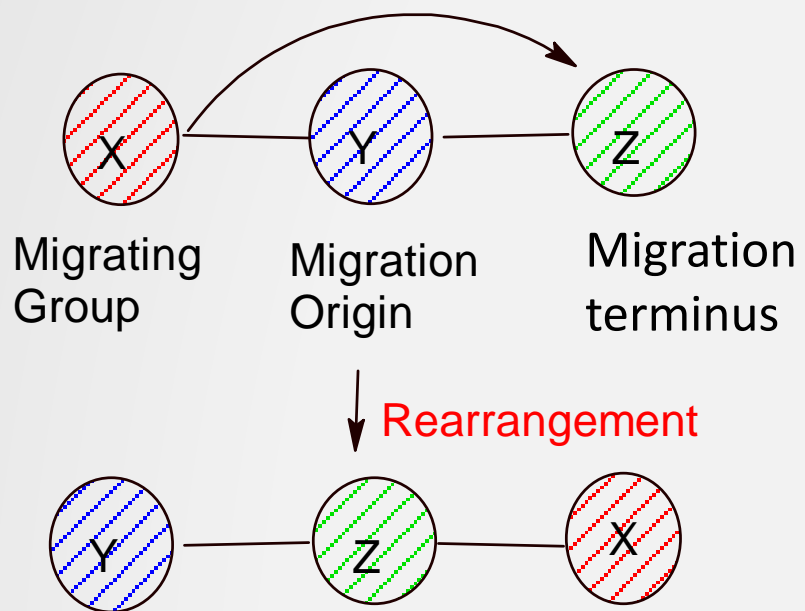


Rearrangement Reactions

- A reaction in which carbon skeleton or the functional group or both are modified is called rearrangement reaction.
- Migration of an atom or group from one center (**migration origin**) to another center (**migration terminus**) within the molecule is called rearrangement reaction



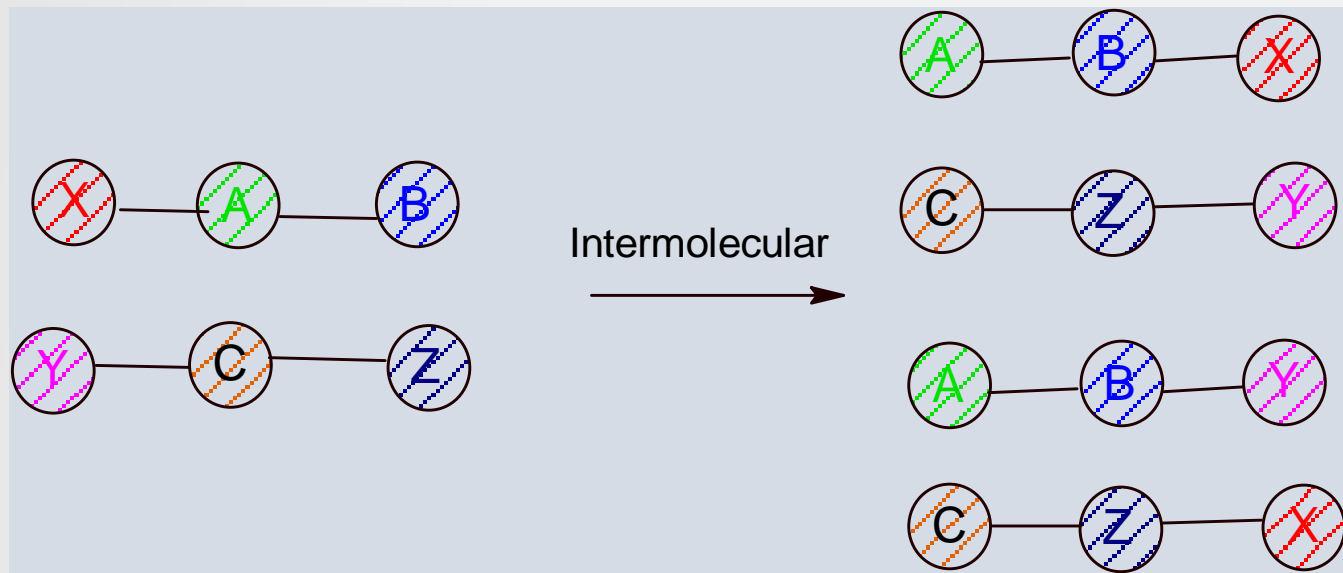
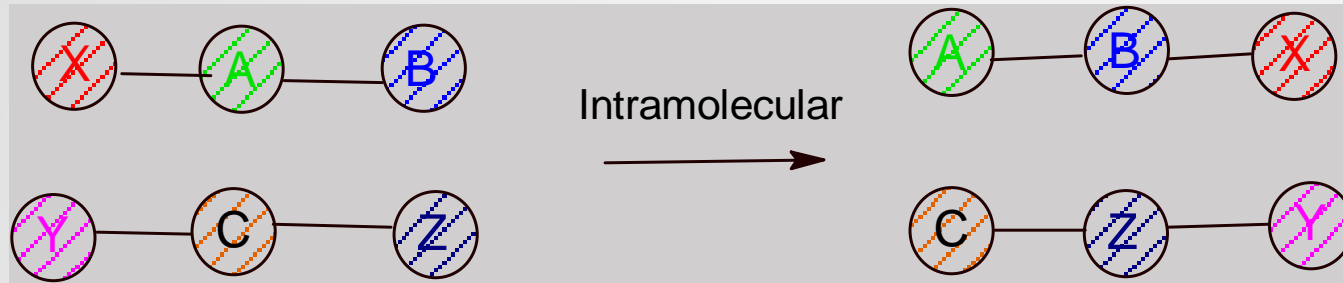
Rearrangement Reactions

- In general migration take place from adjacent centre (1,2-shifts)
- Long range rearrangements are also possible
- **Nucleophilic or anionotropic rearrangements:** migrating group moves with its electron pair.
- **Electrophilic or cationotropic rearrangements :** migrating group moves without electron pair. (Fries rearrangement)
- **Free-radical rearrangements :** migrating group moves with single electron.(photo fries rearrangement)

Crossover Experiment

- Cross over experiment is used to find out whether a rearrangement is intermolecular or Intramolecular.
- A mixture of two structurally related substrates, X- A- B and Y- C- Z are allowed to react and products after rearrangement were observed.
- If product is a mixture of four different species, the reaction is intermolecular. (A-B-X, C-Z-Y, A-B-Y and C-Z-X)
- If Product is a mixture of two species, then reaction is intramolecular. (A-B-X, C-Z-Y)

Crossover Experiment



Types of Rearrangement Reactions



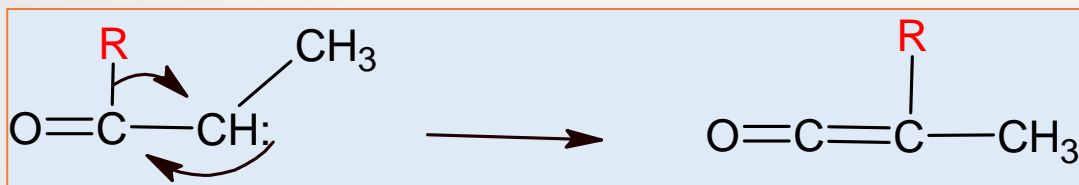
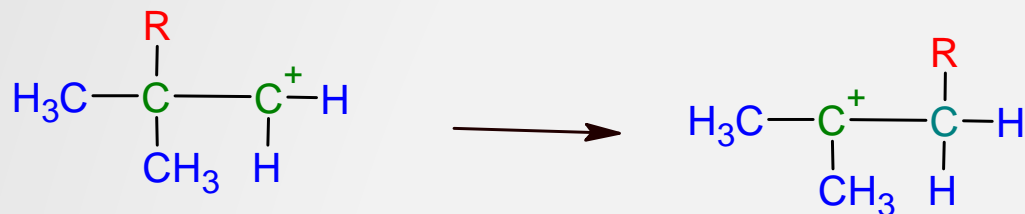
A) 1,2 rearrangement reaction

B) Pericyclic Reactions

C) Olefin metathesis

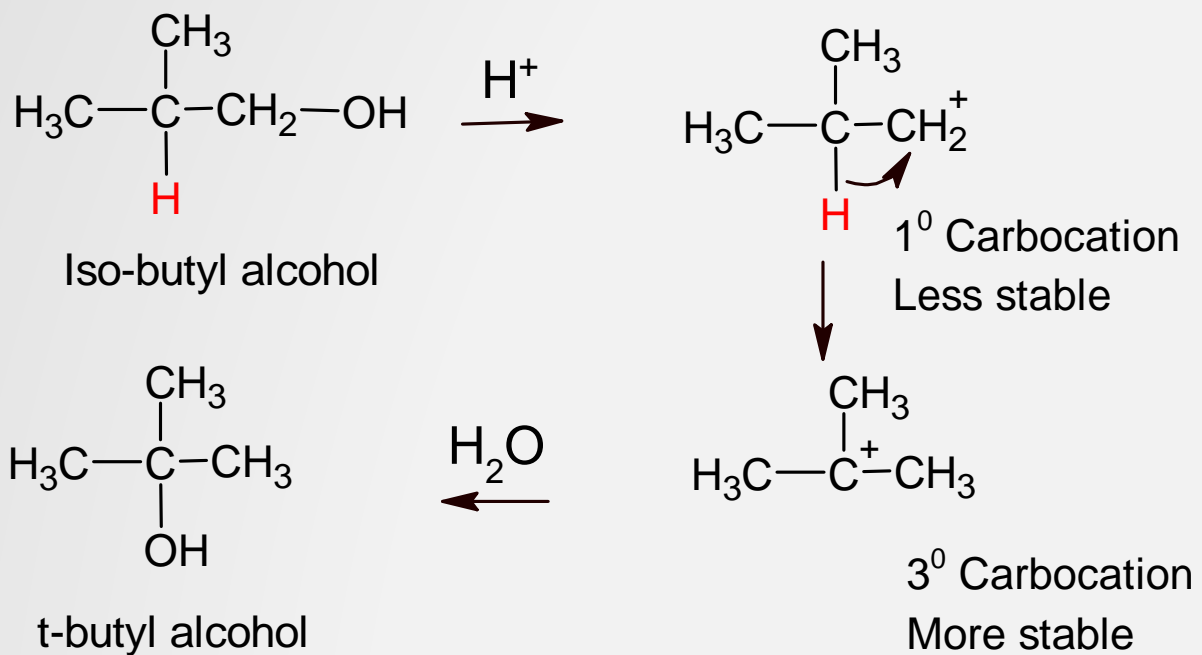
1,2 rearrangement reaction

A rearrangement in which a substituent move from adjacent atom in a chemical compound is called 1,2 rearrangement.



1,2 rearrangement reaction

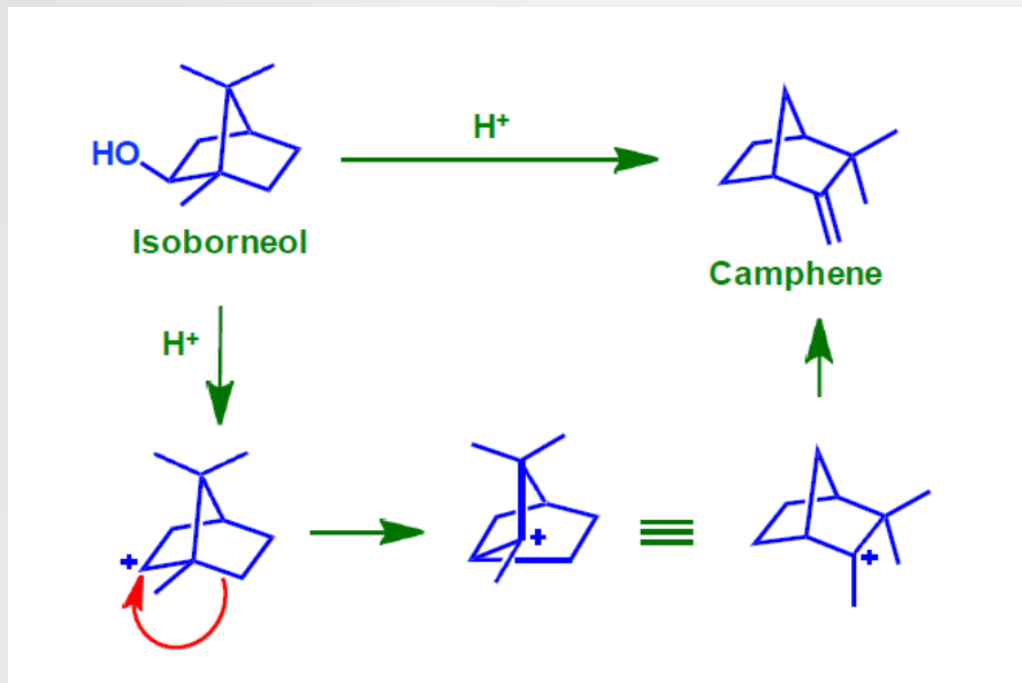
Wagner–Meerwein rearrangement



Stability of carbocations is $3^\circ > 2^\circ > 1^\circ$

1,2 rearrangement reaction

Wagner–Meerwein rearrangement

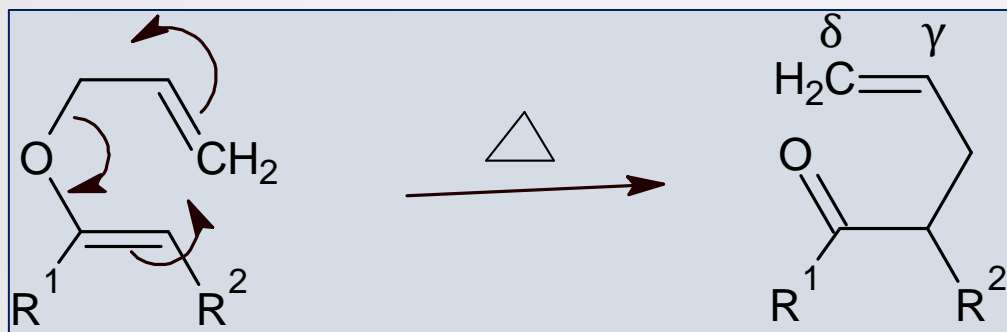


Bond migration take place to produce stable carbocation

Pericyclic Reactions

- It involves multiple bond breaking and bond making process.
- Transition state has a cyclic geometry.
- Reaction proceed with concerted mechanism

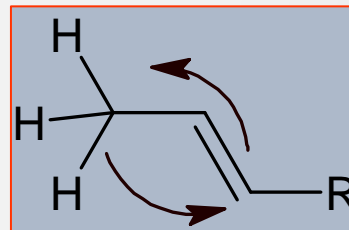
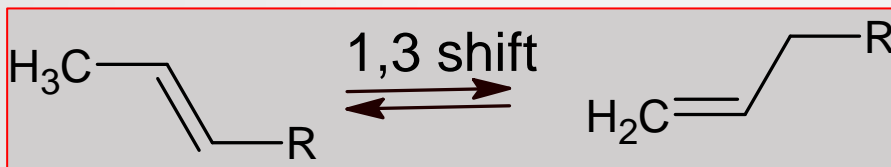
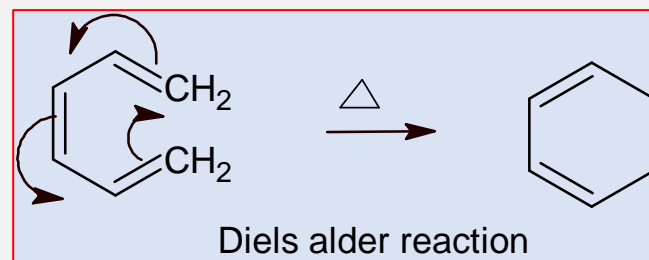
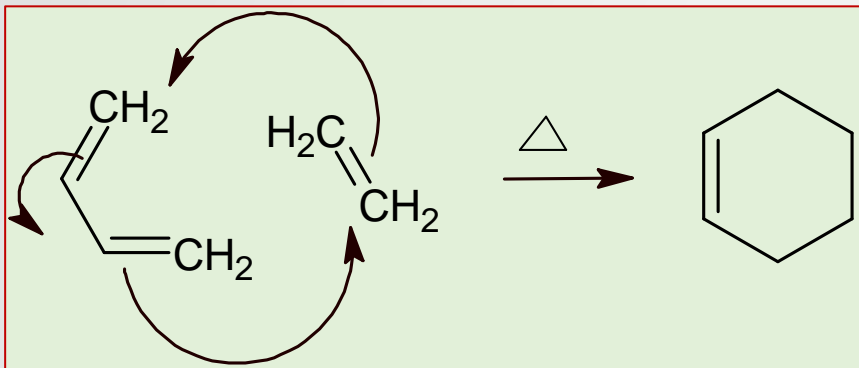
Example : Claisen rearrangement



Allyl vinyl ether on heating undergo [3,3]sigmatropic rearrangement and produce γ, δ -unsaturated carbonyl compound

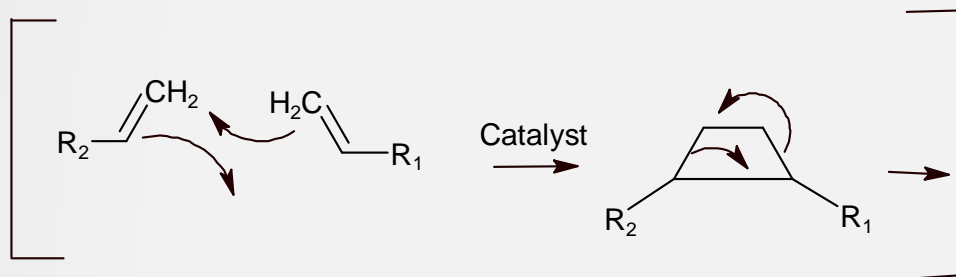
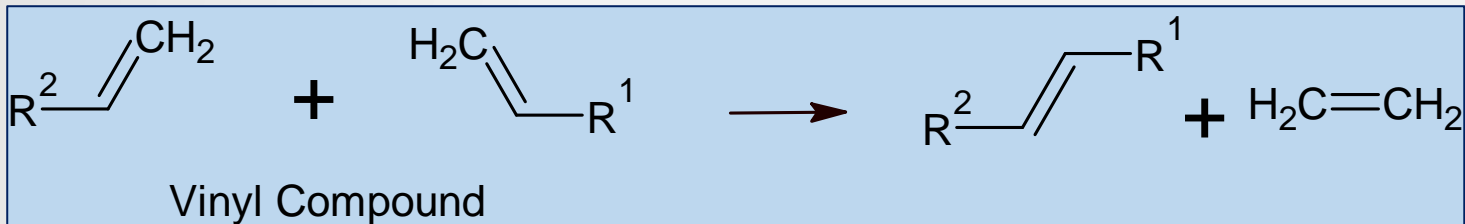
Pericyclic Reactions

Diels Alder reaction

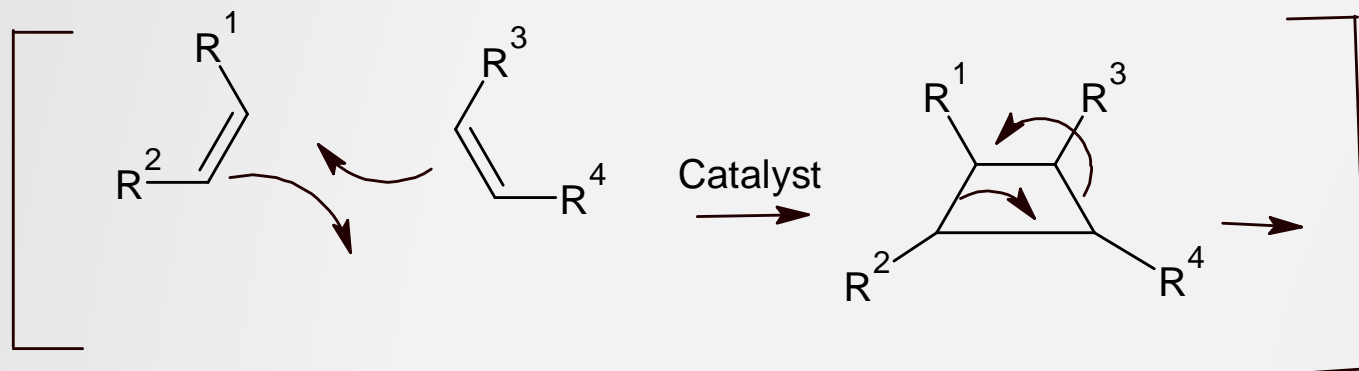
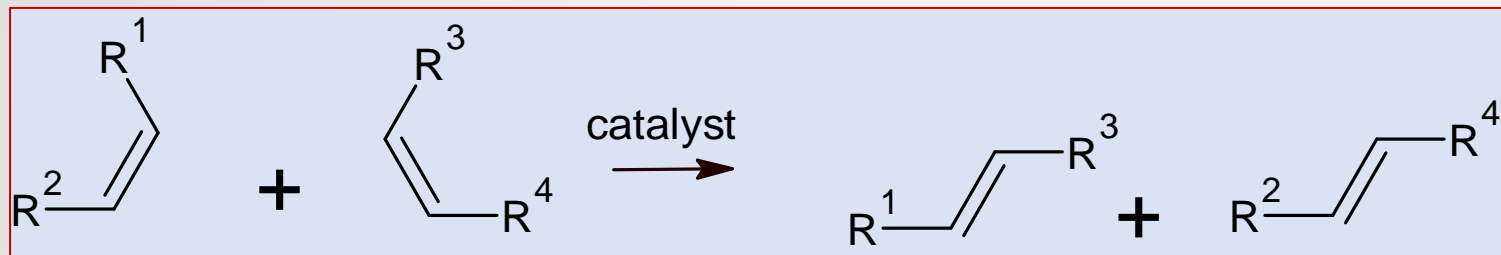


Olefin Metathesis

- Olefin metathesis is formal exchange of alkylidene fragments in between two alkenes.
- It proceed through four membered ring intermediate
- Rearrangement of substituents take place to form two new carbon-carbon double bonds



Olefin Metathesis



Classification

➤ Rearrangement to electron deficient carbon

Pinacol-Pinacolone rearrangement

Wagner-Meerwein rearrangement

➤ Rearrangement to electron deficient nitrogen

Beckmann rearrangement

Hofmann rearrangement

➤ Rearrangement to electron deficient oxygen

Bayer villiger Oxidation

➤ Sigmatropic rearrangement

Claisen rearrangement

Rearrangement to electron deficient carbon (Carbocation Intermediate)



- Less stable carbocation can rearrange to more stable carbocation by various structural shift within the molecule.
- Stability of carbocation is $3^\circ > 2^\circ > 1^\circ$
- Stability of carbocation also depends on various structural effects.
- These rearrangements involve Hydride, alkyl or aryl shift.
- Some rearrangement involve formation of non classical carbocation

Rearrangement to electron deficient carbon (Carbocation Intermediate)

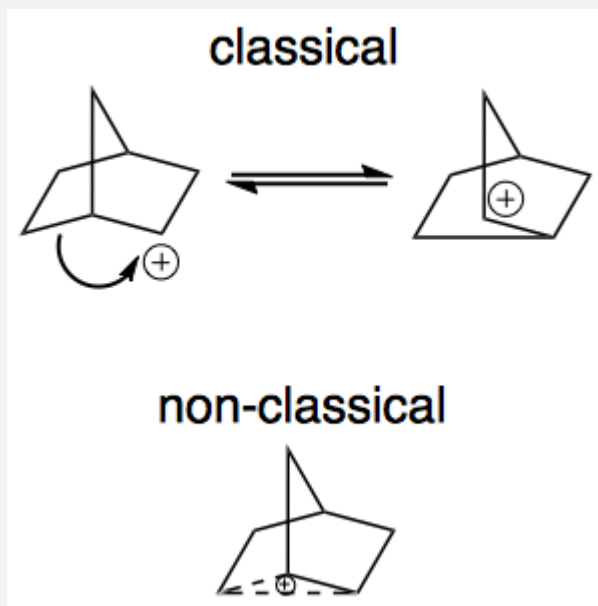
- Classical and non classical carbocation

- Classical carbocation:

Carbocation which has six electrons involved in three chemical bonds.

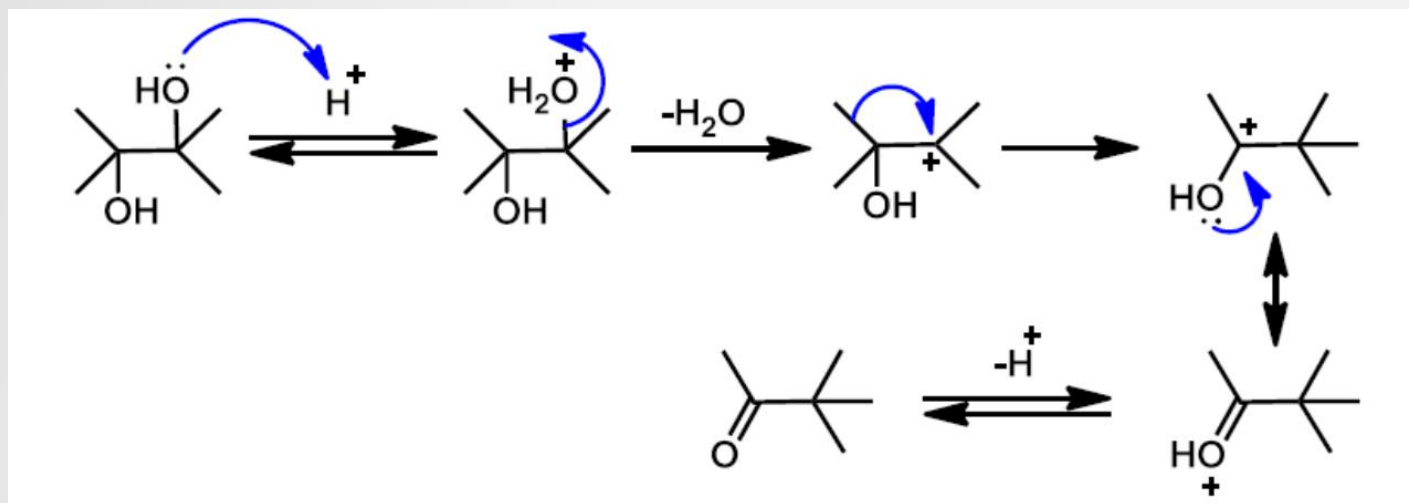
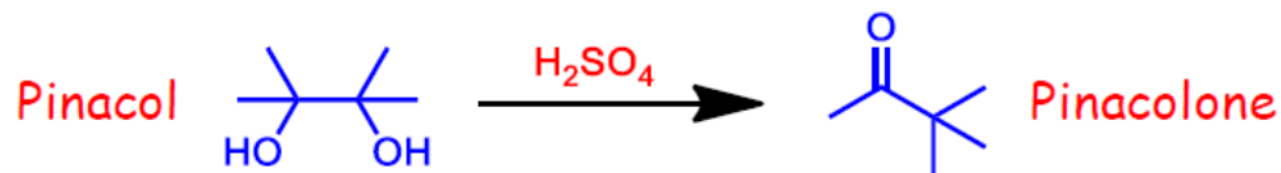
- Nonclassical carbocation:

Carbocation with three-center two-electron bond.
(three atoms sharing two electrons)



Rearrangement to electron deficient carbon (Carbocation Intermediate)

Pinacol-Pinacolone Rearrangement

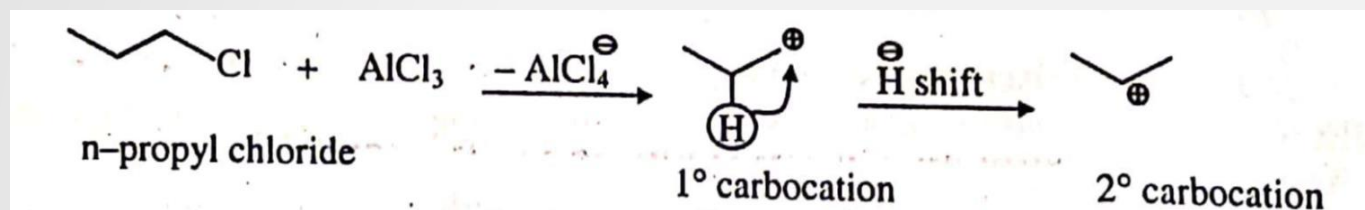
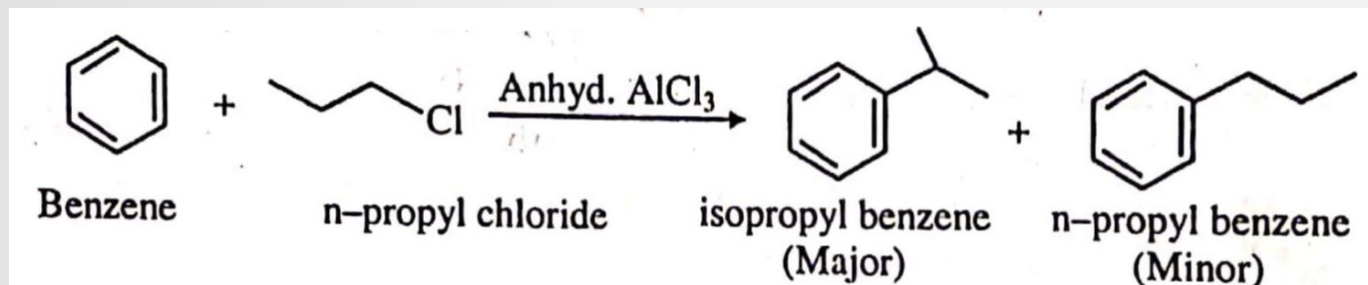


The lone pair of electrons on the oxygen stabilizes the carbocation generated after methyl migration

Rearrangement to electron deficient carbon

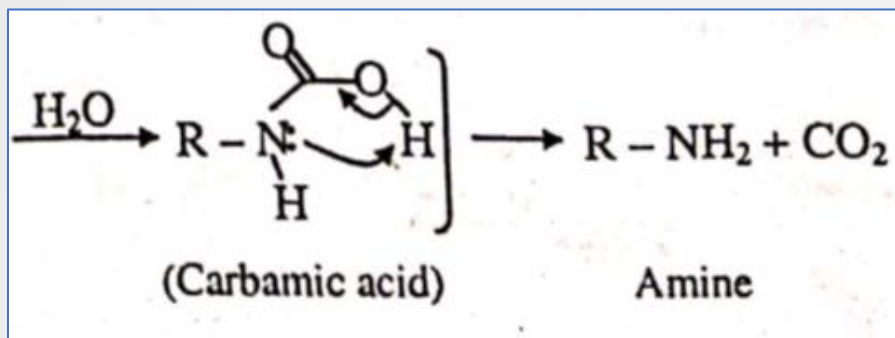
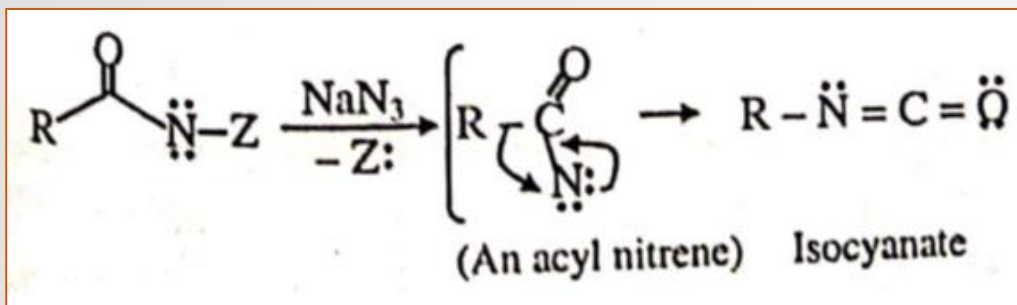
Stability of Carbocation is $3^\circ > 2^\circ > 1^\circ$

Friedel Craft Alkylation reaction



Rearrangement to electron deficient nitrogen

Mechanism involving nitrene intermediate



When, $\text{Z} = \text{Br}/\text{Cl}$ Hofmann rearrangement
 $\text{Z} = \text{N}_2^+$ Curtius rearrangement or
 Schmidt rearrangement
 $\text{Z} = \text{OCOR}$ Lossen rearrangement

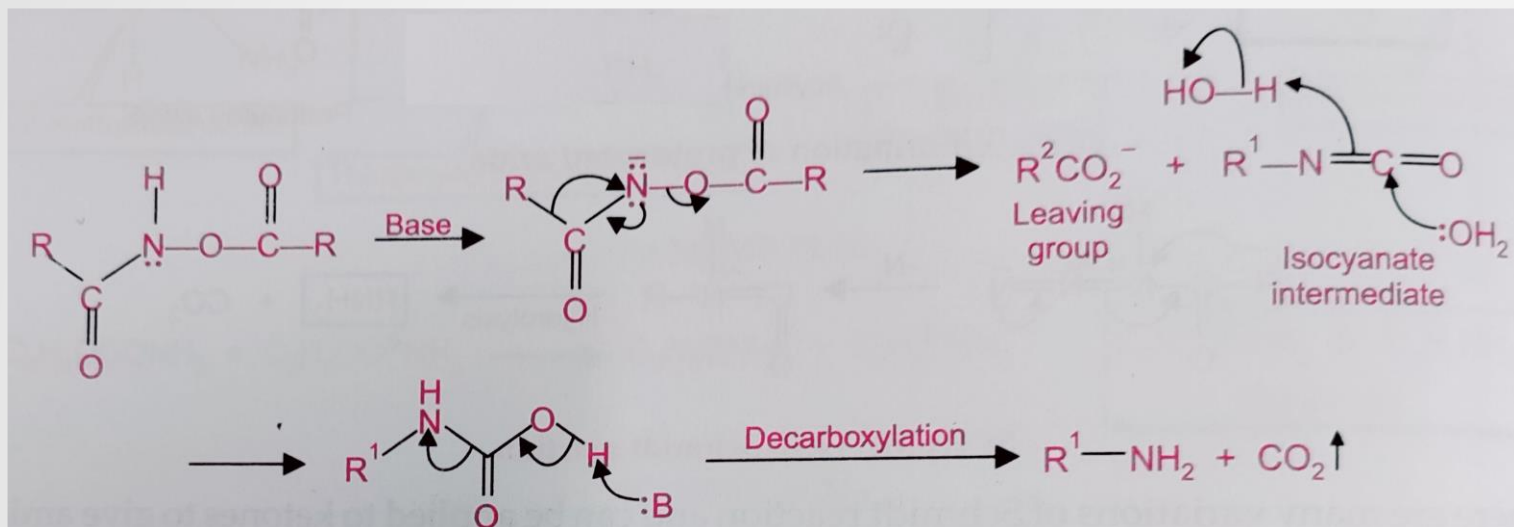
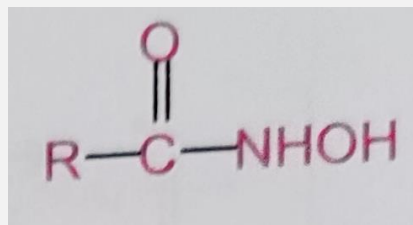
Rearrangement to electron deficient nitrogen

- These rearrangement involve degradation of carboxylic acid derivatives to amines
- Rearrangement of acyl nitrene to isocyanate
- Nitrogen atom in nitrene is electron deficient and serve as center for 1,2 rearrangement
- Addition of water to isocyanate produce unstable carbamic acid, which on decomposition produce amine

Rearrangement to electron deficient nitrogen

Lossen Rearrangement

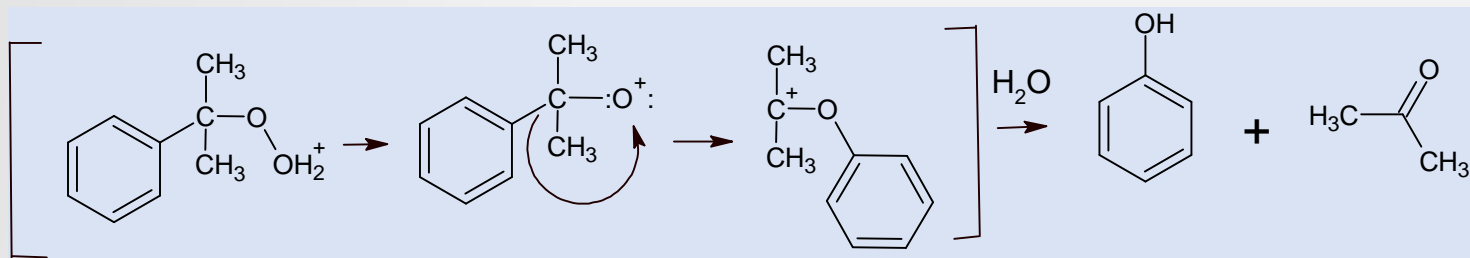
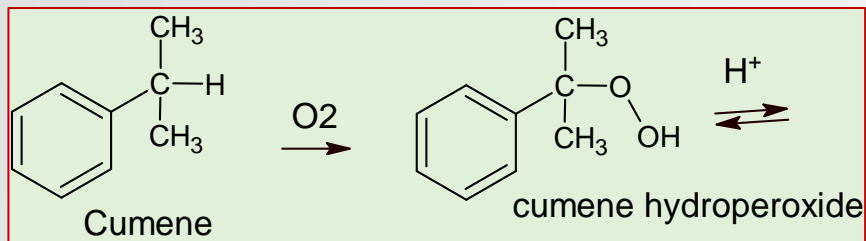
- Rearrangement of an activated hydroxamate generated from corresponding **hydroxamic acid**.
- Activation is done through O-acylation, O-arylation, O-sulphonylation.



