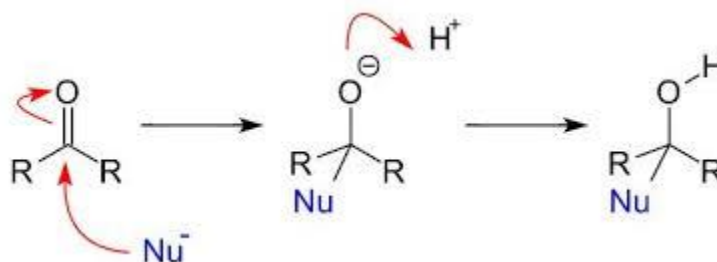


BASE CATALYZED REACTIONS OF CARBONYL COMPOUNDS

Bases convert a weak neutral nucleophile to a strong one by removing a proton. The strong nucleophile (Nu^-) then attacks the positively charged carbonyl carbon to form a new bond and thus oxygen acquires a negatively charge. The electrophile (H^+) attacks the negatively charged oxygen to form addition product.

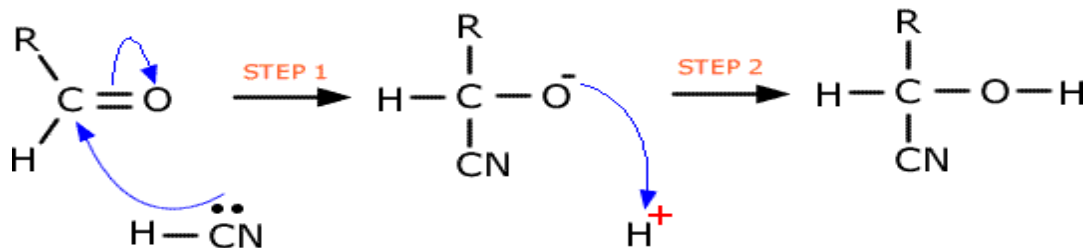


Aldehydes and ketones offers the following base catalyzed addition reactions:

1. Addition of Hydrogen Cyanide
2. Addition of sodium bisulphite
3. Addition of Grignard Reagents
4. Condensation reactions
 - Aldol Condensation
 - Cannizzaro's Reaction
 - Benzoin condensation
5. Haloform reaction

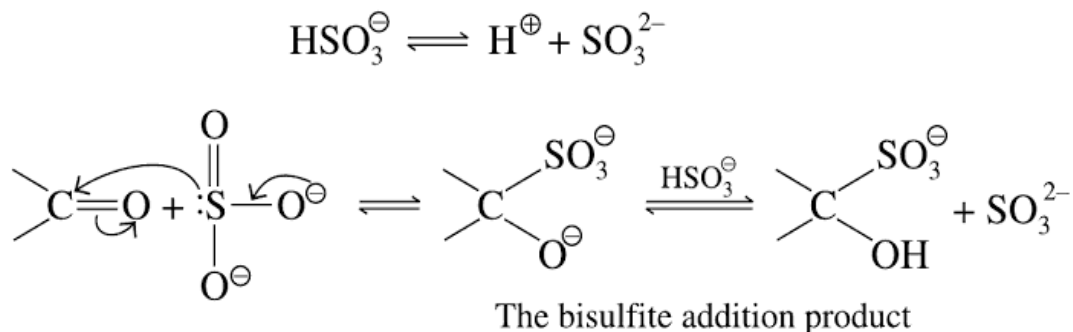
1. Addition of Hydrogen Cyanide

The addition of HCN to a $\text{C}=\text{O}$ (carbonyl group) of an aldehyde or most ketones produces a cyanohydrin. Sterically hindered ketones, however, don't undergo this reaction. The mechanism for the addition of hydrogen cyanide is a straightforward nucleophilic addition across the carbonyl oxygen bond.



