

alkane+one → "alkanone"

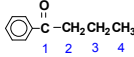
- The parent chain must contain the C=O group, and this chain is numbered to give the carbonyl group as low a number as possible. In cyclic ketones, the carbonyl group is assigned the number '1'.



2-butanone

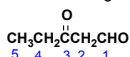


2-chloro-4-methyl-3-pentanone



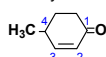
1-phenyl-1-butanone

- Ketones are just below aldehydes in nomenclature priority.
- A ketone group is named as an 'oxo' substituent in an aldehyde.



3-oxopentanal

An olefinic ketone is named as an 'enone', literally: "#-alken-#-one".



4-methyl-2-cyclohexen-1-one

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13

Isomerism in aldehydes and ketones

- Aldehydes and ketones are constitutional isomers
- Aldehydes and ketones can have skeletal and positional isomers if there are enough carbons.
- Stereoisomers are also possible if there is a ring or C=C in the molecule

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14

Preparation of Aldehyde and Ketone

Aldehydes, syntheses:

- Oxidation of 1° alcohols
- Oxidation of methylaromatics
- Reduction of acid chlorides

Ketones, syntheses:

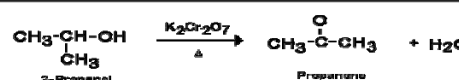
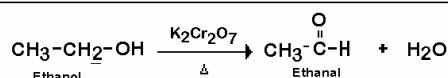
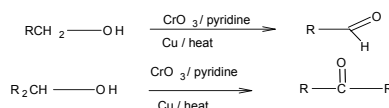
- Oxidation of 2° alcohols
- Friedel-Crafts acylation
- Coupling of R₂CuLi with acid chloride

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15

Preparation of Aldehyde and Ketone

1- Oxidation of alcohols

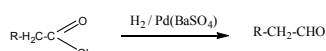


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16

Preparation of Aldehyde and Ketone

2- Reduction of acid chloride

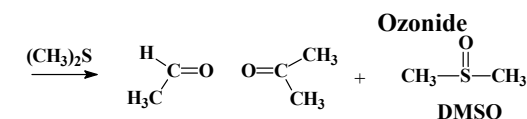
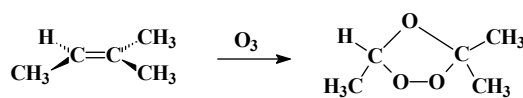
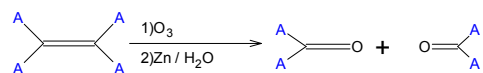


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17

Preparation of Aldehyde and Ketone

3- Ozonolysis of alkenes

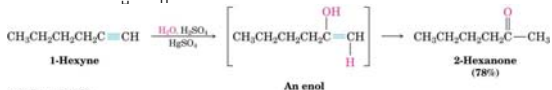
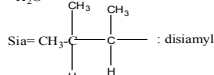
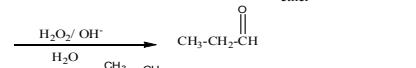
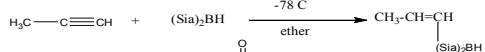
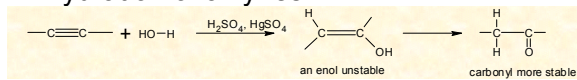


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18

Preparation of Aldehyde and Ketone

4- Hydration of alkynes



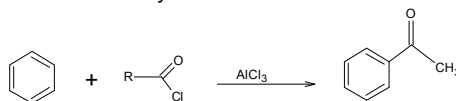
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Preparation of Aldehyde and Ketone

5- Friedel Crafts acylation

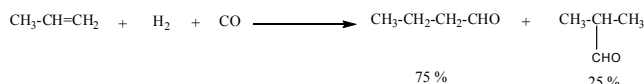


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Preparation of Aldehyde and Ketone

6-Oxo reaction - Hydroformylation reaction

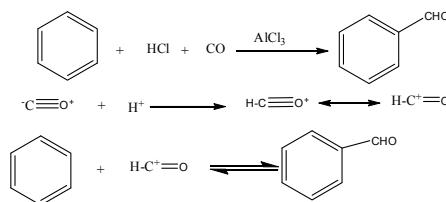


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Preparation of Aldehyde and Ketone

7- Gattermann-Koch reaction

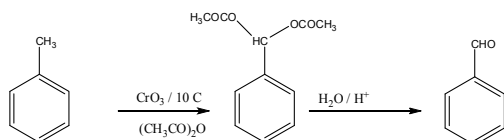


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Preparation of Aldehyde and Ketone

8- Oxidation of an Alkyl Side of aromatic ring

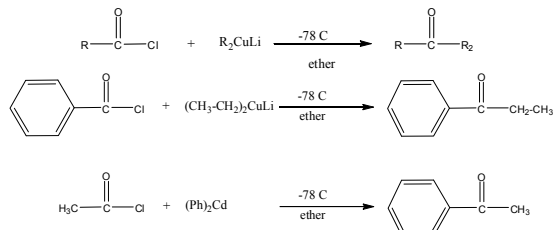


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23

Preparation of Aldehyde and Ketone

9- From acid chloride and lithium dialkyl cuprate or R₂Cu



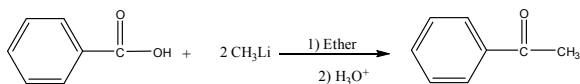
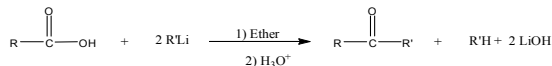
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24

Aldehydes and Ketones

Preparation of Aldehyde and Ketone

10- From Carboxylic acid and RLi

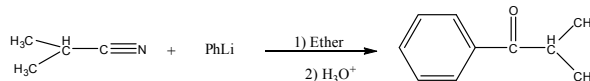
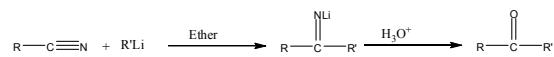
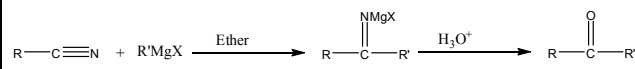


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Preparation of Aldehyde and Ketone

11- From nitrile and Grignard reagent or alkyl lithium

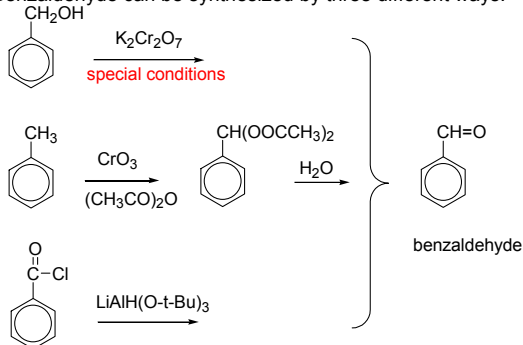


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26

Preparation of Aldehyde and Ketone

Benzaldehyde can be synthesized by three different ways.

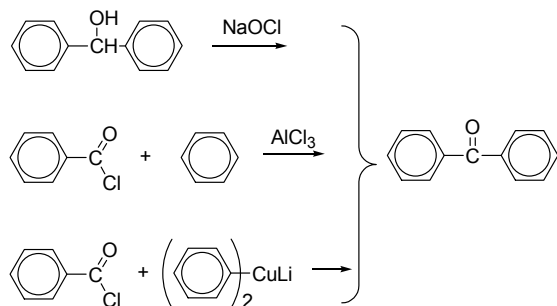


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27

Preparation of Aldehyde and Ketone

Benzophenone can be synthesized by three different ways

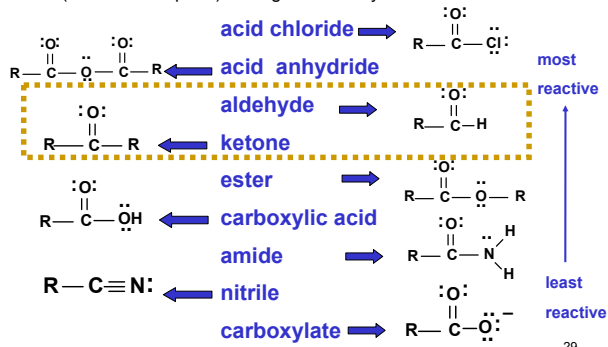


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28

Aldehydes and Ketones are Electrophiles

Aldehydes and ketones are moderately reactive as electrophiles (electron acceptors) among the carboxylic acid derivatives.

