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# Stereochemical aspects and Reactsivity of Carbonyl group, An overview

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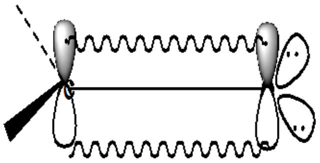
**ABSTRACT**

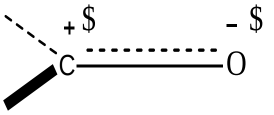
The most important aspect of organic chemical reactivity is the chemistry of carbonyl group (>C=O) .It directly undergoes nucleophilic attack by different substrates and yields a series of compounds.The prostereogenic carbon gets converted to stereogenic carbon by a nucleophilic attack on either side of the plane of carbonyl group. Different organic compounds containing >C=O group undergo photocyclisation or photoreduction reactions and result a variety of compounds of both chemical and mechanistic interest. β-diketones an important class of carbonyl compounds afford stable ylides and Aldol adducts when interacted with different reagents under varying conditions.

## Introduction

In this article I have highlighted the polar nature of carbonyl group which directly undergoes nucleophilic addition reactions with different substrates and yields a series of products of both pharmaceutical and chemical interest.Its UV-Visible and IR spectra have been precisely explained.Interaction of 1,2 and 1,3-diketo compounds with different reagents/substrates leads to the formation of a variety of mechanistically interesting products.Stereochemical aspects with special reference to Cram's and Prelog's Rules have also been discussed in this article.

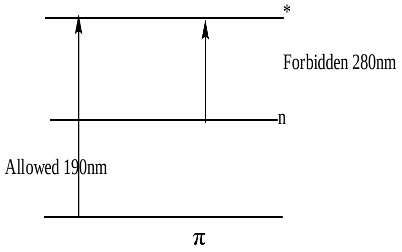
The chemistry of carbonyl group is probably the most important feature of organic chemical reactivity.The C-O double bond of carbonyl group is similar in many ways to the C-C double bond of alkenes.The carbonyl carbon atom is sp$^2$ hybridised and forms three sigma bonds.The fourth valence electron remains in a carbon p-orbital and forms a pi-bond to oxygen by overlap with an oxygen p-orbital.The oxygen atom has also two non-bonding pairs of electrons which occupy its remaining two orbitals.





The carbon-oxygen double bond is both shorter (122pm verses 143pm) and stronger (175kcal/mol verses 92kcal/mol) than C-O single bond.

1) Carbonyl compounds have two principle transitions,the allowed $\pi$-$\pi^*$ transition and the forbidden n-$\pi^*$ transition.



Of the two ,only n-$\pi^*$ transition, although week( forbidden ),is commonly observed above the usual cut-off points of solvents.

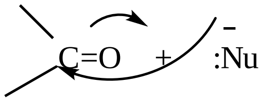
The carbonyl group absorbs strongly in the range of 1850-1650 cm$^{-1}$ because of large change in its dipole moment.The C=O frequency of a ketone is usually considered the reference point for comparison for the other base values of C=O group.

The normal base values for the carbonyl stretching vibrations for carbonyl group are:-

Aldehydes=1725cm$^{-1}$,Ketones=1715cm$^{-1}$,Esters=1735cm$^{-1}$,Acid chlorides=1800cm$^{-1}$, Anhydrides=1810cm$^{-1}$ ……….…………

However, conjugation,α,β-unsaturation,resonance factors etc.alter the fundamental stretching vibrations.

Carbon-Oxygen double bonds are polarized and their polar character is practically demonstrated by the measurements ofdipolemoments.e.g.Aldehyde(acetaldehyde)=2.72D,Ketone( Me$_2$C=O)=2.88D,Carboxylic acid (CH$_3$COOH)=1.74D etc. Dueto this bipolar nature ,the carbonyl carbon becomes electron deficient ,so it can easily be attacked by a nucleophile,or can act as a proton donar (Scheme-1)