2. Addition of Sodium bisulphate

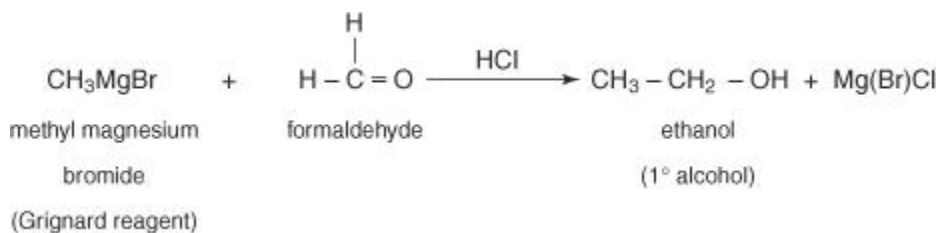
Aldehydes and small ketones react with a saturated aqueous solution sodium bisulphite to give crystalline addition products. The reaction does not need any catalyst as the bisulphite ion itself is a strong nucleophile. The aldehydes and ketones are shaken with a saturated solution of sodium bisulphite in water. Where the product is formed, it separates as white crystals.



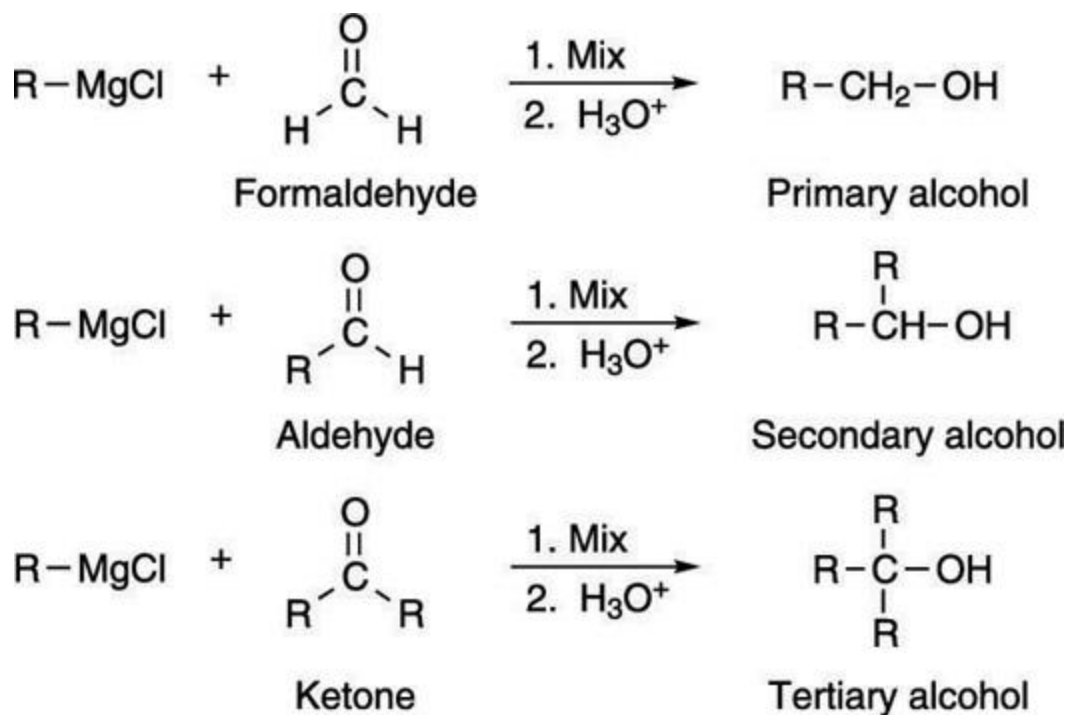
This reaction is usually used during the purification of aldehydes (and any ketones that it works for). The addition compound can be split easily to regenerate the aldehyde or ketones by treating it with either dilute acid or dilute alkali.

3. Addition of Grignard Reagents

Grignard's reagent react with carbonyl compounds to give alcohols.



Primary, secondary and tertiary alcohols are obtained when Grignard's reagent is made to react with formaldehyde, aldehyde and ketone respectively.



4. Condensation Reactions:

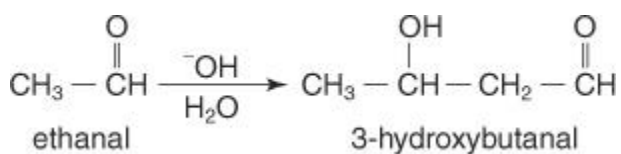
The reactions in which two molecules of the same or different compounds combine to form a new compound with or without the elimination of small molecules like water and ammonia are called condensation reaction.