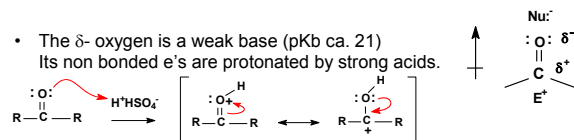


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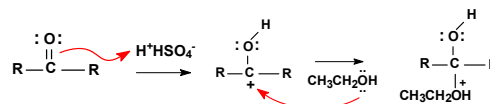
Basicity of Aldehydes and Ketones

The δ^- oxygen is a weak base (pK_b ca. 21). Its non-bonded e⁻s are protonated by strong acids.



The + charge is shared with the carbonyl C by resonance forming a carbocation – a very good E⁺.

Even weak Nu⁻'s (like H₂O and ROH) will donate electrons to an aldehyde or ketone in the presence of a strong acid catalyst, e.g., H₂SO₄ or HCl.



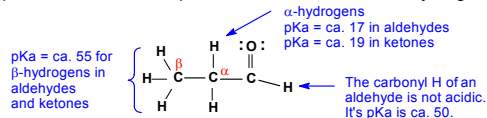
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30

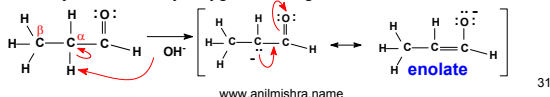
Aldehydes and Ketones

Acidity of Aldehydes and Ketones

- The α -carbon is the carbon bonded to the carbonyl, not the carbonyl carbon itself.
- Hydrogens bonded to the carbonyl carbon, the α -carbon, the β -carbon, etc. are not polar and thus are not acidic hydrogens.

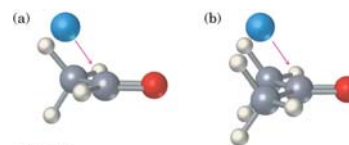


- The α -hydrogens can be removed by strong bases because the carbanion that forms is stabilized by resonance with the adjacent carbonyl oxygen forming an enolate.



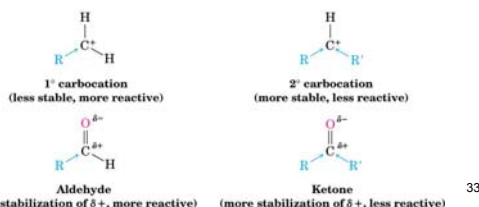
Relative Reactivity

- Aldehydes are generally more reactive than ketones in nucleophilic addition reactions
- The transition state for addition is less crowded and lower in energy for an aldehyde (a) than for a ketone (b)
- Aldehydes have one large substituent bonded to the C=O; ketones have two



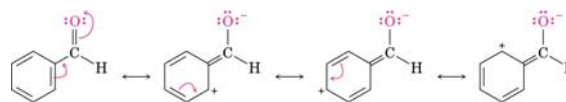
Electrophilicity of Aldehydes and Ketones

- Aldehyde C=O is more polarized than ketone C=O
- As in carbocations, more alkyl groups stabilize + character
- Ketone has more alkyl groups, stabilizing the C=O carbon inductively



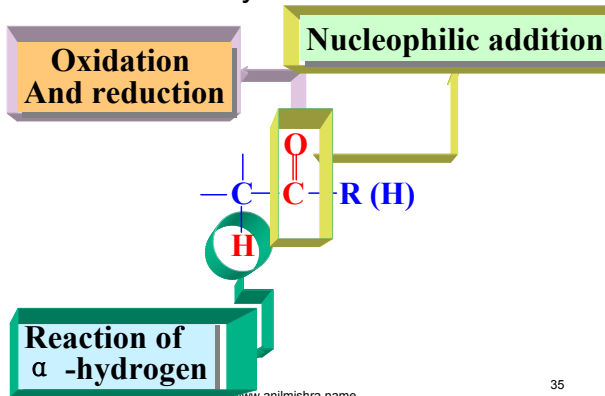
Reactivity of Aromatic Aldehydes

- Less reactive in nucleophilic addition reactions than aliphatic aldehydes
- Electron-donating resonance effect of aromatic ring makes C=O less reactive electrophilic than the carbonyl group of an aliphatic aldehyde

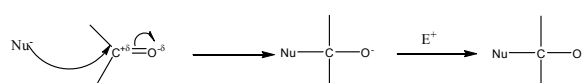
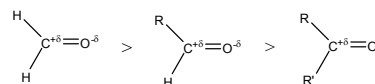


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Reaction sites and reactions of aldehydes and ketones



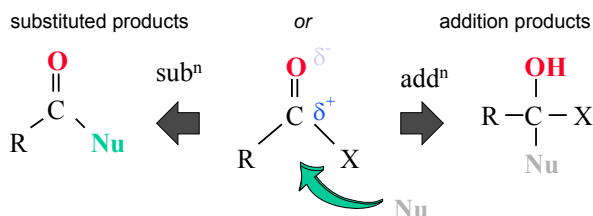
Reactions of Aldehydes and Ketones



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Reactivity of the Carbonyl

The δ^+ carbonyl carbon is susceptible to nucleophilic attack
two product types are possible

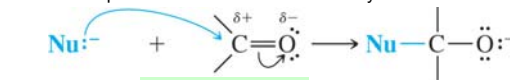


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Reactivity of the Carbonyl

- Carbonyl groups can undergo nucleophilic addition
 - The nucleophile adds to the δ^+ carbon
 - The π electrons shift to the oxygen
 - The carbon becomes sp^3 hybridized and therefore tetrahedral
 - Hydride ions and carbanions are two examples of nucleophiles that react with the carbonyl carbon

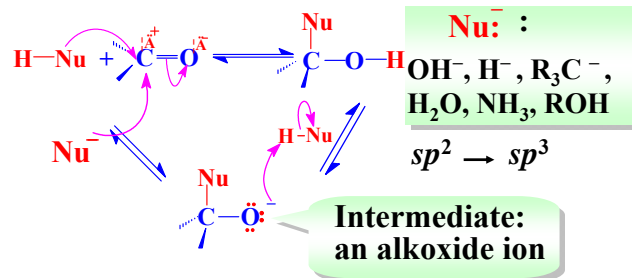


Hybridization: $sp^2 \rightarrow sp^3$
The bond angle: $120^\circ \rightarrow 109.5^\circ$

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38

Nucleophilic Addition



The trigonal planar structure of $C=O$ is relatively open to attack from above or below by Nu^- .

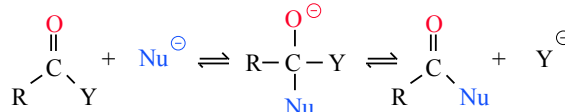
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39

Addition vs Substitution

Substitution

When "Y" is a good leaving group, substitution is favoured



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40

Carbonyl Addition Reactions

Addition Reactions

If "Y" cannot stabilize a $-ve$ charge, it is a poor leaving group
 \therefore Nu attacks yields addition products



e.g. if $Y = "H"$ leaving group would be a hydride ion
if $Y = "CH_3"$ leaving group would be a 1° methyl ion
both examples are not stabilized \therefore are poor leaving groups
 \therefore Nu addition reaction occurs

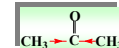
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41

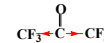
Factors affecting the reactivity:

1. Electronic effects of alkyl groups

- Electron-donating effect of alkyl Substituents stabilizes the carbonyl group



- Electron-withdrawing effect destabilizes the carbonyl group



the more electronegative "Y"....the greater the δ^+ on the carbonyl carbon

\therefore the more reactive to Nu attack



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42

Factors affecting the reactivity:

2. Steric effect of alkyl groups

- the more highly substituted the carbonyl, the less susceptible to Nu attack



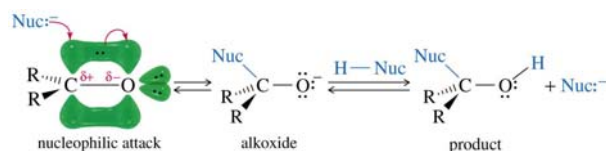
- The crowding in the products is increased by the larger group

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43

Nucleophilic Addition

- A strong nucleophile attacks the carbonyl carbon, forming an alkoxide ion that is then protonated.
- A weak nucleophile will attack a carbonyl if it has been protonated, thus increasing its reactivity.
- Aldehydes are more reactive than ketones.