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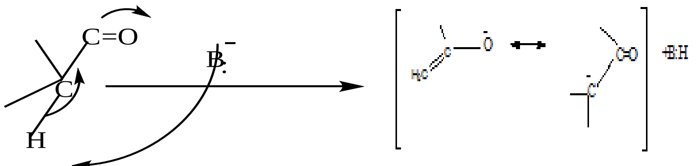
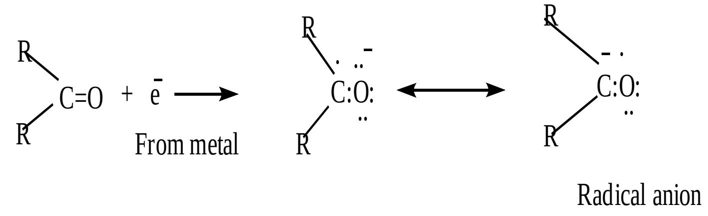


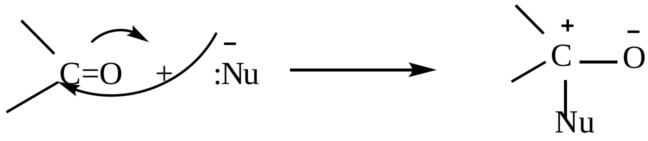
**Scheme-1**

Since oxygen of carbonyl group possesses two lone pairs of electrons ,it can act as an electron donar (Lewis base) as well as an electron acceptor (Lewis acid).e.g

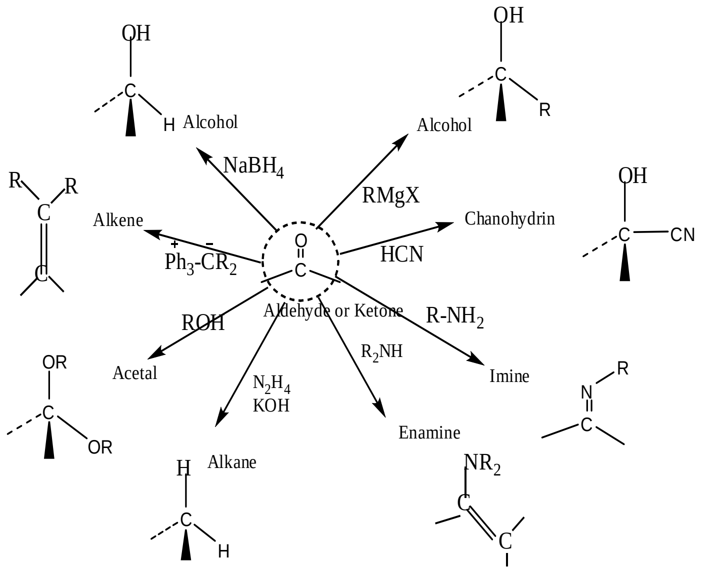


Radical anions are generally unstable and tend to acquire another electron to form various products.(e.g.Bouvoult Blanc reduction of esters).

Nucleophilic addition reactions are the most common reactions of carbonyl group.



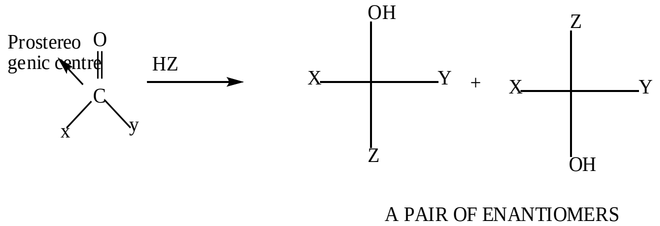
**Summary of Nucleophlic addition Reactions(Aldehydes&Ketones)**[Ref]



**Scheme-2**

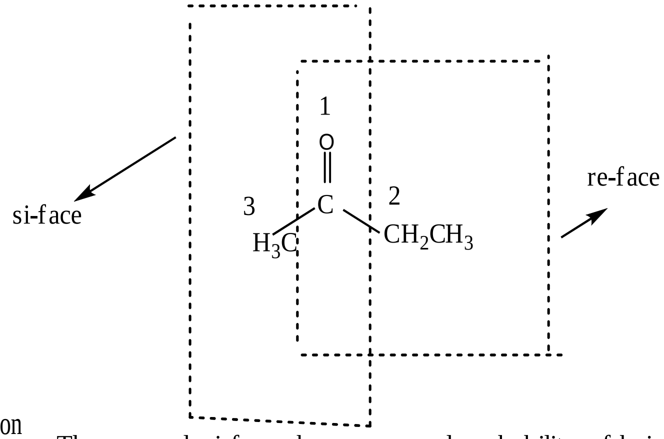
**Stereochemistry of Nucleophilic addition reactions.**

A carbonyl carbon bonded to two substituents is a prostereogenic carbonyl carbon and becomes stereogenic only if it is attacked by a third different group.The addition product will be a pair of enantiomers.