Following are the types of condensation reactions:

- i. Aldol Condensation reaction
- ii. Cannizzaro's Reaction
- iii. Benzoin Condensation Reaction

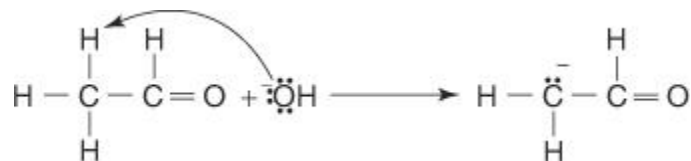
i. Aldol condensation:

Aldehydes or ketones that have α -hydrogen react in the presence of a dilute aqueous acid or base. The resulting compounds, β -hydroxyl aldehydes, are referred to as **aldol compounds** because they possess both an aldehyde and alcohol functional group.

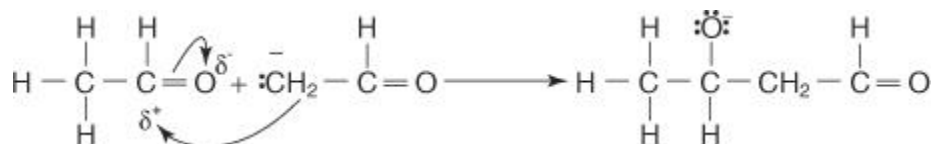


The aldol condensation proceeds via a carbanion intermediate. The mechanism of base-catalyzed aldol condensation follows these steps:

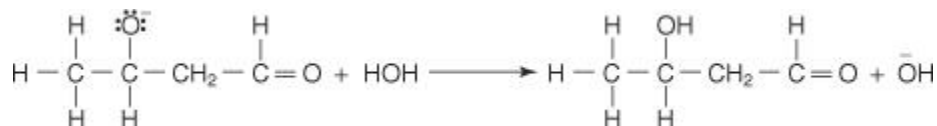
1. The base removes an α -hydrogen.



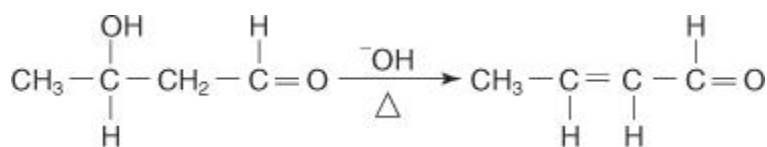
2. The carbanion undergoes nucleophilic addition with the carbonyl group of a second molecule of ethanal, which leads to formation of the condensation product.



3. A reaction with water protonates the alkoxide ion.

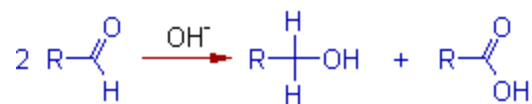


If the aldol is heated in basic solution, the molecule can be dehydrated to form an α - β -unsaturated aldehyde.



ii. Cannizzaro's Reaction:

Those carbonyl compounds with no α -hydrogen undergo disproportionation reaction in the presence of a strong base to form an alcohol and a carboxylic acid is called Cannizzaro reaction. One molecule of aldehyde is reduced to the corresponding alcohol, while a second one is oxidized to the carboxylic acid.

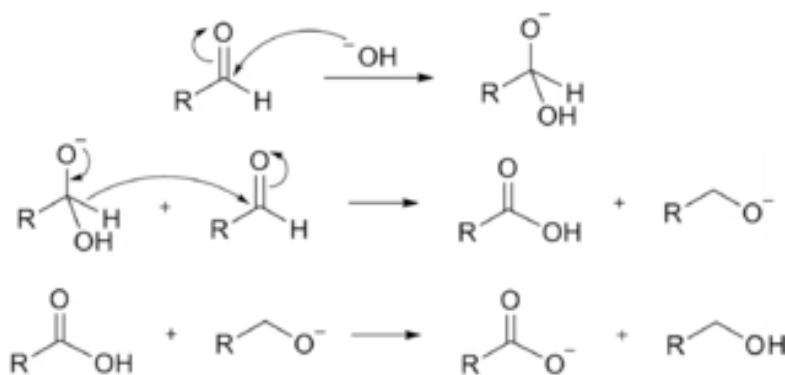


- i. The applicability of Cannizzaro reaction in organic synthesis is limited as the yield is not more than 50% for either acid or alcohol formed.
- ii. In case of aldehydes that do have α -hydrogens, the aldolcondensationreaction takes place preferentially.
- iii. The α, α, α -Trihalo aldehydes undergo haloform reaction in strongly alkaline medium.
e.g. Chloral will give chloroform in presence of an alkali.