Ref. Organic reactions and their mechanisms by P.S. Kalsi

Rearrangement to electron deficient oxygen

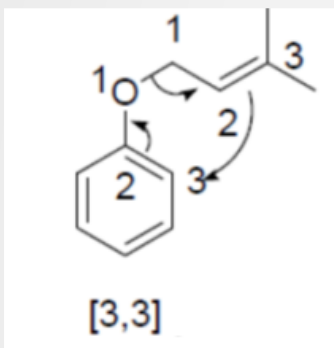
Mechanism involving oxonium ion



- Divalent oxygen atom tricoordinate oxonium ion.
- tricoordinate oxonium ion is converted to electron deficient Unicoordinate oxonium ion.
- 1,2 alkyl or aryl shift convert less stable oxonium ion to more stable carbocation

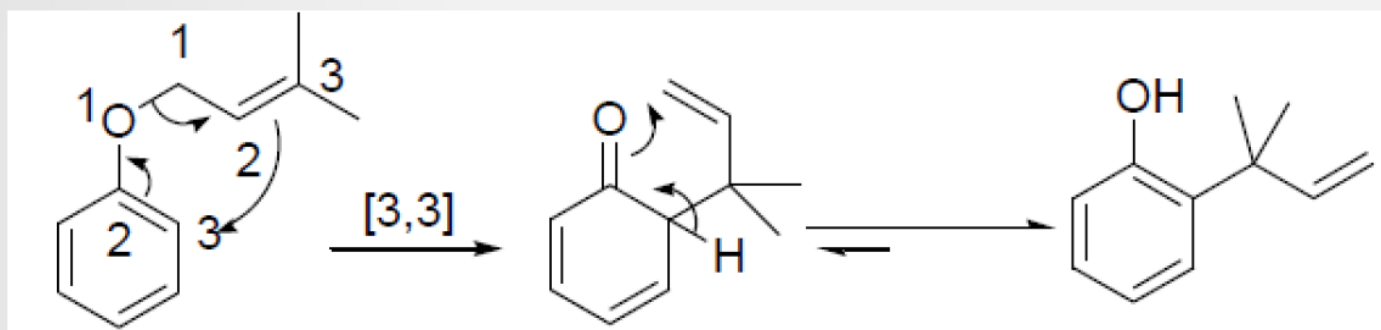
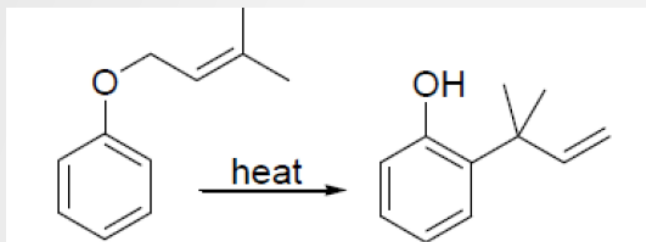
Sigmatropic rearrangement

- In sigmatropic rearrangement σ -bonded atom or group, present between one or more π electron systems, shifts to a new location with reorganization of the π -bonds.
- The total number of σ bonds and π bonds remain unchanged.
- Rearrangements are described by two numbers in brackets, which refer to the relative distance (in atoms) each end of the σ -bond has moved,



Sigmatropic rearrangement

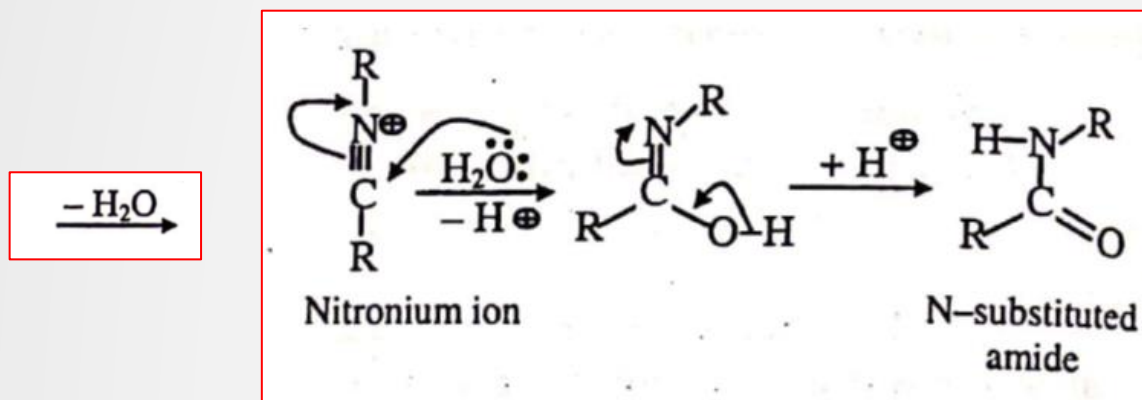
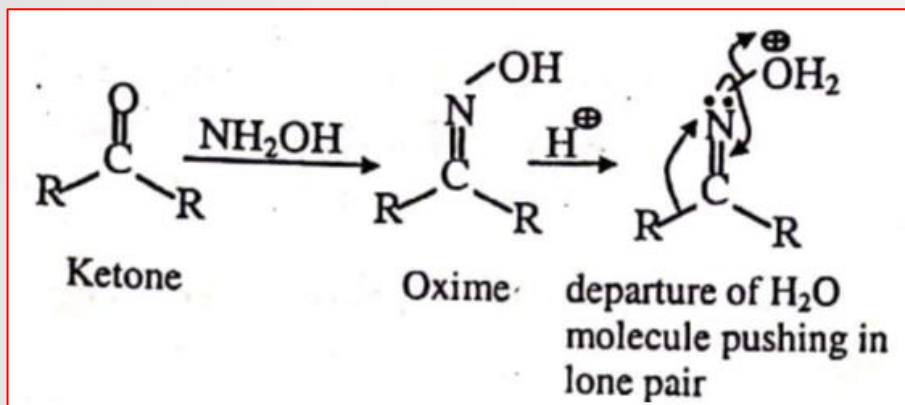
Claisen rearrangement is a $[3,3]$ -sigmatropic rearrangement of an allyl vinyl ether to form a γ, δ -unsaturated carbonyl compound under heating or acidic conditions



Rearrangement to electron deficient nitrogen

Beckmann Rearrangement

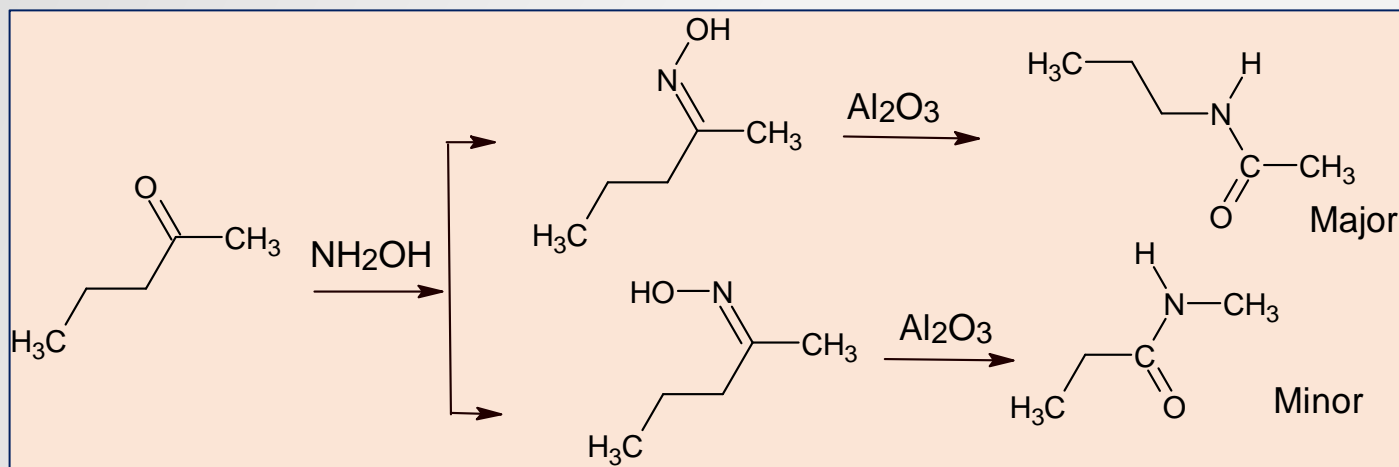
Rearrangement of ketoxime in acidic medium produce N-substituted amide



Beckmann rearrangement

- Rearrangement is generally catalyzed by acid.
- Some other reagents like thionyl chloride, tosyl chloride, phosphorus pentachloride can be used.
- Acid convert -OH group of oxime to good leaving group.
- Alkyl or aryl group migration anti with respect to leaving group take place
- Addition of water to intermediate carbocation produce corresponding amide.

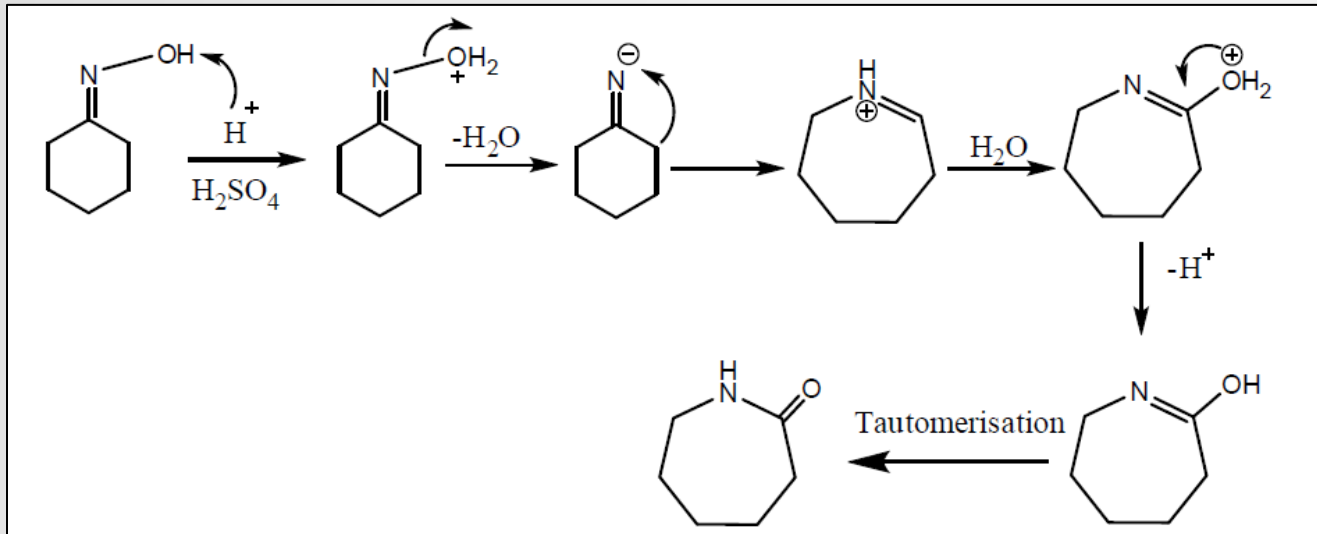
Beckmann rearrangement



In unsymmetrical ketones, two different geometrical isomers of oxime are formed.

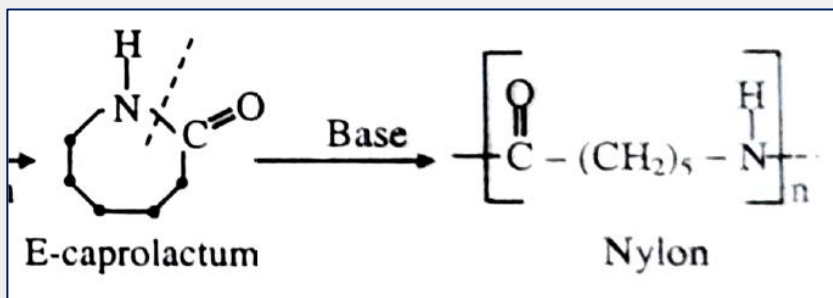
The group which is trans with respect to OH group migrate to give major product.

Beckmann rearrangement

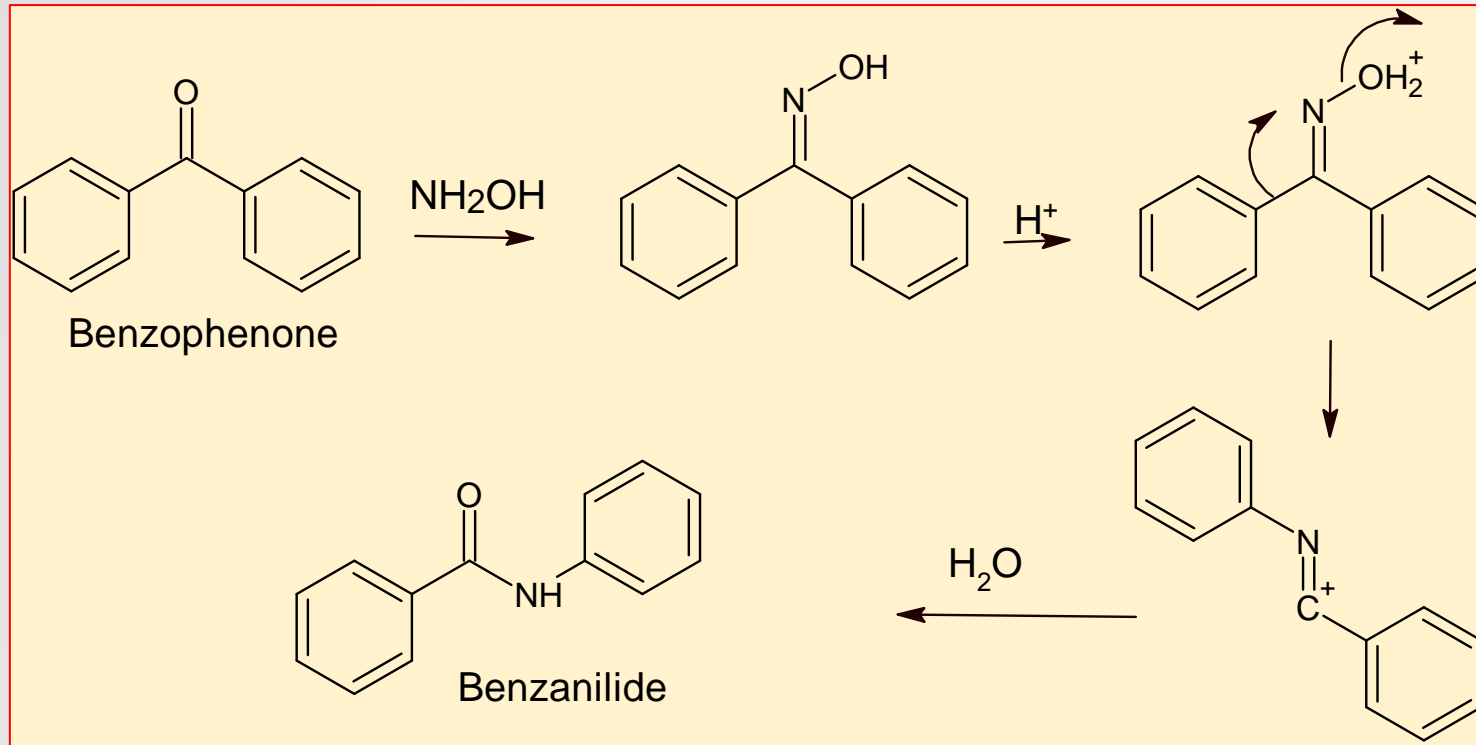


Cyclohexanol undergo Beckmann rearrangement and produce ϵ -caprolactam.

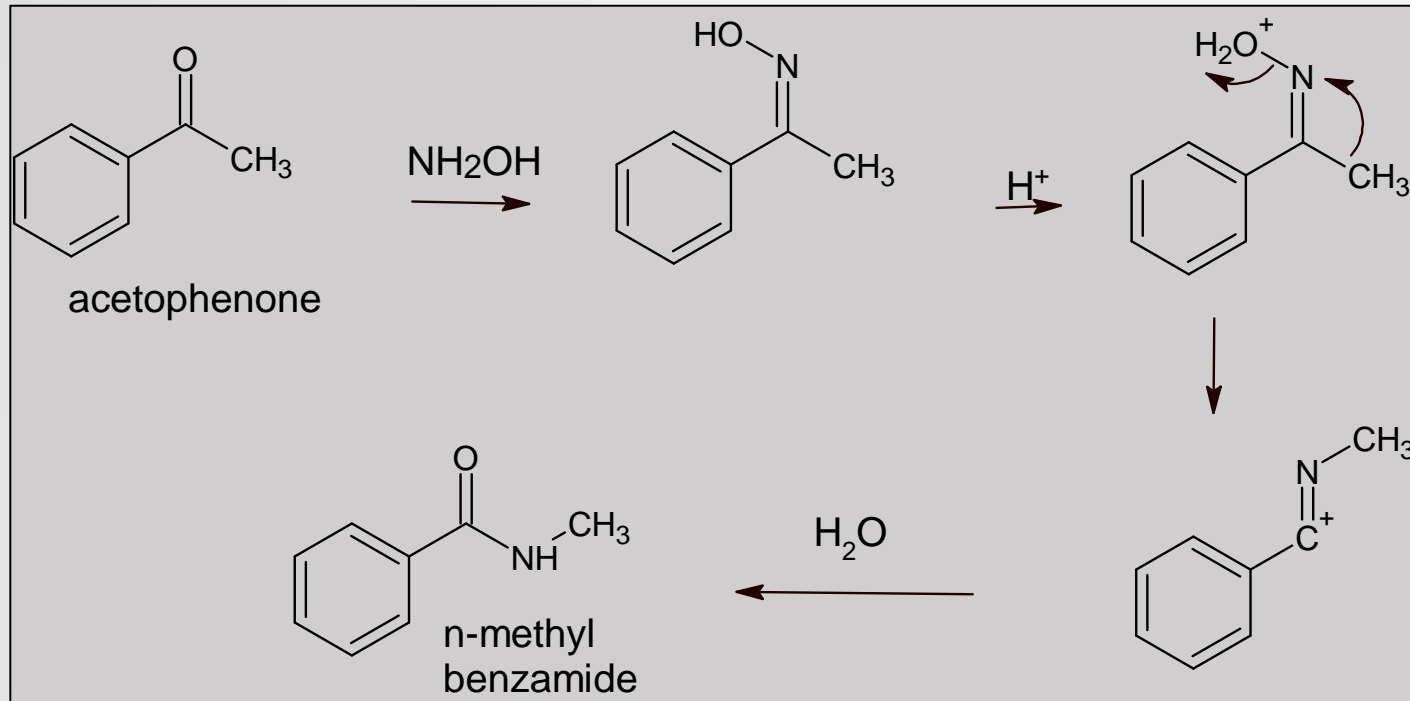
ϵ -caprolactam on treatment of base produce nylon



Beckmann rearrangement

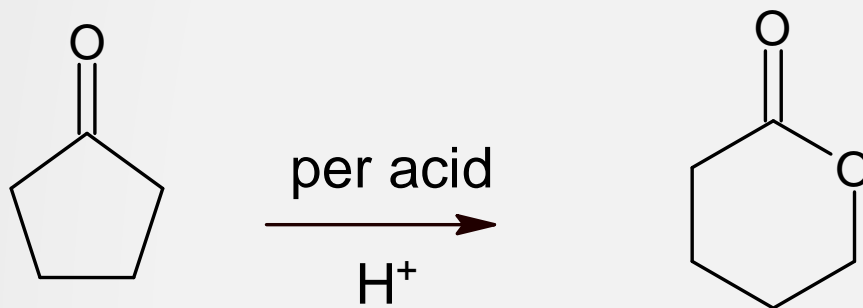
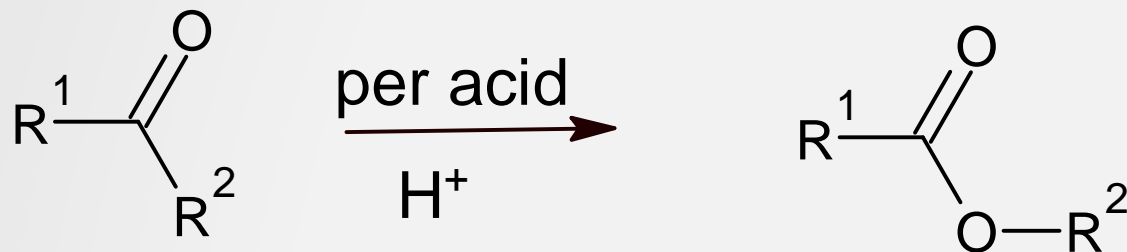


Beckmann rearrangement



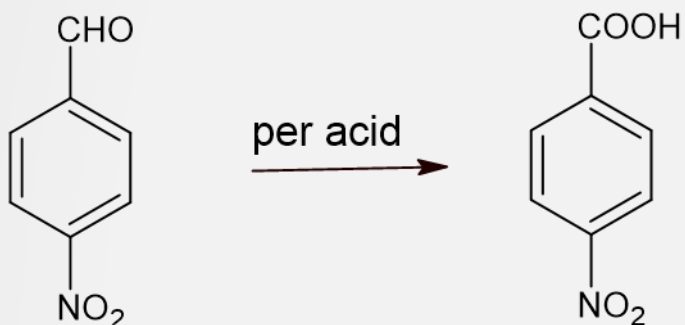
Baeyer- Villiger rearrangement

- The reaction was discovered in 1899 by Adolf von Baeyer and Victor Villiger.
- Treatment of ketone with peroxy acid gives ester.(or lactone from aromatic ketone)
- It is also called as Baeyer Villiger Oxidation

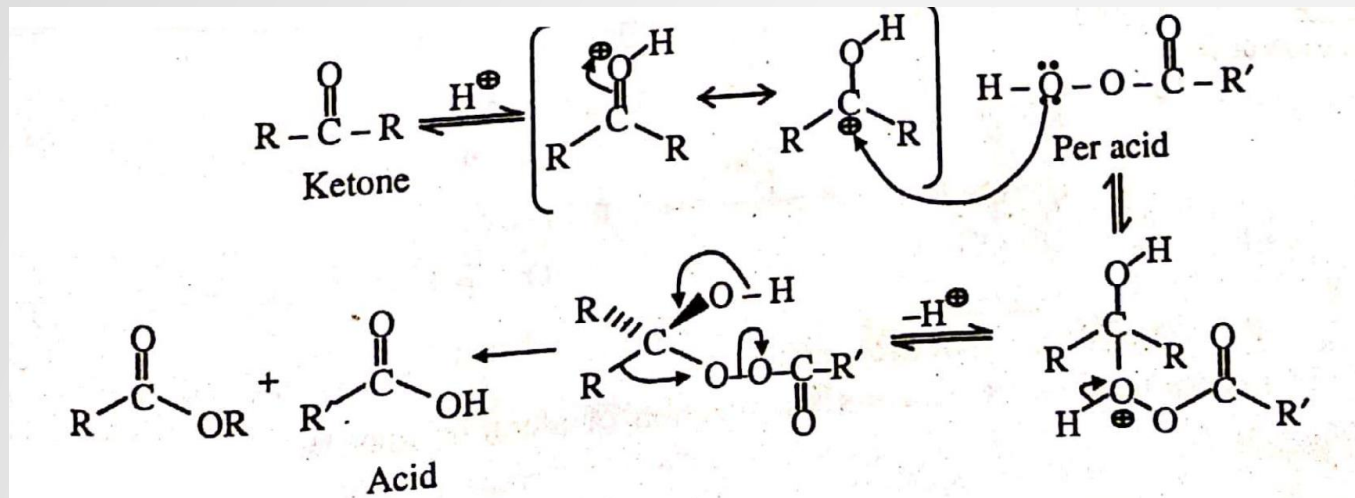


Baeyer- Villiger rearrangement

- Antiperiplanar orientation of migrating group and leaving group favours migration.
- Common peracids used: per benzoic acid, per acetic acid m-chloro per benzoic acid, per oxy trifluoroacetic acid etc.
- Under reaction conditions aldehydes get oxidised to acid

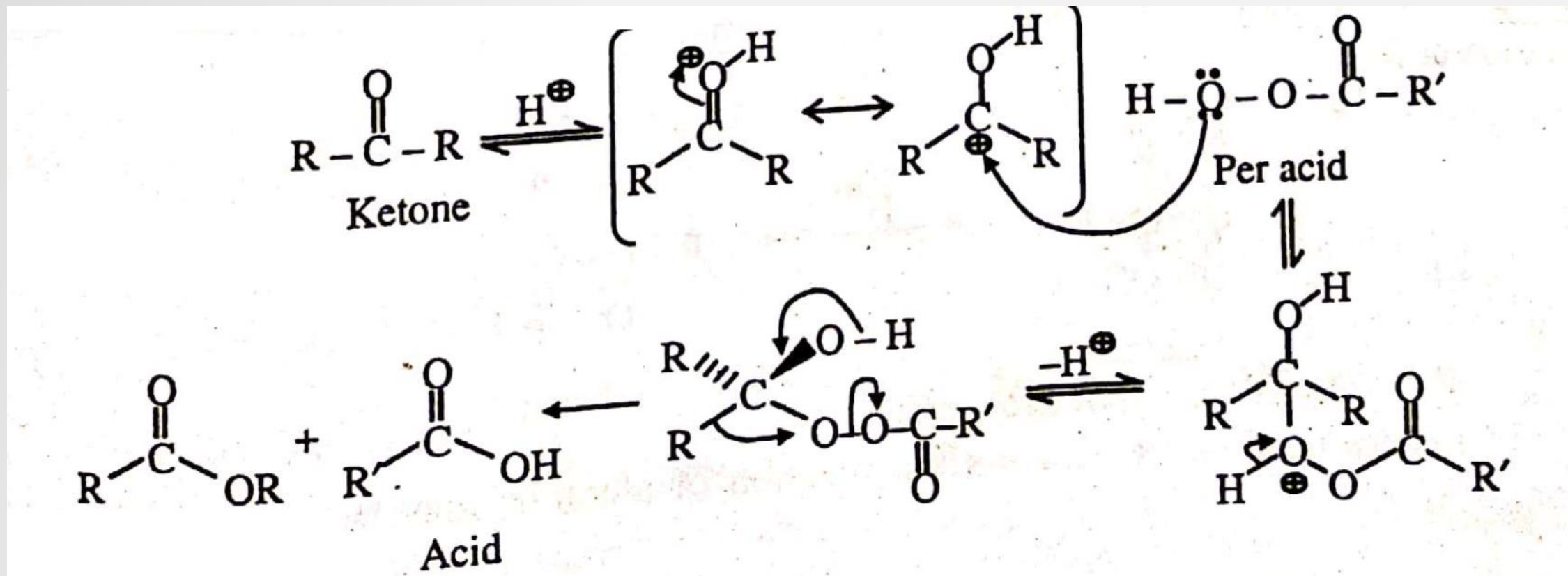


Baeyer- Villiger rearrangement



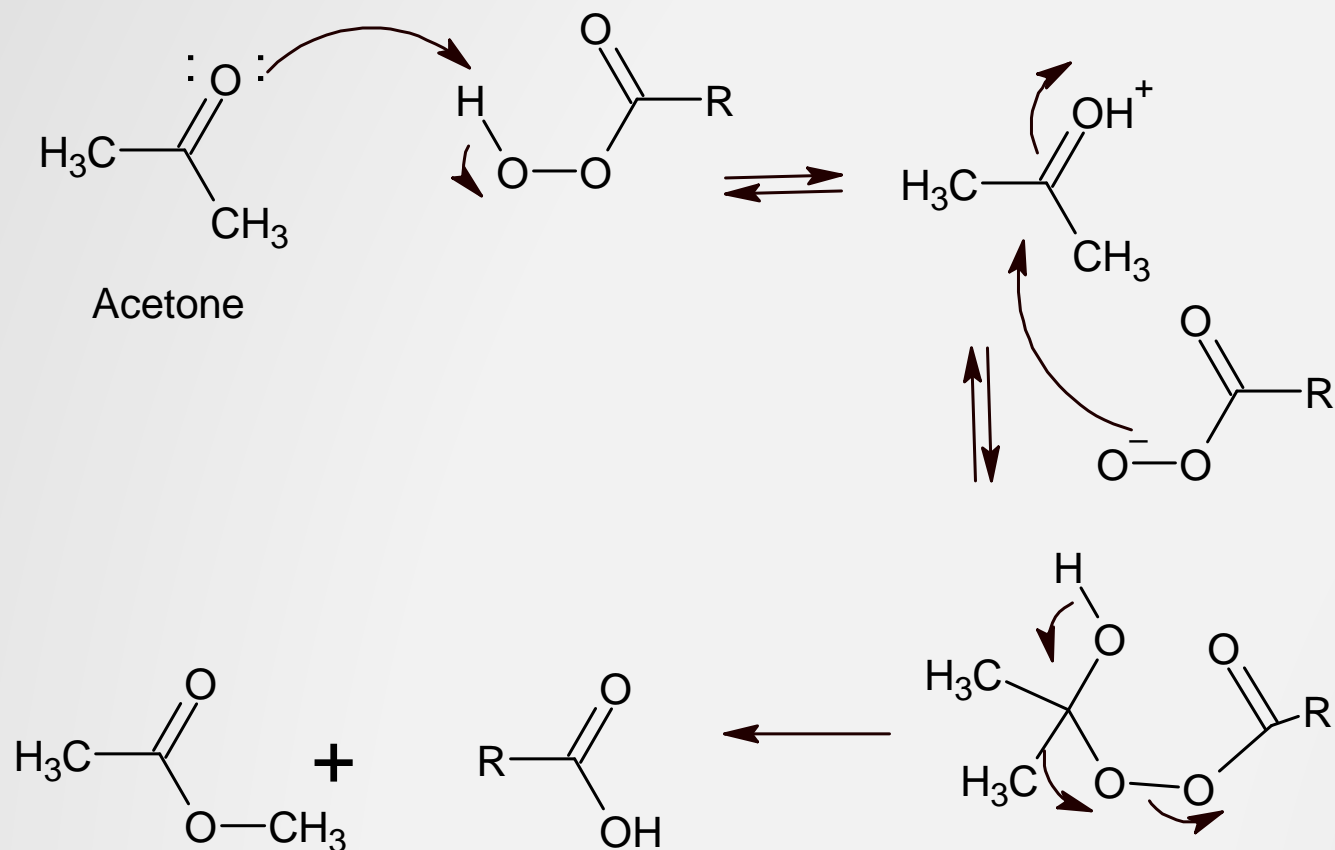
- In first step addition of peroxy acid to the carbonyl carbon take place.
- In second step, migration of the migrating group and loss of carboxylic acid take place simultaneously.

Baeyer- Villiger rearrangement

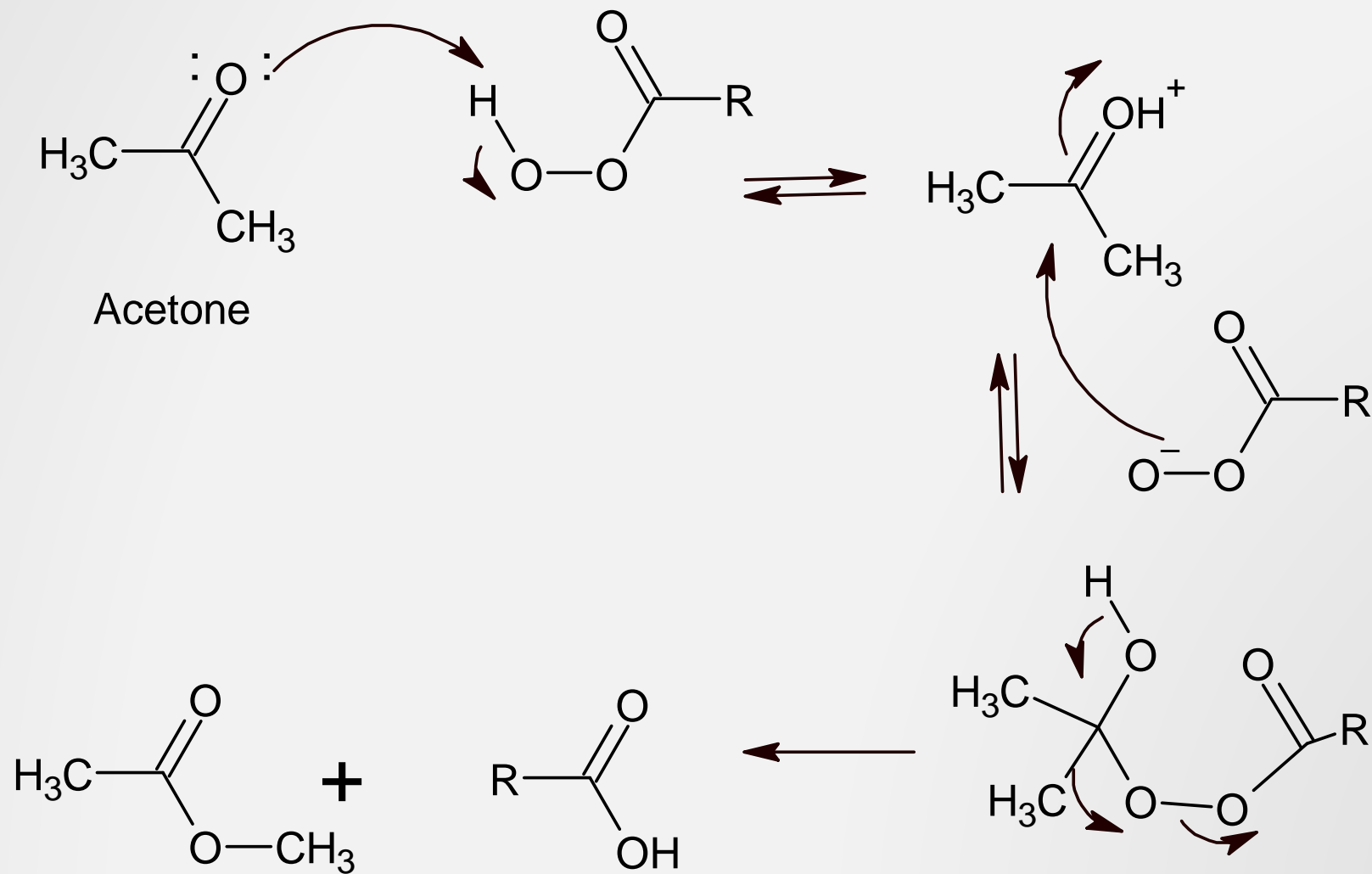


- In first step addition of peroxy acid to the carbonyl carbon take place.
- In second step, migration of the migrating group and loss of carboxylic acid take place simultaneously.