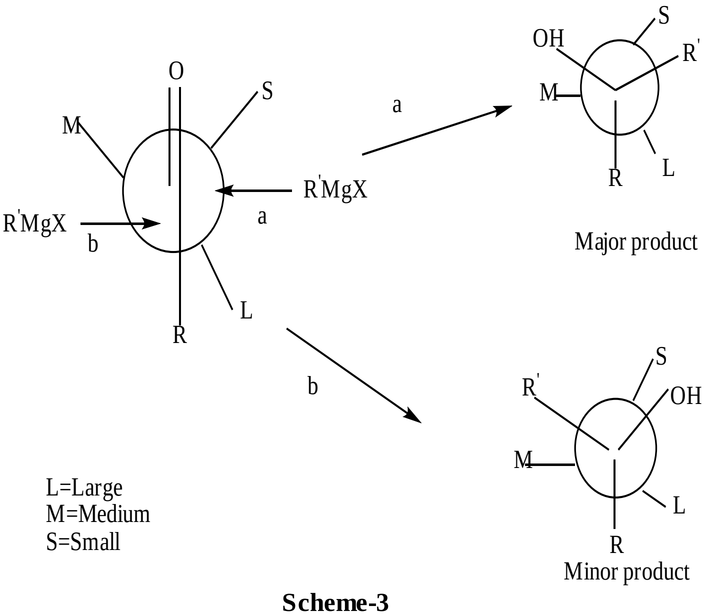
A PAIR OF ENANTIOMERS

Nucleophile can approach on either side of the plane.One is **re**-face and the other is **si**- face.(using EZ&RS systems).



The re- and si faces have an equal probability of being attacked.Consequently the two enantiomers formed will be of equal amounts.

**Crams Rule.**If a carbonyl group is adjacent to a stereogenic centre,it will be easier to attack one side of the carbonyl group then the other.Consequently more of the one addition product will be formed than the other.The preferred product can be determined by using Crams Rule,which states that a Ketone will react in that conformation in which the oxygen of the carbonyl group is anti to the largest of the three substituents on the α-carbon.Preferential nucleophilic attack (e.g. RMgx) will then take place from the least hindered side of the carbonyl carbon i.e.(a)

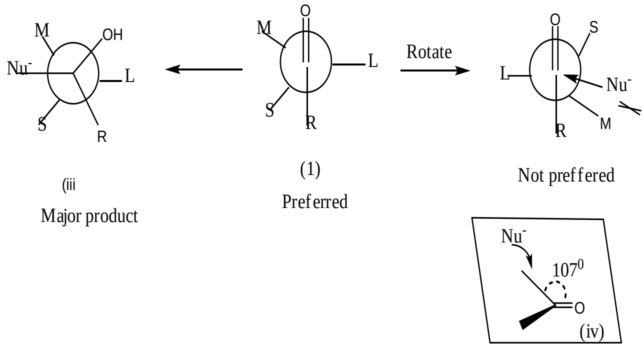


**Scheme-3**

**Felkin-Ahn (FA)Model**

The Felkin-Ahn model differs from Cram's Rule in the conformation adopted by the carbonyl compound.In FA-model the larger group (L) is placed perpendicular to the carbonyl group in the Newman projection( unlike Cram's Rule where "L'is assumed to be antiperiplanar to the C=O group )and the remaining two groups on the stereocenter can then be arranged in two ways i.e. the smaller group towards or away from the carbonyl group.

