
CHEM2201: Section 1

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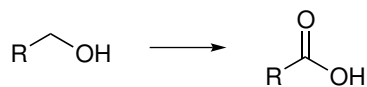
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1 Oxidation and Reduction Reactions

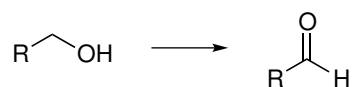
Alcohol to Carboxylic Acid



Use:

- KMnO_4
- CrO_3
- $\text{Na}_2\text{Cr}_2\text{O}_7$

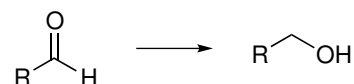
Alcohol to Aldehyde



Use:

- PCC

Aldehyde to Alcohol (+ Ketones and $\text{C}=\text{O}$ of higher reactivity)



Use:

- NaBH_4
- LiAlH_4

Ester to Alcohol and RCONHR to RCH_2NHR



Use:

- LiAlH_4

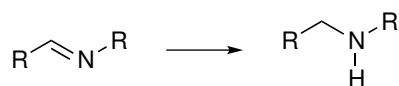
Carboxylic Acid to Alcohol



Use:

- LiAlH_4
- BH_3THF

$\text{RCH}=\text{NR}^1$ to RCH_2NHR^1



Use:

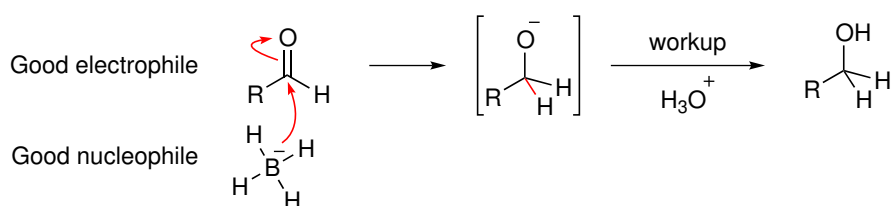
- NaCNBH_3

The basic principles of addition to C=O groups are:

- How reactive is the C=O group
- How reactive is the nucleophile
- Which is more reactive, the starting material or the product (Example 3)
- Will an unreactive C=O need activation (e.g. H^+)? If the nucleophile is unreactive?
- Can H_2O be eliminated.

1.1 Example Reactions

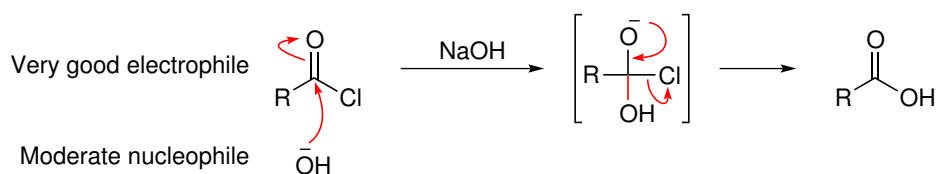
1. Reduction of aldehyde with $NaBH_4$



No further reactions can take place as there are no leaving groups

This reaction will not take place with esters as the electrophile is not sufficiently reactive. Instead use $LiAlH_4$

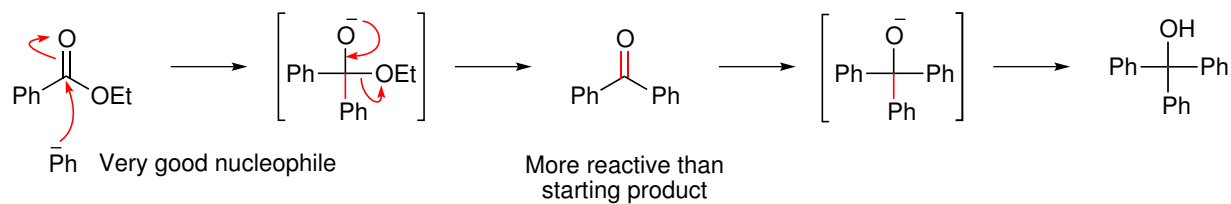
2. Carboxylic acid from acid chloride with $NaOH$