Baeyer-Villiger rearrangement



Baeyer-Villiger rearrangement



Baeyer– Villiger rearrangement

- Migratory aptitude
- 3° alkyl > cyclohexyl > 2° alkyl > benzyl > phenyl > 1° alkyl > CH_3
- The most electron-rich alkyl group migrates most readily.
- Migrating group ability of aryl group increases if electron donating group is present

:

Baeyer–Villiger rearrangement

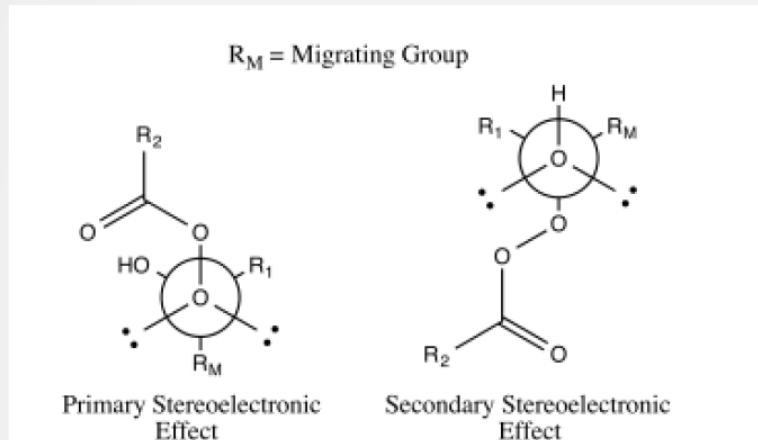
Stereoelectronic effect

a) Primary stereoelectronic effect

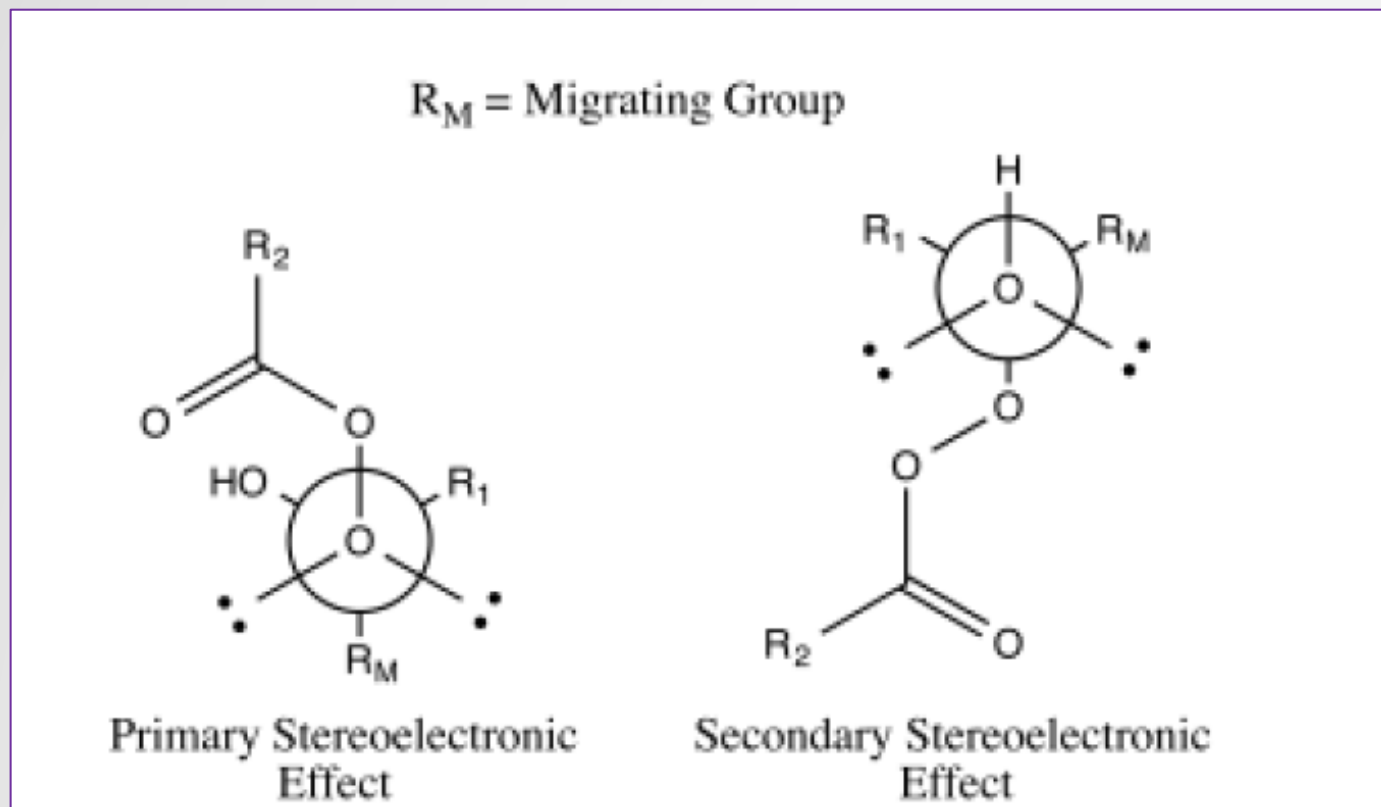
Antiperiplanar orientation of migrating group and leaving group favours migration.

b) Secondary stereoelectronic effect

Antiperiplanar alignment of the lone pair of electrons on the oxygen with migrating group.



Baeyer–Villiger rearrangement



Stereoelectronic effect

a) Primary stereoelectronic effect

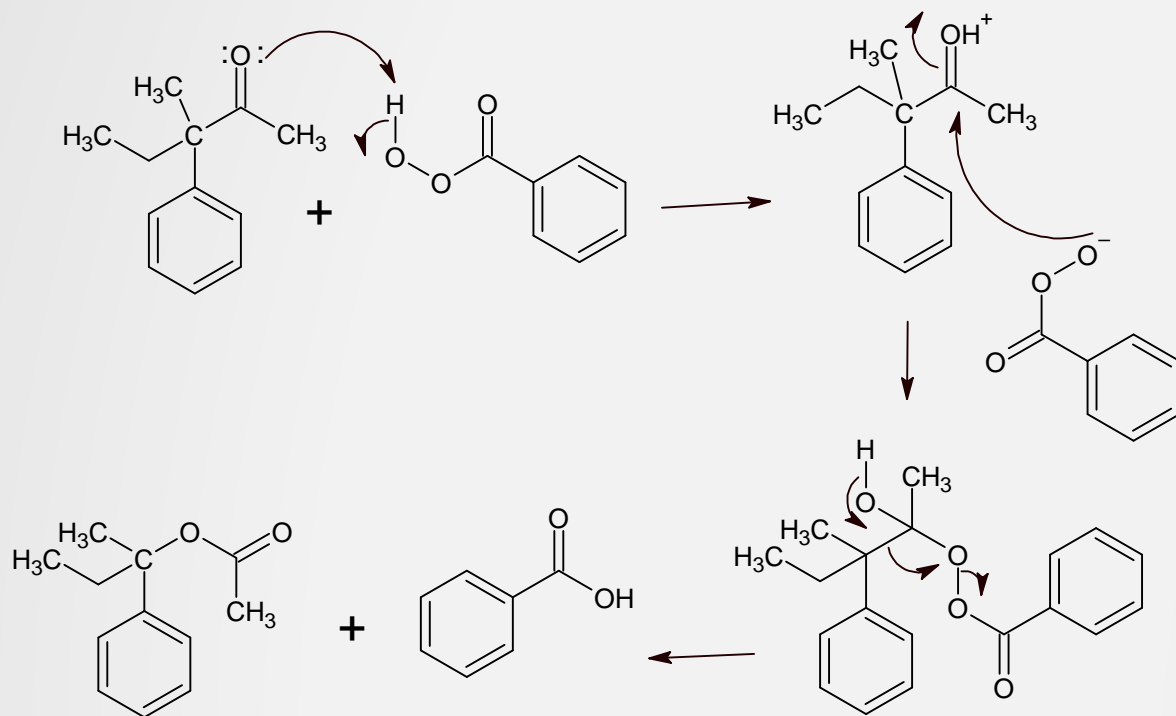
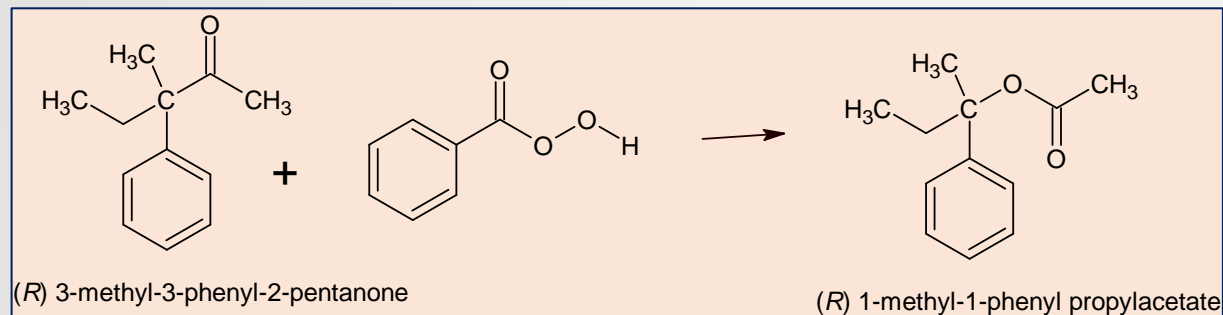
Antiperiplanar orientation of migrating group and leaving group favours migration.

b) Secondary stereoelectronic effect

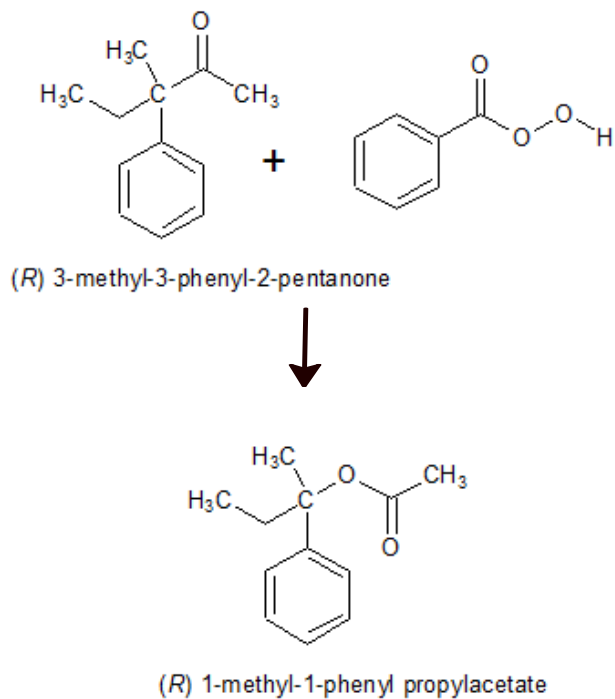
Antiperiplanar alignment of the lone pair of electrons on the oxygen with migrating group.

Baeyer–Villiger rearrangement

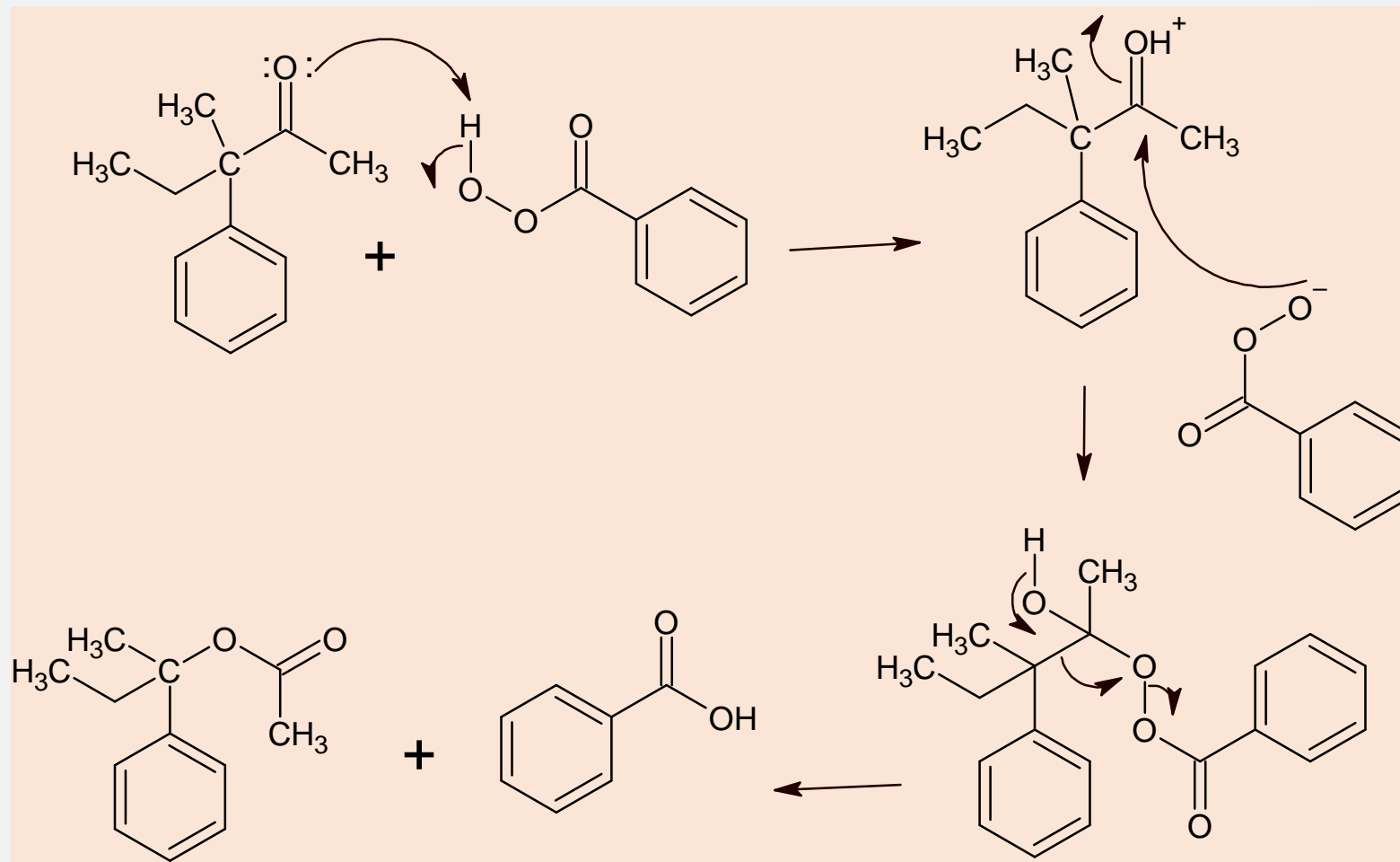
Migration of alkyl group occurs with retention of configuration



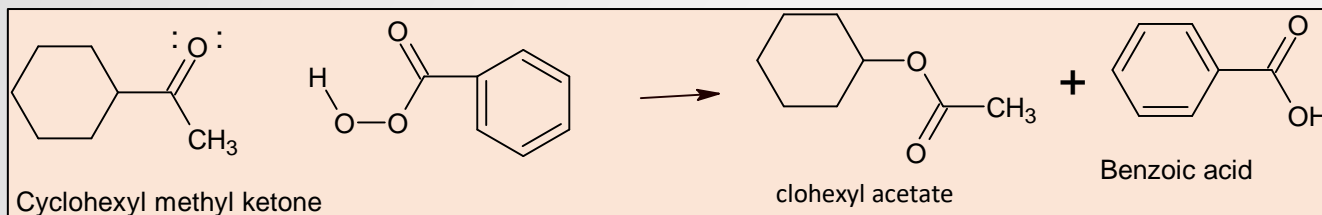
Baeyer-Villiger rearrangement



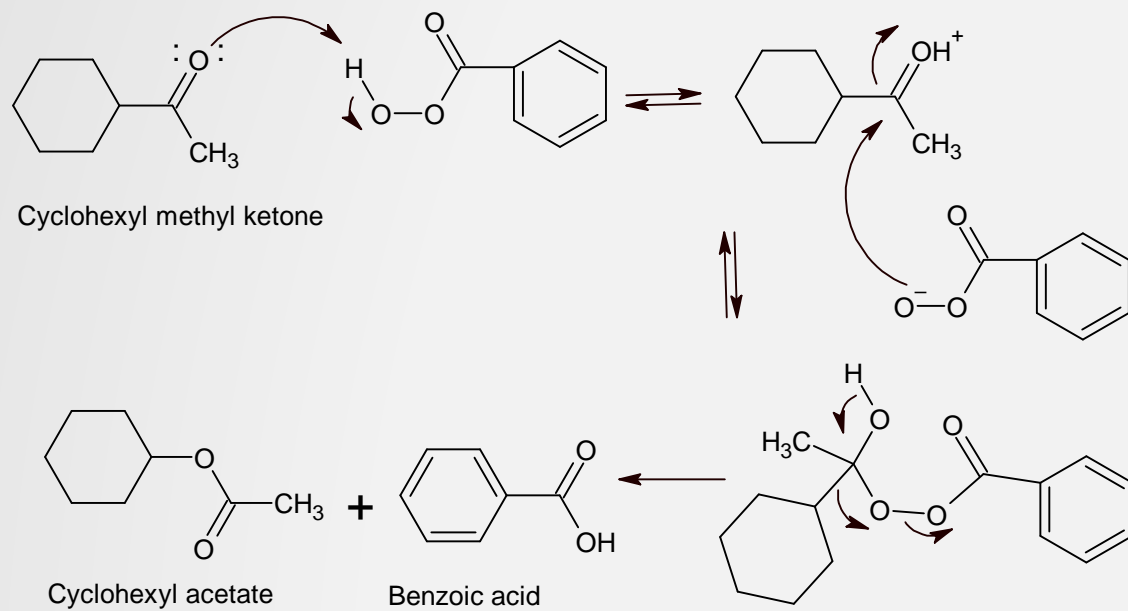
Migration of alkyl group occurs with retention of configuration



Baeyer-Villiger rearrangement

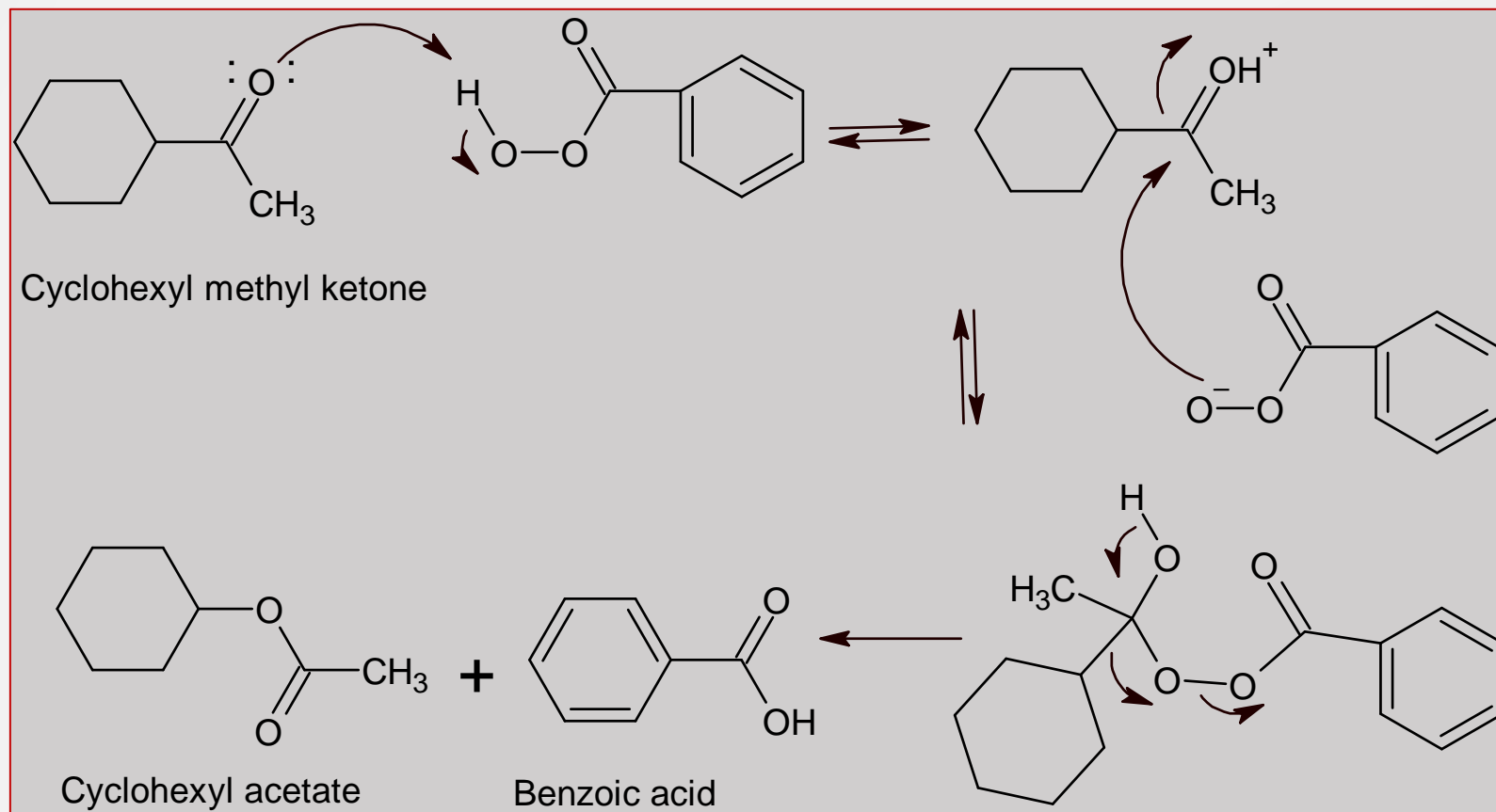
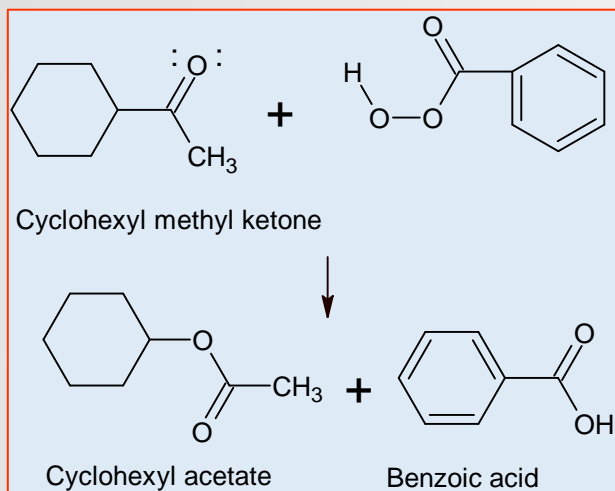


Mechanism

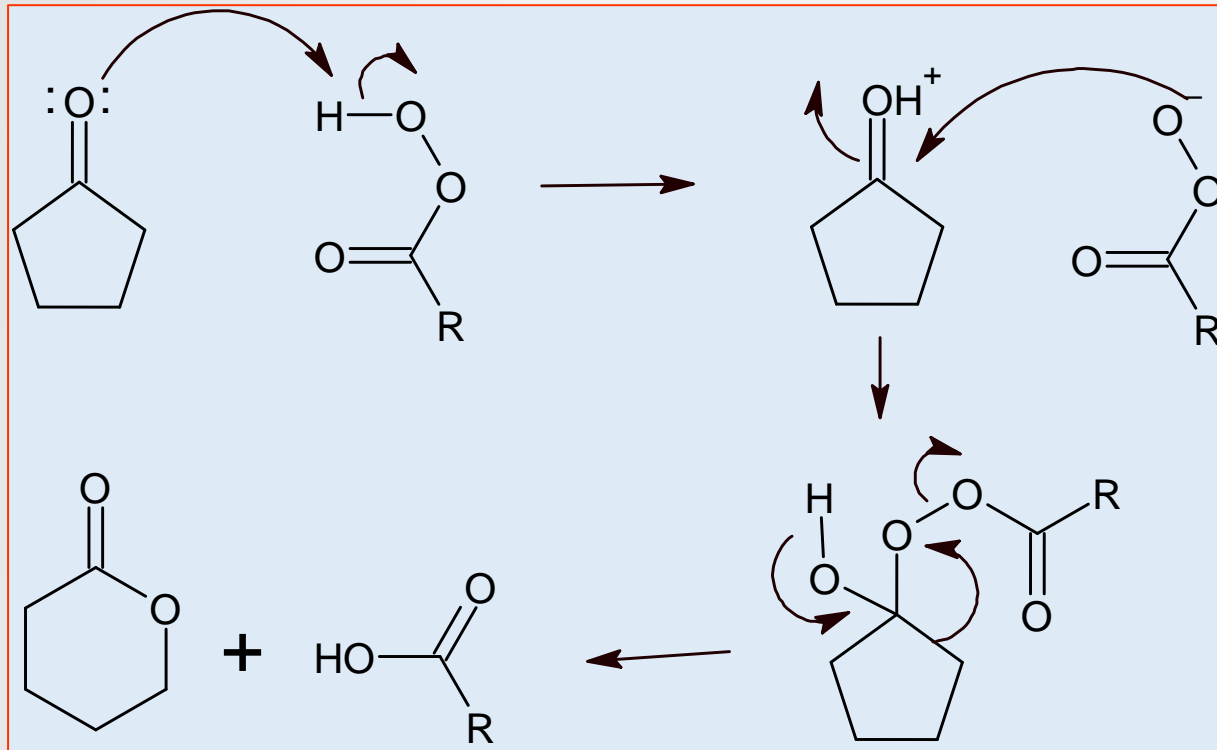
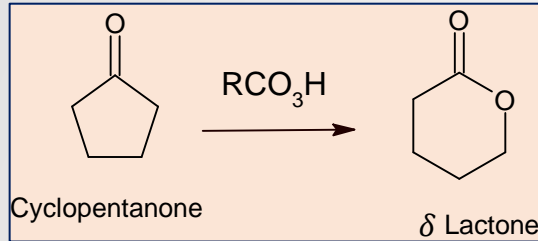


Baeyer-Villiger rearrangement

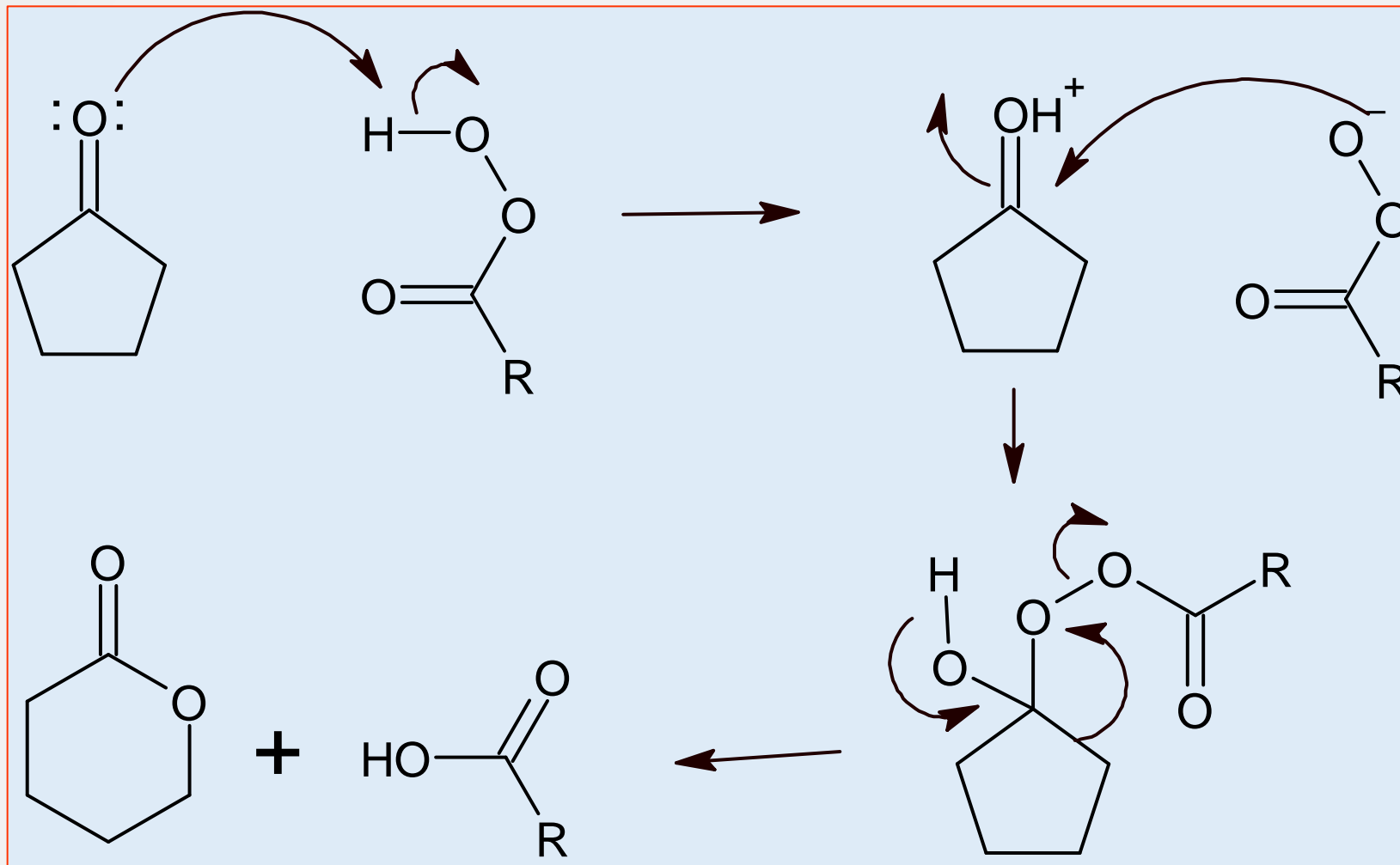
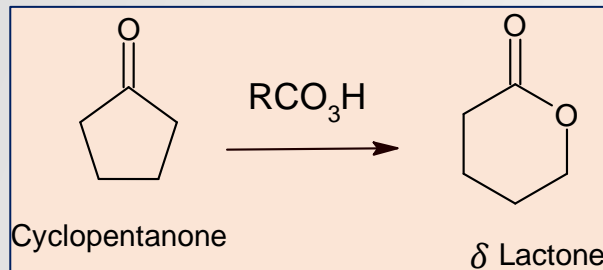
Mechanism



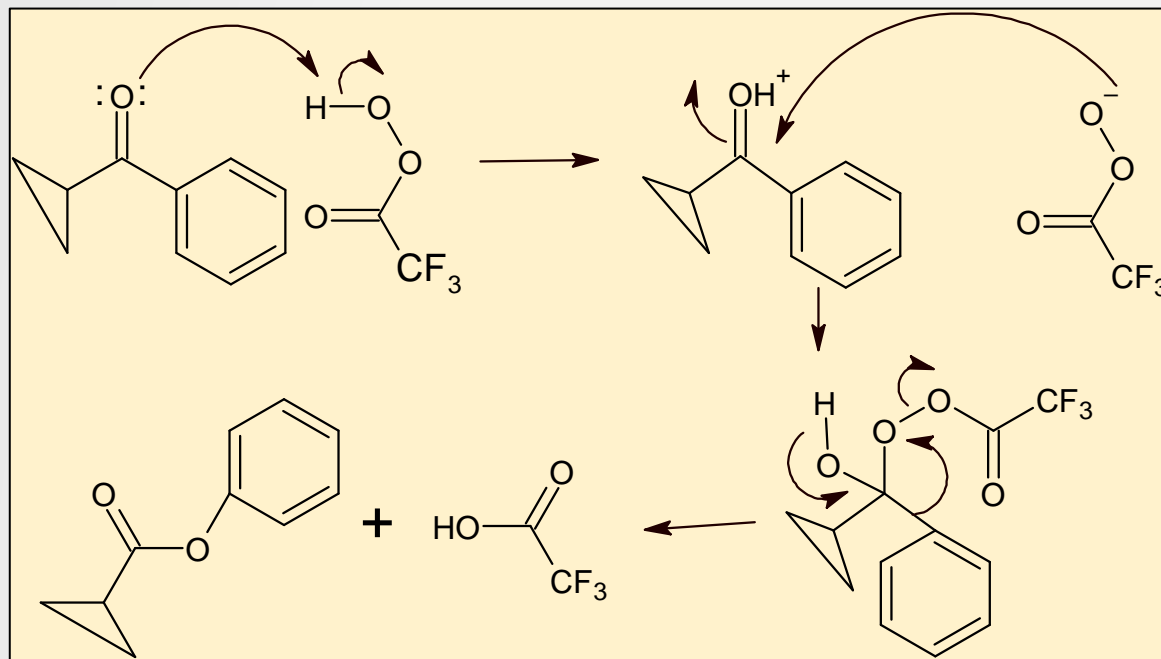
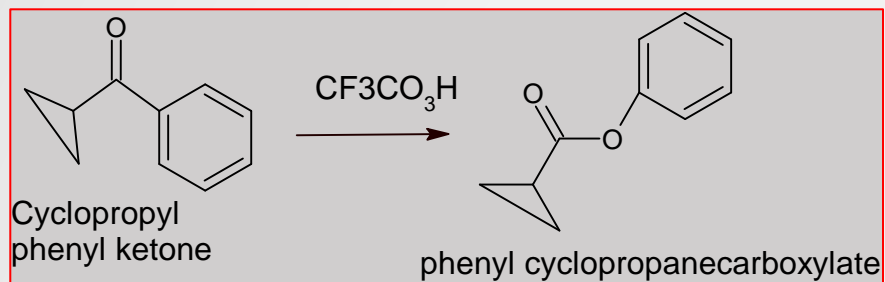
Baeyer-Villiger rearrangement