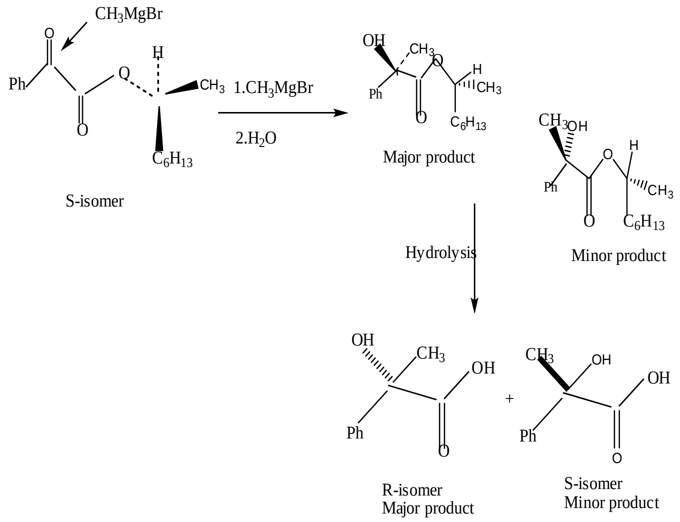
The nucleophile approaches to the carbonyl group from the face opposite to the largest group at an optimum angle of about $107^0$ i.e.from the small sized group,since it will be hindered by the medium sized group.Scheme-4.



**Scheme-4**

Conformatiom (i) is of lower energy dueto less steric interaction between the nucleophile and the smallest group "S" to give (iii) as a major product.

**Nucleophilic Addition to _-Keto EstersThe Prelog's Rule**



**Scheme-5**

Prelog's Rule: Nucleophilic attack on the carbonylgroup takes place from the side of the medium sized methyl group (backside) in preference to attack from the side of the larger octyl group.Scheme-5

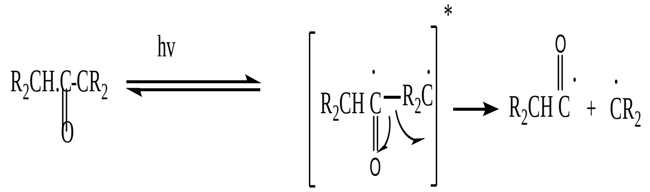
**Intramolecular reactions of carbonyl group.(Photochemical reactions)**

There are many Carbonyl group reactions initiated by n-π≠ excitation and reaction can occur from both the singlet and triplet excited states.

Some examples of intramolecular reactions are;

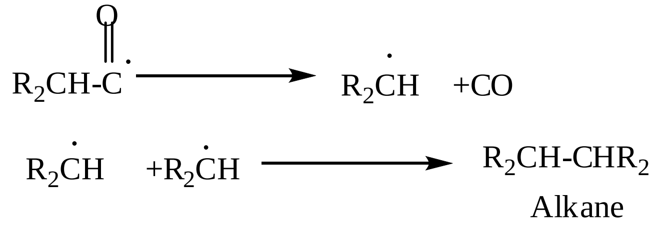
1.Saturated acyclic compounds.:-These are dominated by three reaction processes known as Norrish type -1,Norrish type -11 and Photoreductions.

**NORRISH TYPE-1** :-This reaction is initiated by initial cleavage of the Carbonyl carbon bond to give an acyl and alkyl radical.It applies mainly to ketones in gaseous phase



**n-π*transition**

These free radicals then react subsequently by disproportionation,Decarboxylation or loss of CO can occur followed by dimerisation.e.g.Decarboxylation of acyl radical to give CO and alkyl radical,the latter reacting with another alkyl radical to give an alkane.



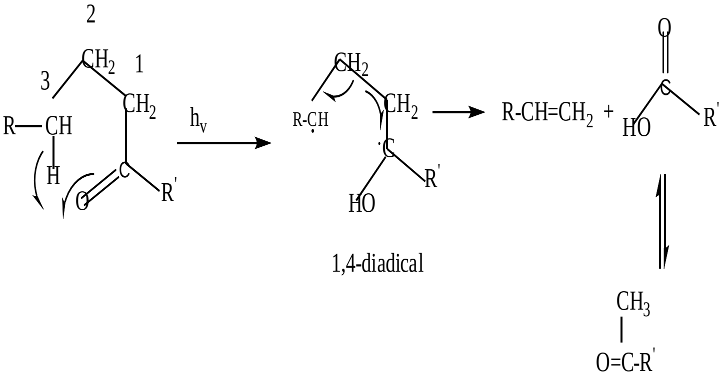
$$R_2CH\text{-}\overset{O}{\overset{||}{C}}\cdot \longrightarrow R_2\dot{C}H + CO$$