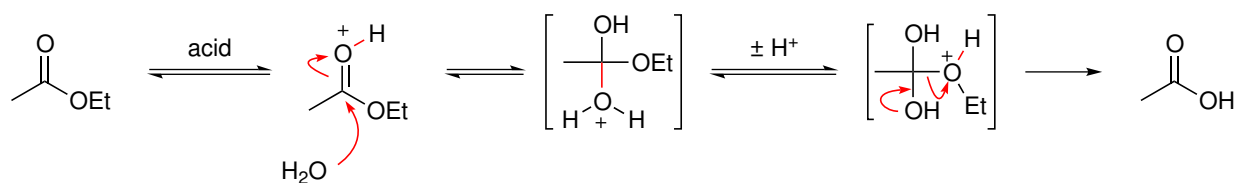
Cl is a good leaving group therefore there is a further reaction

3. Ester with a grignard reagent

Poor electrophile

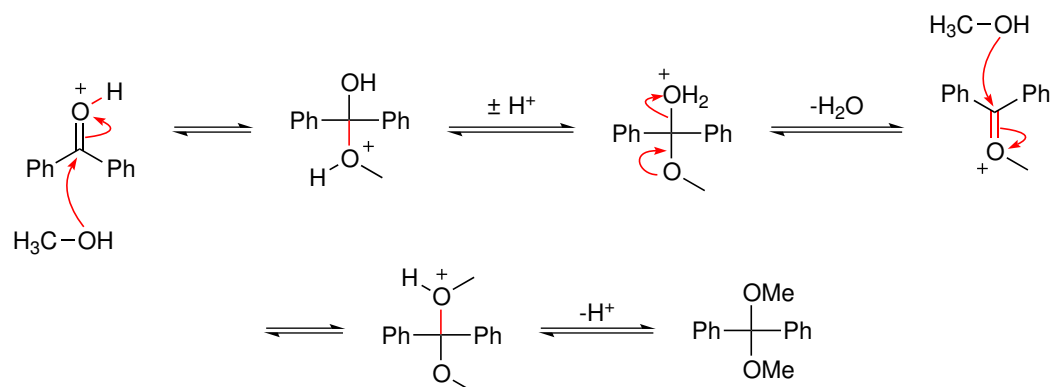


4. Addition of water



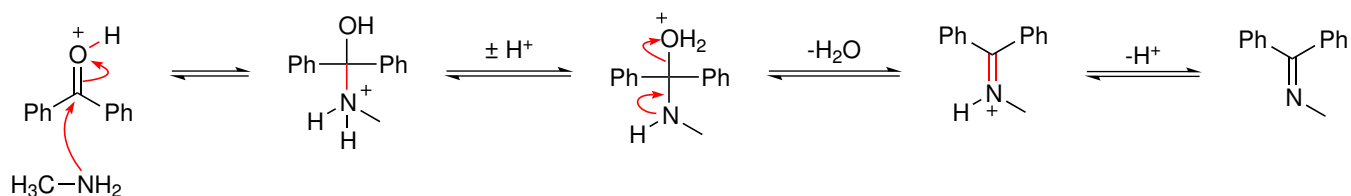
Poor electrophile and poor nucleophile therefore the C=O group is activated by adding water.

5. Elimination of H₂O



Reasonable electrophile and a poor nucleophile therefore activation of C=O required.

6. Elimination of H₂O using methylamine



Reasonable electrophile and poor nucleophile therefore activation of C=O required.