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44

Nucleophilic Addition of H₂O: Hydration

- Aldehydes and ketones react with water to yield 1,1-diols (**geminal (gem) diols**)
- Hydration is reversible: a gem diol can eliminate water

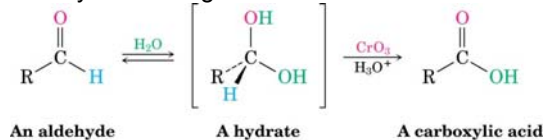


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45

Hydration

- Aldehyde oxidations occur through 1,1-diols ("hydrates")
- Reversible addition of water to the carbonyl group
- Aldehyde hydrate is oxidized to a carboxylic acid by usual reagents for alcohols



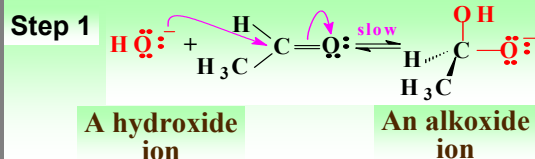
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46

Mechanism of Hydration

Base-catalyzed reaction

The addition of water is subject to catalysis by both an acid and a base.



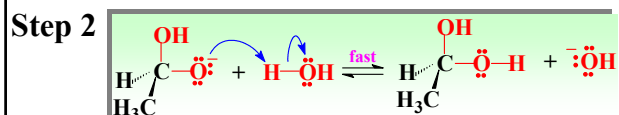
A hydroxide ion attacks the carbon of the carbonyl group. This step is rate-determining.

Nucleophile:
HO⁻ > H₂O

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Mechanism of Hydration

Base-catalyzed reaction



An alkoxide ion attracts a proton from water, yielding geminal diol.

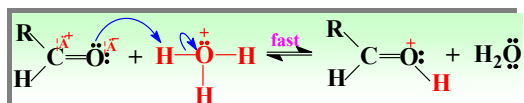
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48

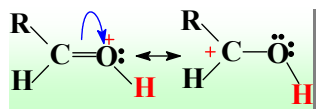
Mechanism of Hydration

Acid-catalyzed reaction

Step 1



Protonation of carbonyl group:



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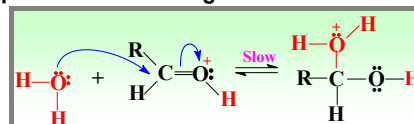
49

Mechanism of Hydration

Acid-catalyzed reaction

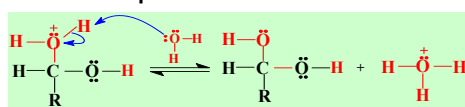
- Water as a nucleophile attacks the protonated carbonyl group
- The step is rate-determining

Step 2



Transformation of the proton

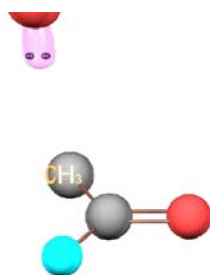
Step 3



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50

The mechanism for the base-catalyzed reaction:

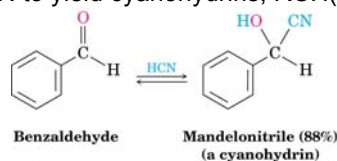


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51

Nucleophilic Addition of HCN: Cyanohydrin Formation

- Aldehydes and unhindered ketones react with HCN to yield cyanohydrins, $RCH(OH)C\equiv N$

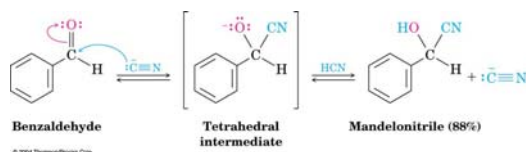


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52

Mechanism of Formation of Cyanohydrins

- Addition of HCN is reversible and base-catalyzed, generating nucleophilic cyanide ion, CN^-
- Addition of CN^- to $C=O$ yields a tetrahedral intermediate, which is then protonated
- Equilibrium favors adduct

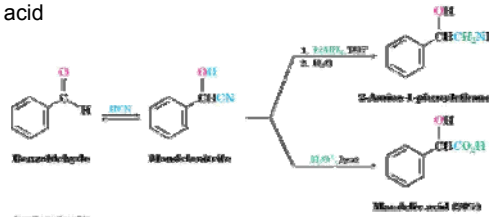


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53

Uses of Cyanohydrins

- The nitrile group ($-C\equiv N$) can be reduced with $LiAlH_4$ to yield a primary amine (RCH_2NH_2)
- Can be hydrolyzed by hot acid to yield a carboxylic acid



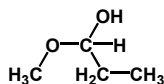
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54

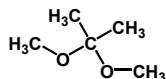
Addition of Alcohol

Hemiacetal and Acetal Functional Groups

➤ Hemiacetal (Hemiketal): alcohol and ether on same carbon



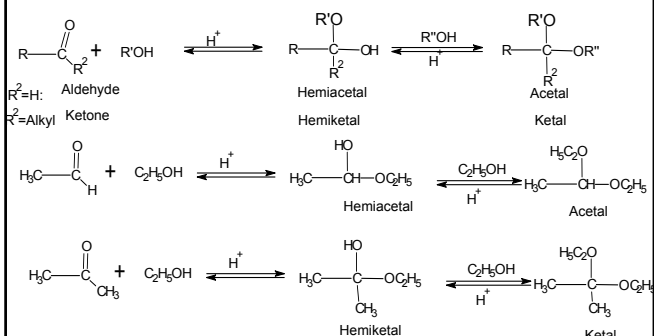
➤ Acetal (Ketal): Two ethers on same carbon



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Addition of Alcohol



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56

Addition of Alcohol Mechanism

- Must be acid-catalyzed.
- Adding H^+ to carbonyl makes it more reactive with weak nucleophile, ROH.
- Hemiacetal forms first, then acid-catalyzed loss of water, then addition of second molecule of ROH forms acetal.
- All steps are reversible.

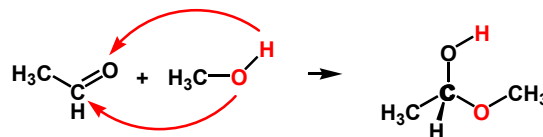
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57

Hemiacetal Formation

Hemiacetal Synthesis: aldehyde + alcohol

- Alcohol + aldehyde \rightarrow hemiacetal
- Ethanal + methanol
- Alcohol oxygen becomes an ether
- Carbon double bond oxygen becomes an alcohol



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58

Acetal Formation

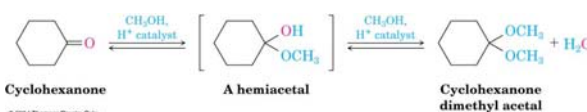
- Alcohols are weak nucleophiles but acid promotes addition forming the conjugate acid of $\text{C}=\text{O}$
- Addition yields a hydroxy ether, called a hemiacetal (reversible); further reaction can occur
- Protonation of the $-\text{OH}$ and loss of water leads to an oxonium ion, $\text{R}_2\text{C}=\text{OR}^+$ to which a second alcohol adds to form the acetal

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59

Formation of Acetals

- Alcohols are weak nucleophiles but acid promotes addition forming the conjugate acid of $\text{C}=\text{O}$
- Addition yields a hydroxy ether, called a hemiacetal (reversible); further reaction can occur
- Protonation of the $-\text{OH}$ and loss of water leads to an oxonium ion, $\text{R}_2\text{C}=\text{OR}^+$ to which a second alcohol adds to form the acetal



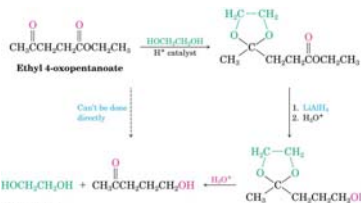
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60

Uses of Acetals

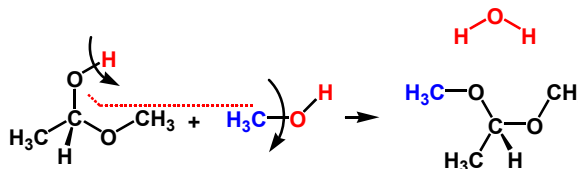
- Acetals can serve as protecting groups for aldehydes and ketones
- It is convenient to use a diol, to form a *cyclic* acetal (the reaction goes even more readily)