$$R_2\dot{C}H + R_2\dot{C}H \longrightarrow R_2CH\text{-}CHR_2$$

Alkane

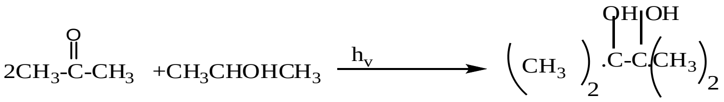
**NORRISH TYPE II**

This reaction is characterized by intramolecular hydrogen transfer from the ϒ-carbon atom to the carbonyl oxygen resulting in a 1,4-diradical which subsequently cleaves to an olefin and an enol. Scheme-6



**Scheme-6**

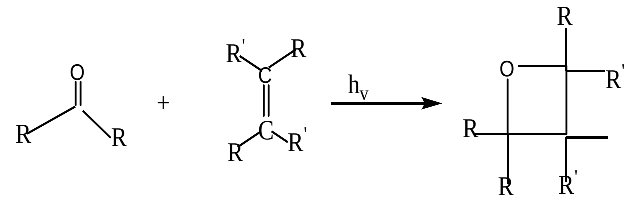
Photoreduction e.g.



It can be performed with a large number of aliphatic and aromatic ketones.

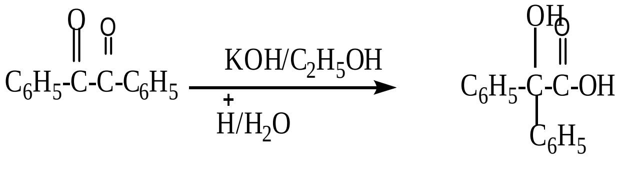
**The Peterno Buchi Reaction**

Carbonyl compounds yield oxetanes in the presence of olefins in this photocyclo addition reaction.



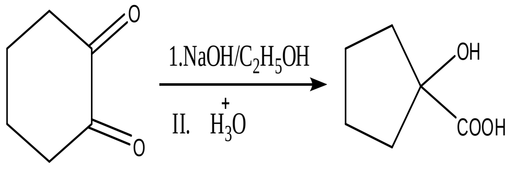
Oxetane

**1,2-diketo compounds is an important class of carbonyl compounds.e.g.Benzillic acid rearrangement.**



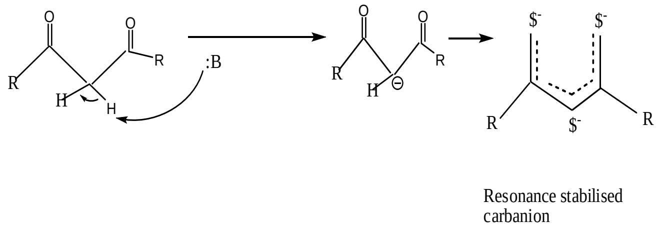
Benzillic acid

Some other examples are



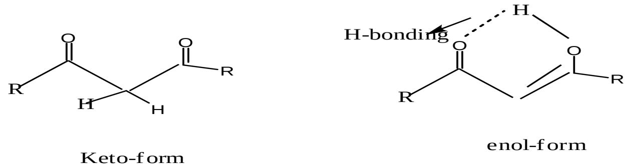
**1,3-di-keto compounds.**

An important class of carbonyl compounds is β-diketones(1,3-diketo compounds).Those bearing α-hydrogen such as $CH_3COCH_2COCH_3$ or $CH_3CH_2COOC_2H_5$ are much more acidic than monocarbonyl compounds such as $CH_3COCH_3$ and as such are easily converted to the corresponding resonance stabilized carbanions.Scheme-7.



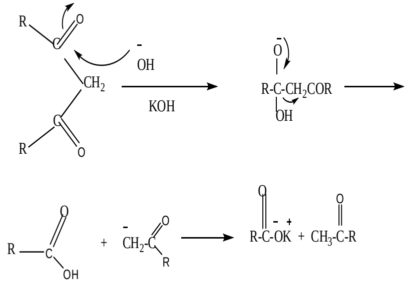
**Scheme-7**

In presence of α-hydrogen ,like other carbonyl compounds,β-diketones also exhibit keto-enol tautomerism and the equilibrium shifts towards enol form which is stabilized through intramolecular hydrogen bonding.