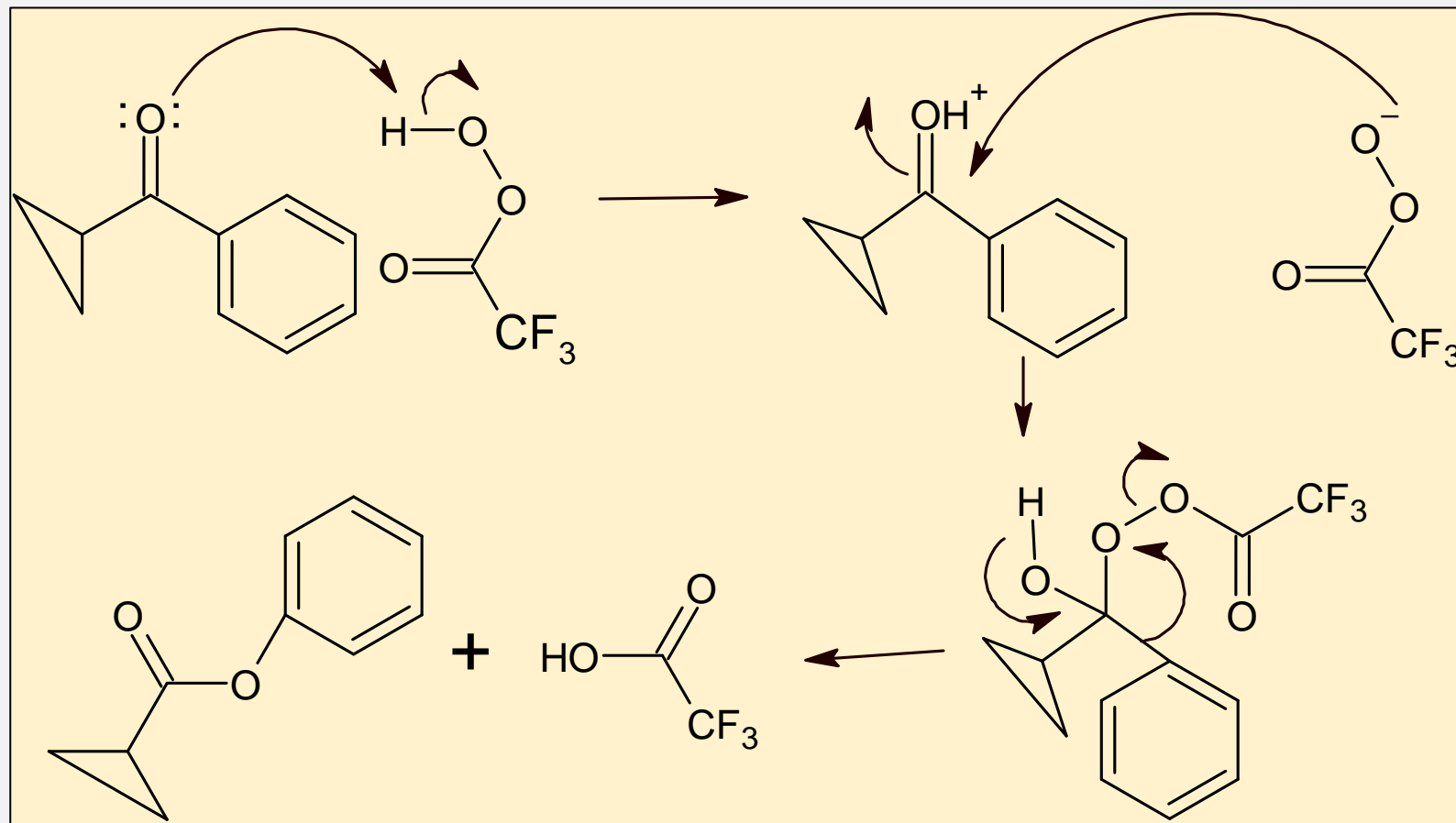
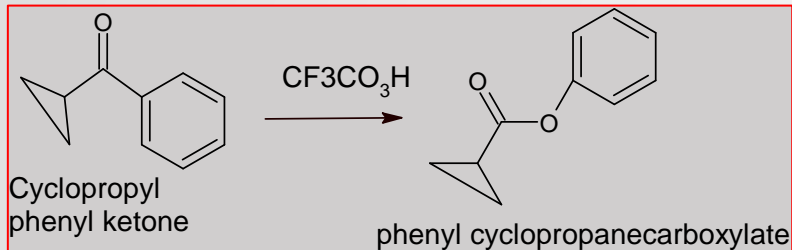
Baeyer-Villiger rearrangement



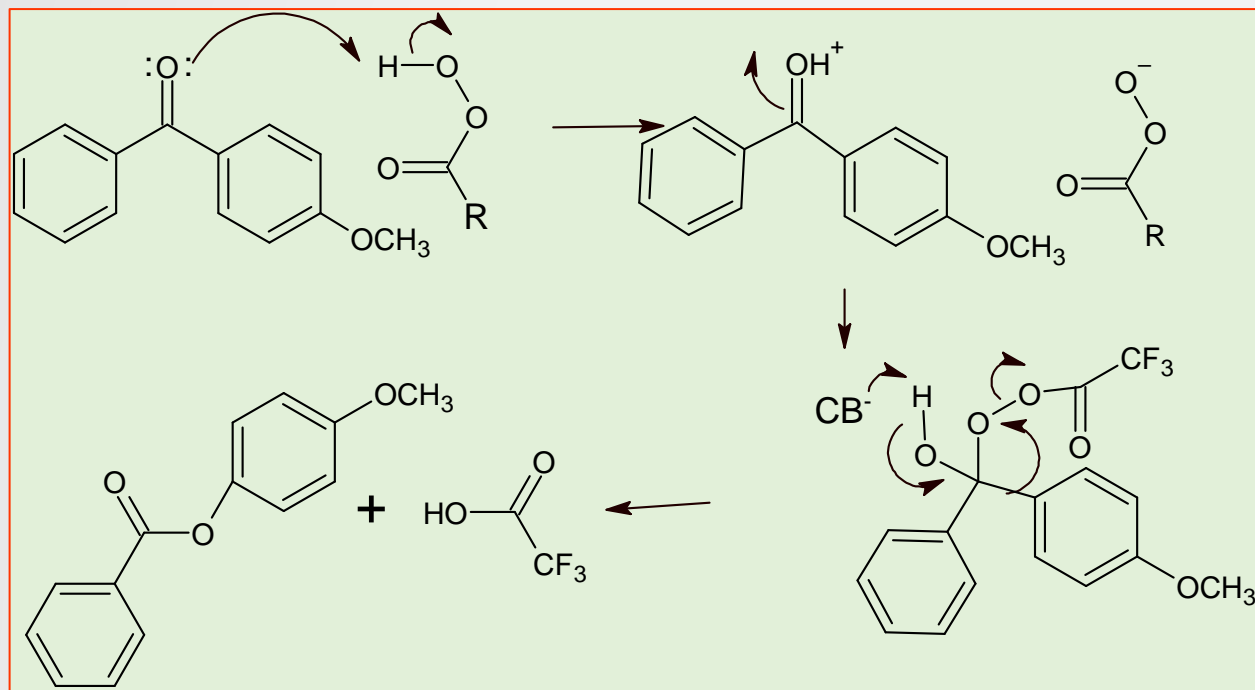
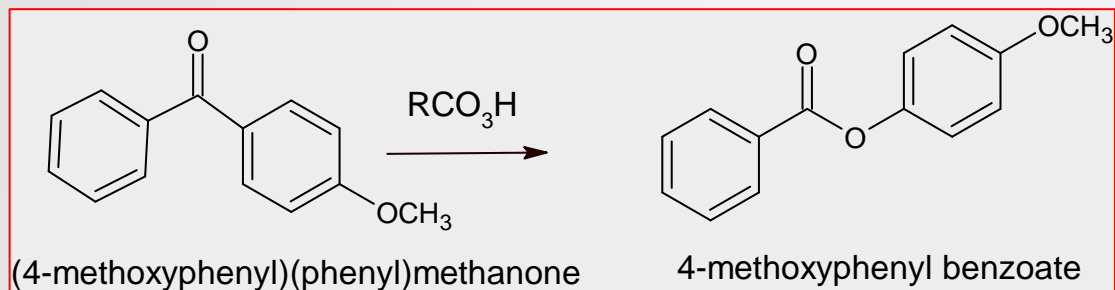
Baeyer-Villiger rearrangement



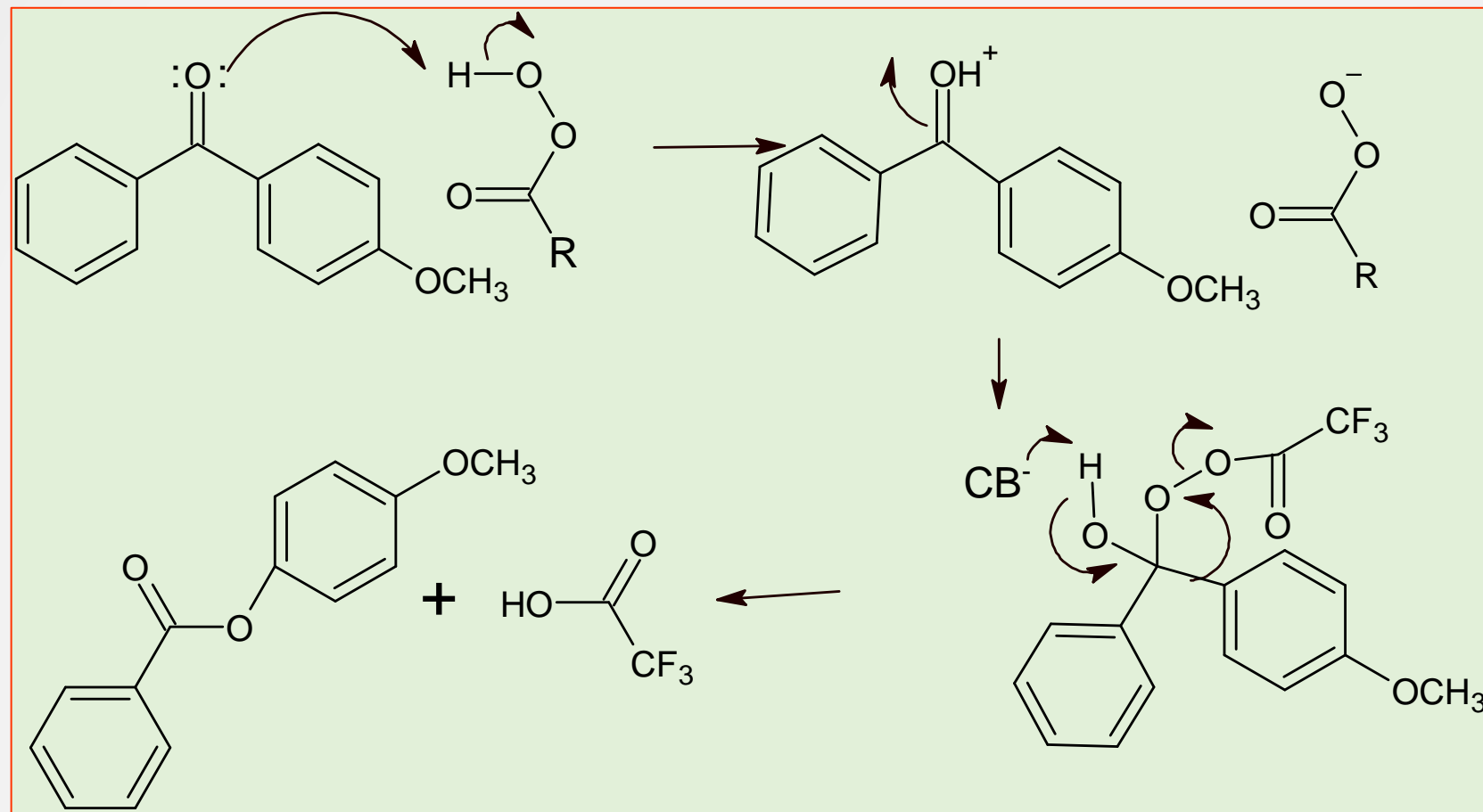
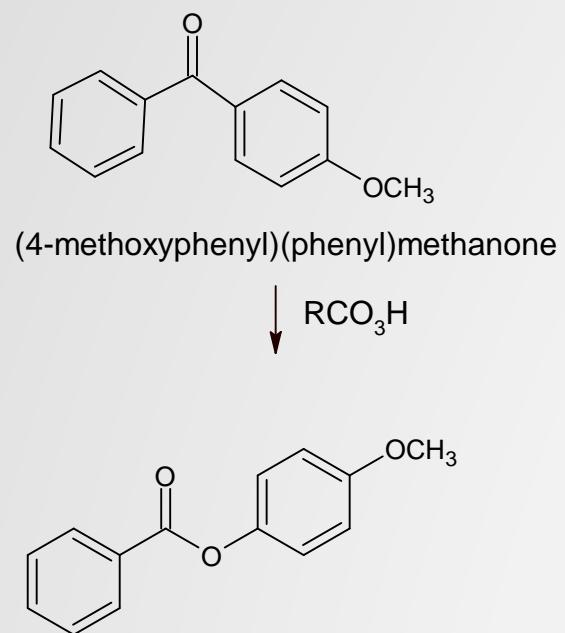
Baeyer-Villiger rearrangement



Baeyer-Villiger rearrangement



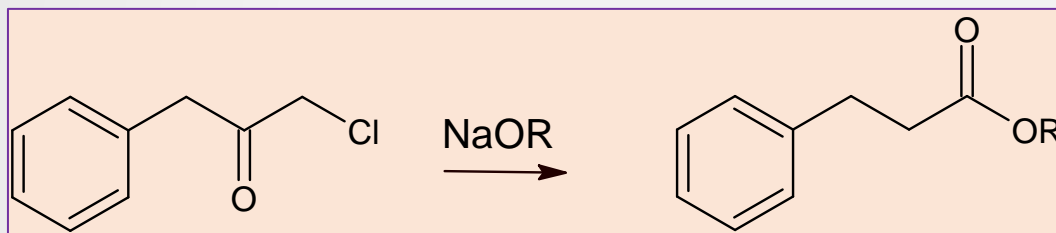
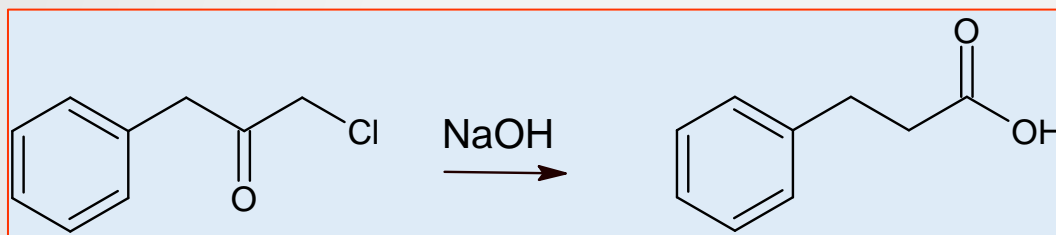
Baeyer-Villiger rearrangement



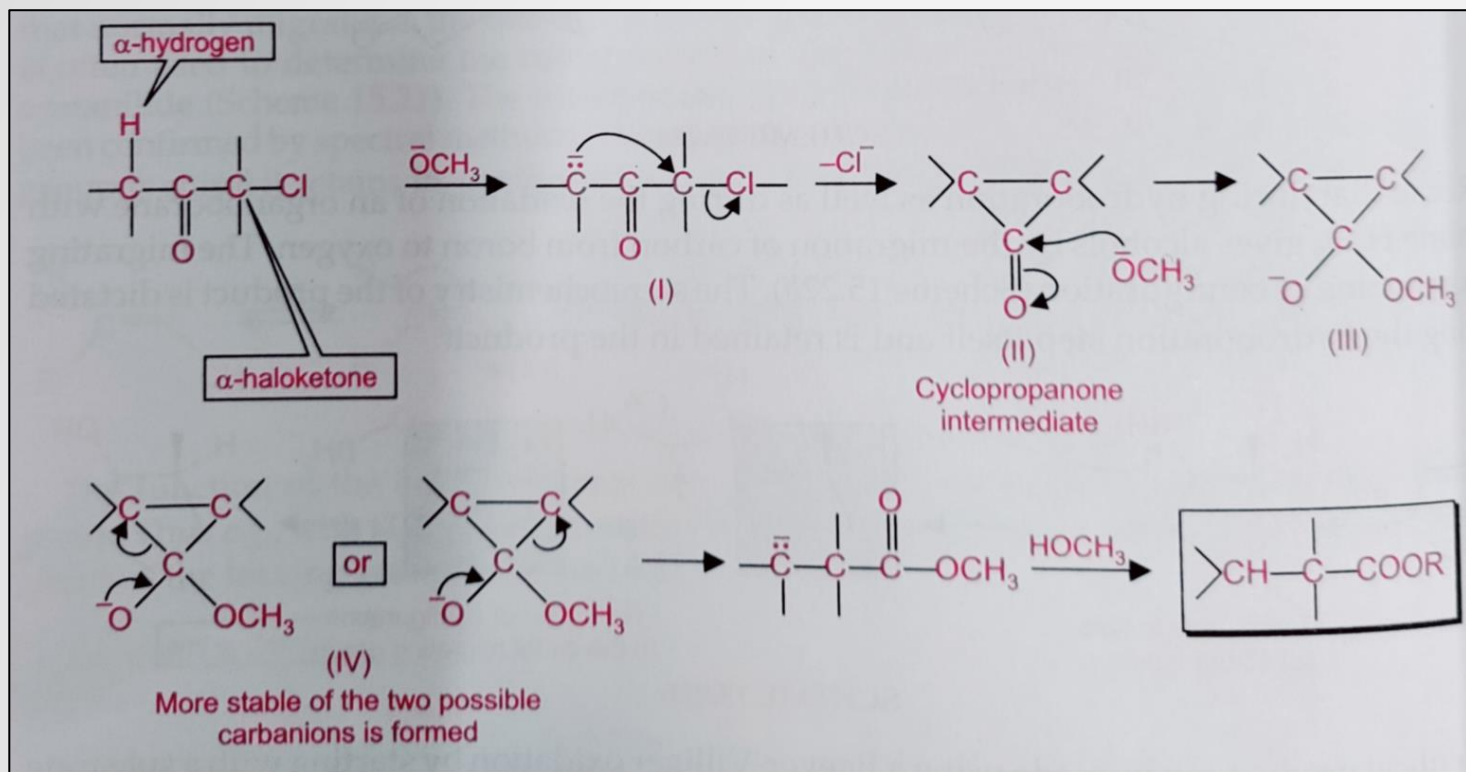
Favorskii rearrangement

Discovered by the Russian chemist Favorskii

α -Haloketones on treatment with strong base (hydroxide/alkoxide) undergo rearrangement and produce carboxylic acid or its derivatives via cyclopropenone intermediate.



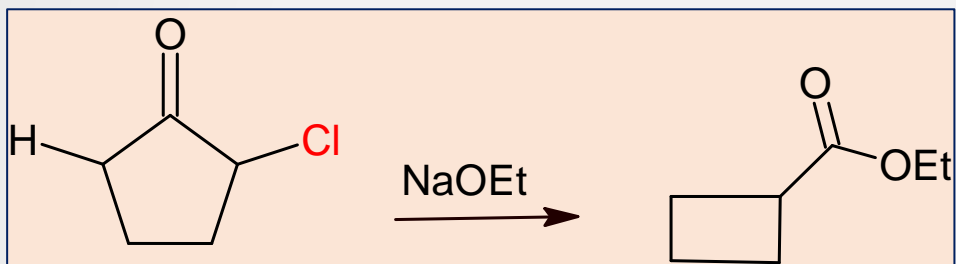
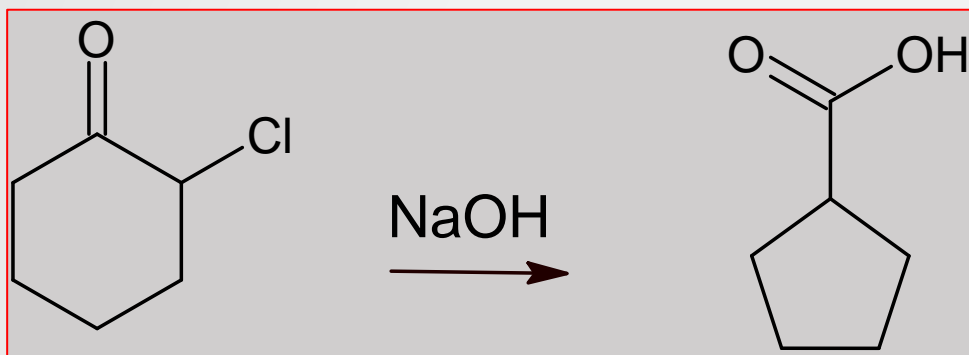
Favorskii rearrangement



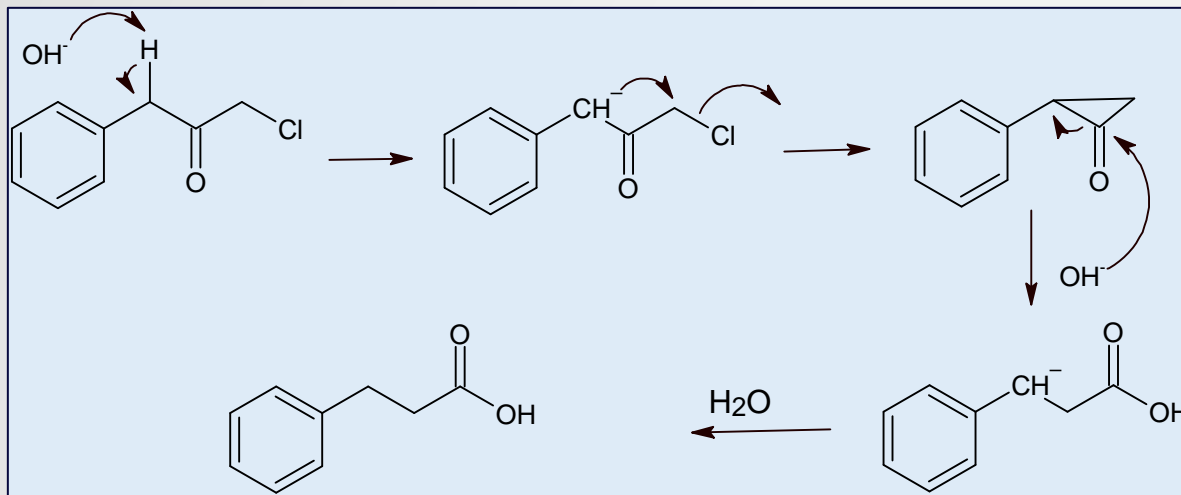
Ref. Organic reactions and their mechanisms by P.S. Kalsi

Favorskii rearrangement

In case of cyclic α -haloketone, ring contracted product is obtained.

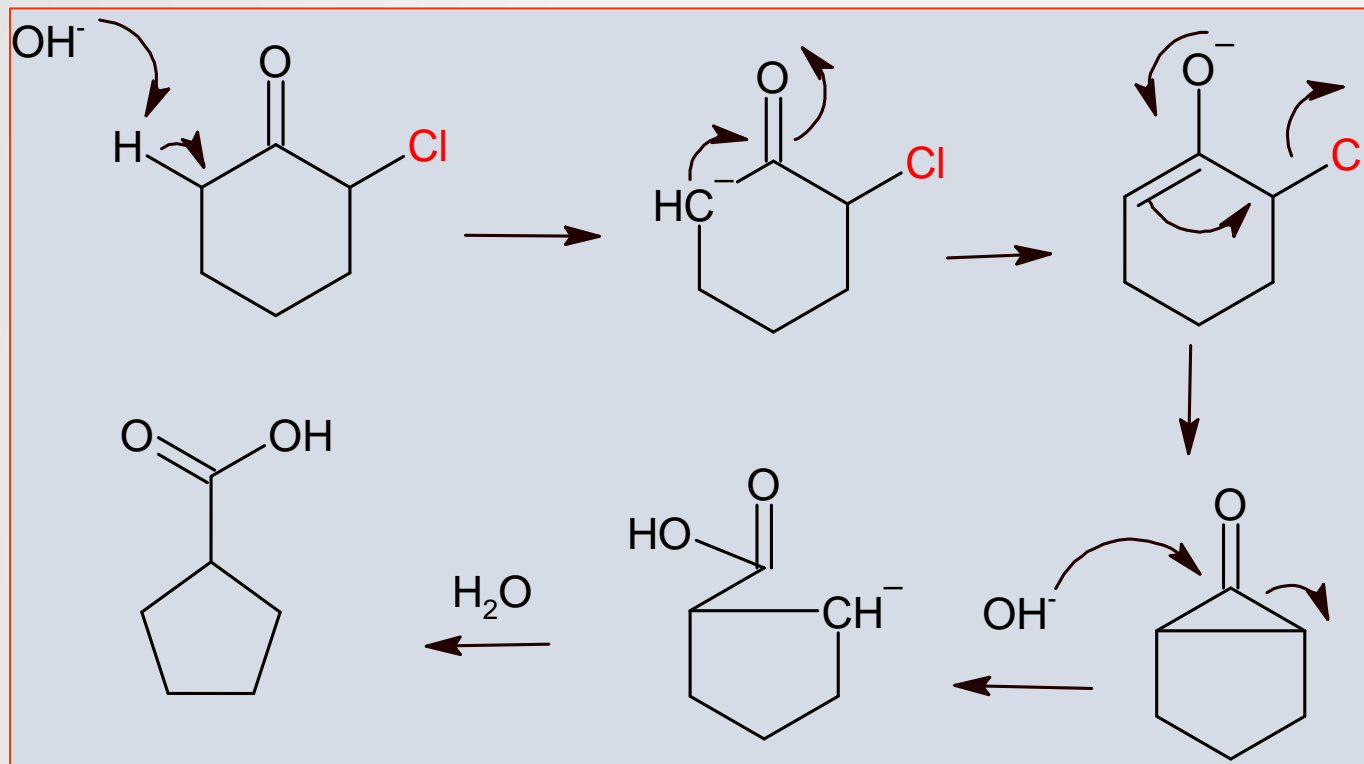
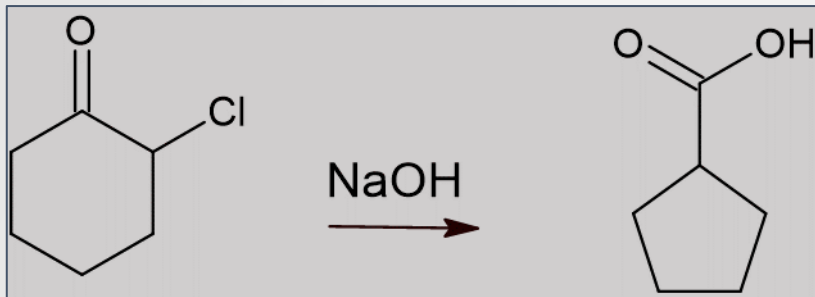


Favorskii rearrangement

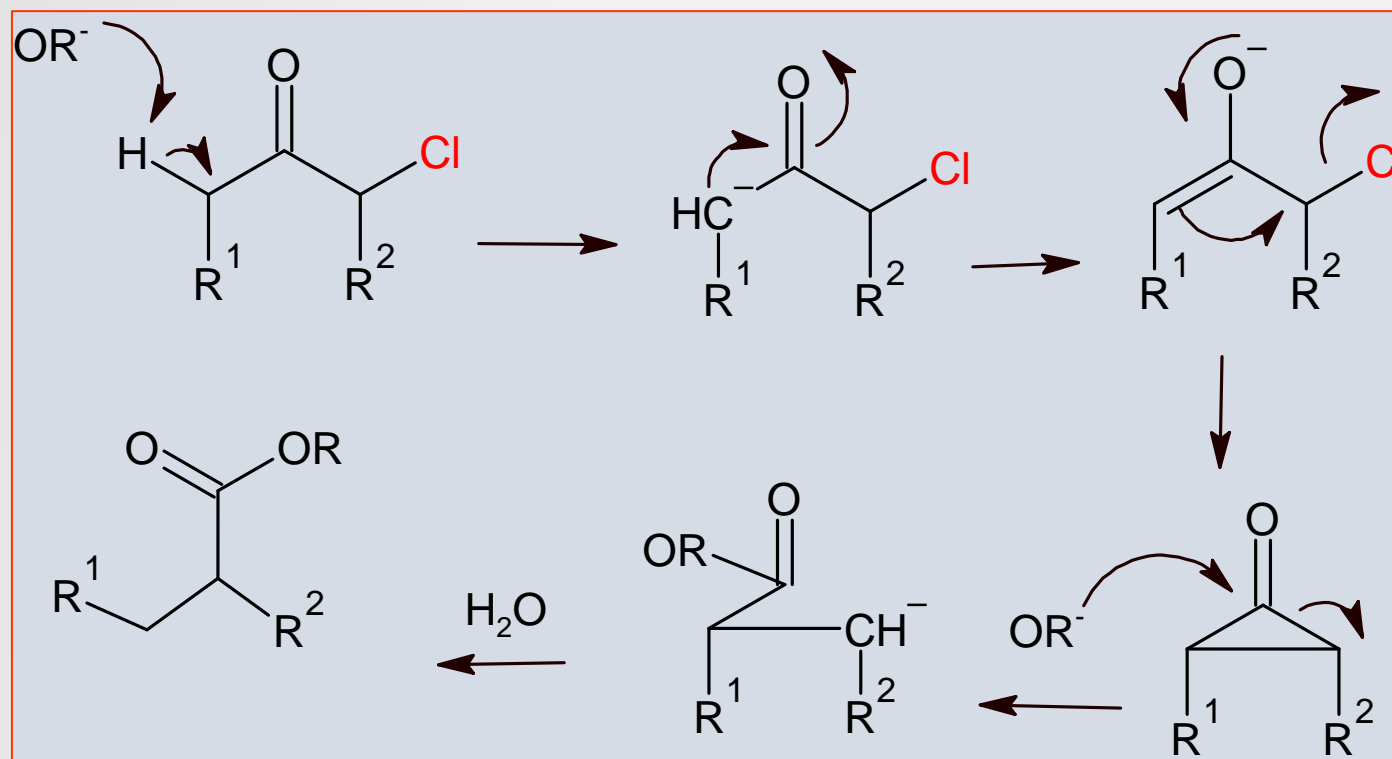
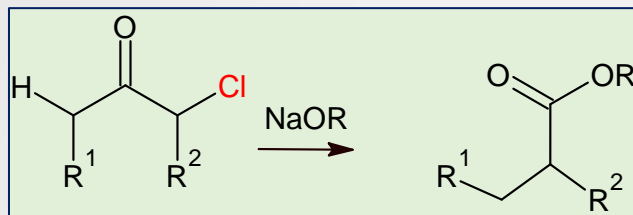


- Abstraction of α proton and formation of carbanion / enolate
- Formation of cyclopropenone ring intermediate
- Opening of an intermediate by attack of base
- Generation of corresponding anion
- Proton transfer from water/solvent

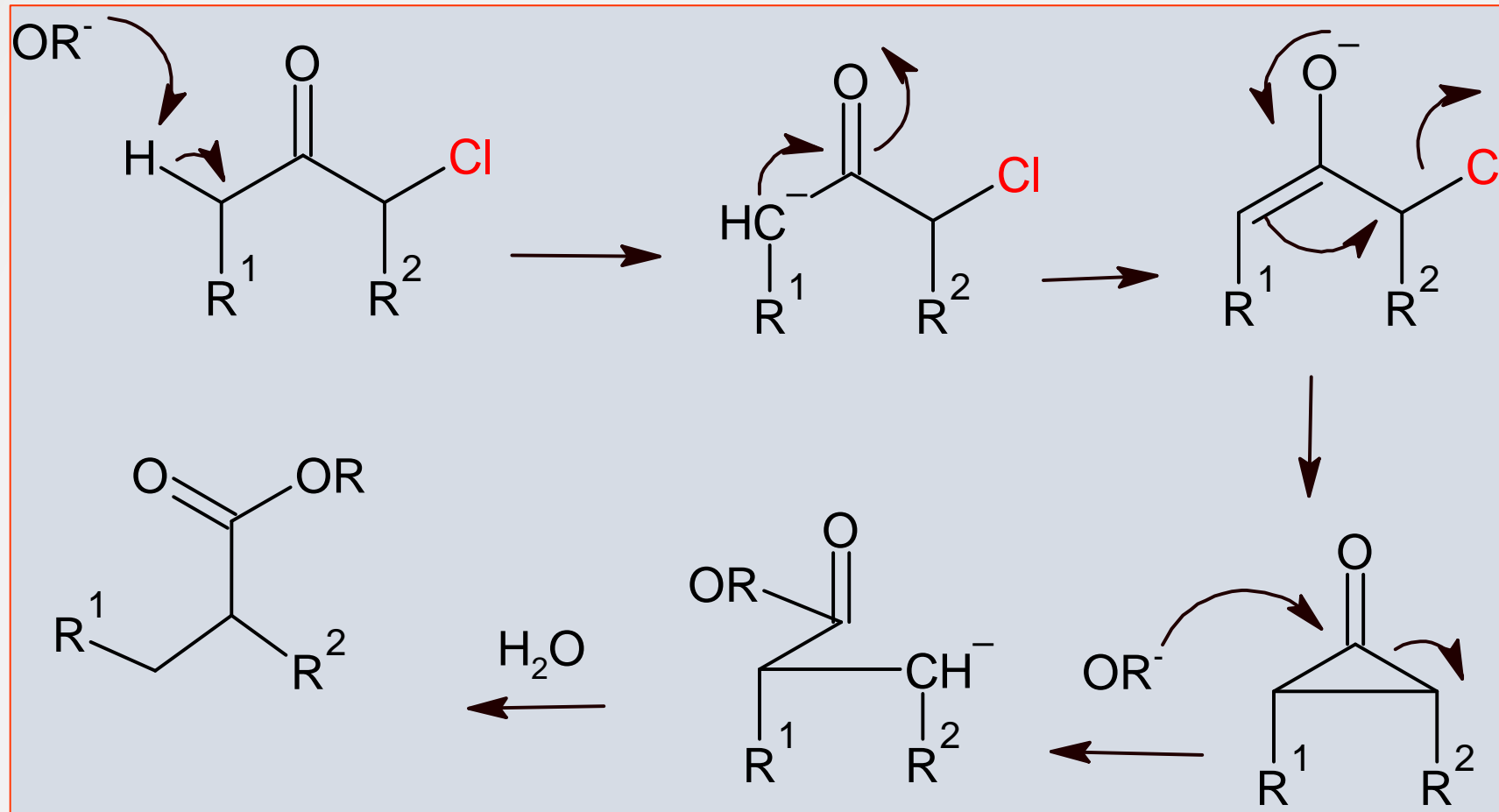
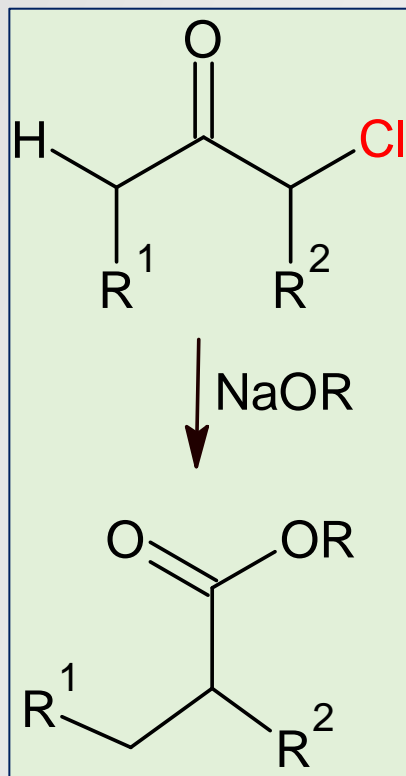
Favorskii rearrangement