61

Acetal Formation

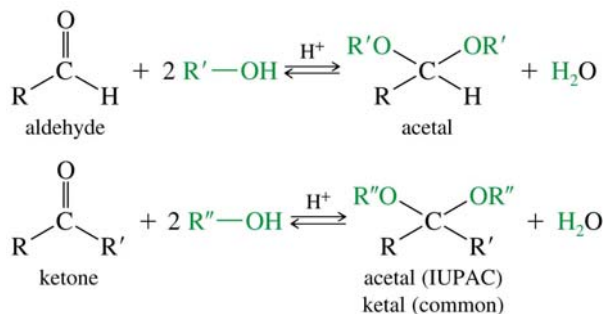
- Acetal: alcohol plus hemiacetal (ether synthesis)
- Acetal: Two ethers on same carbon



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62

Acetal Formation

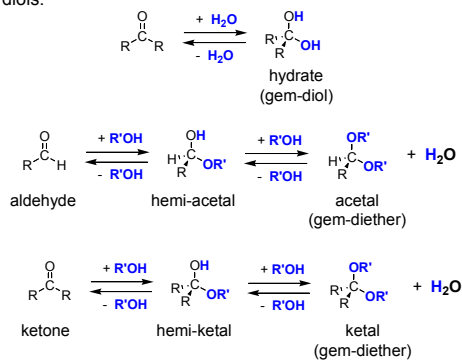


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63

Acetal Formation

Acetals are geminal diethers- structurally related to hydrates, which are geminal diols.



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64

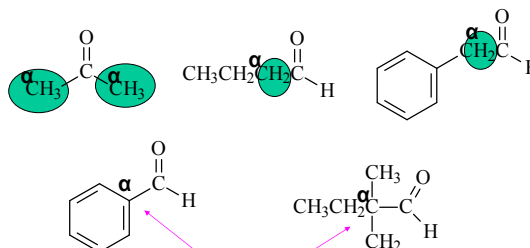
Carbonyl Condensation Reactions

- What is needed?
 - > A Ketone or aldehyde
 - > ONE reactant must have α -Hydrogens
 - > Base (NaOH)

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Carbonyl Condensation Reactions

NO α -HYDROGENS

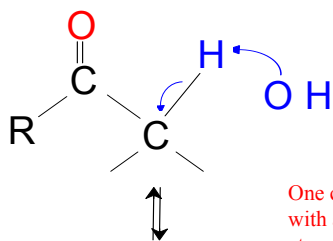
- An α -carbon is the carbon directly attached to the C=O
- Hydrogens attached to these C are called α -hydrogens

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66

Carbonyl Condensation Reactions

General Mechanism

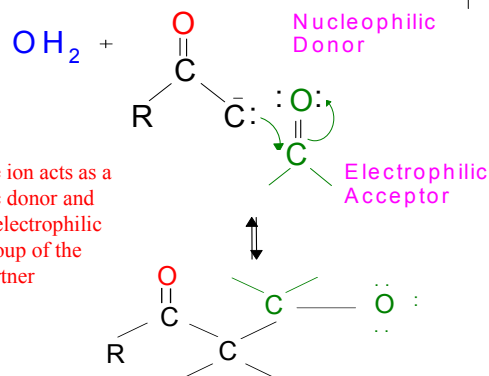


One carbonyl partner with an alpha hydrogen atom is converted by base into its enolate ion.

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67

Carbonyl Condensation Reactions

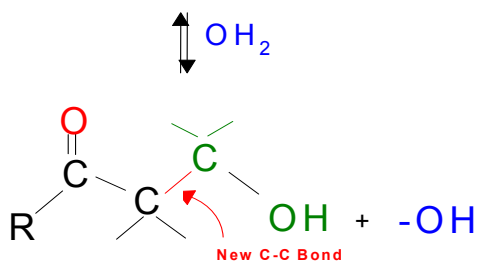


This enolate ion acts as a nucleophilic donor and adds to the electrophilic carbonyl group of the acceptor partner

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Carbonyl Condensation Reactions



Protonation of the tetrahedral alkoxide ion intermediate gives the neutral condensation product.

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Carbonyl Condensation Reactions

ALDOL REACTION

- occurs between two aldehyde or ketone molecules with a catalytic base
- reaction can occur between two components that have alpha hydrogens
- reversible condensation reaction
- two highlights: enolate formation and nucleophilic attack at a carbonyl carbon
- Aldol products are: alpha-β-unsaturated aldehydes/ketones and β-hydroxy aldehydes/ketones

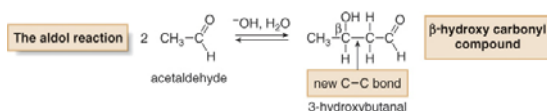
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70

Carbonyl Condensation Reactions

The Aldol Reaction

- In the **aldol reaction**, two molecules of an aldehyde or ketone react with each other in the presence of a base to form a **β-hydroxy carbonyl compound**.

