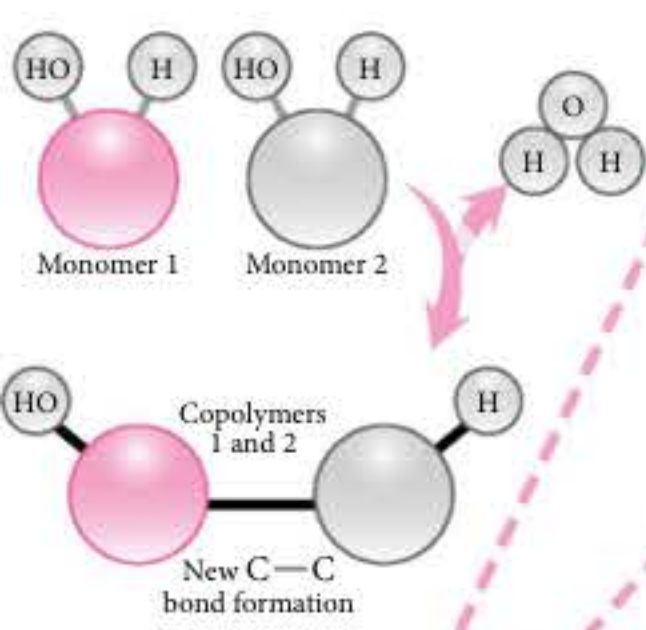


CONCEPT MAP

CONDENSATION REACTIONS



A reaction in which two or more molecules combine to form a larger molecule, with the simultaneous loss of a small molecule such as water or methanol. This term is used for the reaction in which new C—C bond is formed.

Acyloin Condensation

$$2R-C(=O)OR \xrightarrow{-Na} R-C(OH)(R)-C(=O)R$$

Acyloins belong to the class of α -hydroxyketones. In absence of proton source, esters undergo bimolecular reduction when reacted with sodium. Reaction is carried out by refluxing the reactants in aprotic solvents such as ether, benzene, etc. The reaction is most successful when R is alkyl.

Aldol Condensation

The addition reaction of enol or enolate to the carbonyl group of aldehydes or ketones is known as aldol (aldehyde + alcohol) addition. The β -hydroxyaldehyde and the β -hydroxyketone so obtained undergo dehydration in the second step to produce a conjugated enone. The first part of the reaction is an addition reaction and the second part is an elimination reaction. Aldol condensation is seen in case of carbonyl compounds containing α -hydrogens. Dilute bases such as NaOH, KOH, Ba(OH)₂, etc. are used as reagents. Aldol condensations are also catalysed by acids.

Claisen Condensation

The Claisen condensation is a carbon-carbon bond forming reaction between two esters or one ester and another carbonyl compound in presence of a strong base. The product is a β -keto ester or a β -diketone.

$$R-CH_2-C(=O)OR' + H-C(=O)R'' \xrightarrow[2. H_3O^+]{1. NaOEt} R-CH_2-C(=O)-CH(R'')-C(=O)OR' + R'-OH$$

β -Keto ester

Though sodium ethoxide is commonly used as base, strong bases such as NaH, NaNH₂ or KH often increase the yield.

Knoevenagel Condensation

Compounds containing active hydrogens condense with aldehydes or ketones in a reaction known as Knoevenagel condensation.

$$R_2C=O + H_2C=C(Z)Z' \xrightarrow{Base} R_2C=C(Z)Z' + H_2O$$

Darzens Condensation

The condensation of aldehyde or ketone with an α -halo ester to produce an α, β -epoxy ester or a glycidic ester is the Darzens condensation.

$$R-CHO + Cl-CH_2-COOC_2H_5 \xrightarrow{NaOEt} R-C(O)CH(Cl)COOC_2H_5$$

Mechanism

The mechanism involves the formation of an enolate. The enolate then attacks the carbonyl group to form a halo-alkoxide ion. The next step is an intramolecular S_N2 reaction, an example of Neighbouring Group Participation (NGP). The reaction follows third order kinetics.

$$Cl-CH_2-COOC_2H_5 + EtO^- \rightleftharpoons Cl-CH^--COOC_2H_5 \rightleftharpoons [Cl-CH_2-COOC_2H_5]^- \xrightarrow{R-CHO} R-C(O)CH(Cl)COOC_2H_5$$

Mechanism

$$2RCO_2R + 2e^- \xrightarrow{-2Na} 2RC(O^-)OR \rightleftharpoons 2RO^- + RC(=O)OR \xrightarrow{2Na} RC(O^-)OR \rightleftharpoons RC(OH)OR \xrightarrow{tautomerises} RC(=O)R$$

Dieckmann condensation (Intramolecular Claisen Condensation in dibasic acid esters) competes with acyloin condensation, particularly during the synthesis of 5, 6 or 7 membered rings. However, this can be prevented by using chlorotrimethylsilane (Me₃SiCl) instead of Na.

Simple Aldol Condensation

Base catalysed: Aldol condensation between two molecules of same aldehyde or ketone is called simple aldol condensation.

$$2H_3C-CHO \xrightarrow{Base} H_3C-CH(OH)-CH_2-CHO \xrightarrow{Base} H_3C-CH=C-CHO + H_2O$$

Acetaldoal → Crotonaldehyde

The aldol undergoes dehydration to give a stable conjugated aldehyde. Now the reaction can be designated as aldol condensation, as two molecules have united with the elimination of a water molecule.

In base catalysed mechanism, it is the enolate, which attacks the carbonyl molecule. But in acid catalysed mechanism, it is the enol that attacks the protonated carbonyl molecule. Base catalysed dehydration follows E1cB, whereas acid catalysed dehydration follows E1 mechanism.

Comparison with Aldol Condensation

In the first step, we have an impressive difference as well as a remarkable similarity. Claisen condensation uses an alkoxide as base rather than hydroxide in aldol condensation. Hydroxide would hydrolyse the ester. However, there is also a notable similarity here, both generate enolate. The enolates then attack their respective substrates, both reactions now going in a very similar way. Next is the turn for the real difference. The dimer from aldol condensation gets protonated, whereas that obtained from ester rejects ethoxide ion to complete the addition-elimination sequence.

Aldol Condensation:

$$CH_3-CH_2-CHO + CH_3-CH_2-CHO \xrightarrow{H^+} CH_3-CH(OH)-CH_2-CHO$$

Claisen Condensation:

$$CH_3-CH_2-CO_2H_5 + CH_3-CH_2-CO_2H_5 \xrightarrow{(-C_2H_5O)} CH_3-CH_2-CO-CH_2-CO_2H_5$$

Mechanism

$$Z-CH_2-Z' \xrightarrow{Base} Z-CH^--Z' \rightleftharpoons Z-CH=C(Z)Z' \rightleftharpoons Z-CH-C(O^-)-R' \xrightarrow{BH} Z-CH(OH)-R' \xrightarrow{Base} Z-C(OH)=C(Z)Z' \rightleftharpoons Z-C=C(Z)Z'$$

Aldehydes or ketones used here usually do not contain α -hydrogen. Z and Z' of the active compound are strong electron pullers like -CHO, -COR, -CN, -NO₂ and -COOR. Even compounds containing only one electron withdrawing group, if strong enough can cause condensation in presence of strong base.

- ### Applications of Condensation Reactions
- Condensation reactions are mainly used for organic synthesis.
 - Condensation reactions are also very important in biological synthesis like, glycosylation, phosphorylation, polypeptide and polynucleotide synthesis.
 - Condensation reactions are also very important in polymer industry for example in preparation of nylon, dacron, etc.