Favorskii rearrangement

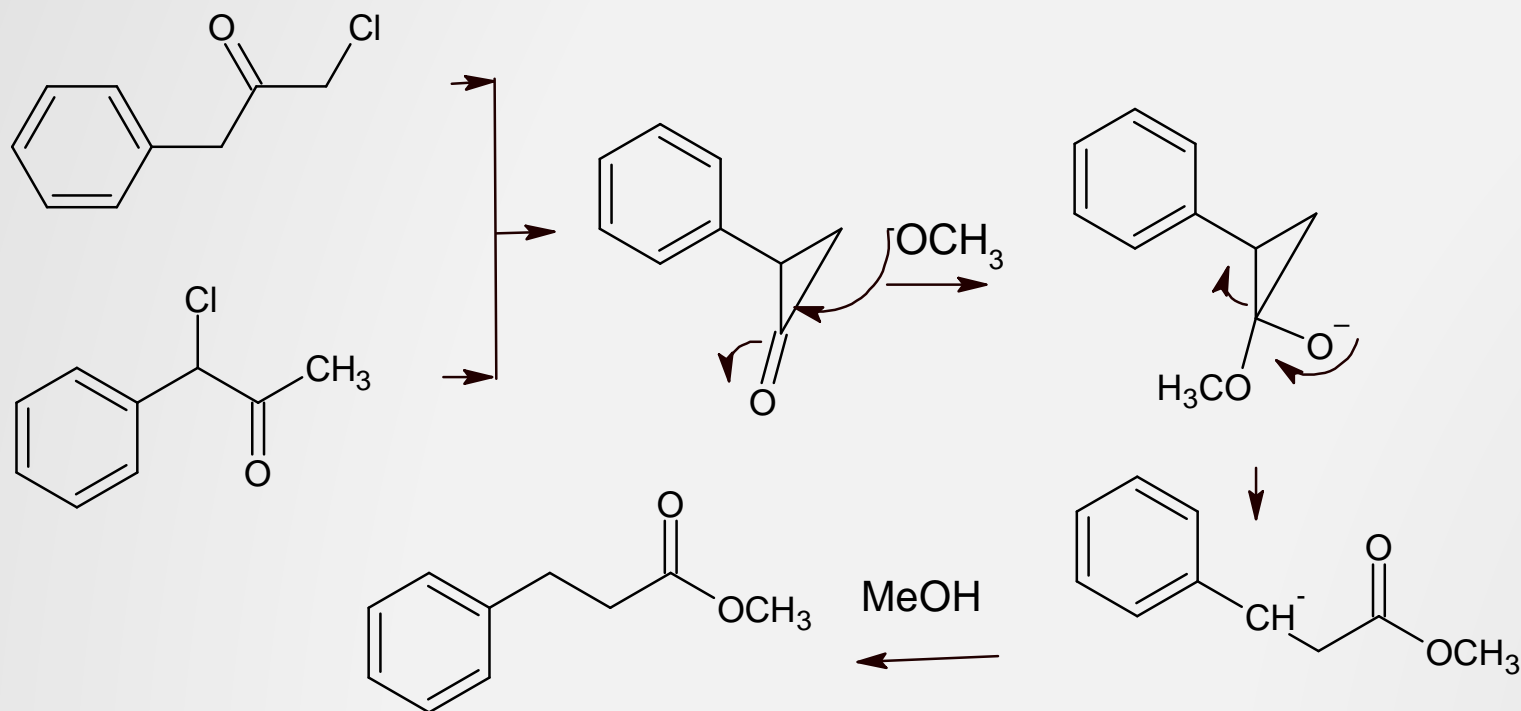


Favorskii rearrangement



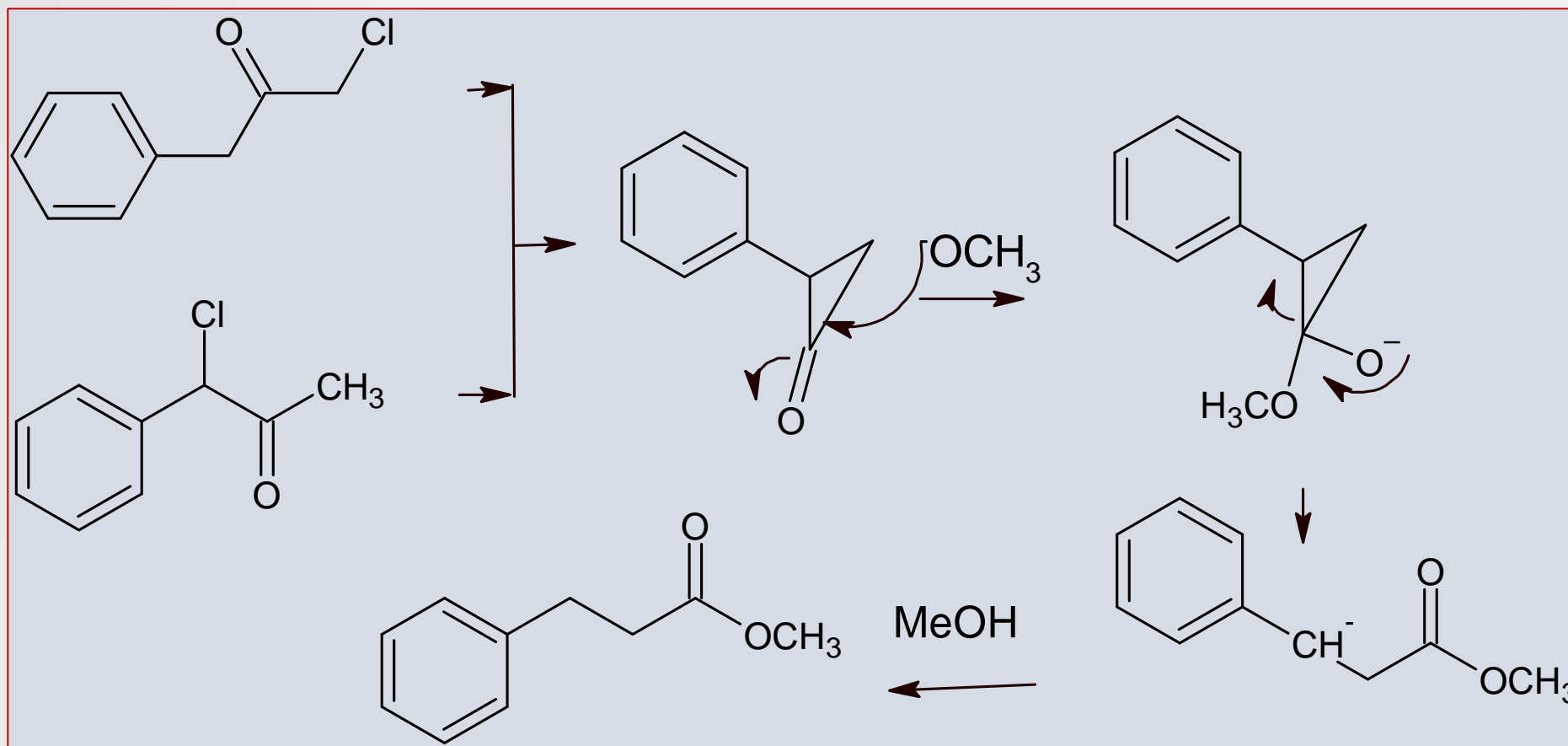
Favorskii rearrangement

The direction of ring opening of cyclopropanone is determined by the more stable carbanion formed in the reaction



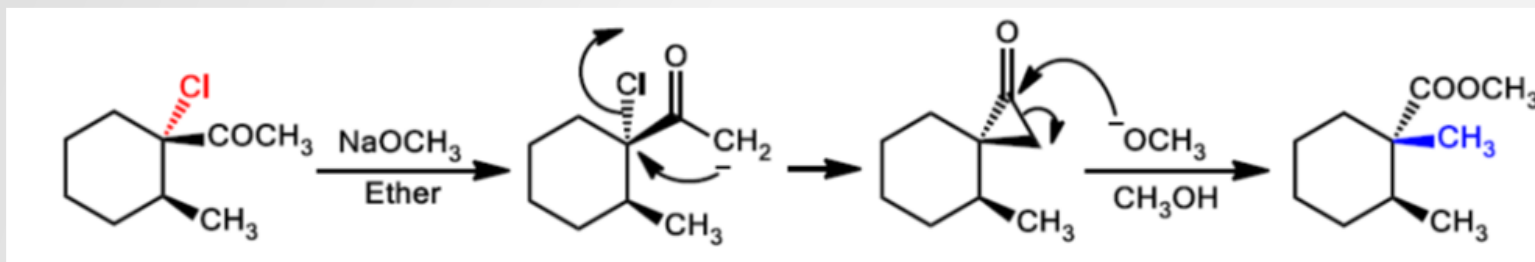
Favorskii rearrangement

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Favorskii rearrangement

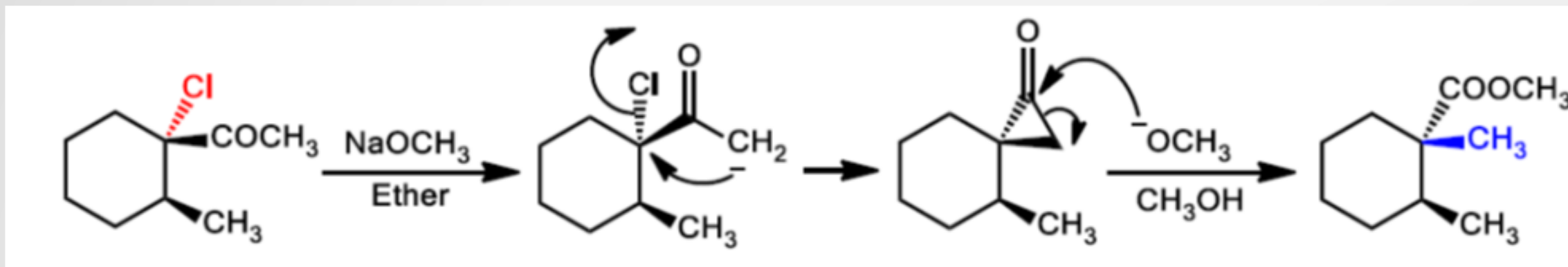
In some cases, intramolecular substitution take place.



In above reaction displacement of Cl group by CH_3 group take place

Favorskii rearrangement

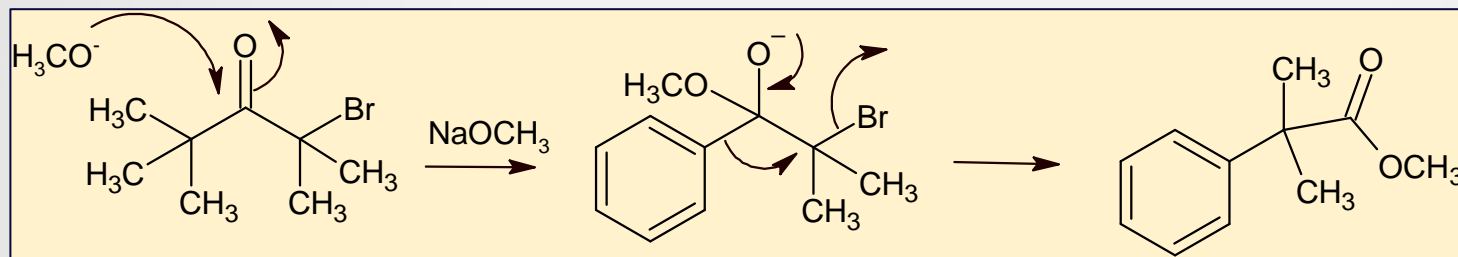
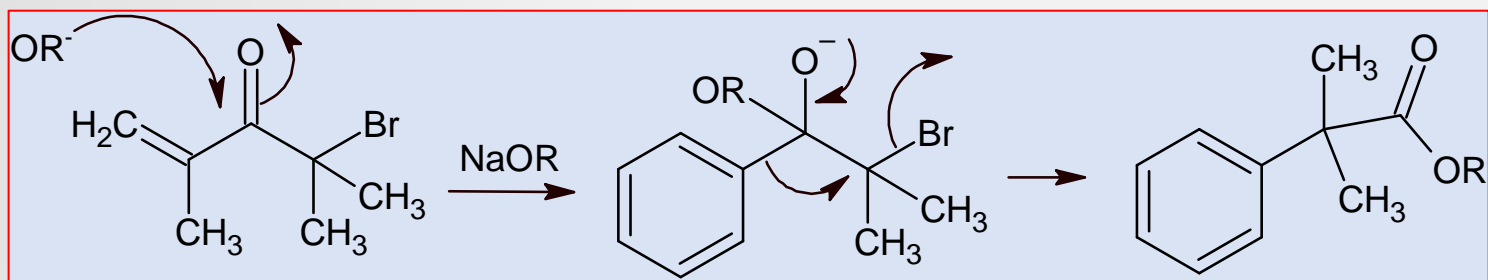
In some cases, intramolecular substitution take place.



In above reaction displacement of Cl group by CH₃ group take place

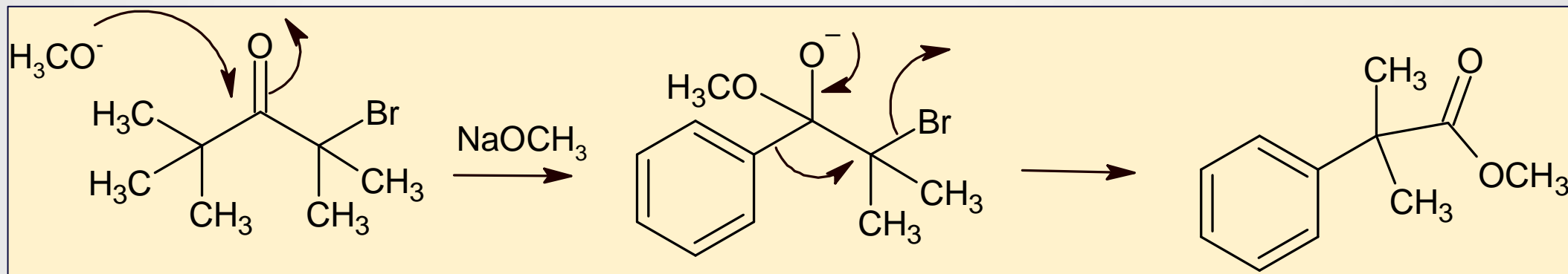
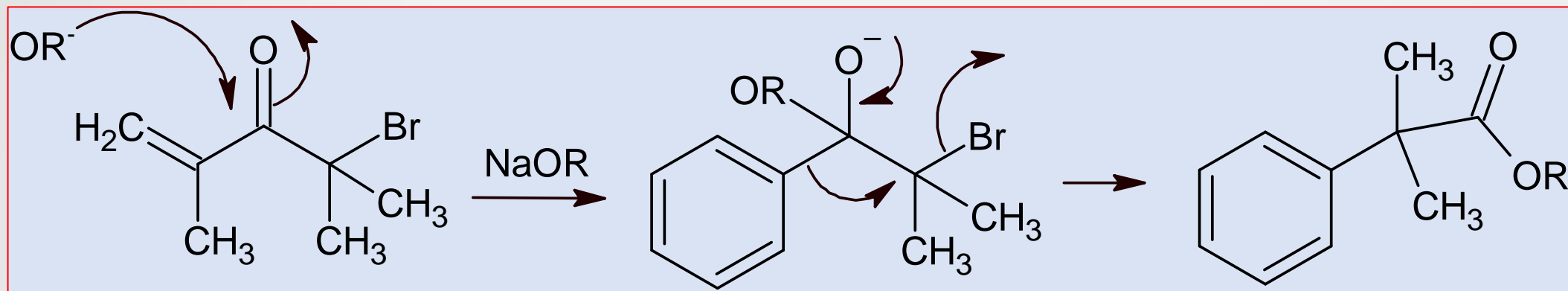
Quasi-Favorskii rearrangement

Ketone which does not have α hydrogen atom undergo a benzil-benzylic acid rearrangement and product obtain is similar to favorskii rearrangement



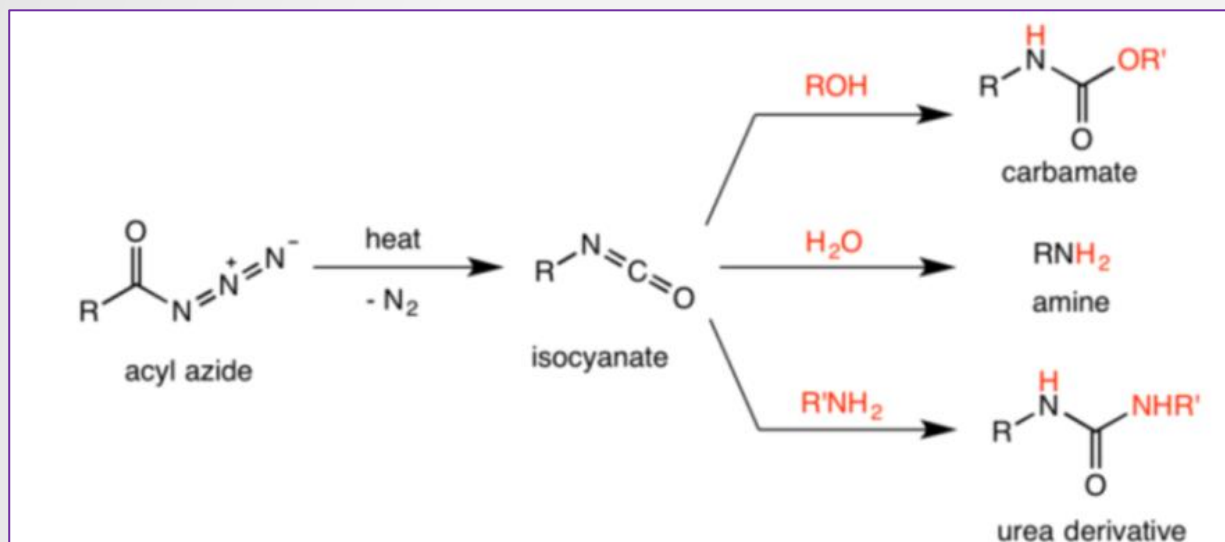
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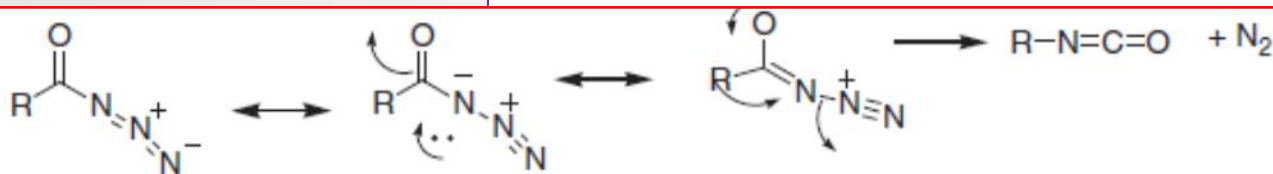
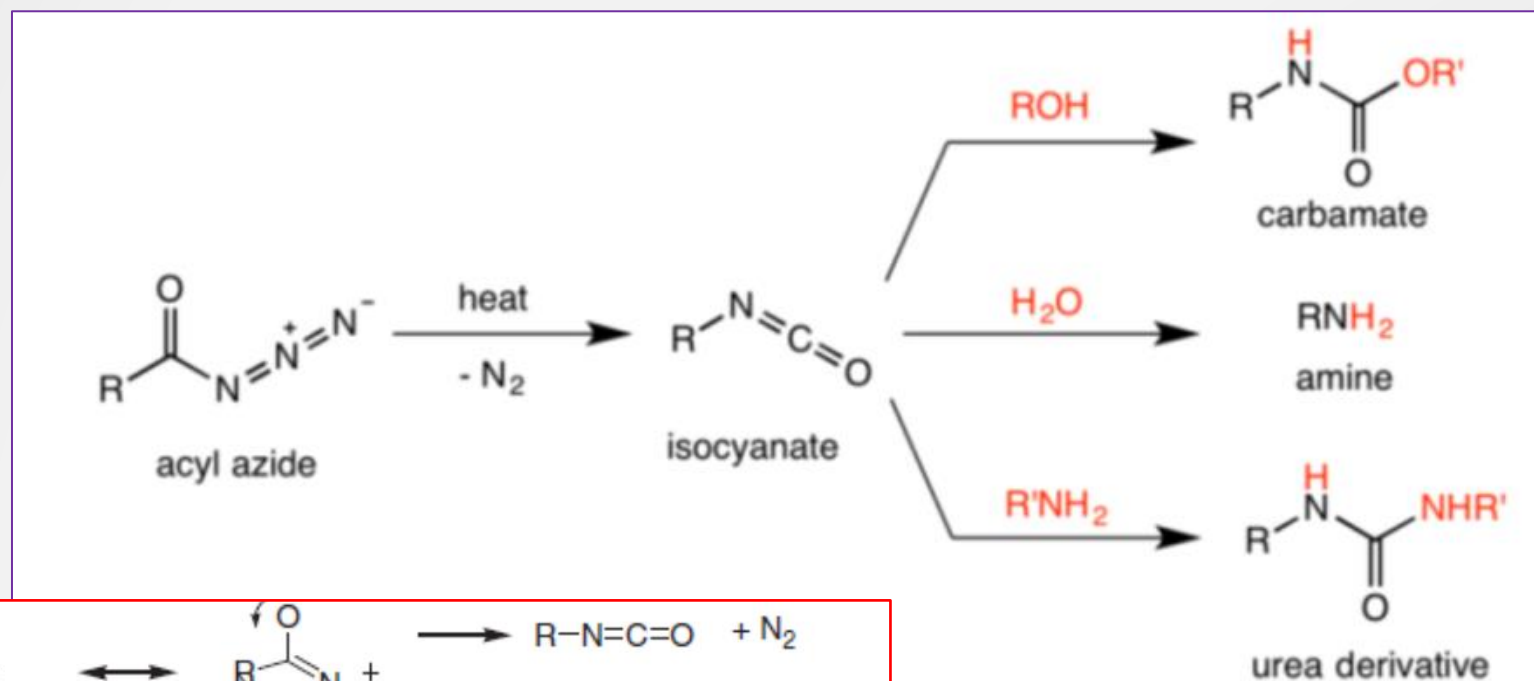
Curtius Rearrangement

- Thermal conversion of an acyl azide to an isocyanate via nitrene intermediate..
- Reaction of isocyanate with nucleophiles such as water, amines and alcohols, gives primary amine, carbamate or urea derivative respectively.



Curtius Rearrangement

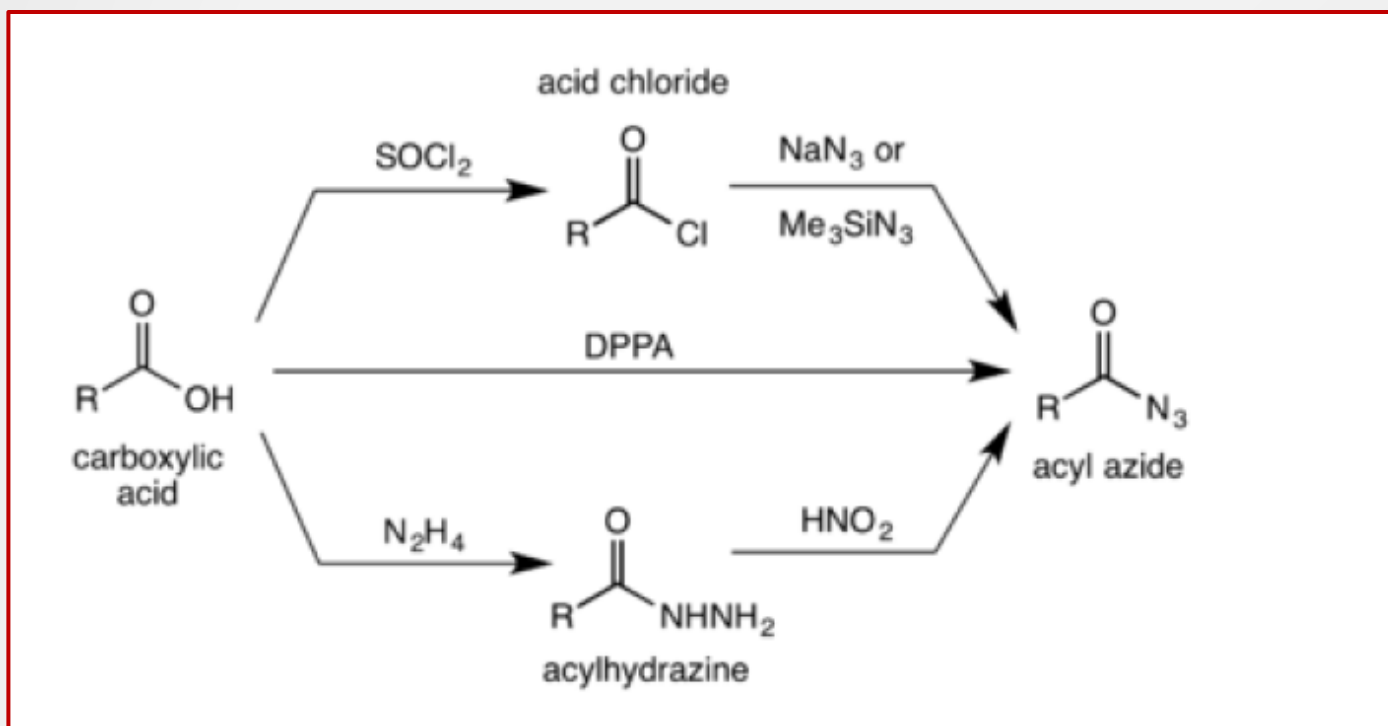
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Curtius Rearrangement

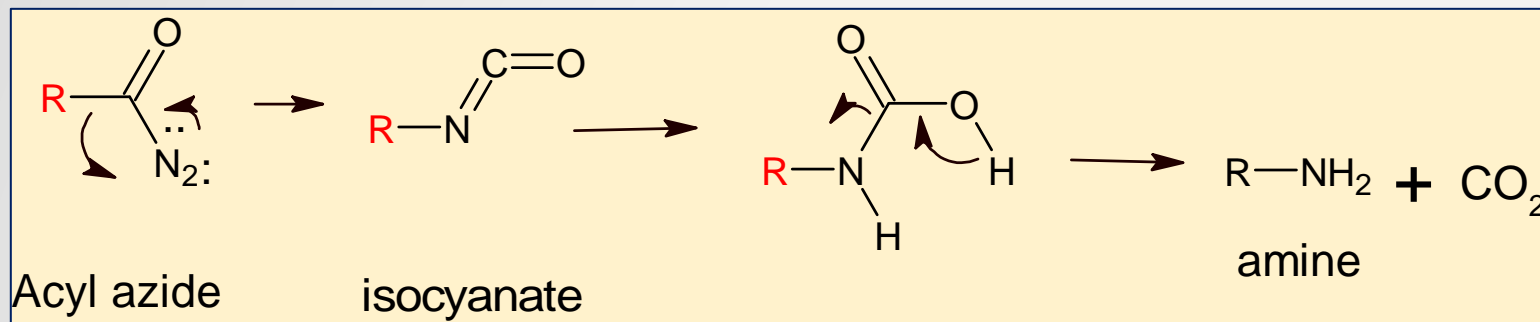
Preparation of acyl azide

- Reaction of acid chloride or acid anhydride with sodium azide
- Carboxylic acid on treatment with diphenyl phosphoryl azide
- Carboxylic acid on treatment with hydrazine followed by reaction with HNO_2



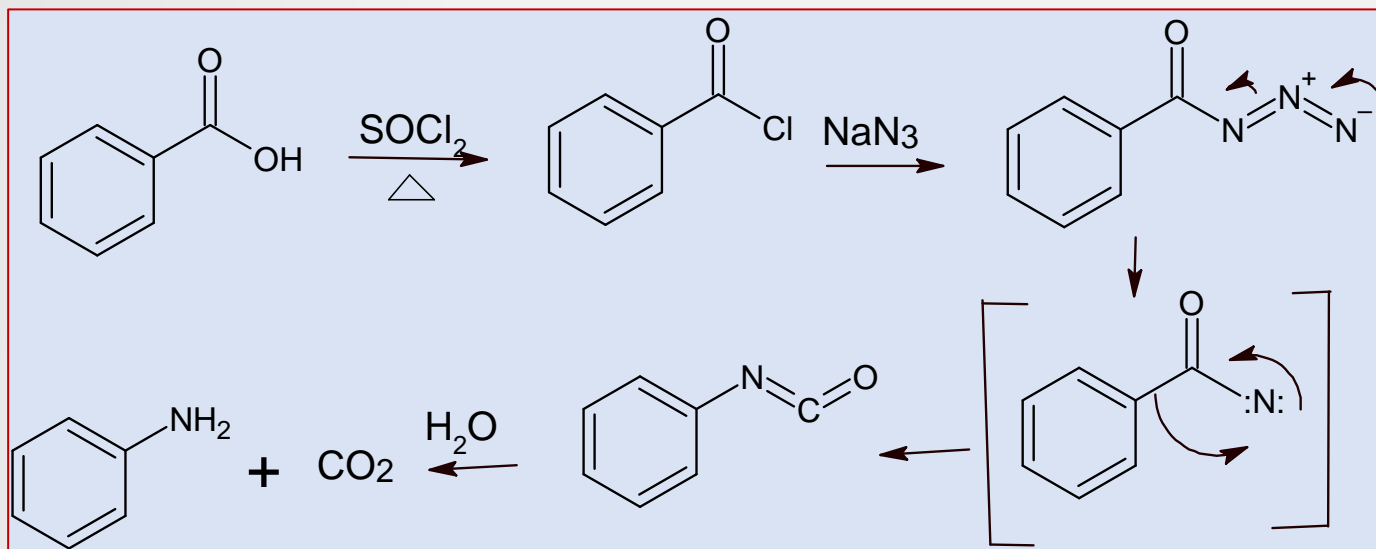
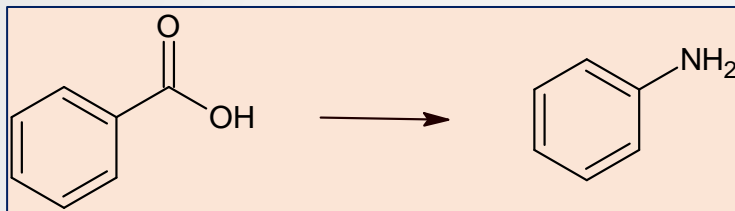
Curtius Rearrangement

Mechanism



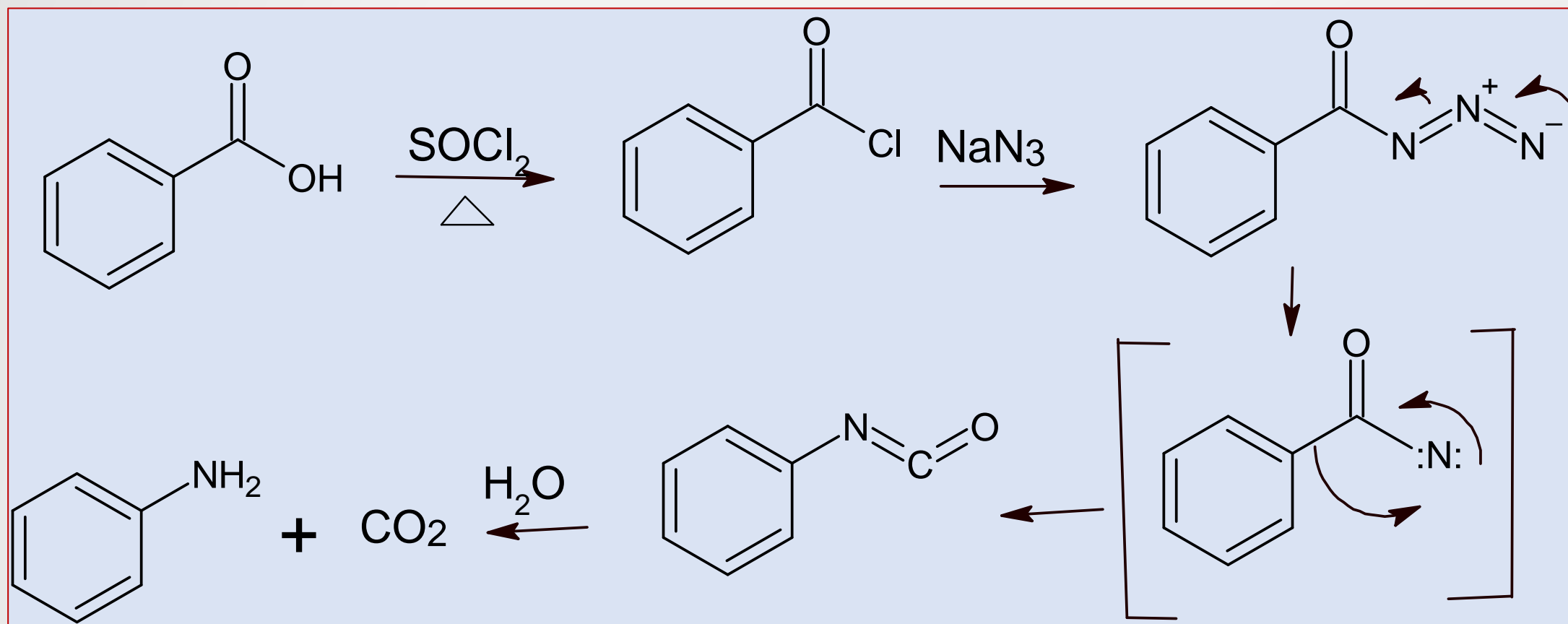
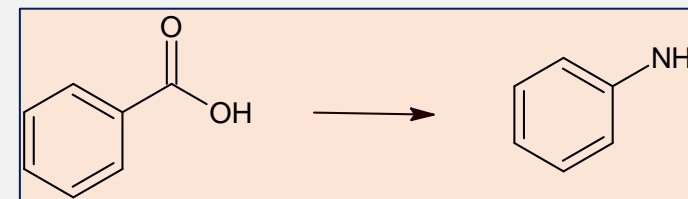
Curtius Rearrangement