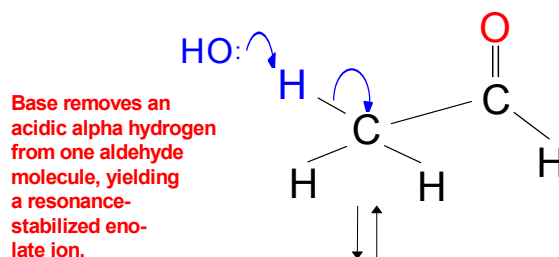


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71

Carbonyl Condensation Reactions

Mechanism of the Aldol Reaction

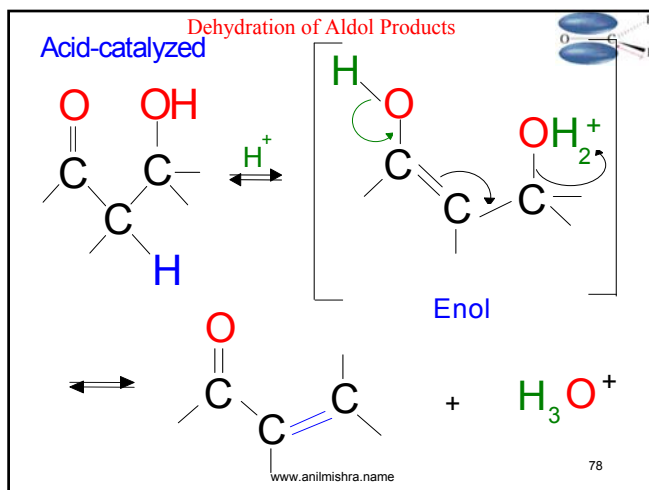
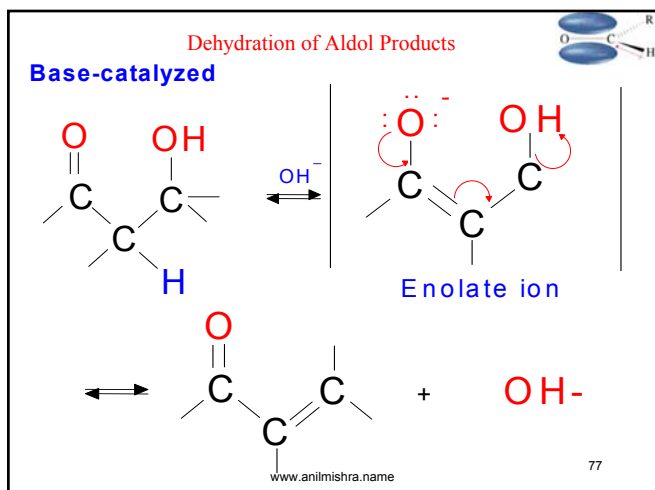
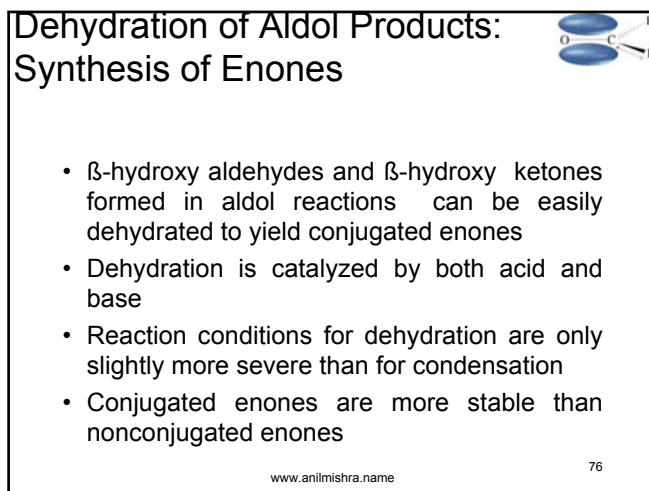
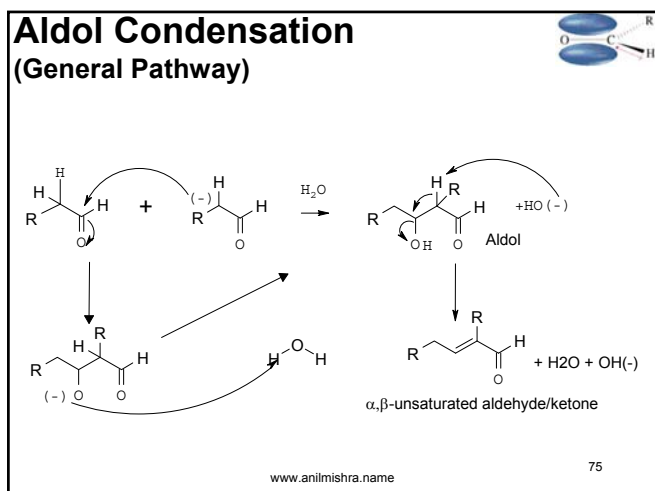
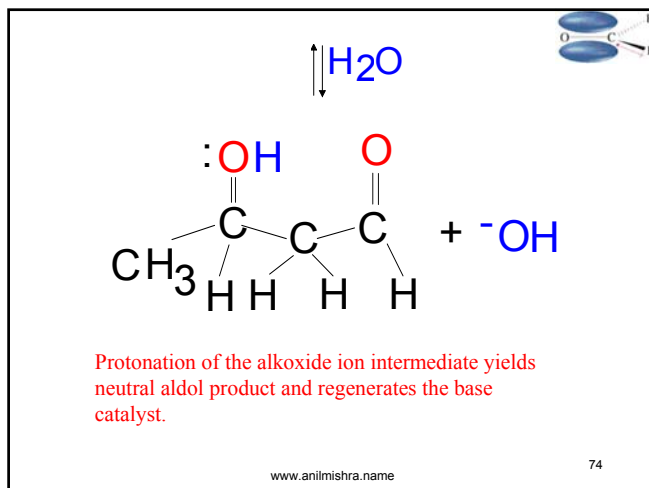
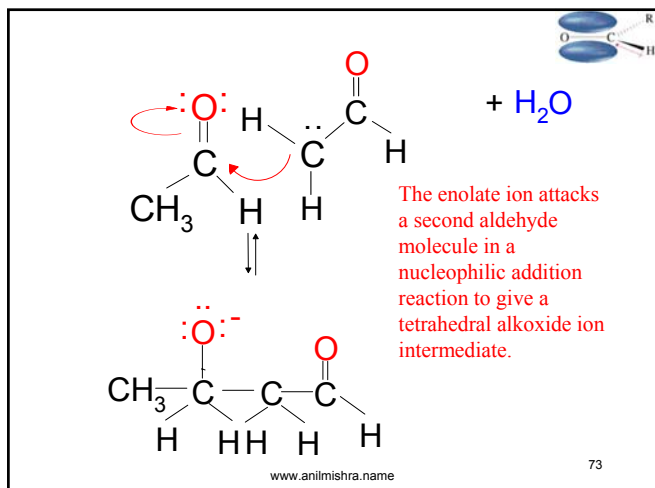


Base removes an acidic alpha hydrogen from one aldehyde molecule, yielding a resonance-stabilized enolate ion.

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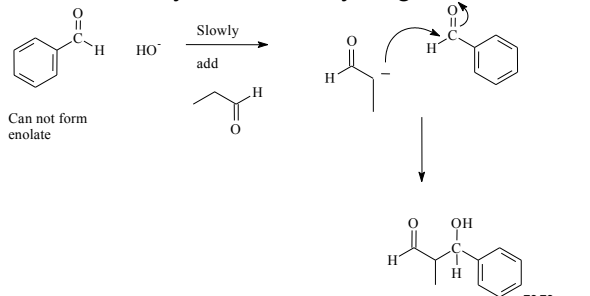
72

Aldehydes and Ketones



Mixed Aldol Reaction

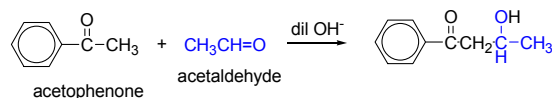
- One carbonyl has no α -hydrogens



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Mixed Aldol Reaction

A crossed aldol can also be done between an aldehyde and a ketone to yield one product. The enolate carbanion from the ketone adds to the more reactive aldehyde.



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80

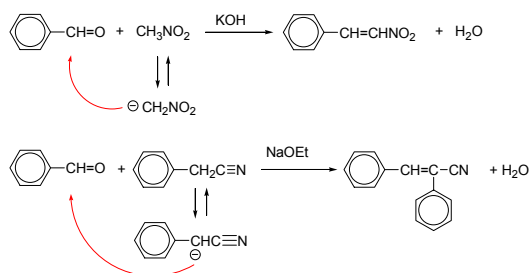
Mixed Aldol Reaction

- If two similar aldehydes/ketones react under aldol conditions, 4 products may be formed
- A single product can be formed from two different components :
 - If one carbonyl component has no α -hydrogens or if one carbonyl compound is much more acidic than the other.

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81

Mixed Aldol Reaction

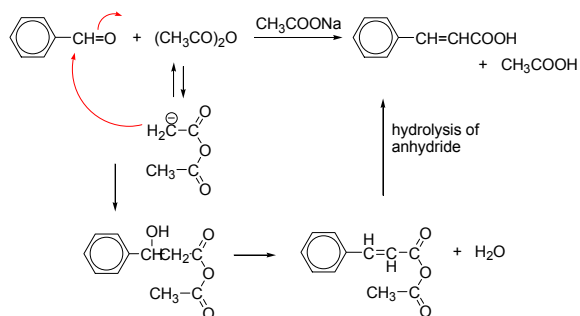


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82

Mixed Aldol Reaction

Perkin Condensation



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83

Intramolecular Aldol Reaction:

- Treatment of certain dicarbonyl compounds with base can lead to cyclic products
- A mixture of cyclic products may result, but the more strain-free ring is usually formed

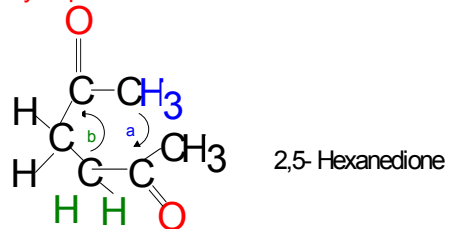
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84

Aldehydes and Ketones

Intramolecular Aldol Reaction:

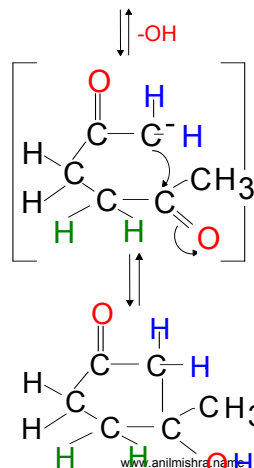
Intramolecular Aldol Reaction of 2, 5-hexanedione yields 3-methyl-2-cyclopentenone