MECHANISM OF CANNIZZARO REACTION:

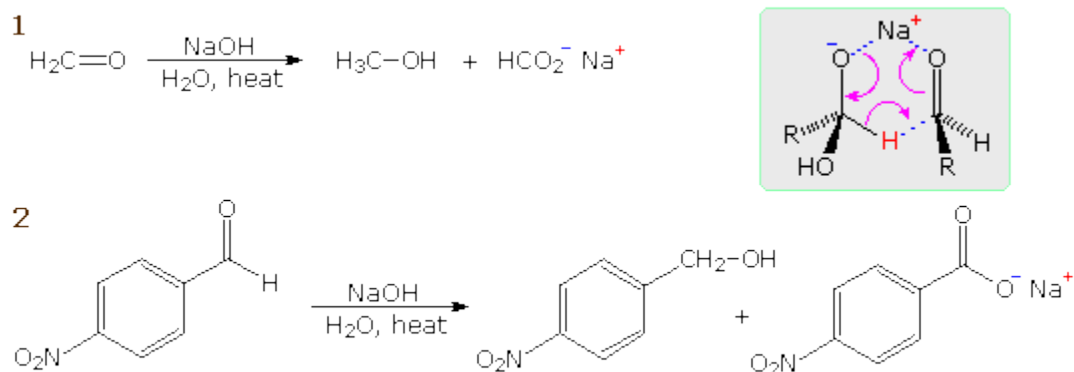
The cannizzaro reaction is initiated by the nucleophilic attack of a hydroxide ion to the carbonyl carbon of an aldehyde molecule by giving a hydrate anion. This hydrate anion can be deprotonated to give an anion in a strongly alkaline medium. In this second step, the hydroxide behaves as a base.

Now a hydride ion, H^- is transferred either from the monoanionic species or dianionic species onto the carbonyl carbon of another aldehyde molecule. The strong electron donating effect of O^- groups facilitates the hydride transfer and drives the reaction further. This is the rate determining step of the reaction.



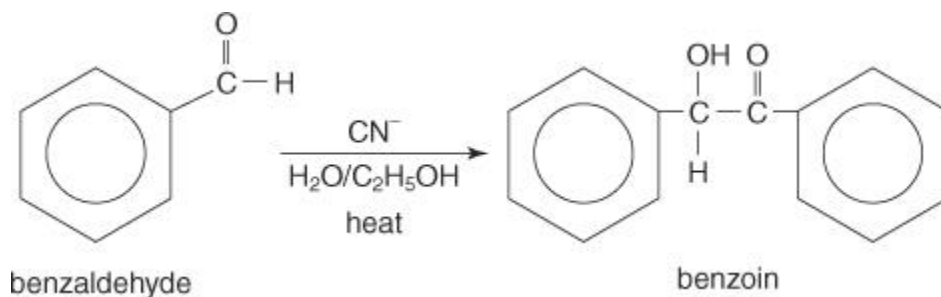
Thus one molecule is oxidized to carboxylic acid and the other one is reduced to an alcohol.

When the reaction is carried out with H₂O as solvent, the resulting alcohol does not show carbon bonded deuterium. It indicates the hydrogen is transferred from the second aldehyde molecule, and not from the solvent. The Cannizzaro's reaction takes place very slowly when electron-donating groups are present. But the reaction occurs at faster rates when electron withdrawing groups are present.



iii. The Benzoin Condensation Reaction:

Aromatic aldehydes form a condensation product when heated with a cyanide ion dissolved in an alcohol-water solution. This condensation leads to the formation of α hydroxy ketones.