Mechanism



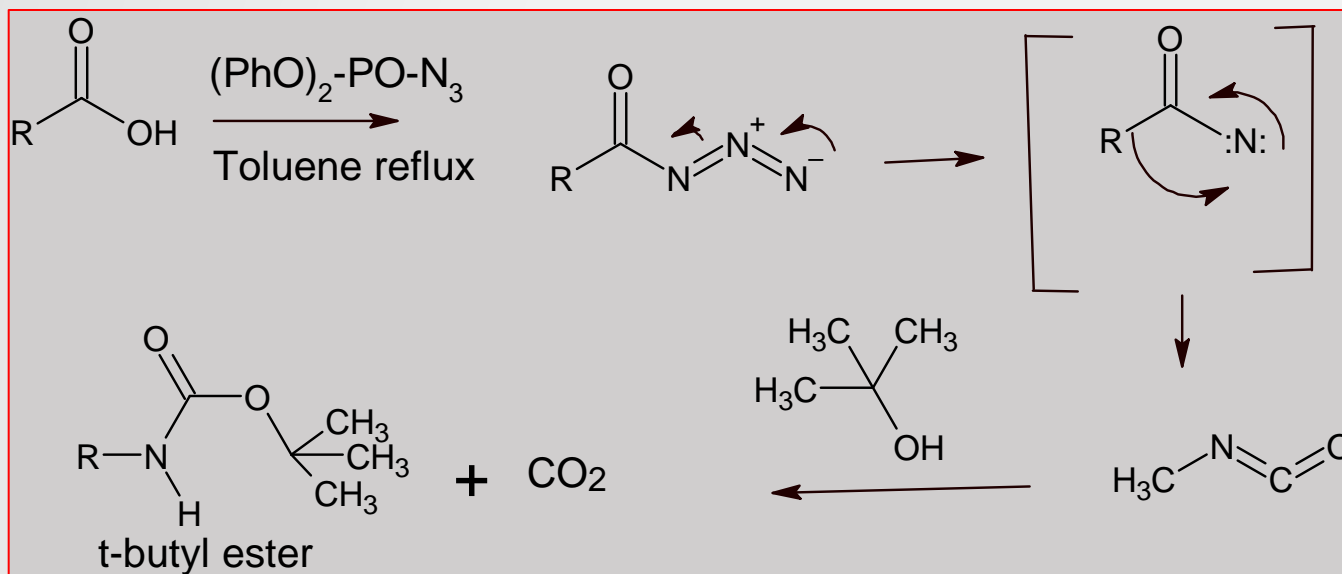
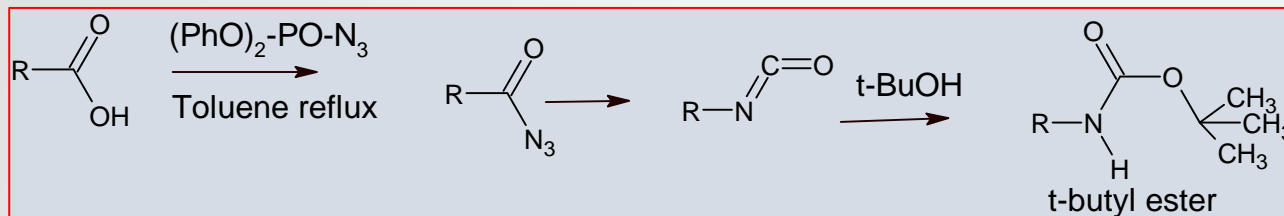
Curtius Rearrangement

Benzoic acid to aniline



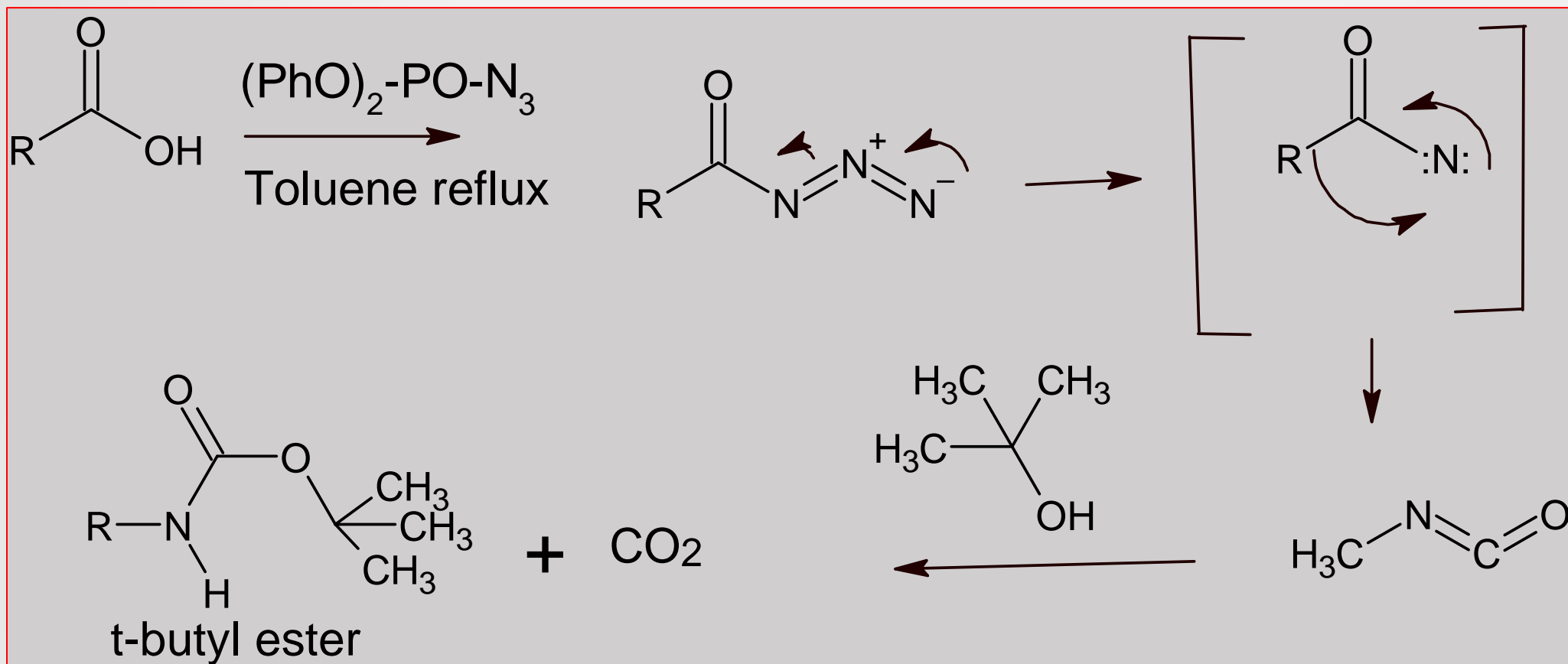
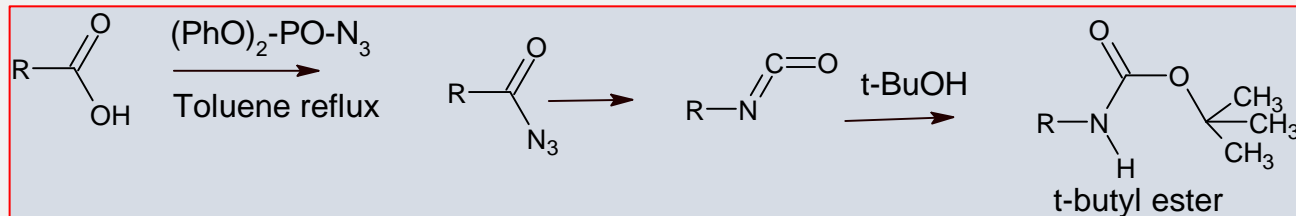
Curtius Rearrangement

Carboxylic acid to ester

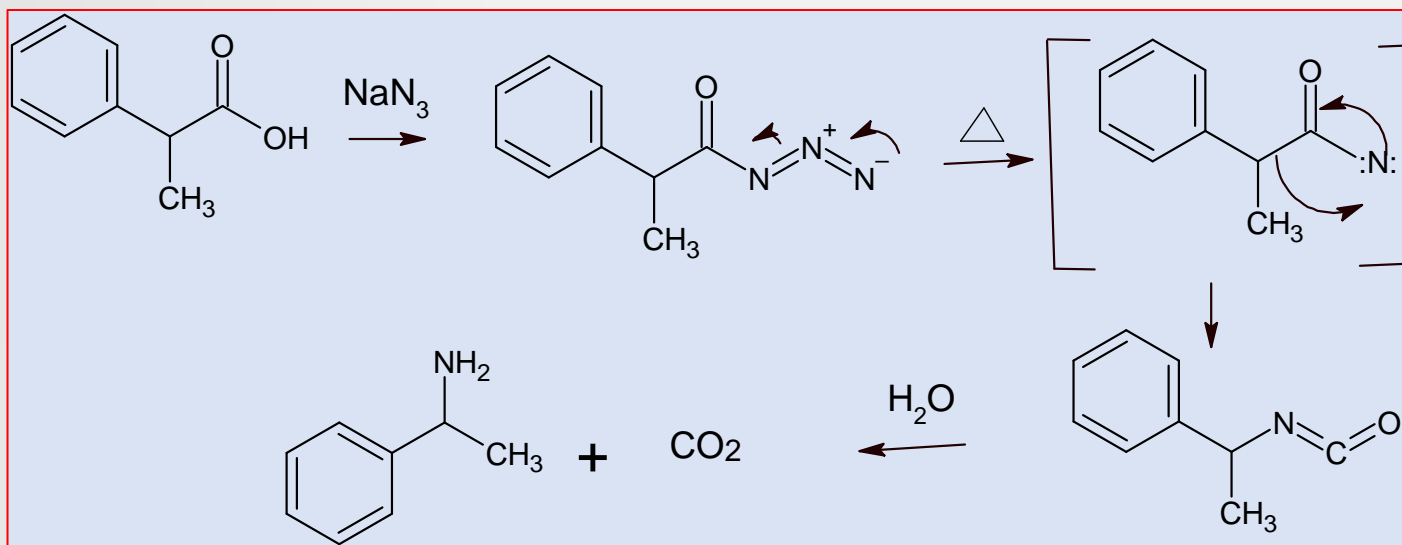
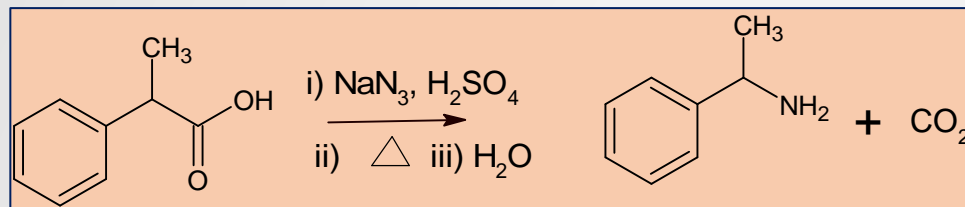


Curtius Rearrangement

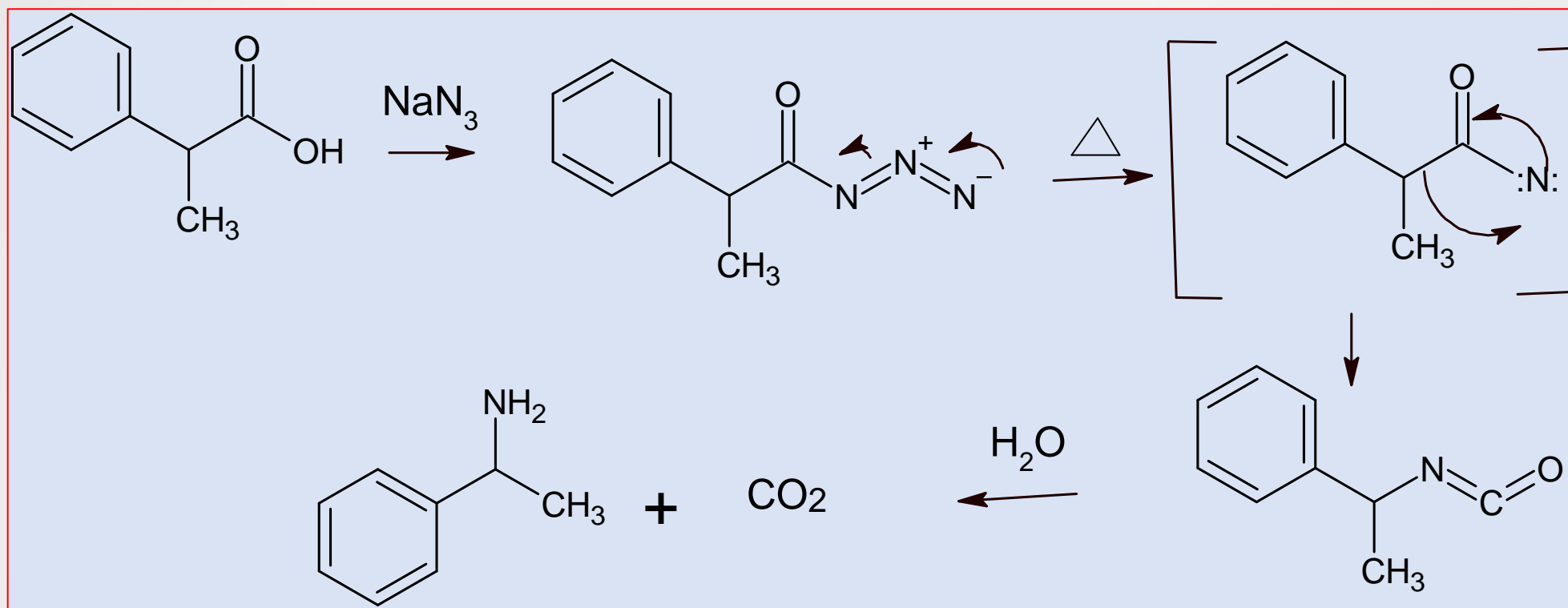
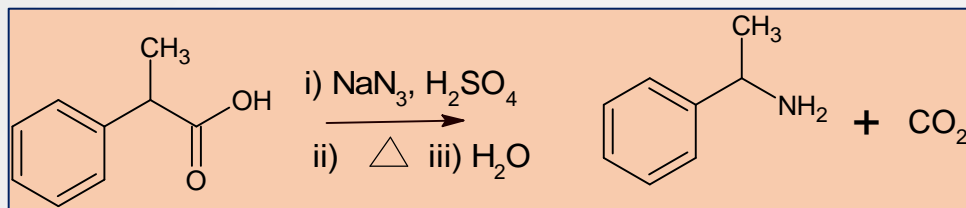
Carboxylic acid to ester



Curtius Rearrangement



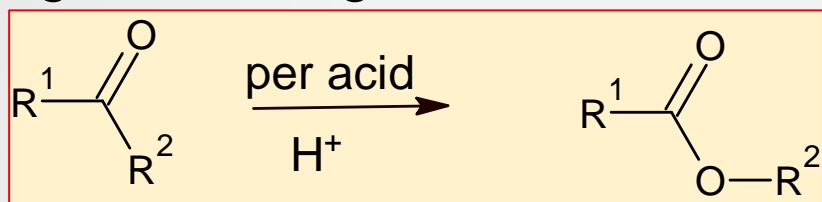
Curtius Rearrangement



Precap

Introduction , mechanism and examples of

➤ Baeyer-Villiger rearrangement



Catalyst: per benzoic acid, per acetic acid m-CPBA

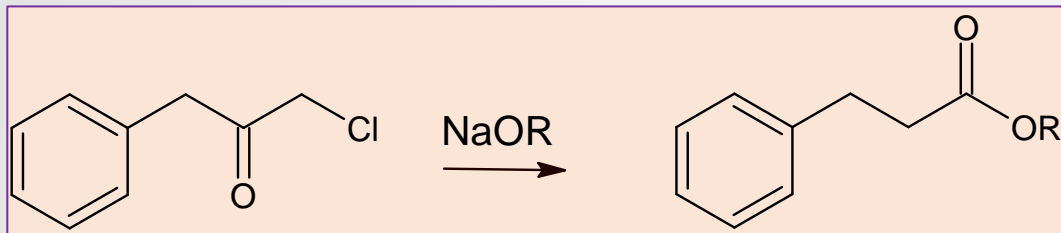
Migratory aptitude

3° alkyl > cyclohexyl > 2° alkyl > benzyl > phenyl > 1° alkyl > CH_3

Antiperiplanar geometry of migrating and leaving group

Precap

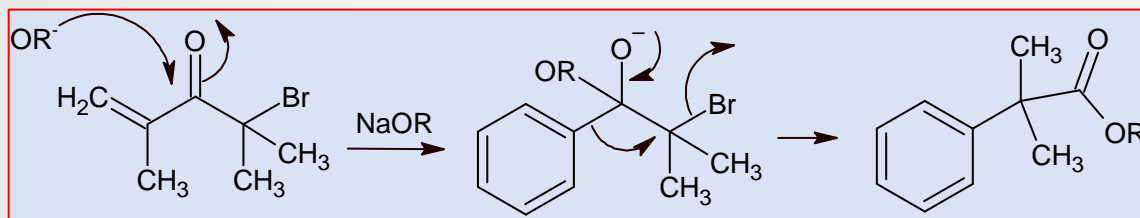
Favorskii rearrangement



α -Haloketones produce carboxylic acid or its derivatives via cyclopropenone intermediate.

cyclic α -haloketone undergo ring contraction

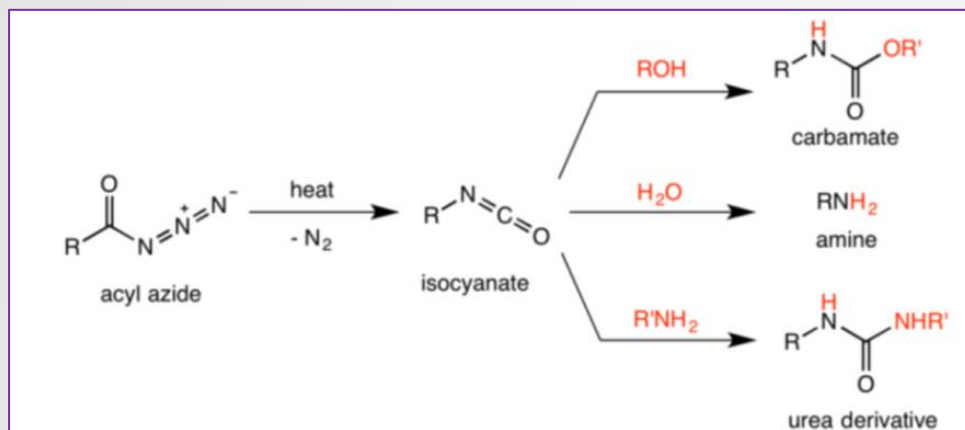
Quasi-Favorskii rearrangement



Ketone which does not have α hydrogen

Precap

➤ Curtius rearrangement



- Thermal conversion of an acyl azide to an isocyanate
- Reaction of isocyanate with nucleophiles such as water, amines and alcohols, gives primary amine, carbamate or urea derivative respectively.
- acyl azide are prepared by reaction of acid chloride or acid anhydride with sodium azide

SESSION AGENDA



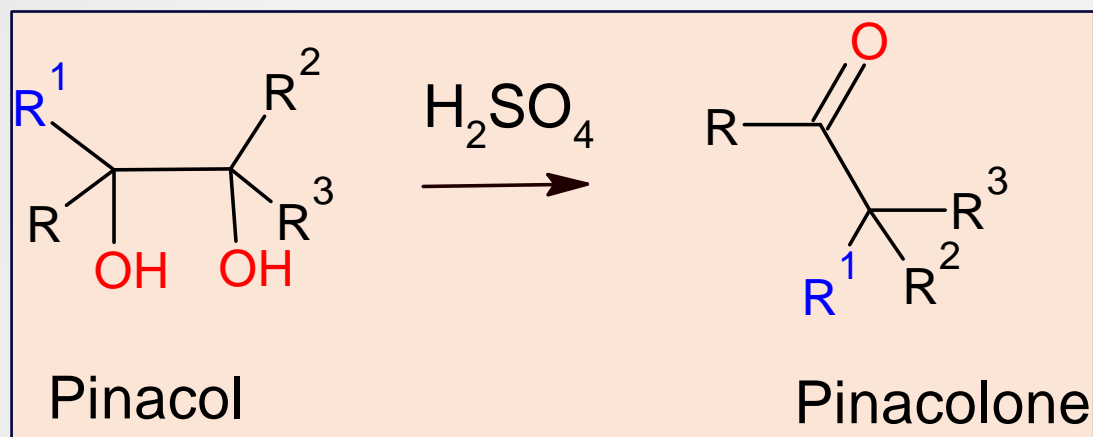
Introduction, Mechanism and examples of

- Pinacol-Pinacolone Rearrangement,
- Lossen Rearrangement and
- Schmidt Rearrangement

Pinacol-Pinacolone Rearrangement

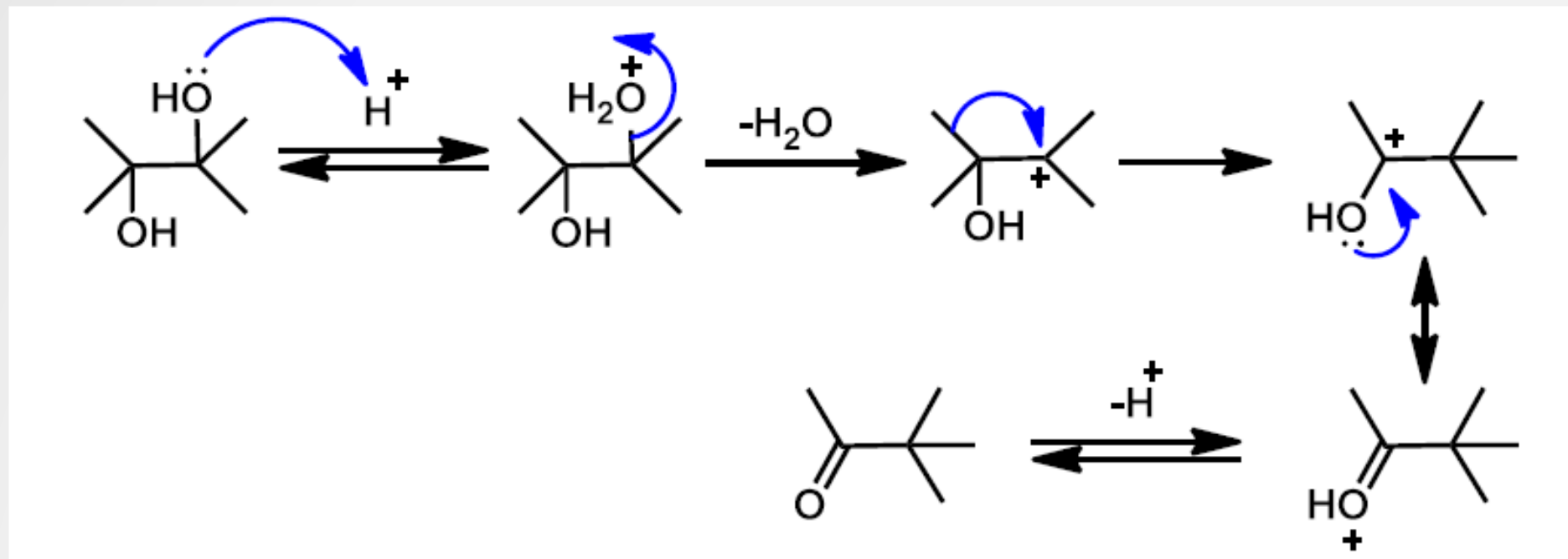
Reaction was first described by scientist Fittig in 1860.

Acid catalysed rearrangement of vicinal diol to aldehyde or ketone is called Pinacol-Pinacolone Rearrangement



Pinacol-Pinacolone Rearrangement

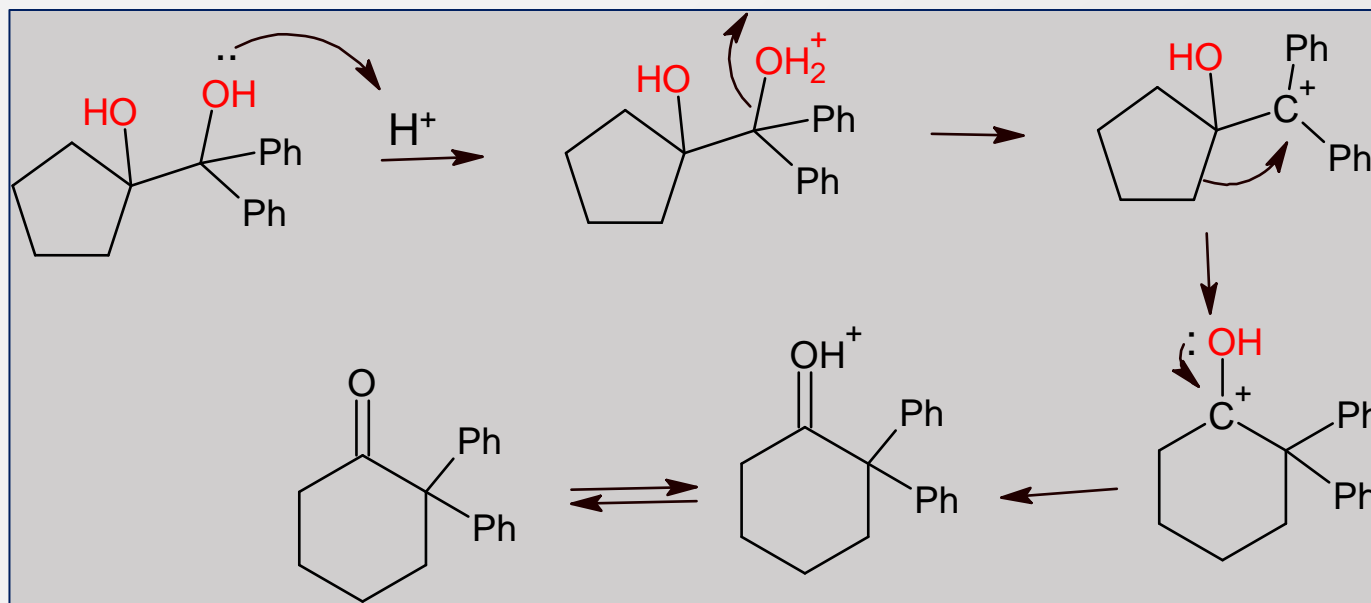
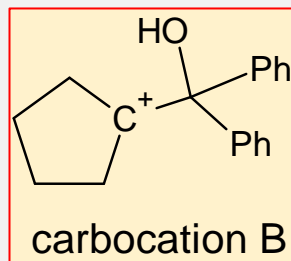
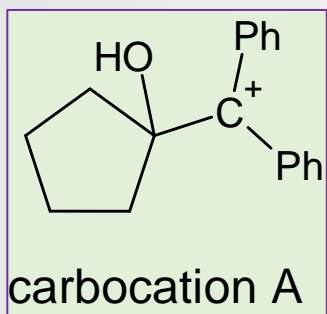
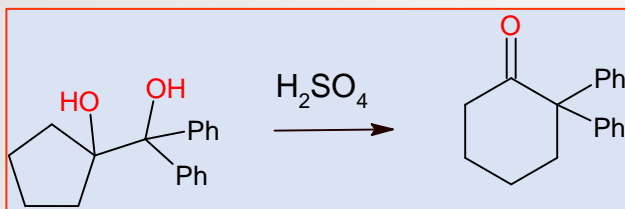
Mechanism



- Protonation of one hydroxyl group.
- Elimination of water and formation of a carbocation
- Migration of one methyl group.
- The loss of proton and formation of final product.

Pinacol-Pinacolone Rearrangement

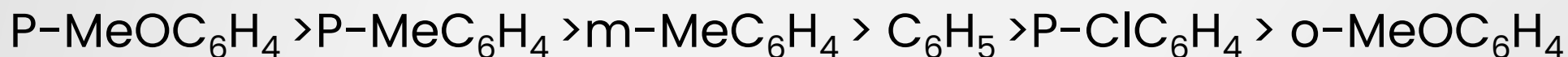
- For unsymmetric diol the -OH groups which produce more stable carbocation undergo protonation.
- In this example Hydroxyl group bearing two phenyl groups get protonated to produce more stable benzylic carbocation.



Pinacol-Pinacolone Rearrangement

Migratory aptitude

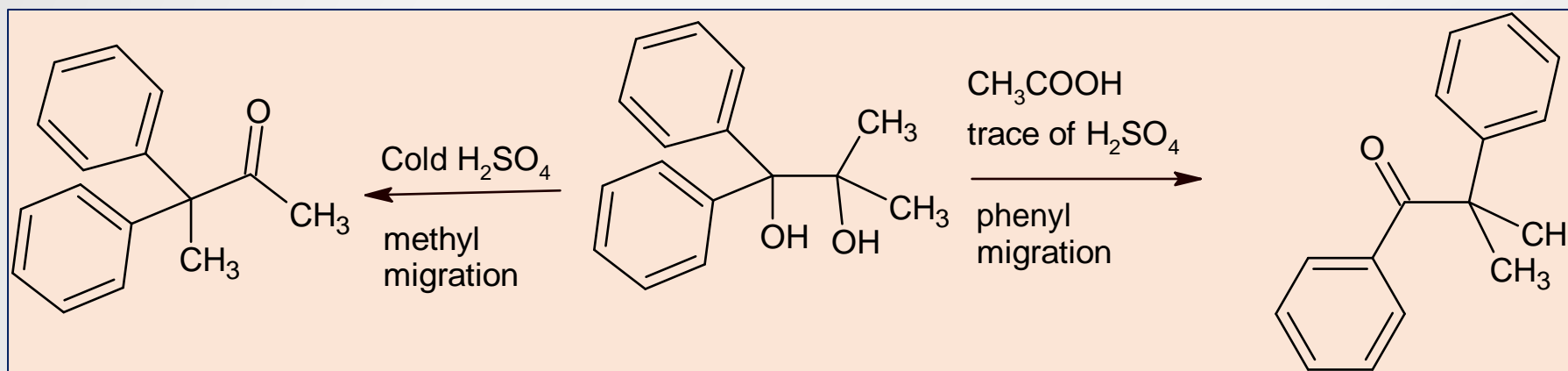
- For unsymmetric diol migratory aptitude is use to decide which group is going to migrate.
- Aryl > 3° alkyl > 2° alkyl > 1° alkyl
- In substituted benzene migratory aptitude is



- Inductive effect, resonance effect and steric effect play an important role in deciding migratory aptitude
- Generally -OH group that become protonated and ultimately eliminated is the one whose loss give rise to the more stable carbocation

Pinacol-Pinacolone Rearrangement

- For trisubstituted and tetrasubstituted unsymmetric diol more than one products are possible.
- Formation of product depends upon reaction condition and migratory aptitude



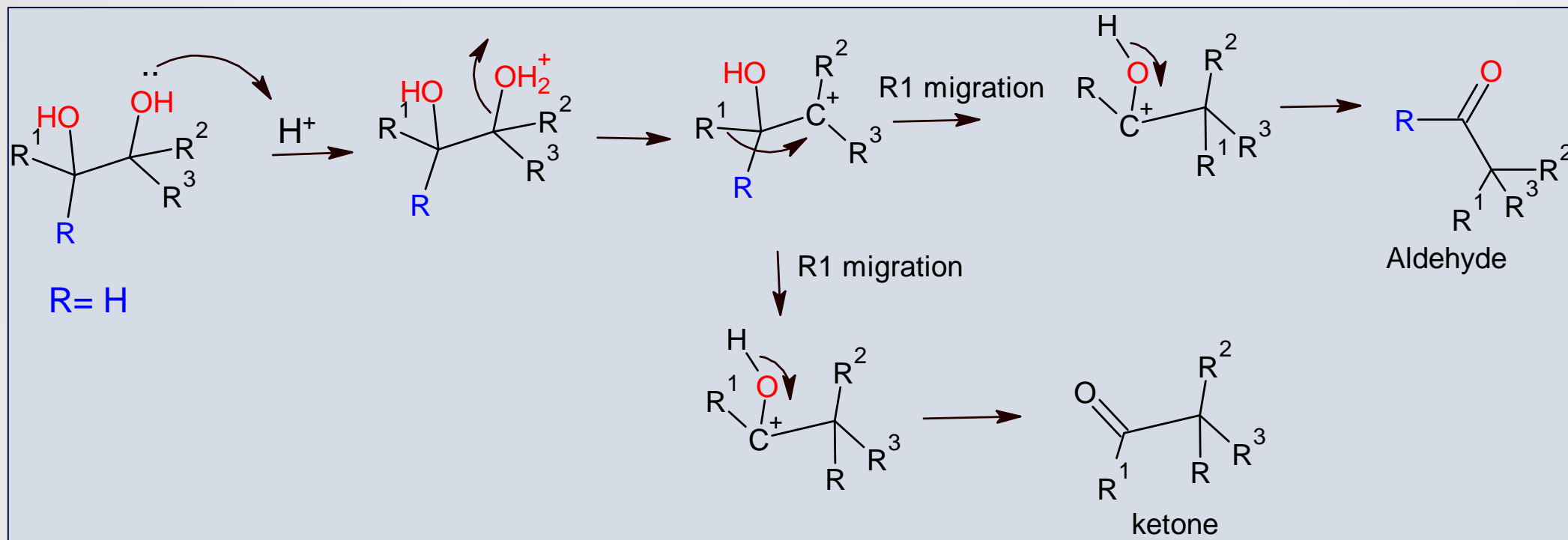
3,3-diphenyl-2-butanone

2-methyl-1,1-diphenylpropane-1,2-diol

2-methyl-1,2-diphenyl-1-propanone

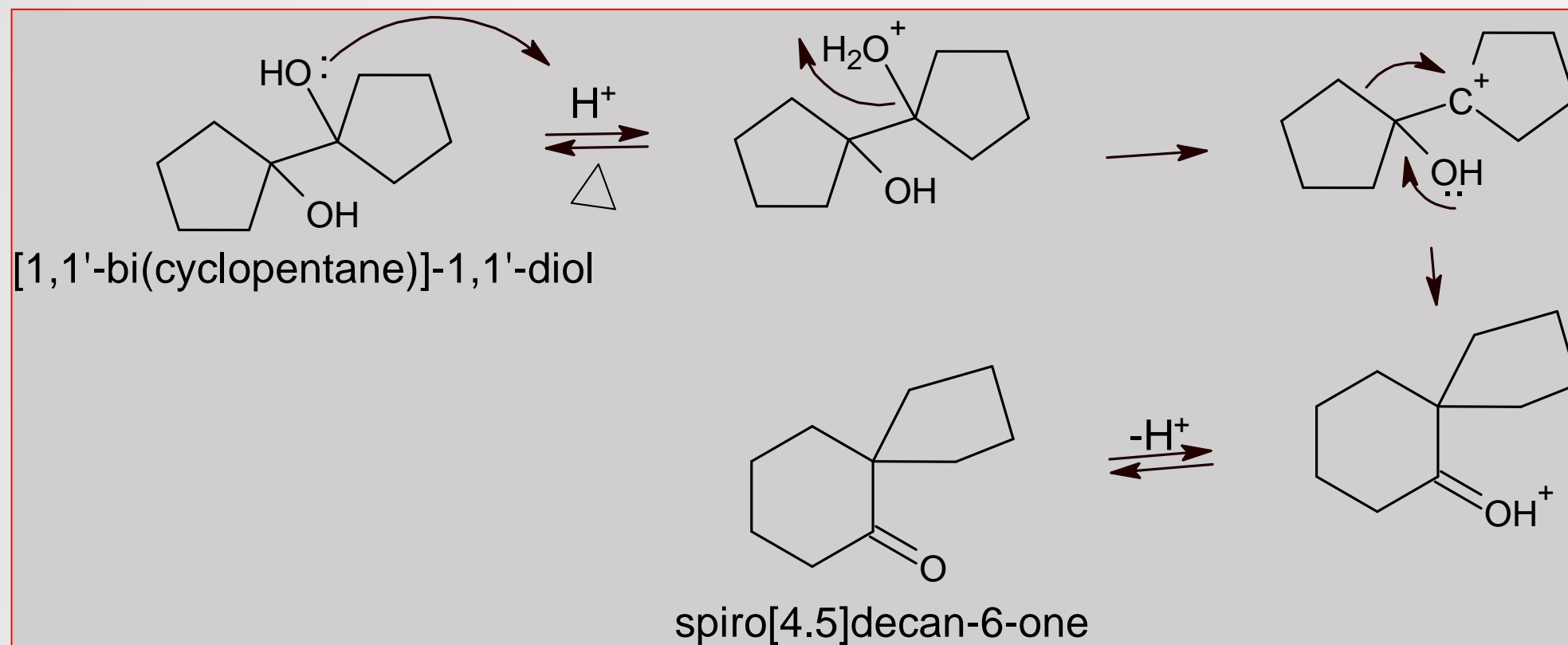
Pinacol-Pinacolone Rearrangement

- For trisubstituted and tetrasubstituted diol when at least one group is hydrogen then aldehyde is obtained along with ketone.