These systems show the IR stretching vibrational band at 1540-1640 $cm^{-1}$instead of normal carbonyl vibrational band at $1715cm^{-1}$.

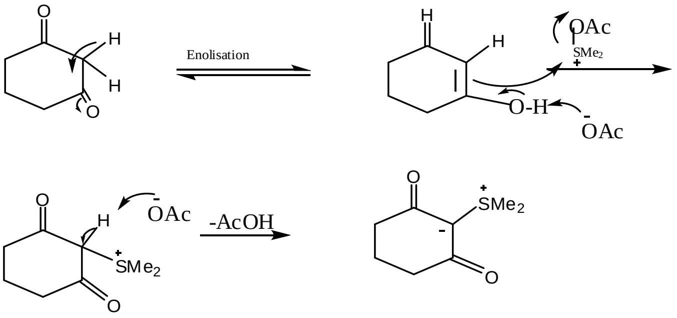
One of the characteristic reactons of β-diketones is base catalysed addition-elimination reaction in the formation of a ketone and salt of a carboxylic acid. Scheme-8



e

**Scheme-8**

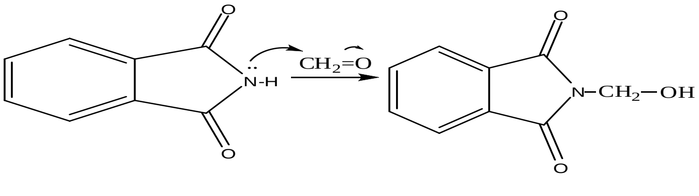
β -dicarbonyl compounds form stable ylides when allowed to interact with DMSO/$Ac_2O$ reagent. Scheme-9.



**Scheme-9**

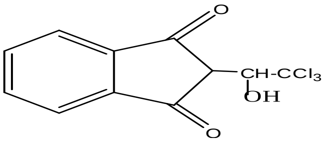
Succinimide,Phthalimide,1,3-indandione etc.are some important members of class of 1,3-diketo-compounds.They yield a wide range of compounds of both chemical and mechanistic interest with different reagents.

N-hydroxy phthalimide (1) has been synthesised by refluxing phthalimide with formaldehyde[1].·

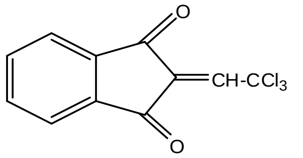


1,3-indandione is an important member of class of 1,3-diketo compounds,yields a wide range of products with different substrates.[2-6].

Aldol condensation between 1,3-indandione and chloral gives 2-(α-hydroxy-β,β,β-trichloroethyl-)1,3-indandione(1) which suffers acid catalysed dehydration to give2-(trichloro ethylidene)-1,3-indandion(ii).

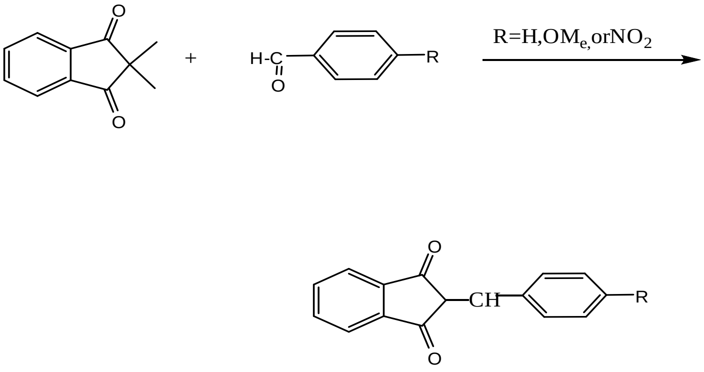


(I)



(II)

Aldol condensation has also been observed between 1,3-indandione with aromatic aldehydes under basic conditions7.Scheme-10.