2 Enols and Enolates

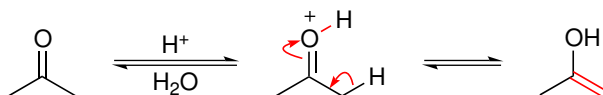


Enol



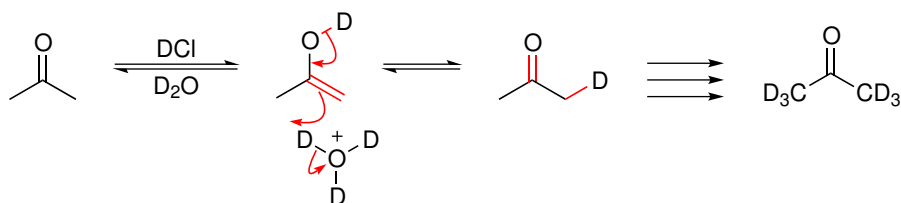
Enolate

Formation of an enol using acid + ketone



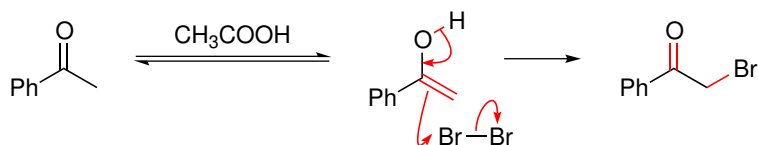
2.1 Example Reactions

Enol + DCl + D₂O



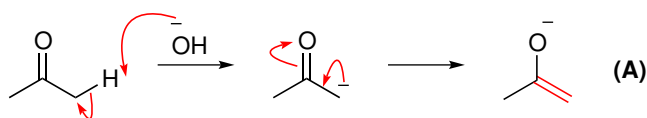
H \longrightarrow D exchange takes place at the α -position

Enol + Acid and Br₂

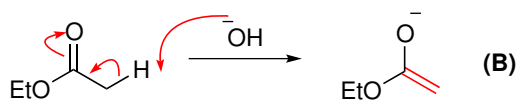


Forms a brominated ketone

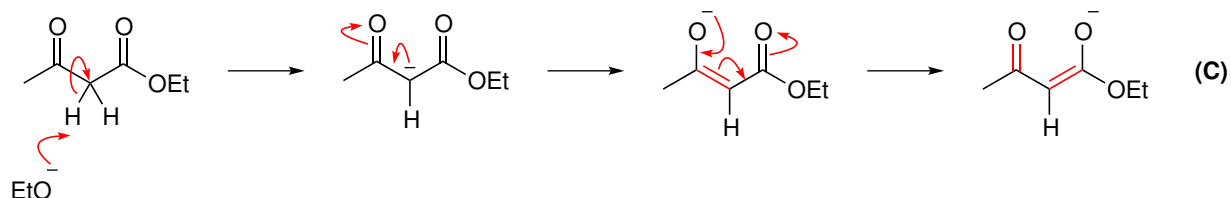
Enolate formation using base + ketone



Enolate formation from esters

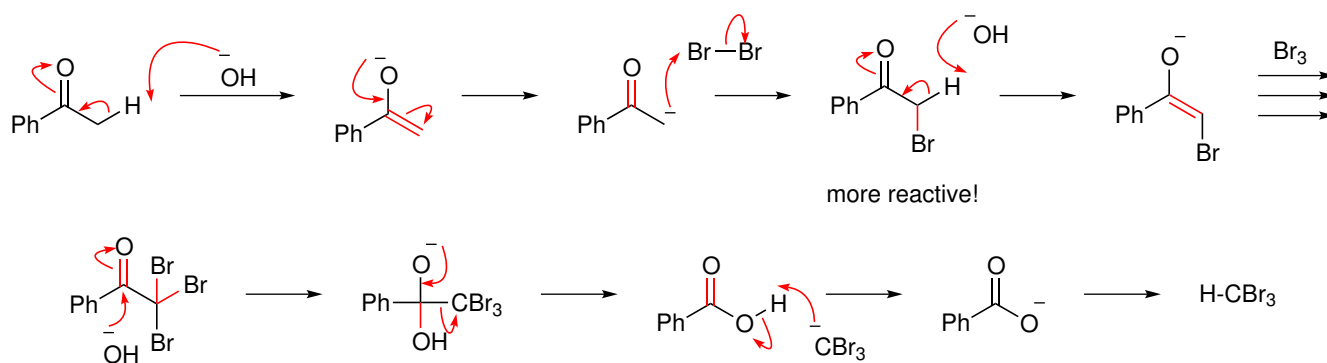


Enolate formation with diketone



Order of stability goes $C > B > A$

Enolate with Br_2 + base



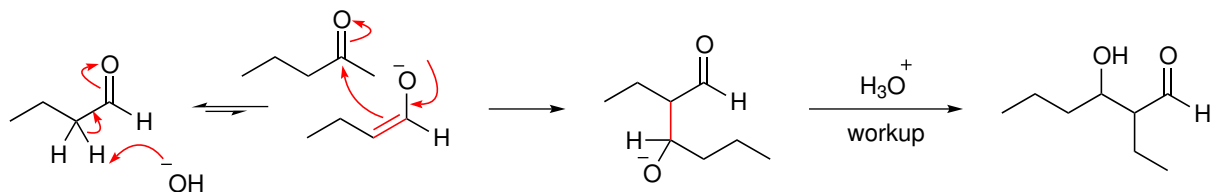
For compounds with $\alpha\text{-H}$'s:

- Central protons are easier to remove as this further delocalises the negative charge.
- The pK_a of the base must be no higher than the compound to deprotonate.

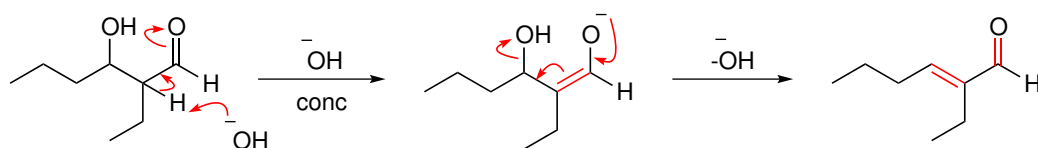
2.2 Aldol Reaction

3 Aldol Reaction

In mild or dilute base, results in the self condensation of an aldehyde or ketone.



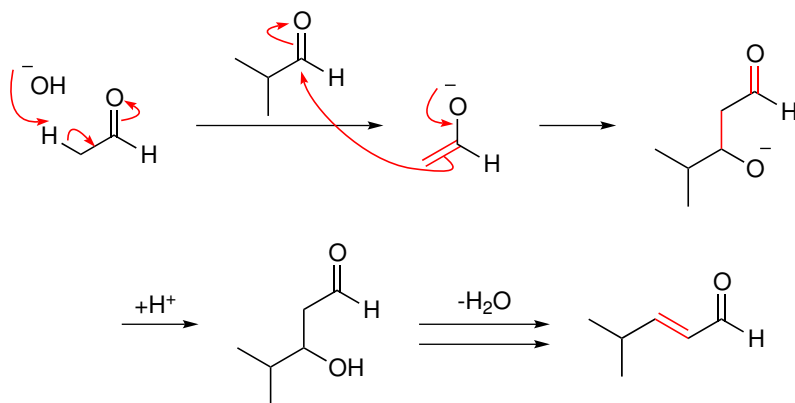
In presence of conc base a further reaction can take place



Forms a α,β -unsaturated aldehyde

If an unsymmetrical ketone with more than one α -H is used then 2 different products will be formed. However if the material only has 1 way to enolise, then the aldol reaction will only form one product.


Aldol reactions can also occur between two different C=O compounds.