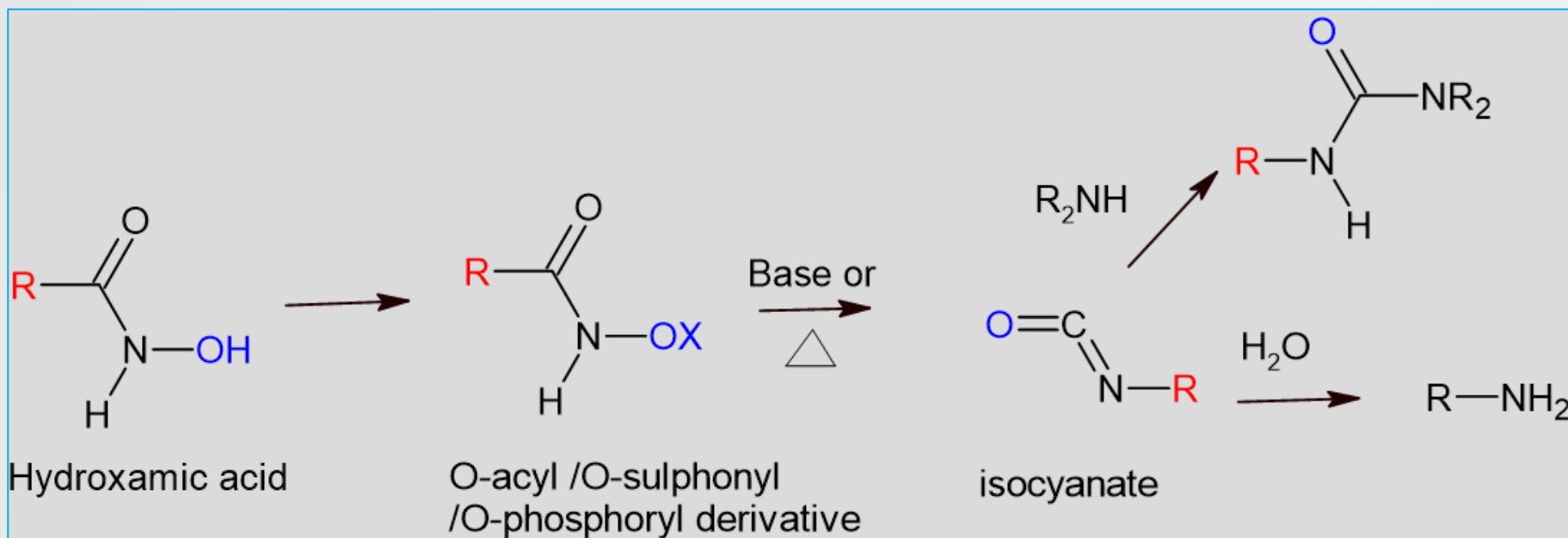
Pinacol-Pinacolone Rearrangement

Formation of Spiro compound



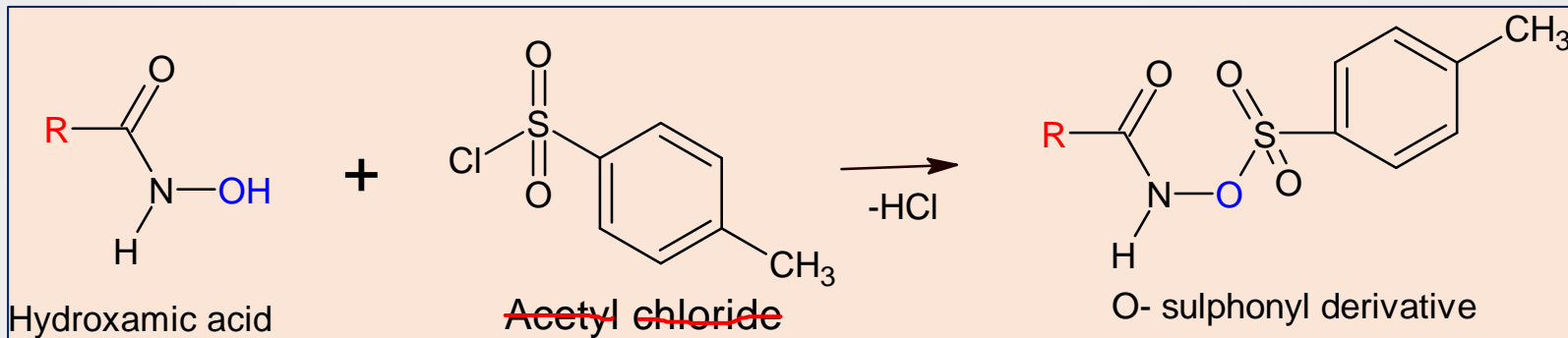
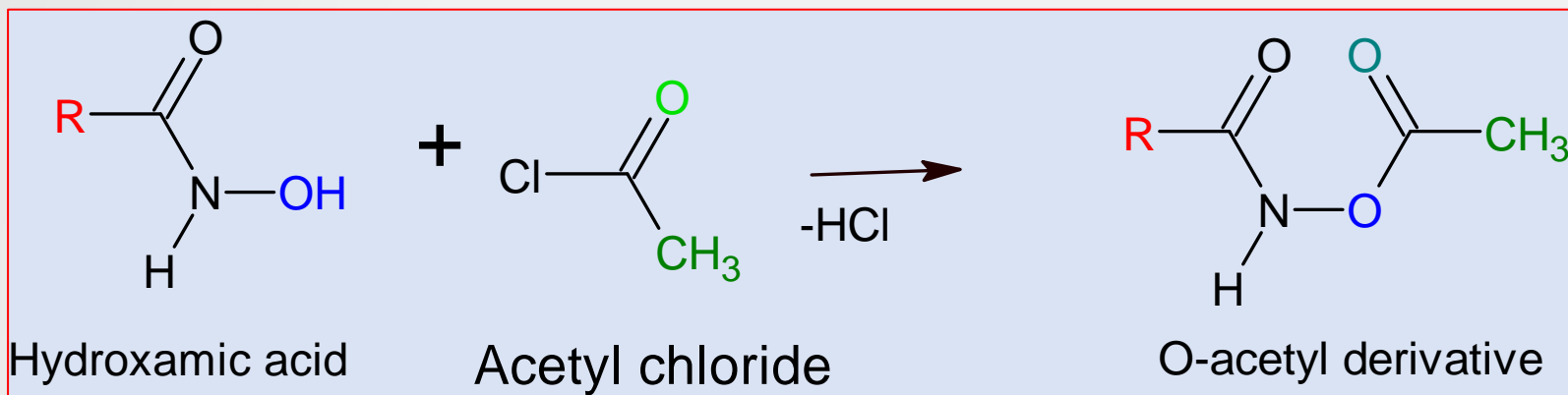
Lossen rearrangement

- O-acyl (O-aroyl, O-sulfonyl) derivatives of hydroxamic acids on heating with a base produce corresponding isocyanate is called lossen rearrangement.
- Isocyanate on hydrolysis converted to corresponding primary amines.

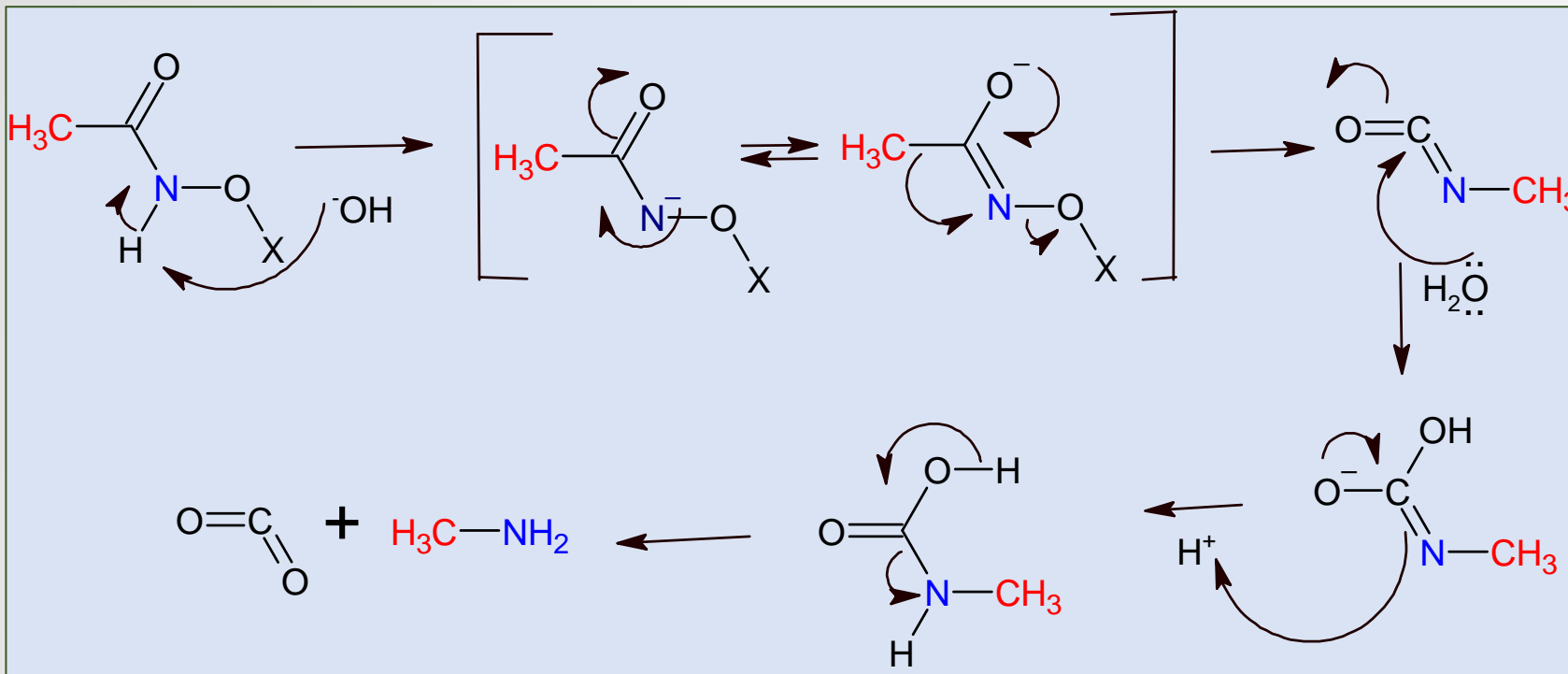


Lossen rearrangement

- Activation of hydroxamic acid is done by converting in to O-acyl, O-aroyl, and O-sulfonyl derivatives



Lossen rearrangement



Abstraction of the proton attached to the N atom.

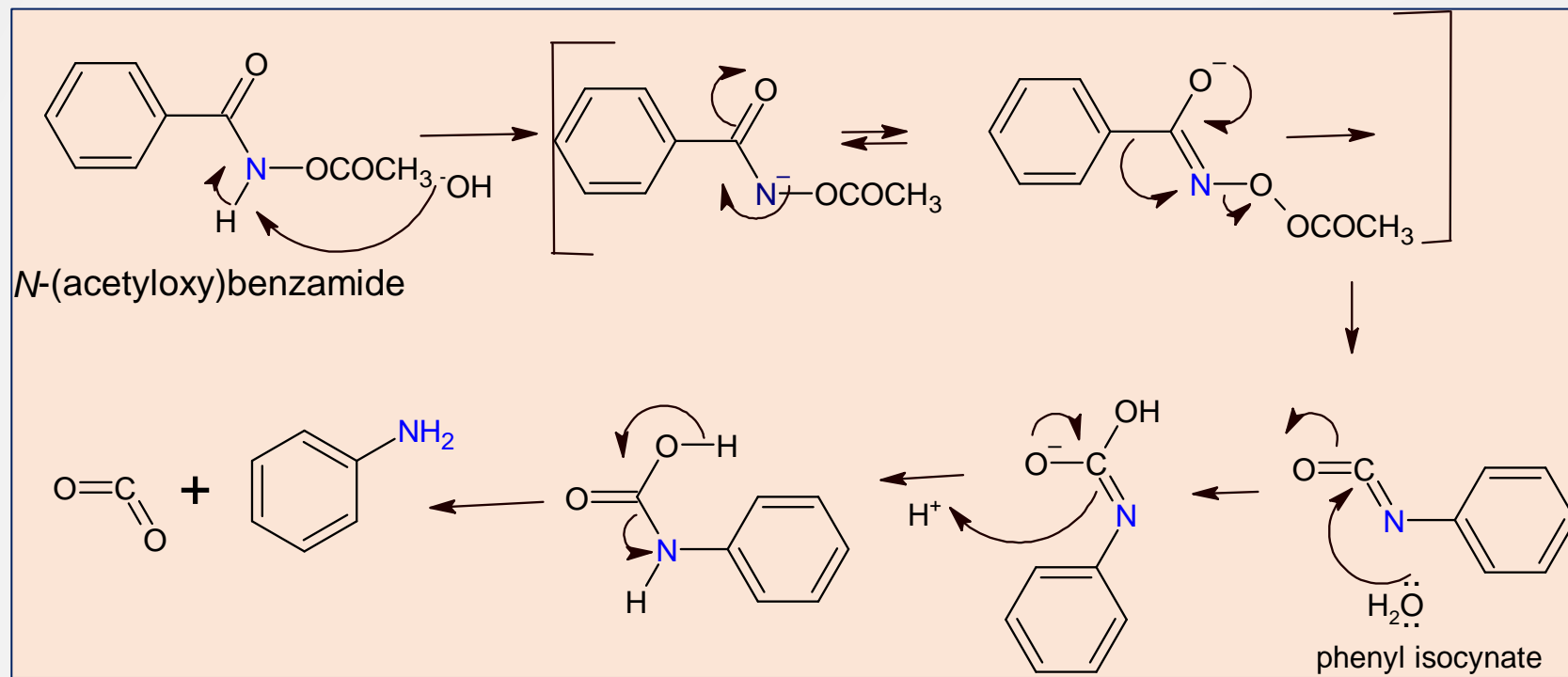
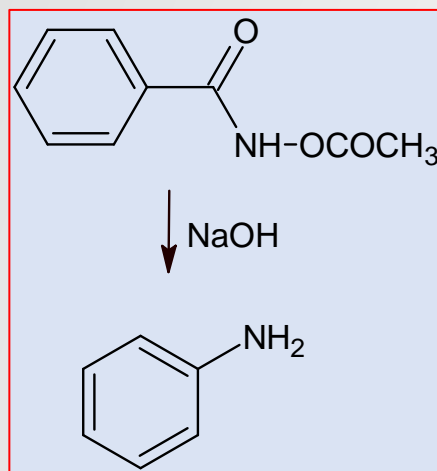
Migration of R1 group to the N -atom and elimination of -OX group

Addition of water to isocyanate

Decarboxylation and formation of amine

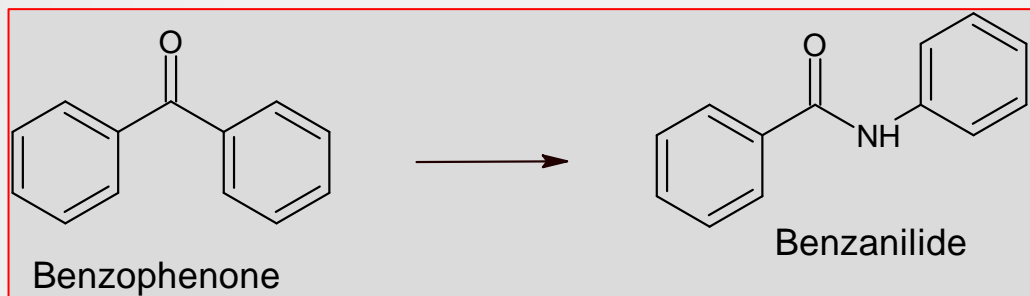
Lossen rearrangement

Write mechanism



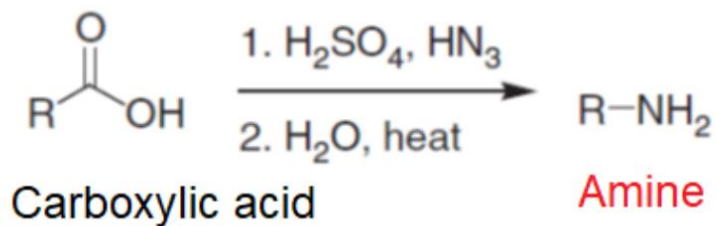
Schmidt rearrangement

In 1924 Schmidt reported the conversion of benzophenone to benzanilide by using hydrazoic acid

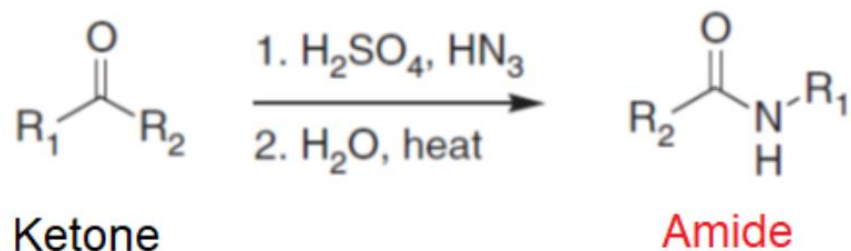
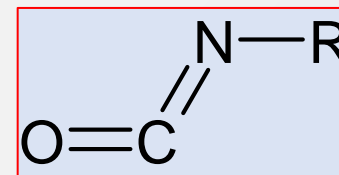


Reaction of carboxylic acid or aldehyde or ketone with **hydrazoic acid** in presence of strong acid give **isocyanate** (for carboxylic acid) or **nitrilium ion** (for aldehyde or ketone) as an intermediate, which on further hydrolysis give corresponding primary amine or amide is known as Schmidt rearrangement.

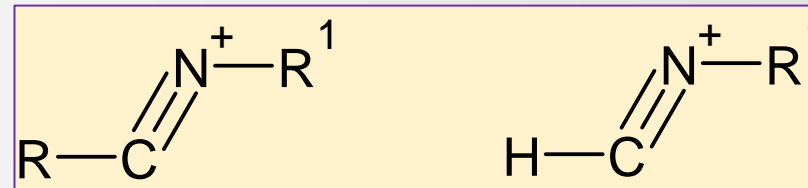
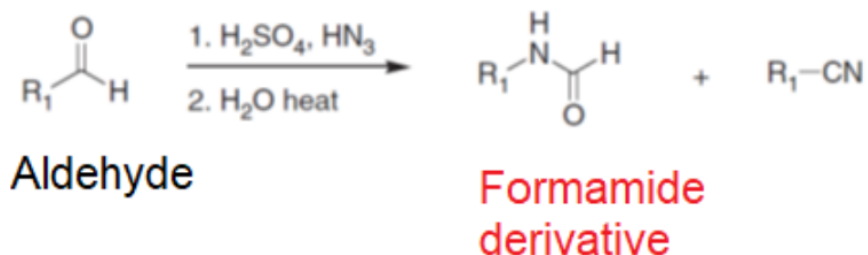
Schmidt rearrangement



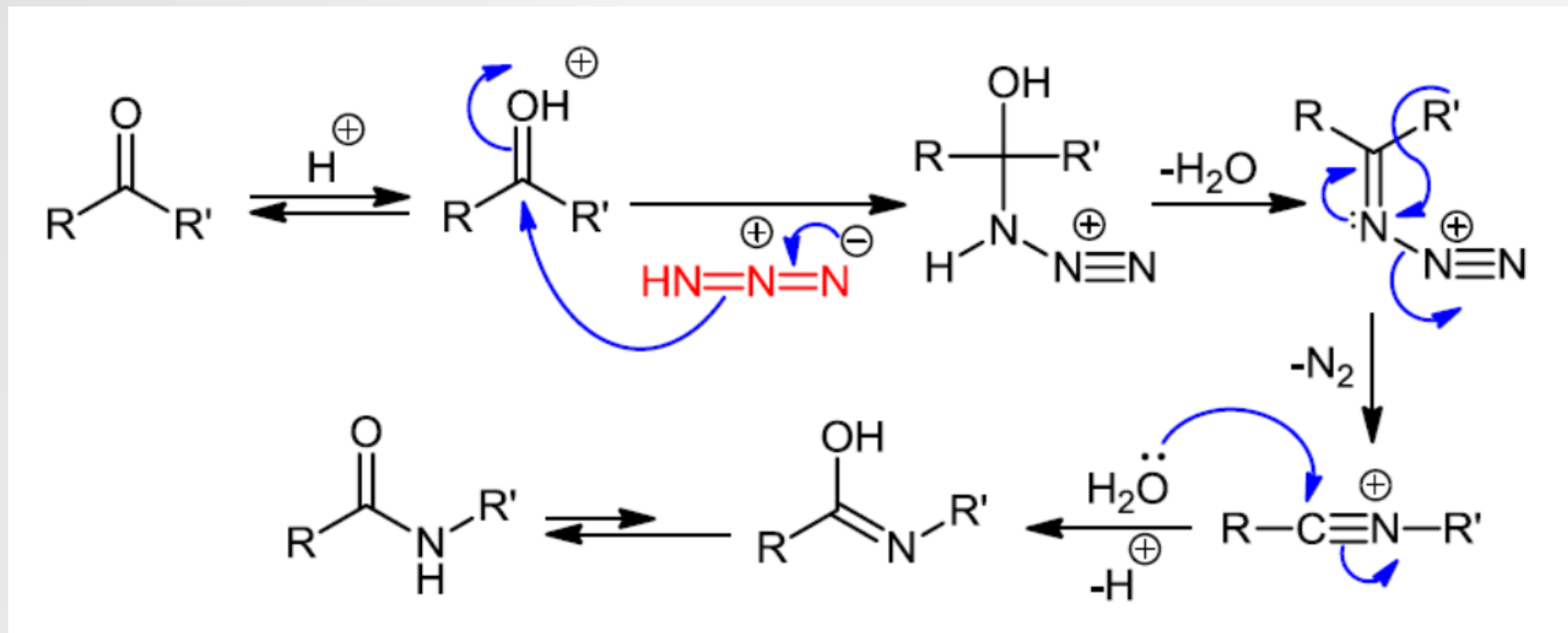
Carboxylic acid produce amine via isocyanate intermediate



Ketone and aldehyde produce amide via nitrilium ion intermediate



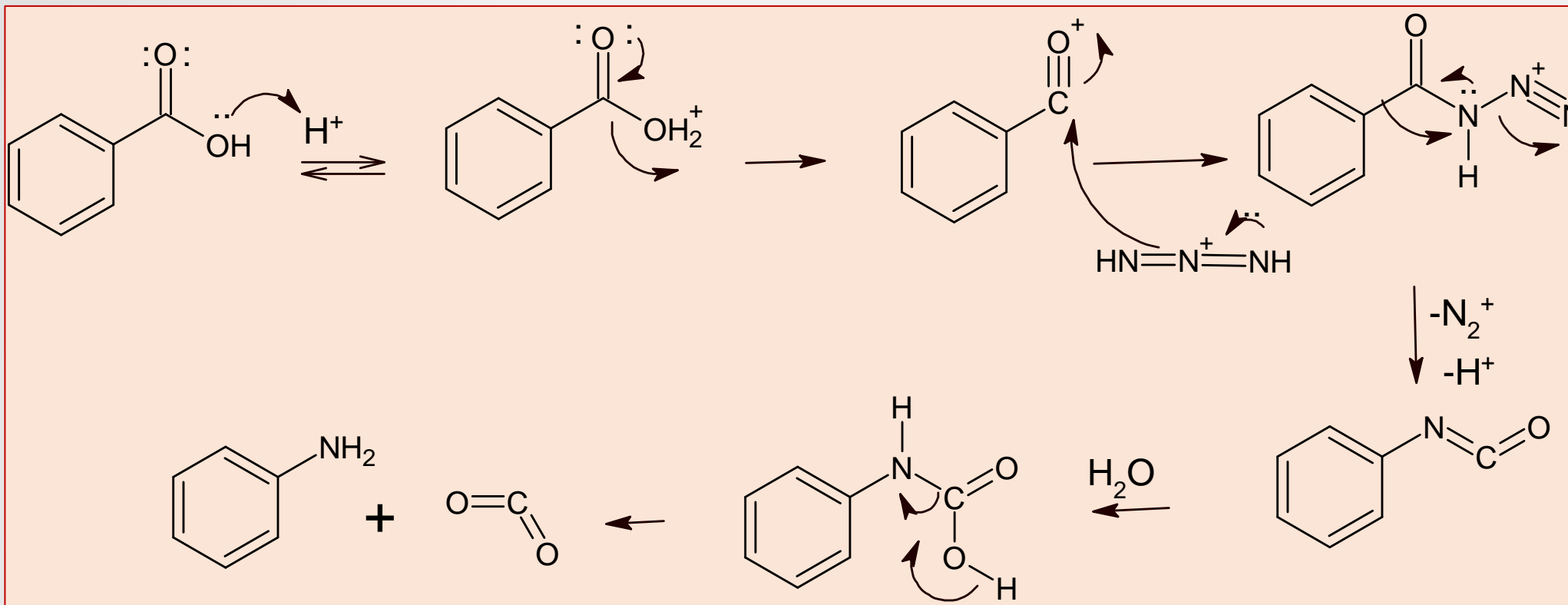
Schmidt rearrangement – Mechanism



- Protonation of oxygen atom of the carbonyl compound.
- Nucleophilic attack by an azide to the electron-deficient carbonyl carbon
- Migration of group to N atom and formation of nitrilium ion with evolution of nitrogen.
- Nucleophilic attack by water and tautomerization

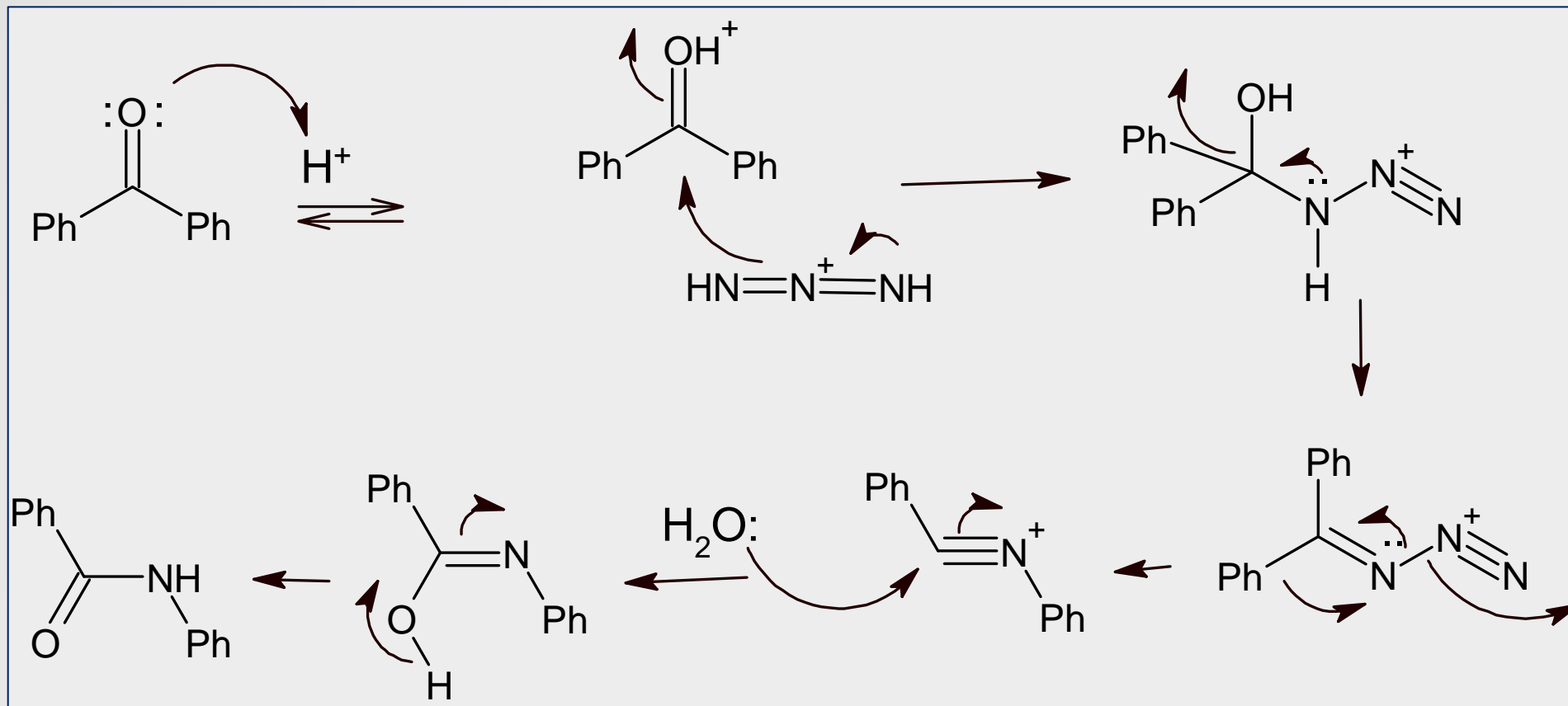
Schmidt rearrangement

Benzoic acid to aniline



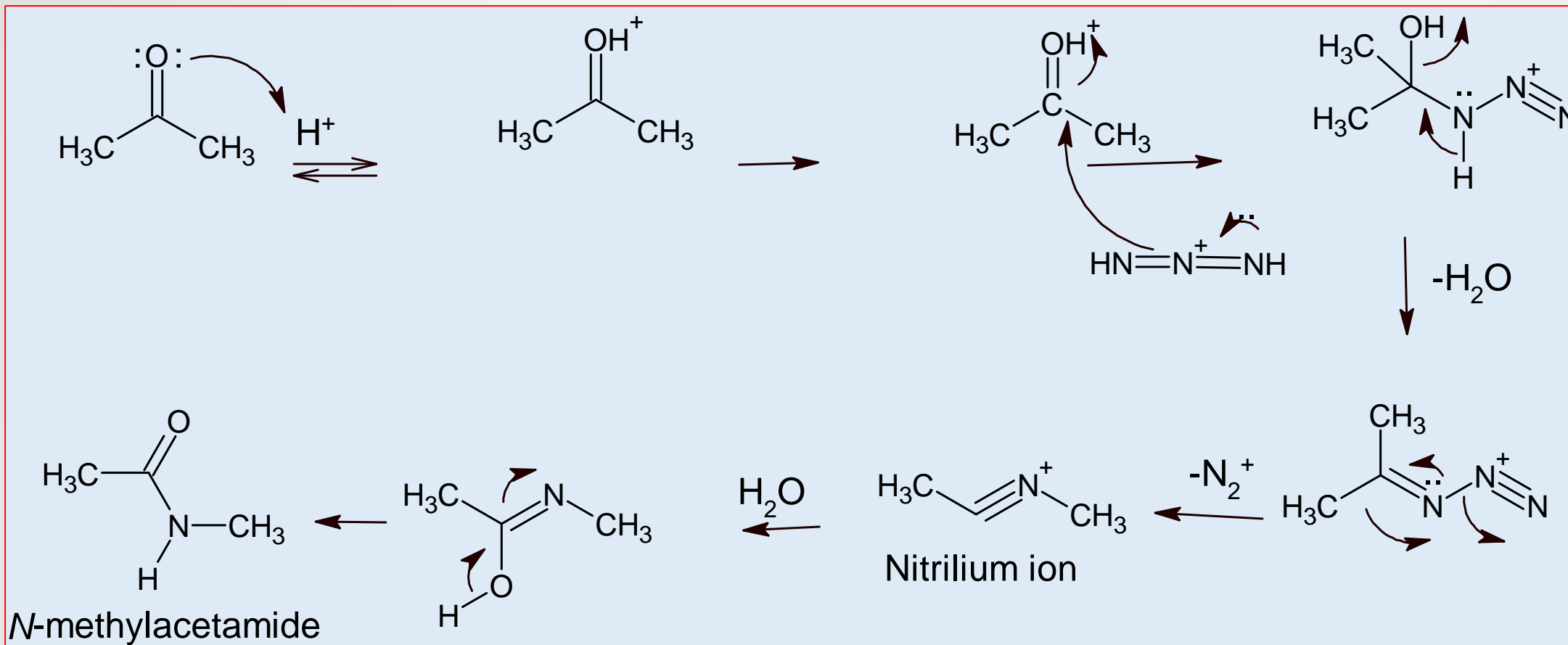
Schmidt rearrangement

Benzophenone to benzanilide



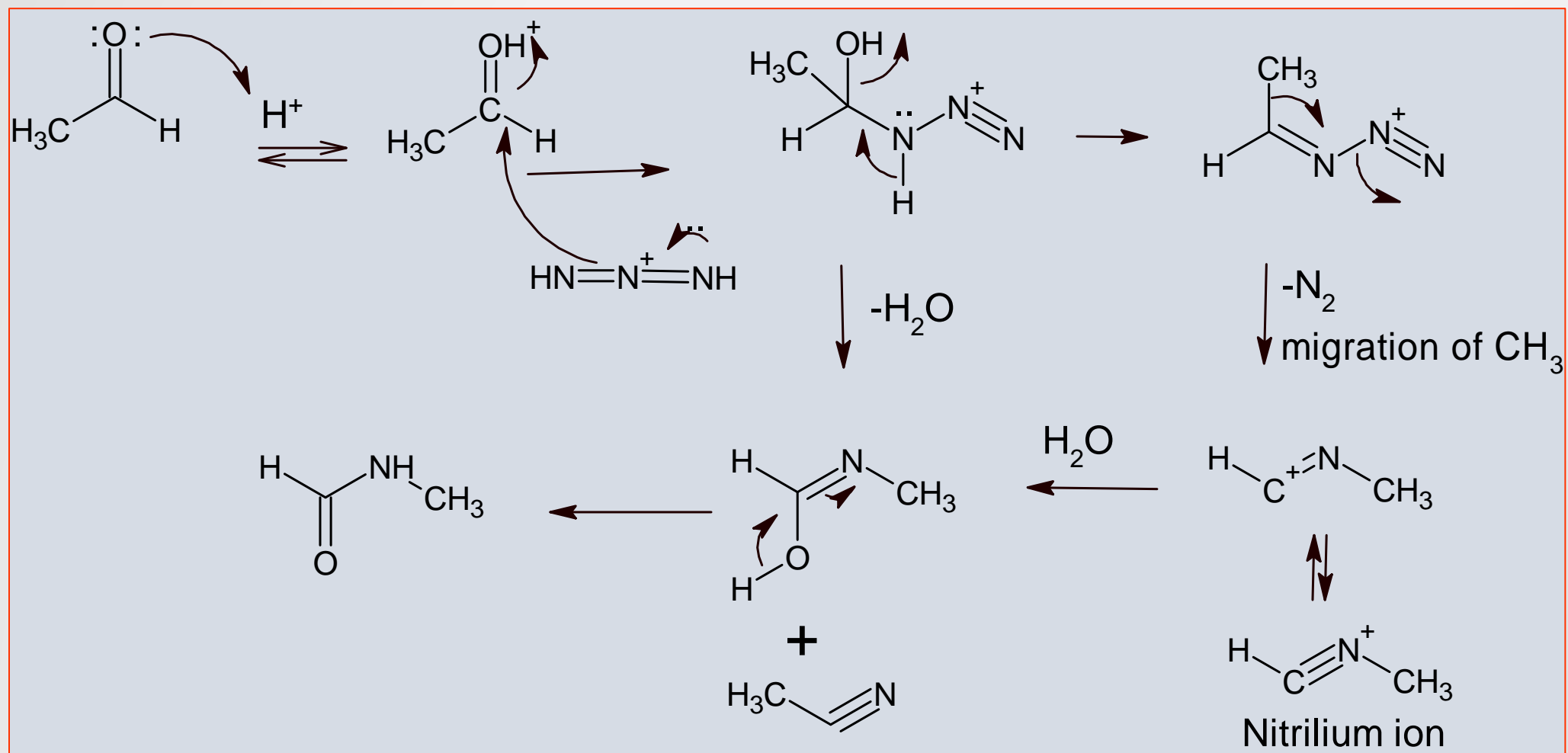
Schmidt rearrangement

Acetone to N-methylacetamide



Schmidt rearrangement

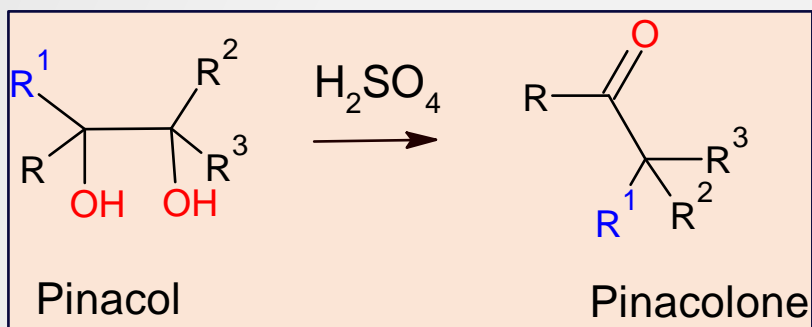
Acetaldehyde to N-methylformamide



Recap

Pinacol-Pinacolone Rearrangement

Acid catalysed rearrangement of vicinal diol to aldehyde or ketone

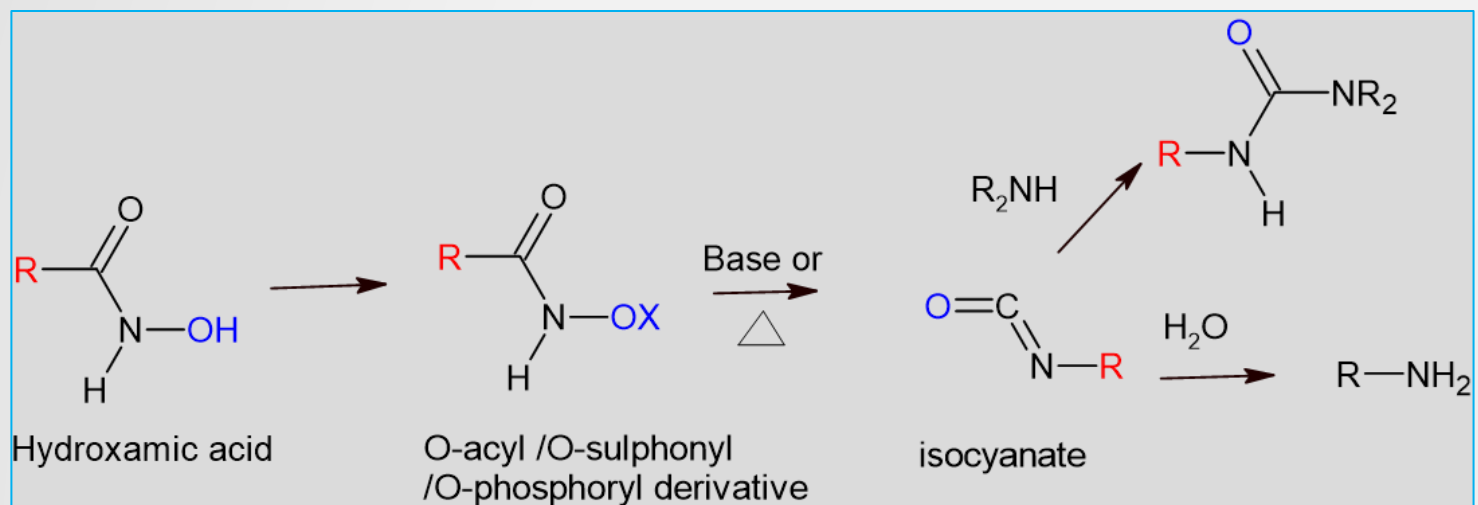


Migratory aptitude

- For unsymmetric diol migratory aptitude is Aryl > 3° alkyl > 2° alkyl > 1° alkyl
- The loss -OH group which produce more stable carbocation is generally protonated.