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85

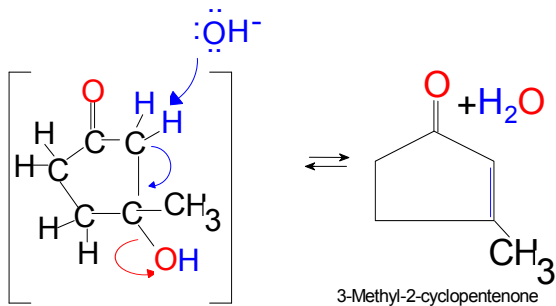
Path A



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86

NaOH, H₂O

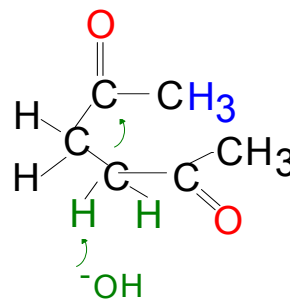


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87

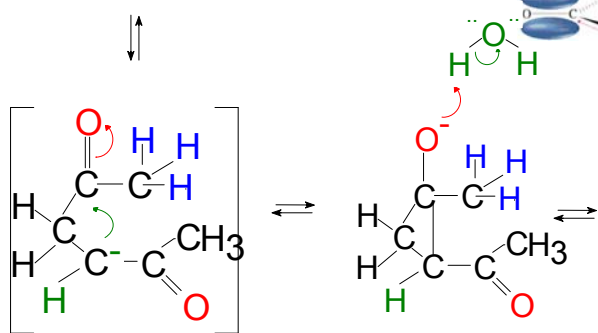
Path b

NaOH, H₂O



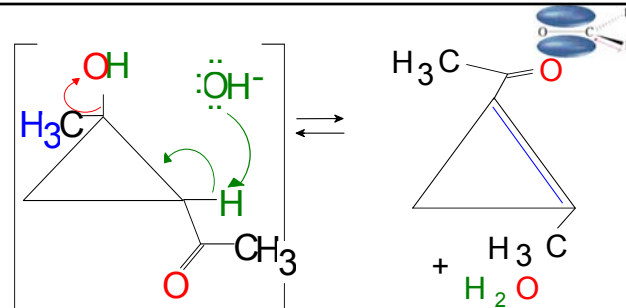
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88



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89

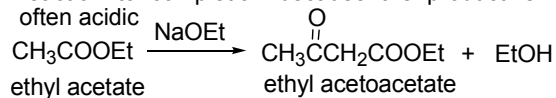


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90

Claisen Condensation

- Carbonyl condensation that occurs between two ester components and gives a β -keto ester product
- Reaction is reversible and has a mechanism similar to aldol reaction
- Major difference from aldol condensation is the expulsion of an alkoxide ion from the tetrahedral intermediate of the initial Claisen adduct
- 1 equivalent of base is needed to drive the reaction to completion because the product is often acidic



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91

Mechanism of Claisen Condensation

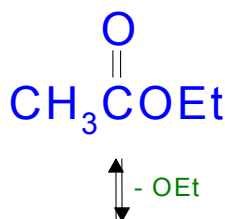
- Involves nucleophilic acyl substitution of an ester enolate ion on the carbonyl group of a second ester molecule
- Tetrahedral intermediate expels an alkoxide leaving group to yield an acyl substitution product

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92

Mechanism of Claisen Condensation

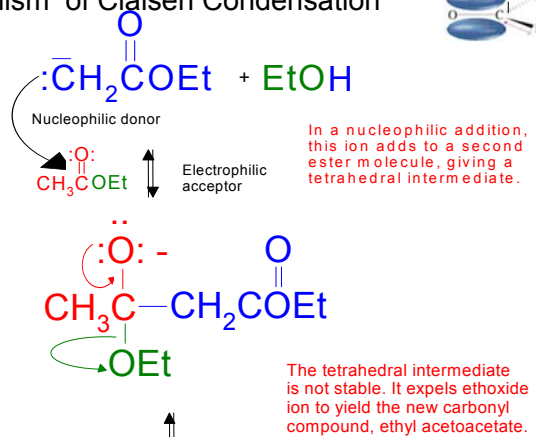
Ethoxide base abstracts an acidic α hydrogen atom from an ester molecule, yielding an ester enolate ion



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93

Mechanism of Claisen Condensation

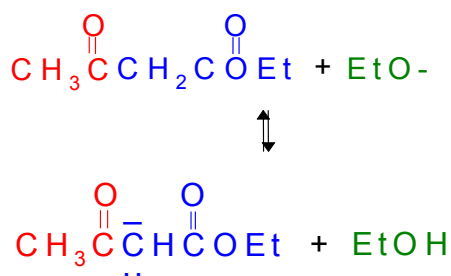


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94

Mechanism of Claisen Condensation

But ethoxide ion is basic enough to convert the β -keto ester product into its enolate, thus shifting the equilibrium and driving the reaction to completion.

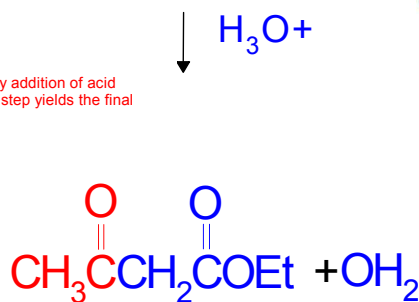


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95

Mechanism of Claisen Condensation

Protonation by addition of acid in a separate step yields the final product.



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96

Mixed Claisen Condensation

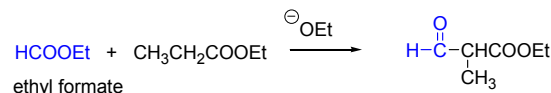
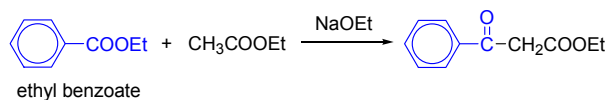
- Occurs only when one of the two ester components has no alpha-hydrogens, and thus can't form enolate ion
- Can also be carried out between esters and ketones resulting a synthesis of β -diketones

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97

Mixed Claisen Condensation

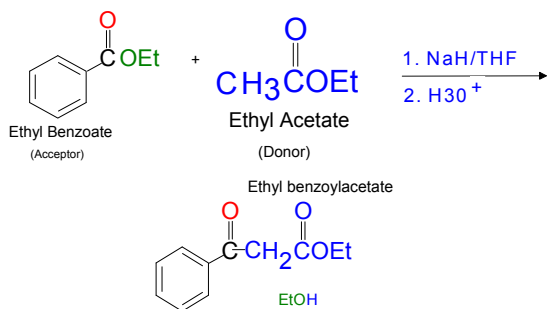
Crossed Claisen Condensation:



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98

Mixed Claisen Condensation



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99

Intramolecular Claisen Condensation

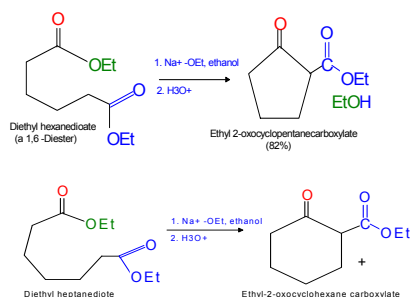
Dieckmann Cyclization

- can be carried out with diesters
- works best on 1,6-diester and 1,7-diester
- 5-membered cyclic β -ketoesters result from Dieckmann cyclization of 1,6-diester
- 6-membered cyclic β -keto esters result from cyclization of 1,7-diester