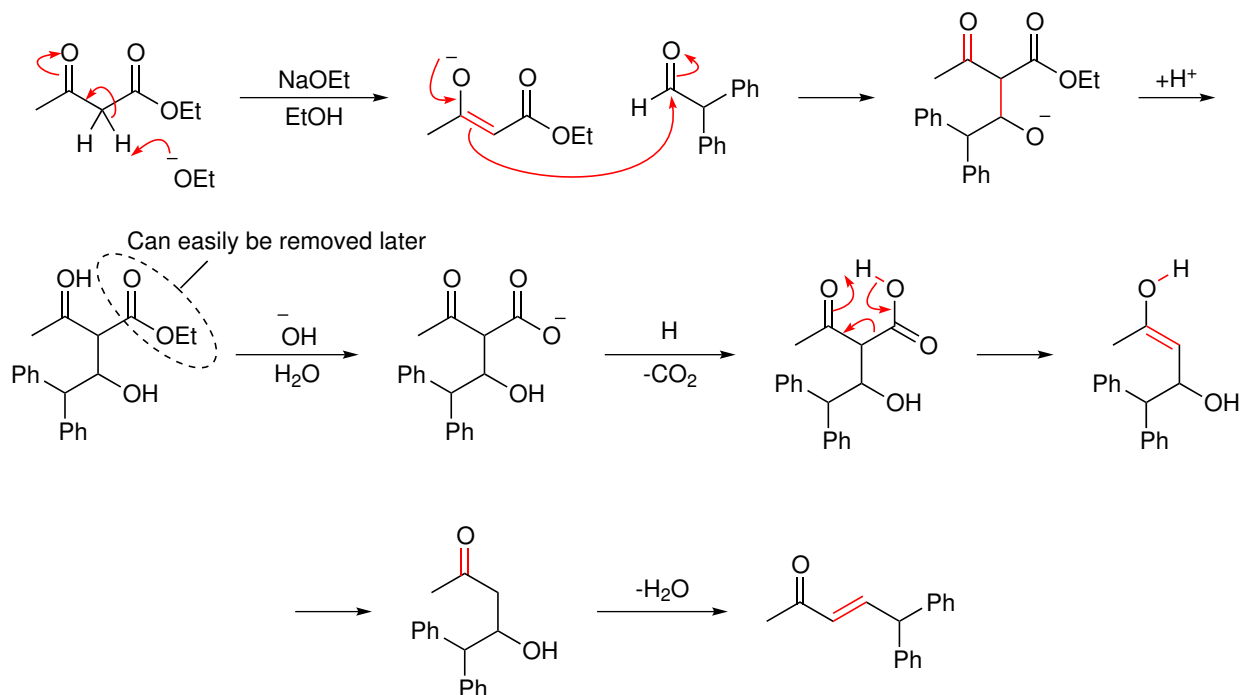


However other reactions can happen, e.g. it will react with itself and the other starting product may also enolise. NaOH is therefore not an efficient way to form a single product. However it is possible to form a single product by taking into account that:

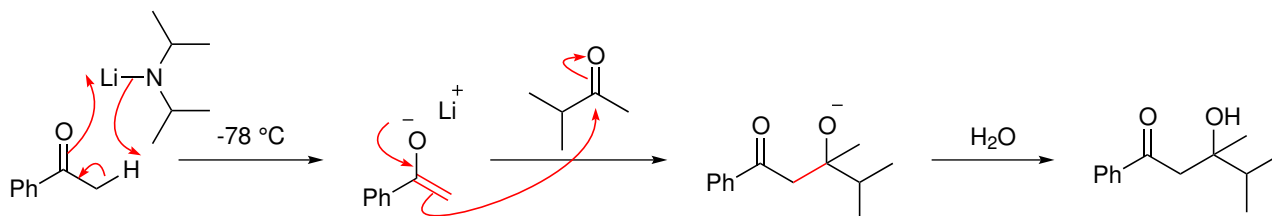
- A compound with no α -H cannot enolise
- Aldehydes are more reactive than ketones

Beware however that if you have a molecule with no α -H and it is a ketone reacting with an aldehyde the ketone will be ignored and a single product will be formed by the aldehyde reacting with itself.

Using acetoacetate as a reagent for 



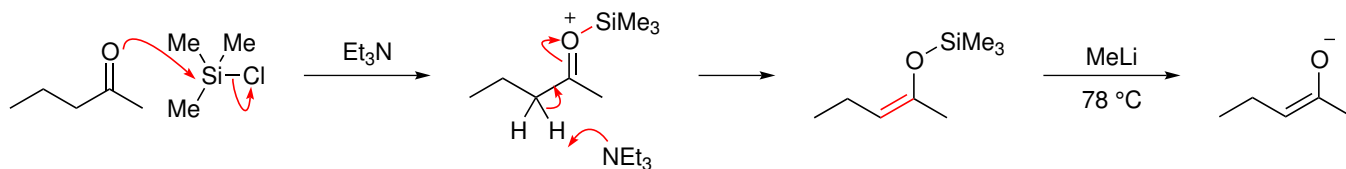
Crossed aldol product reaction with only one product using LDA to form lithium enolates.