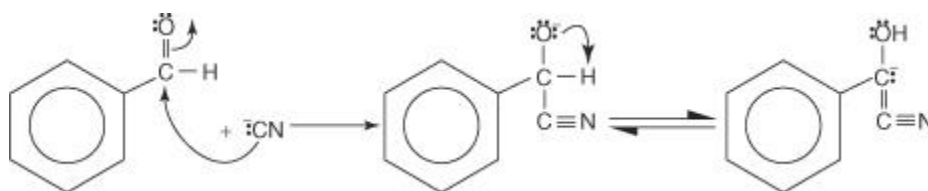


The cyanide ion is the only known catalyst for this condensation, because the cyanide ion has unique properties. For example, cyanide ions are relatively strong nucleophiles, as well as good leaving groups. Likewise, when a cyanide ion bonds to the carbonyl group of the aldehyde, the intermediate formed is stabilized by resonance between the molecule and the cyanide ion. The following mechanism illustrates these points.

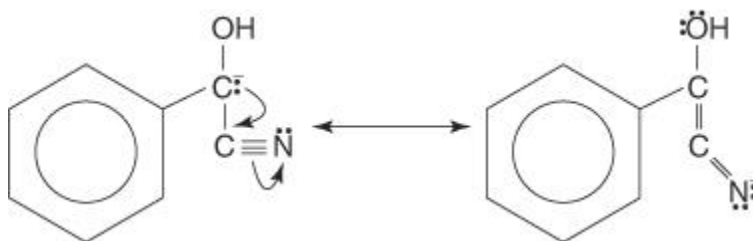
Mechanism

The benzoin condensation reaction proceeds via a nucleophilic substitution followed by a rearrangement reaction.

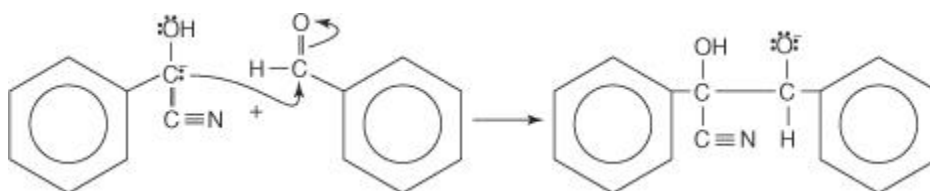
- i. The cyanide ion is attracted to the carbon atom of the carbonyl group.



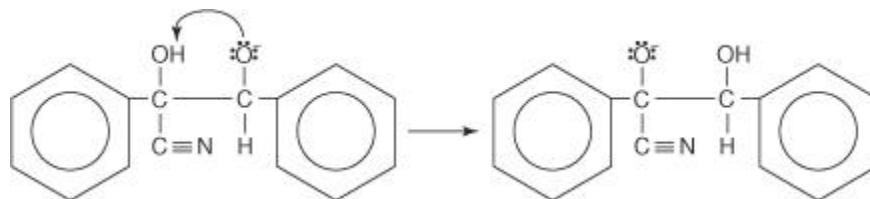
- ii. The carbanion is resonance-stabilized.



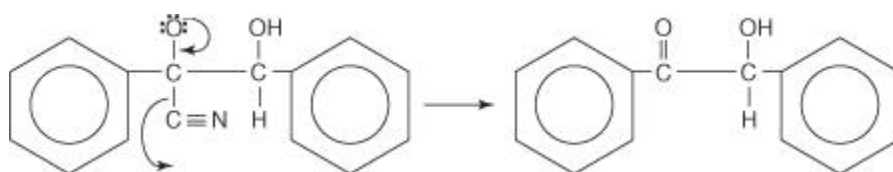
- iii. The carbanion attacks a second molecule of benzaldehyde.



iv. The alkoxide ion removes a proton from the hydroxide group.