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100

Intramolecular Claisen Condensation

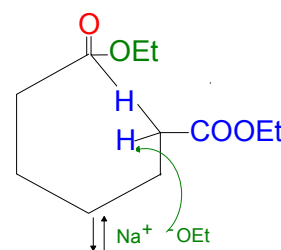


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101

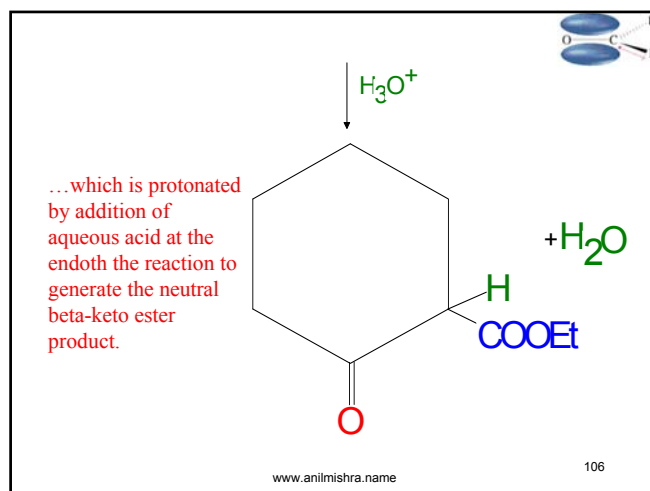
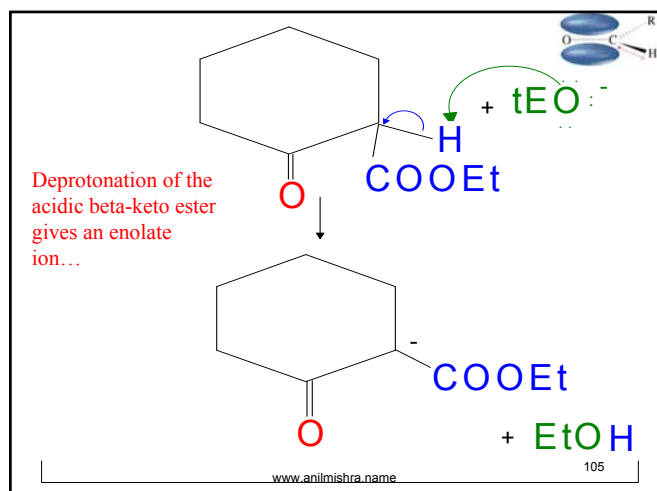
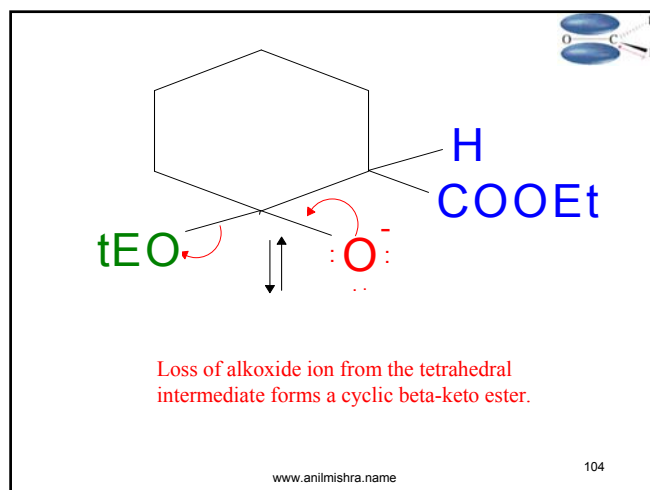
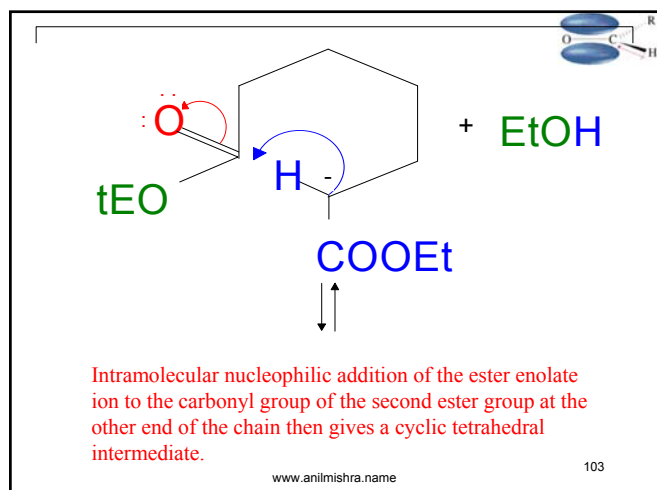
Mechanism of Intramolecular Claisen Condensation

Base abstracts an acidic alpha-proton from the carbon atom next to one of the ester groups, yielding an enolate ion.



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102



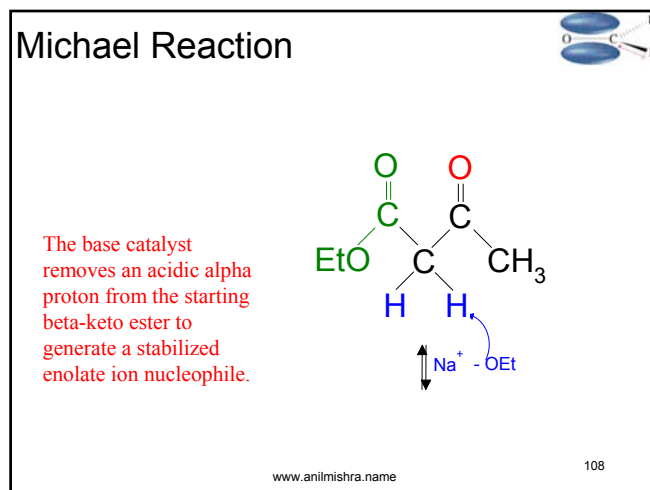
Michael Reaction

- Conjugate addition of a carbon nucleophile to an alpha, β -unsaturated acceptor

Best Michael Reactions:

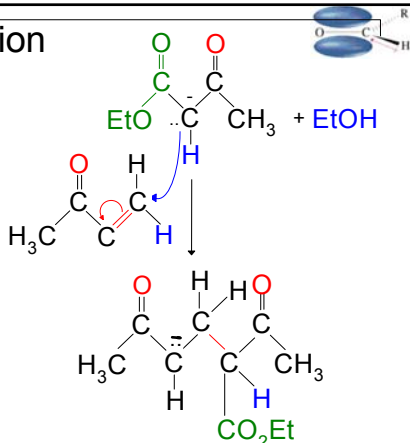
- Between unusually acidic donors (β -ketoesters or β -diketones)
- Unhindered alpha, β -unsaturated acceptors
- Stable enolates are Michael donors, and alpha, β -unsaturated compounds are Michael acceptors

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Michael Reaction

The nucleophile adds to the alpha,beta-keto unsaturated ketone electrophile in a Michael reaction to generate a new enolate as product.

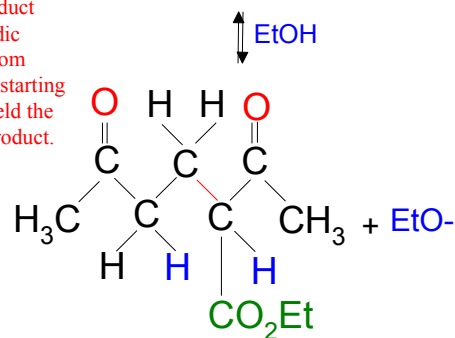


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109

Michael Reaction

The enolate product abstracts an acidic proton, either from solvent or from starting keto ester, to yield the final addition product.



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110

Wittig Reaction

Nucleophilic Addition of Phosphorus Ylides:

- ✓ Converts an aldehyde/ketone into an *alkene*.
- ✓ A phosphorus *ylide* (or phosphorane), acts as the Nu-

Ylide : A compound or intermediate with both a positive and a negative formal charge on adjacent atoms.



The ylide is nucleophilic, owing to the negative charge character on carbon (structure on the right).

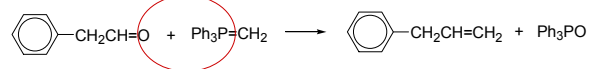
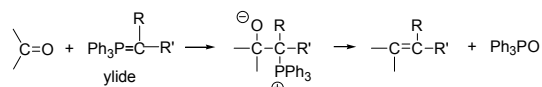
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111

Wittig Reaction

synthesis of alkenes

1975 Nobel Prize in Chemistry to Georg Wittig

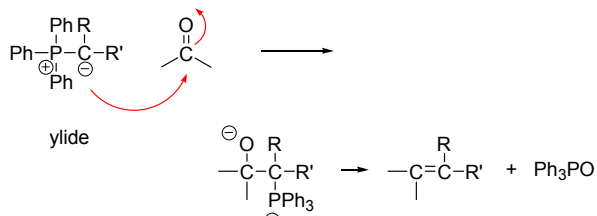


Ph = phenyl

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112

Wittig Reaction

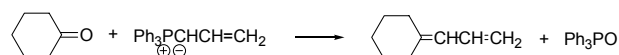


nucleophilic addition by ylide carbanion, followed by loss of Ph_3PO (triphenylphosphine oxide)

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113

Wittig Reaction

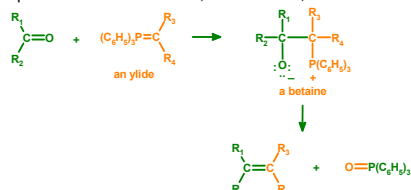


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114

Wittig Reaction

- A phosphorus *ylide*, acts as the Nu- to attack the carbonyl carbon and yields a four-membered ring, dipolar intermediate called the *betaine*.
- The betaine decomposes spontaneously to yield an alkene and a triphenylphosphine oxide.
- Can produce monosubstituted, disubstituted, and trisubstituted alkenes.