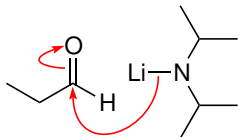
Addition of LDA results in complete conversion to lithium enolate

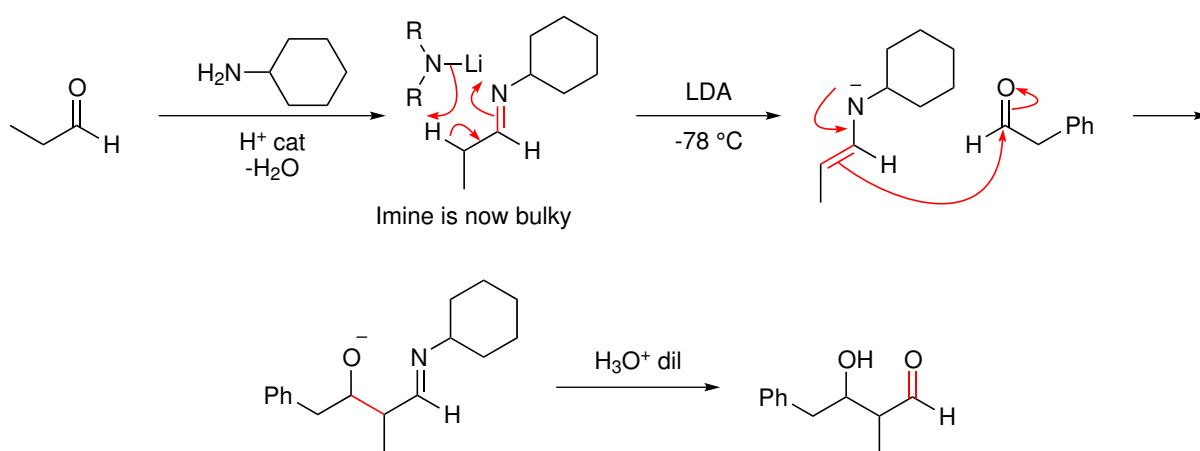
3.1 Unsymmetrical Ketones

To remove the less sterically hindered protons, a bulky base is used. E.g. LDA $-78\text{ }^{\circ}\text{C}$. If we need the more sterically hindered enolate, we can do this by acknowledging that this is the more stable enolate and use Me_3SiCl and Et_3N then MeLi . E.g.

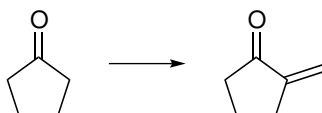


Et_3N is used as a mild unhindered base that can remove either protons

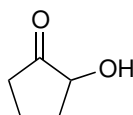
Aldehydes and LDA will not react to form enolates as  Instead to make an enolate from an aldehyde use cyclohexylamine, H^+ and then LDA.



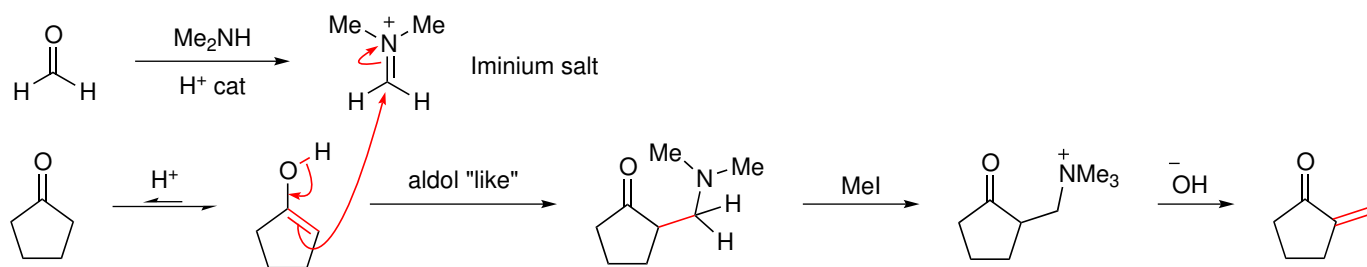
Formaldehyde is even more reactive than other aldehydes, this makes it impossible to control as an enol. Formaldehyde is therefore not useful for adding a $\text{CH}_2\text{-OH}$ group to molecules. To convert



we can't therefore go through:



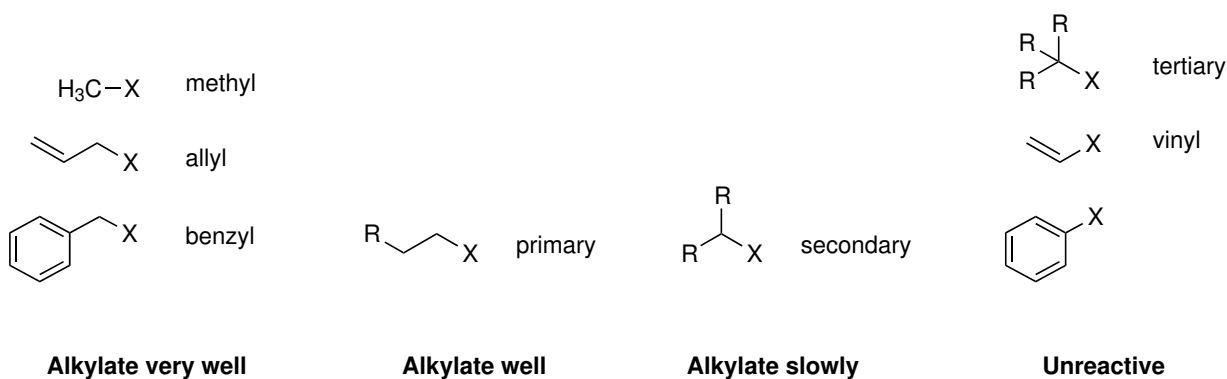
Instead the Mannich reaction is therefore used:



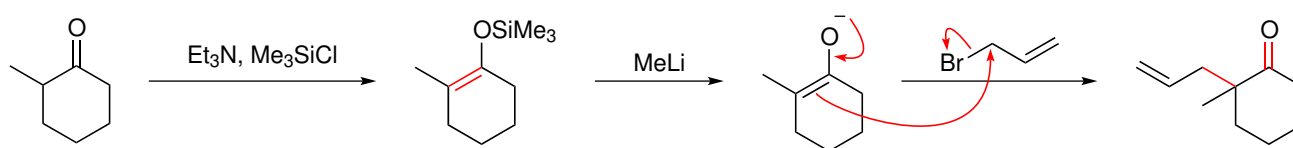
3.2 Electrophiles

The choice of electrophile for enolate alkylation is important:

- Enolate alkylation are S_N2 reactions
- $R-X$: X must be a good leaving group
- Mesylate > Tosylate > I > Br > Cl

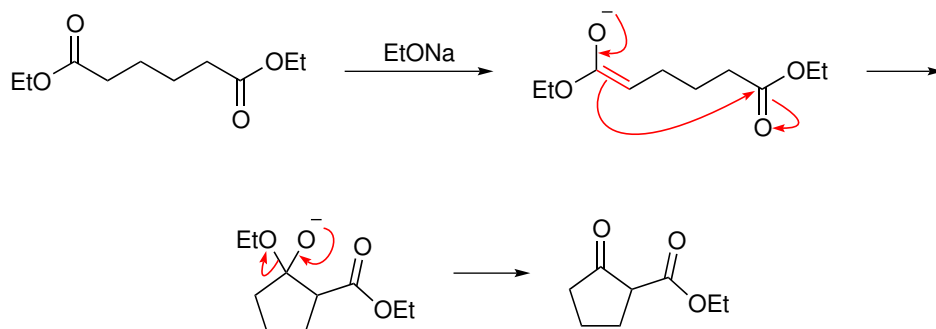


Example:



3.3 Other Reactions

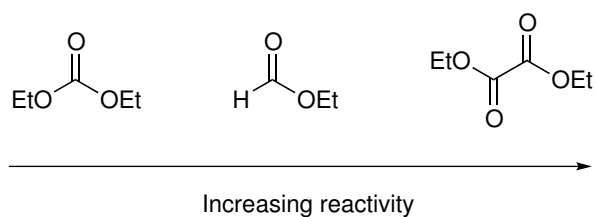
Dieckman Condensation - Both esters in the same molecule:



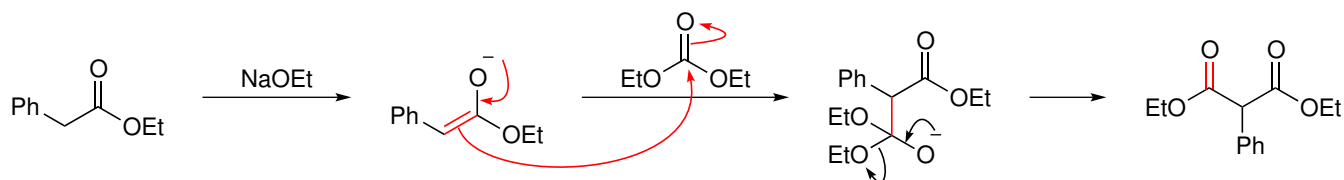
Crossed Claisen Reactions - Between 2 esters or one ester and a ketone. The conditions are:

- Need one ester that can't enolise
- This ester must be a better electrophile

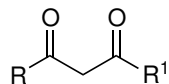
There are only 3 reagents. All are more reactive than simple esters.



Example:



With Claisen you normally end up with a diketone, e.g.



4 Conjugate Addition Reactions

Occurs due to the resonance effects of a α,β -

5 Retrosynthetic Analysis

6 Spectroscopy

6.1 Summary of IR Frequencies

Single Bonds to Hydrogen

- sp^3	C–H	2850 – 2960s
- sp^2	C–H	3010 – 3095
- Aldehyde	O=C–H	2700 – 2900
- sp	C–H	3000 sharp
- Nitrile	N–H	3300 – 3500m
- Free	O–H	3590 – 3600s sharp
- Normally H-bonded	O–H	3200 – 3600s broad
- Strongly H-bonded	O–H	2500 – 3200s broad

Triple Bonds

- Nitriles	RCN	2200 – 2260v
- Alkynes	$\text{RC}\equiv\text{CR}^1$	2150 – 3095w
	$\text{RC}\equiv\text{CH}$	2100 – 2140w

Double Bonds



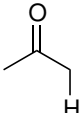

- Alkenes	C=C	1620 – 1680v
- Enones	C=C–C=O	1590 – 1640s
- Aromatics, up to 3 of		1600, 1580, 1500v
- Nitro	NO_2	1560, 1350s

Carbonyl Group, C=O

		1715 \pm 10
- Dialkyl ketone	alkyl	0 (also carboxylic acid is \pm 0)
- Anhydride	OCOR	+35, +110
- Acid chloride	COOCl	+85
- Ester	OCOR	+25
- Aldehyde	H	+15
- Aryl ketone	Ar	–25
- Enone	C=C	–35
- Amide	NH_2	–65

6.2 H^1 NMR

Most signals are from 0 – 12 ppm

- Carboxylic acids	10 – 12
- Aldehydes	9 – 10
- Aromatics	7 – 9
- Alkenes	5 – 7
- 	3 – 5
- 	2 – 3.5
- 	2 – 3
- 	2 – 3
- Alkynes	2 – 3
- Alkanes	0.5 – 1.5

R-OH , R-SH , R-NH_2 are hard to predict. Often 0 – 5 ppm with little H bonding. Higher if more H bonding. The more shielded the hydrogen the further upfield it appears (i.e. lower frequency).

6.2.1 Summary of Chemical Shifts

Methyl Groups

- $\text{CH}_3\text{-C}$	10 – 12
- $\text{CH}_3\text{-C=C}$	9 – 10
- $\text{CH}_3\text{-Ar}$	7 – 9
- $\text{CH}_3\text{-CO-R}$	5 – 7
- $\text{CH}_3\text{-O-R}$	3 – 5
- $\text{CH}_3\text{-N}$	2 – 3.5

Protons Attached to Unsaturated Linkages

- Ar-CHO	9.7 – 10.5
- RCHO	9.4 – 10.0
- H-CO-O	8.0 – 8.2
- Aromatic	6.0 – 9.0 (usually ≈ 7)
- C=CH-CO	5.8 – 6.7
- C=CH	4.5 – 6.0
- $\text{C}\equiv\text{C-H}$	1.8 – 3.1

6.2.2 J Couplings

Methyl Groups

- Open chain single bond	7 Hz
- Trans alkene	12 – 18 Hz (typically 16 Hz)
- Cis alkene	7 – 11 Hz (typically 10 HZ)
- Ortho	6 – 9 Hz
- Meta	1 – 3 Hz
- Para	0 – 1 Hz