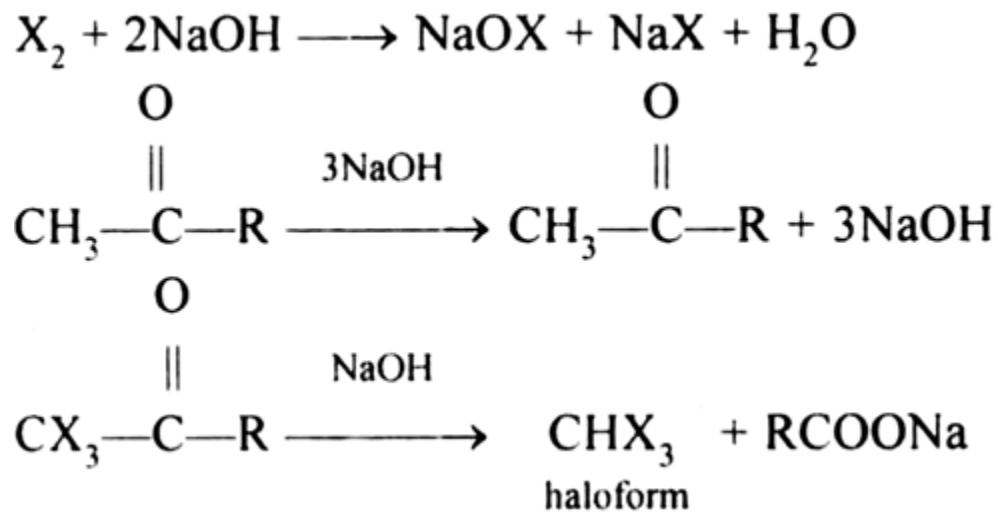


v. A pair of electrons on the alkoxide ion is attracted to the carbon bonded to the cyanide group, which then leaves to generate the product.

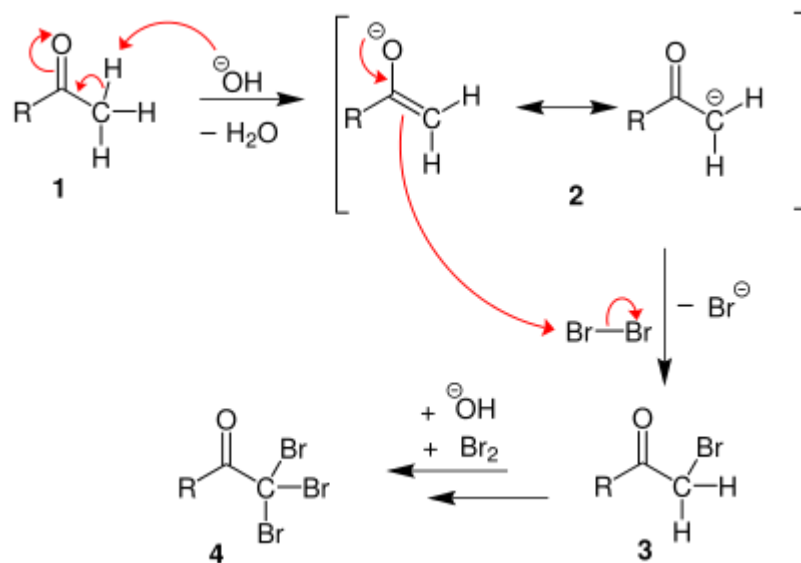


5. Haloform Reactions:

The acetaldehydes and methyl ketones react rapidly with the halogens in the presence of a base to form haloform (chloroform, bromoform or iodoform). This reaction is known as haloform reaction.



Mechanism:



Uses:

This reaction was traditionally used to determine the presence of a methyl ketone, or a secondary alcohol oxidizable to a methyl ketone through the iodoform test. Nowadays, spectroscopic techniques such as NMR and infrared are easy and quick to perform. It was formerly used to produce iodoform, bromoform, and even chloroform industrially. In organic chemistry, this reaction may be used to convert a terminal methyl ketone into the appropriate carboxylic acid.

Iodoform test:

When iodine and sodium hydroxide are used as the reagents, a positive reaction gives iodoform. Iodoform (CHI_3) is a pale-yellow substance. Due to its high molar mass caused by the three iodine atoms, it is solid at room temperature (cf. chloroform and bromoform). It is insoluble in water and has an antiseptic smell. A visible precipitate of this compound will form from a sample only when either a methyl ketone, ethanal, ethanol, or a methyl secondary alcohol is present.