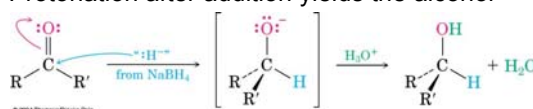


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115

Hydride Addition

- Convert C=O to CH-OH
- LiAlH₄ and NaBH₄ react as donors of hydride ion
- Protonation after addition yields the alcohol



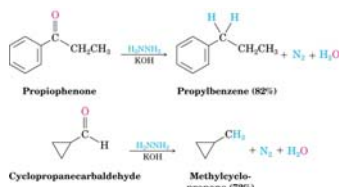
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116

The Wolff-Kishner Reaction

Nucleophilic Addition of Hydrazine

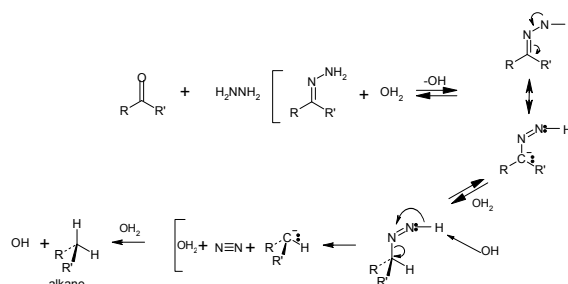
- Treatment of an aldehyde or ketone with hydrazine, H₂NNH₂ and KOH converts the compound to an alkane
- Originally carried out at high temperatures but with dimethyl sulfoxide as solvent takes place near room temperature



117

The Wolff-Kishner Reaction

✓ Addition of hydrazine converts aldehyde/ketone to an alkane. An intermediate hydrazone forms, followed by base catalyzed double bond migration, loss of N₂ gas, finally protonation yields an alkane.

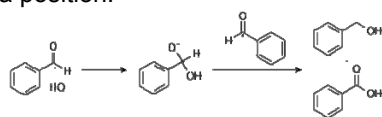


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118 18

The Cannizzaro Reaction

- The **Cannizzaro reaction**, named after its discoverer Stanislao Cannizzaro, is a chemical reaction that involves the base-induced disproportionation of an aldehyde lacking a hydrogen atom in the alpha position.

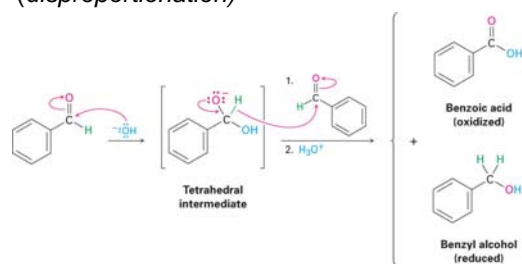


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119

The Cannizzaro Reaction

- The adduct of an aldehyde and OH⁻ can transfer hydride ion to another aldehyde C=O resulting in a simultaneous oxidation and reduction (*disproportionation*)

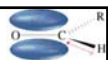


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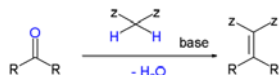
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120

Knoevenagel Condensation



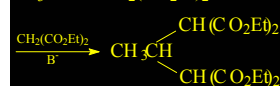
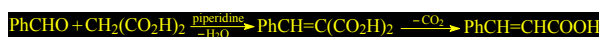
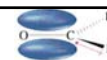
- The **Knoevenagel condensation** reaction is an organic reaction named after Emil Knoevenagel. It is a modification of the aldol condensation.
- A Knoevenagel condensation is a nucleophilic addition of an active hydrogen compound to a carbonyl group followed by a dehydration reaction in which a molecule of water is eliminated (hence *condensation*). The product is often an alpha, beta conjugated enone.



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121

Knoevenagel Condensation

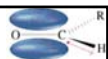


Ketone do not undergo the reaction with malonic acid or its esters, but do so with cyanoacetic acid and its ester. (with more highly active α -hydrogen).

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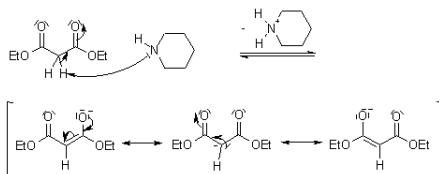
122

Knoevenagel Condensation



Mechanism:

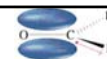
An enol intermediate is formed initially:



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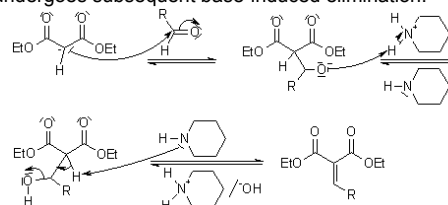
123

Knoevenagel Condensation



Mechanism:

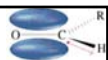
- This enol reacts with the aldehyde, and the resulting aldol undergoes subsequent base-induced elimination:



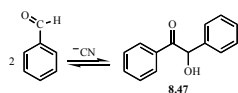
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124

Benzoin Condensation



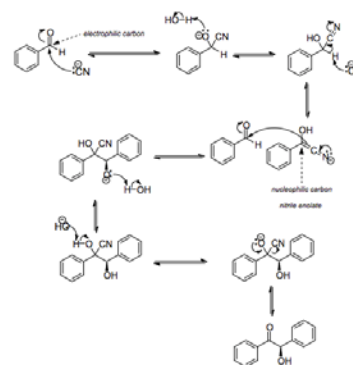
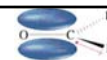
- The **benzoin condensation** is a reaction between two aromatic aldehydes, particularly benzaldehyde.
- The reaction is catalyzed by a nucleophile such as the cyanide anion or an N-heterocyclic carbene.
- The reaction product is an aromatic acyloin with benzoin as the parent compound



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125

Benzoin Condensation

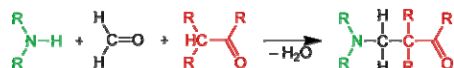


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126

Mannich Reaction

- The **Mannich reaction** is an organic reaction which consists of an **amino alkylation** of an acidic proton placed next to a carbonyl functional group by formaldehyde and a primary or secondary amine or ammonia.
- The final product is a β -amino-carbonyl compound also known as a Mannich base.



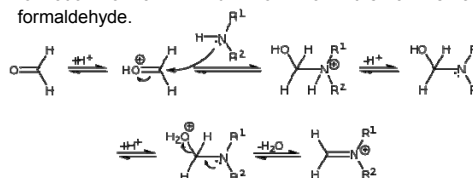
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127

Mannich Reaction

Mechanism

- The mechanism of the Mannich reaction starts with the formation of an iminium ion from the amine and the formaldehyde.



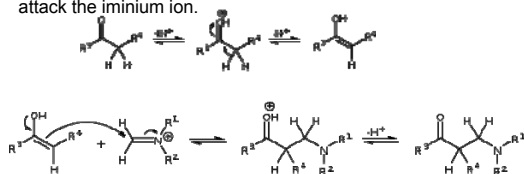
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128

Mannich Reaction

Mechanism

- The compound with the carbonyl functional group (in this case a ketone) can tautomerize to the enol form, after which it can attack the iminium ion.

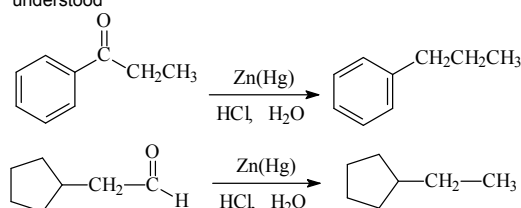


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129

Clemmensen Reduction

- The Clemmensen reduction is an organic reaction used to reduce an aldehyde or ketone to an alkane using amalgamated zinc and hydrochloric acid.
- The mechanism for the Clemmensen reduction is not yet fully understood

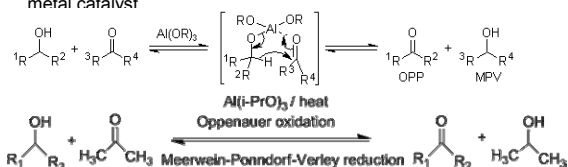


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130

Meerwein-Ponndorf-Verley reduction

- The **Meerwein-Ponndorf-Verley (MPV) reduction** in organic chemistry is the reduction of ketones and aldehydes to their corresponding alcohols utilizing aluminium alkoxide catalysis in the presence of a sacrificial alcohol.
- The beauty in the MPV reduction lies in its high chemoselectivity, and its use of a cheap environmentally friendly metal catalyst



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131