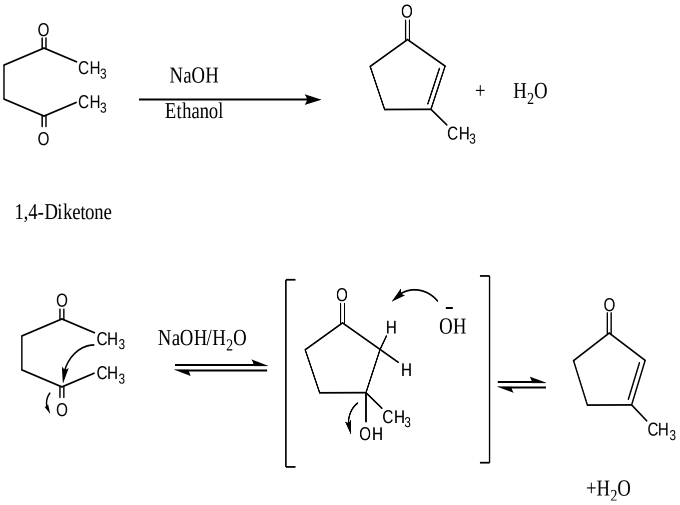


**Scheme-10**

In a similar way 1,3-indandione reacts with cyclic ketones such as cyclo-pentanone and cyclo-hexanone to give the correspondind 2-cycloalkylidene-1,3-1ndandiones.

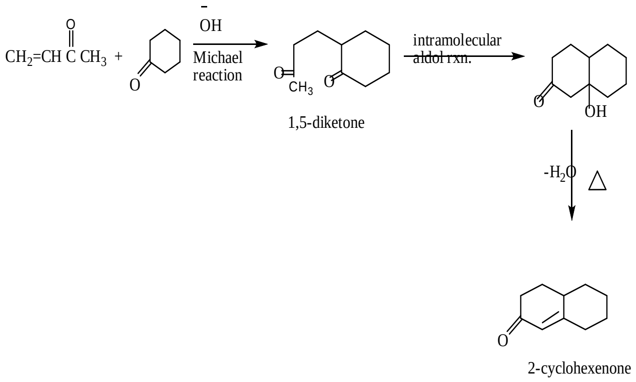
**Intramolecular Aldol reactions**

Certain dicarbonyl compounds when treated with a base form a cyclic product through intramolecular Aldol reaction.Scheme-11



**Scheme-11**

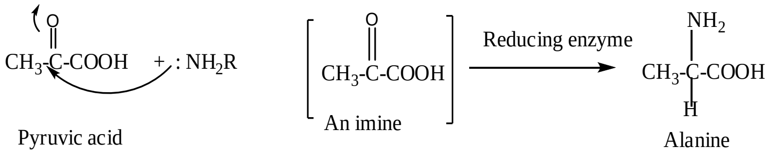
Robinson Annulation;-A process in which Michael reaction and Aldol addition reaction are put together is called the Robinson annulations.Annulation reaction is a ring forming reaction.In the first stage of Robinson annulations a Michael reaction forms a 1,5-diketone.In the second stage 1,5-diketone upon treatment with a base undergoes an intramolecular aldol addition forming a 2-cyclohexenone ring.Scheme-12



Scheme-12

## Some biological nucleophilic addition reactions.

Nucleophilic addition to carbonyl group play a critical role in the biological synthesis of many vital molecules.e.g.The bacterium *Bacillus subtilis* synthesises the amino acid alanine by the nucleophilic addition of an amine to the carbonyl group of pyruvic acid[8]. Scheme-13



Scheme-13

## Acknowledgement

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## References

1.Allen D.Bliss et.al.J.Am.Chem.Soc.77,1913,1995
2.Stephen J.Kuhn and D.Rae;Can.J.Chem,1,49,157-60 (1971),Eng.
3.H.Junck and H.Sterk ,Tetrahedron Lett;40,4309-10(Ger.) 1968.
4.J.Paulins and E.Gudriniece; Latv. PSR.Zinatnu Akad.Vestis.Kim.Ser.2,226-29(1971).
5.F.J.Kunz and Oskar Polansky;Montash Chem,100,1,95-105(Ger.) 1969.
6.L.Geita and Vanags;Chem.Abst;59,7458,1963.
7.I.Zilniece,A.Zicmanis,Chem.Abst.102,95604,1985.
8.John Mc Murry,5th edn.Page 790.