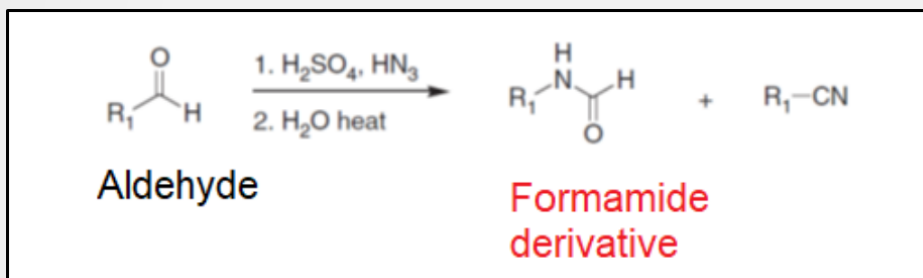
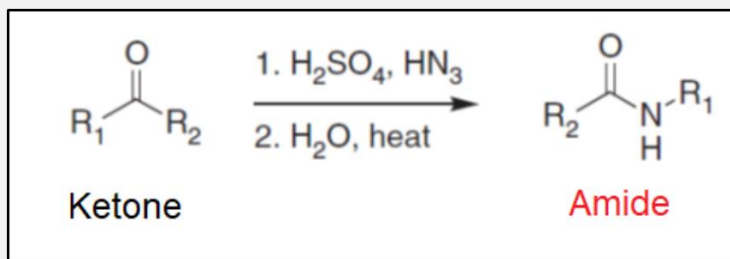
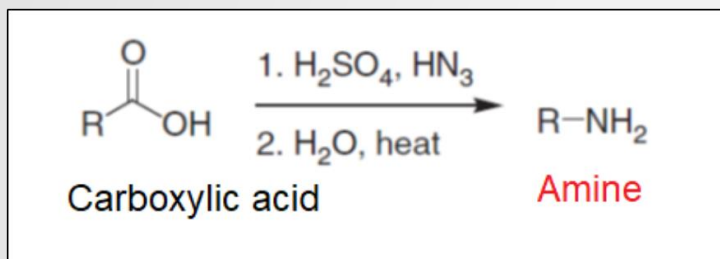
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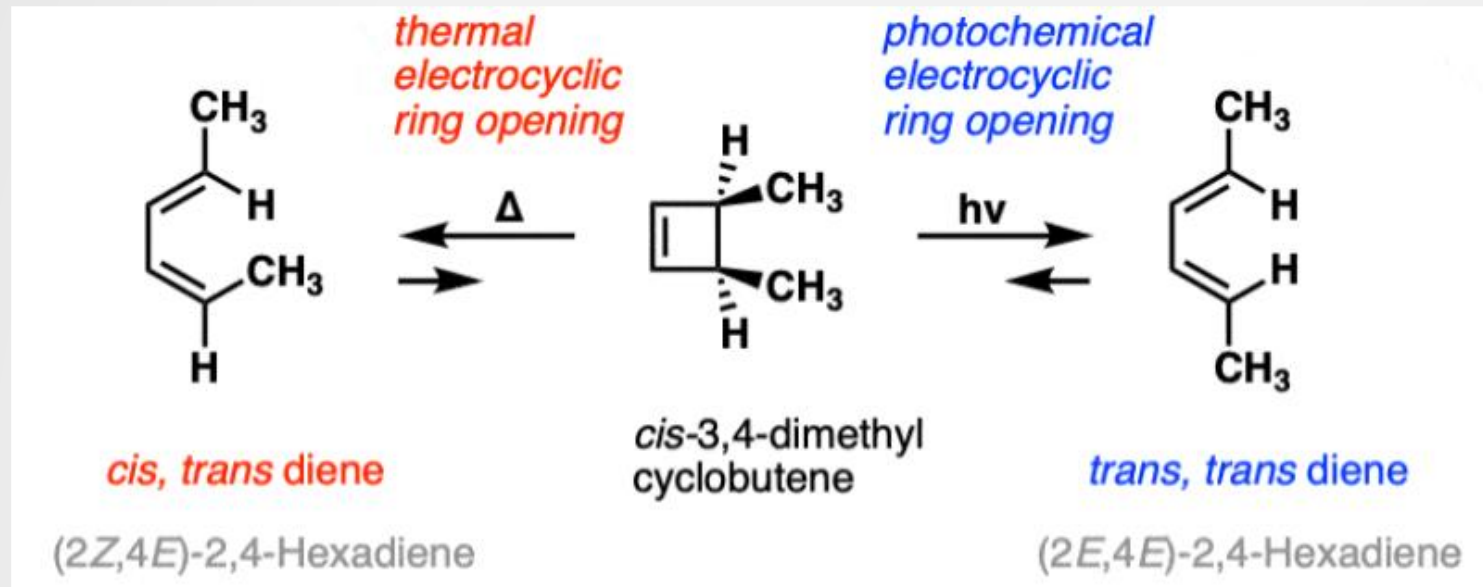
Schmidt rearrangement

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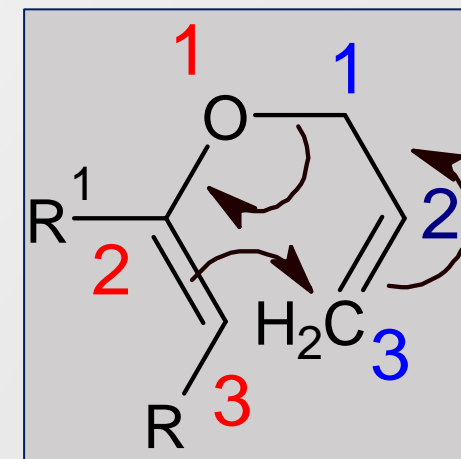
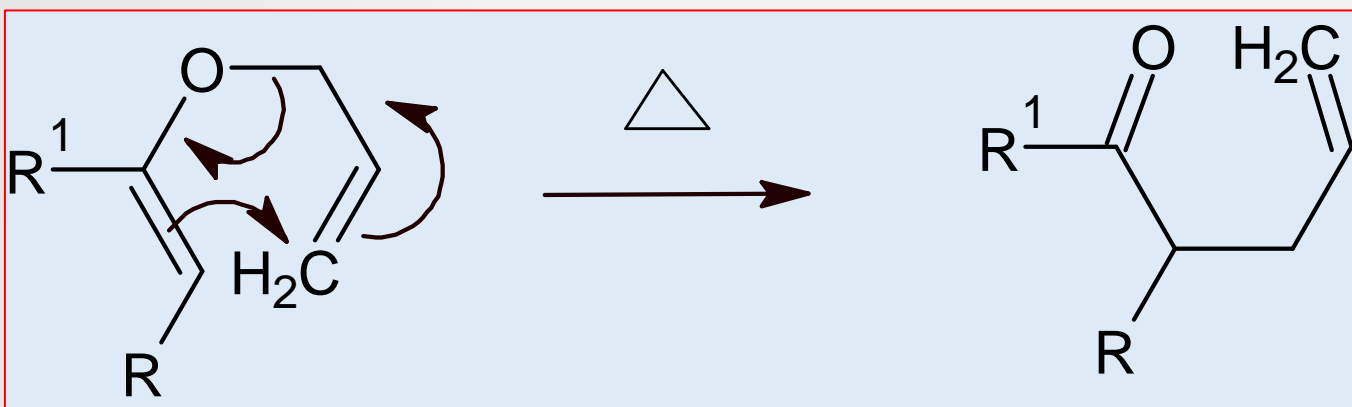
Electrocyclic rearrangement

- Electrocyclic reaction is a type of pericyclic rearrangement where pi bond is converted to sigma bond or vice versa.
- These reactions are either photochemical or thermal.
- Either ring-opening or ring-closing (electrocyclization) take place.



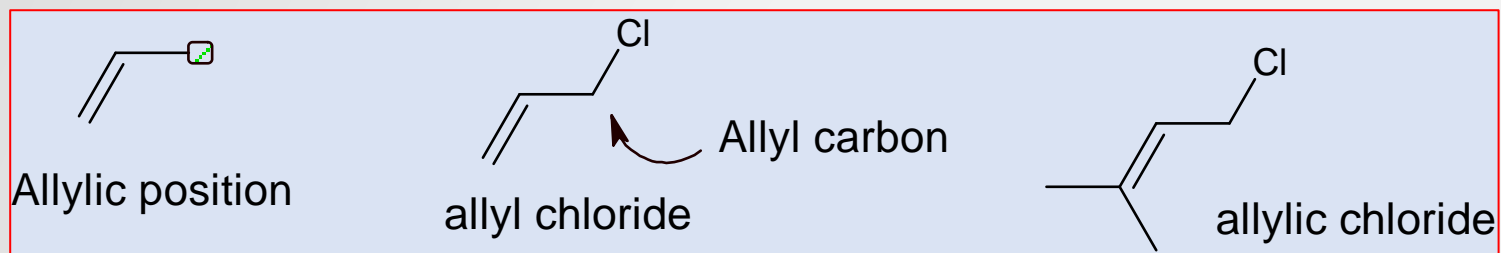
Claisen Rearrangement

- Discovered by Rainer Ludwig Claisen (1912)
- An allyl vinyl ether on heating undergo a [3,3]-sigmatropic rearrangement to give a γ, δ -unsaturated carbonyl compound.
- The reaction is a concerted process where bonds are forming and breaking at the same time

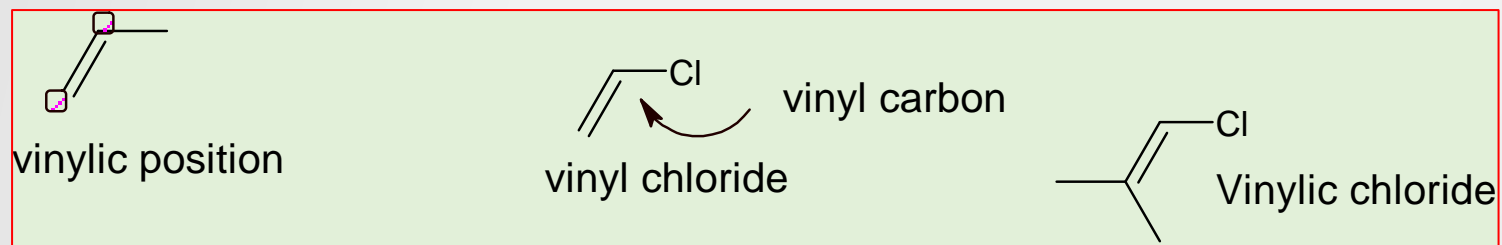


[3,3]-sigmatropic
rearrangement

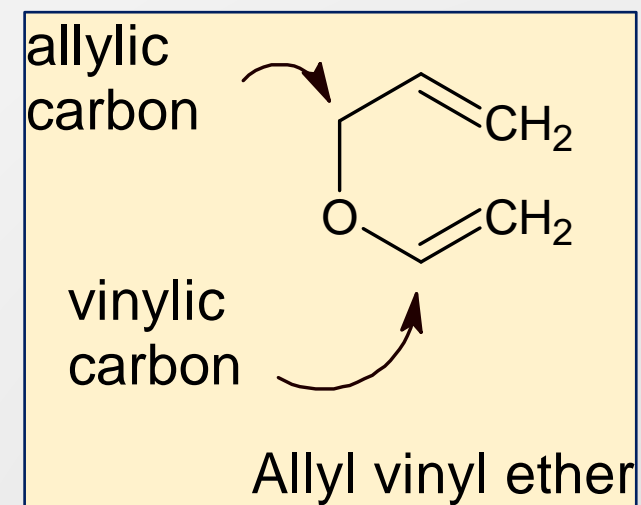
Allylic and vinylic position



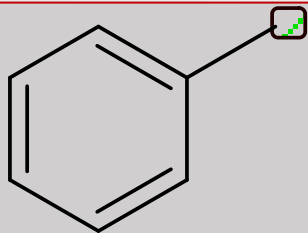
Allylic carbon is a carbon atom attached to a carbon-carbon double bond



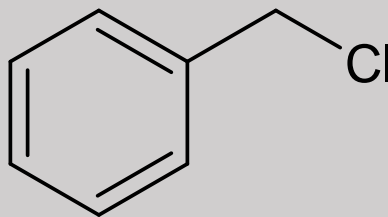
Vinylic carbon is a carbon which involved in a double bond with another carbon



Benzylic and Phenylic position

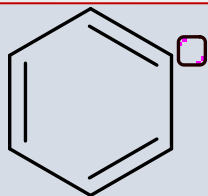


Benzylic position

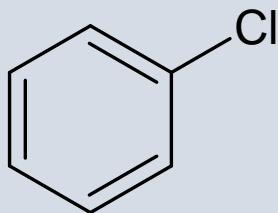


Benzyl chloride

Benzylic carbon is a carbon atom attached to a benzene ring



Phenylic position



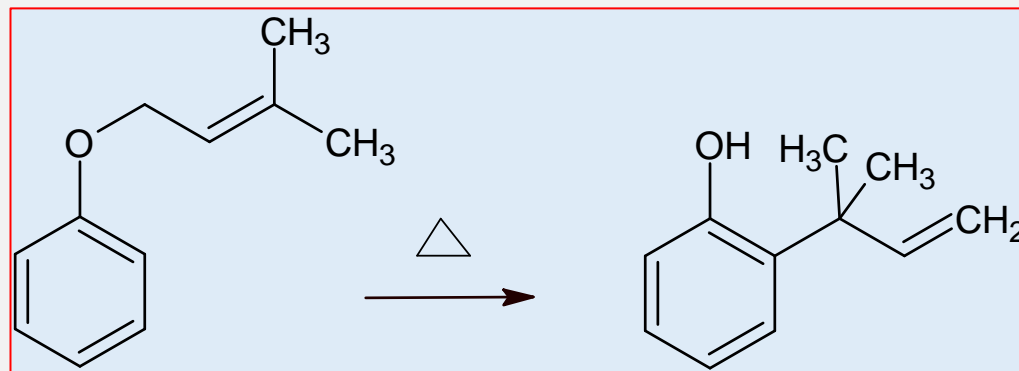
Phenyl chloride or chlorobenzene

Phenylic carbon is a carbon which is the part of benzene ring

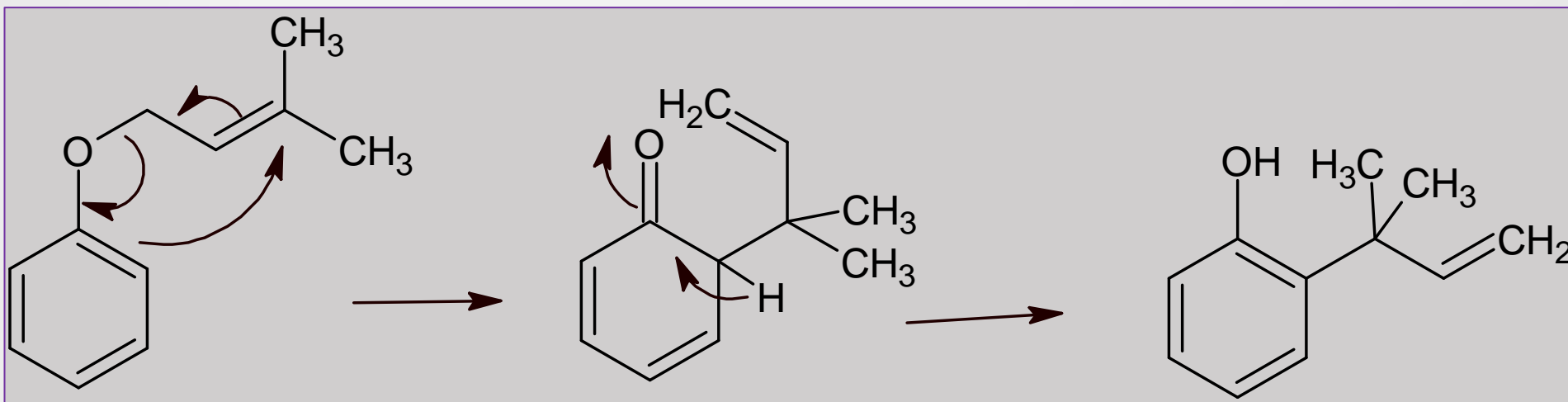
Claisen Rearrangement

- The Claisen rearrangement is an exothermic, concerted (simultaneous bond breaking and bond formation) pericyclic reaction.
- It involved in a six membered transition state.
- There are substantial solvent effects (i.e., polar solvents accelerate the rate of the reaction)
- Solvents involved in Hydrogen-bonding give the highest rate (ex. Ethanol, water)

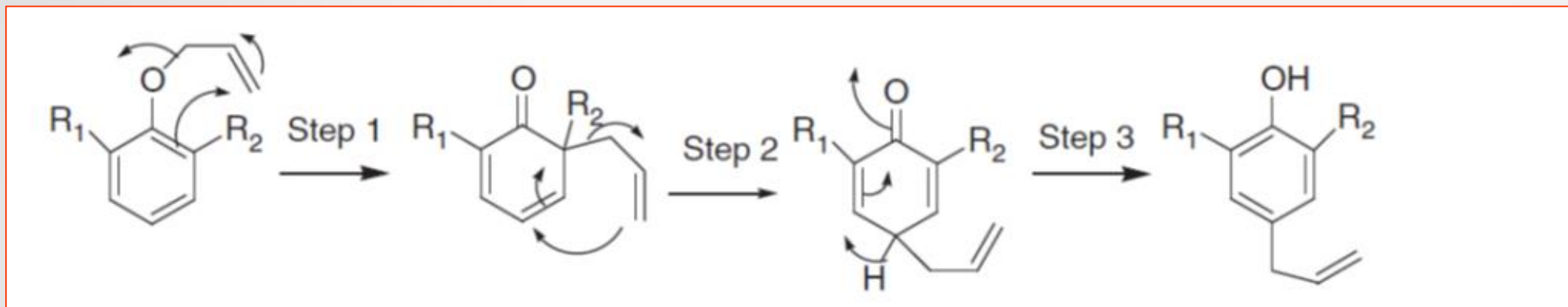
Claisen Rearrangement



Mechanism



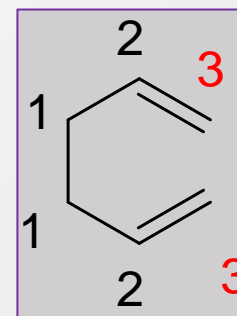
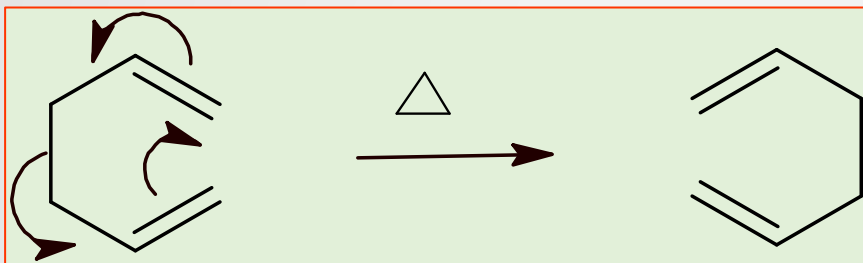
Claisen Rearrangement



- When 2,6-positions are blocked, rearomatization is not possible in one step(there are no *ortho* H atoms.)
- In such case the allyl group first migrate to the *ortho*-position, and then second migration take place to *para*-position.

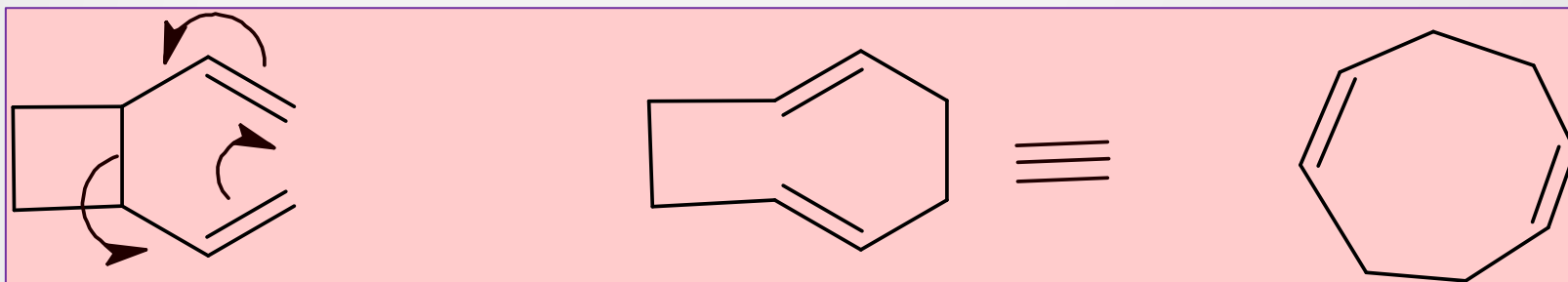
Cope Rearrangement

- It is [3,3]-sigmatropic rearrangement of 1,5 diene to its isomeric 1,5 diene is called cope rearrangement.
- Only carbon atoms are involved in six membered transition state



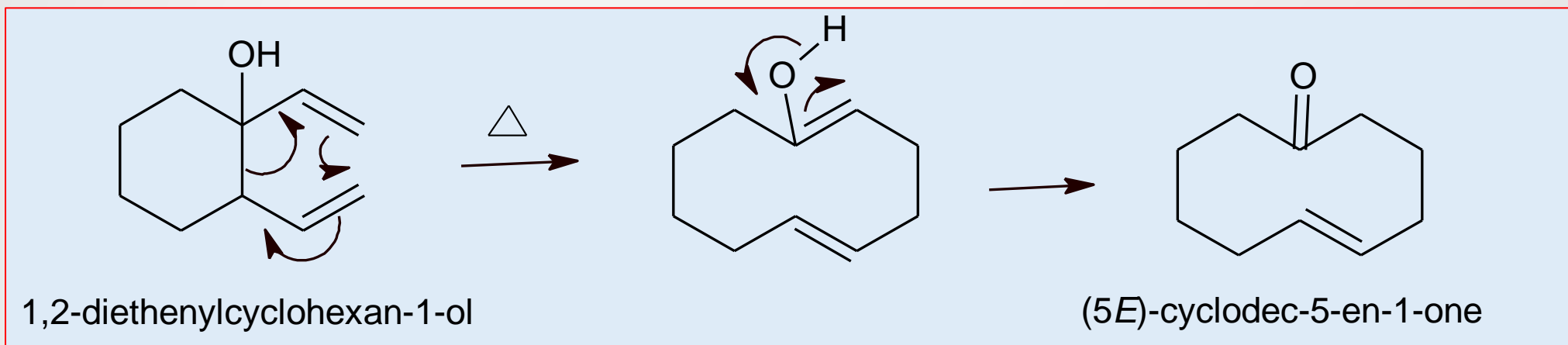
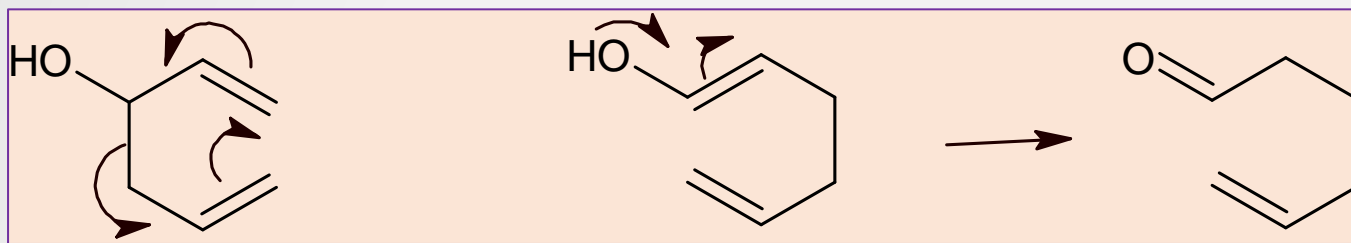
New σ bond has 3,3-relationship with old σ bonds

Expansion of cyclobutene ring to 1,5 cyclooctadiene

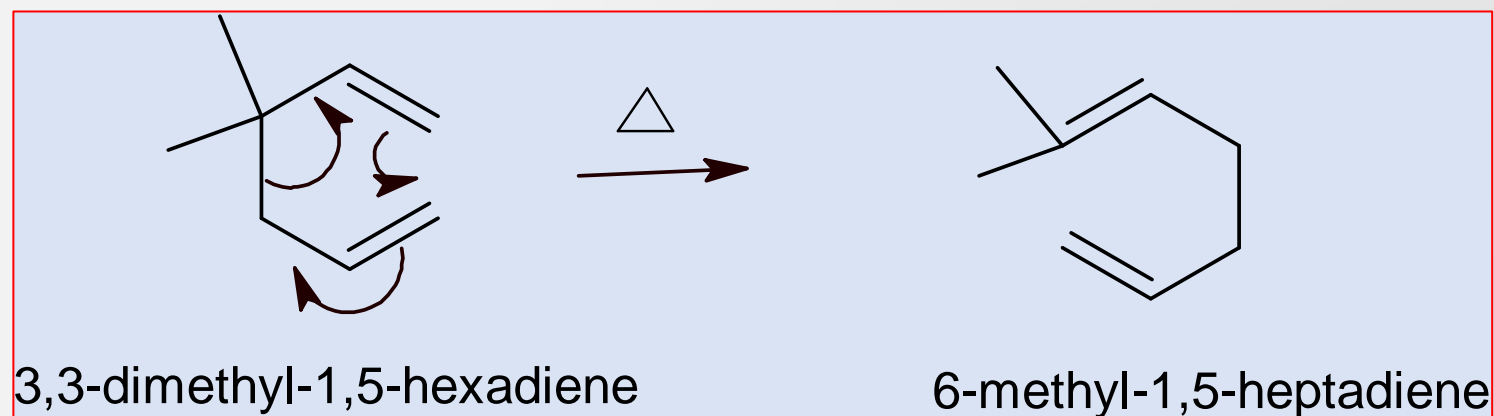
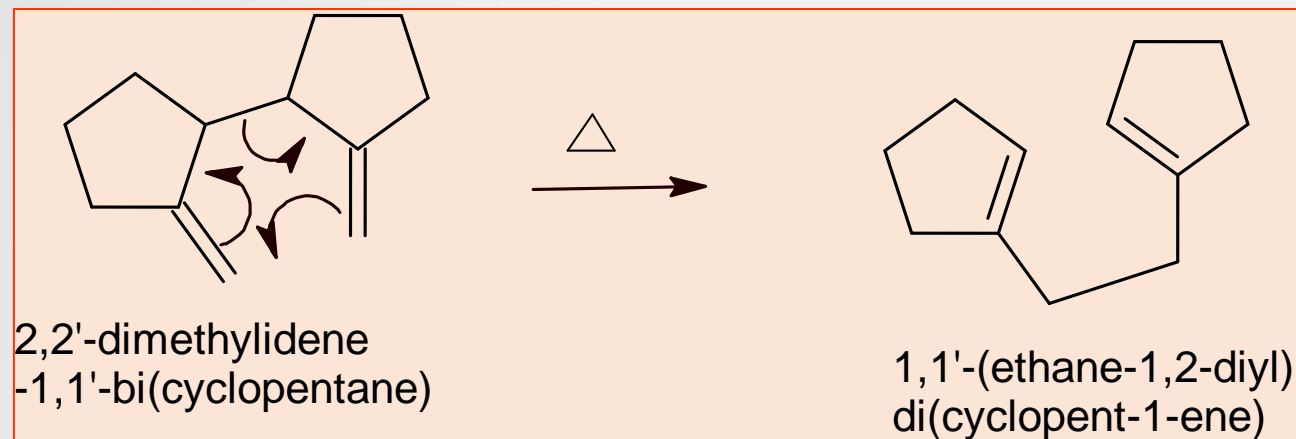


Cope Rearrangement

- The oxy-Cope rearrangement has a hydroxy group on C-3 forming aldehyde or ketone after keto-enol tautomerization.

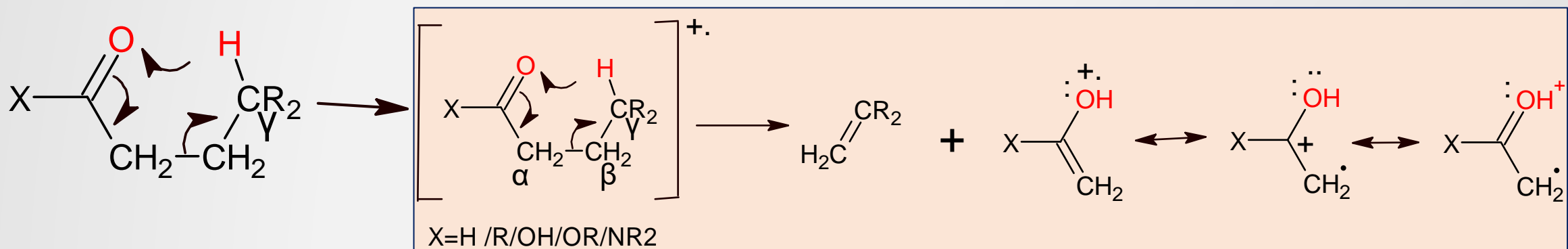


Cope Rearrangement

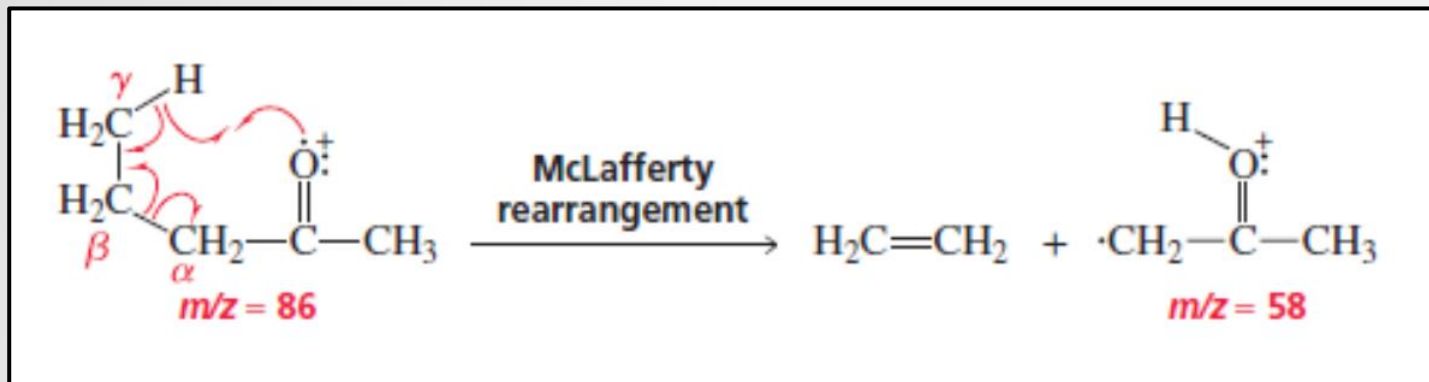


Mc-Lafferty Rearrangement

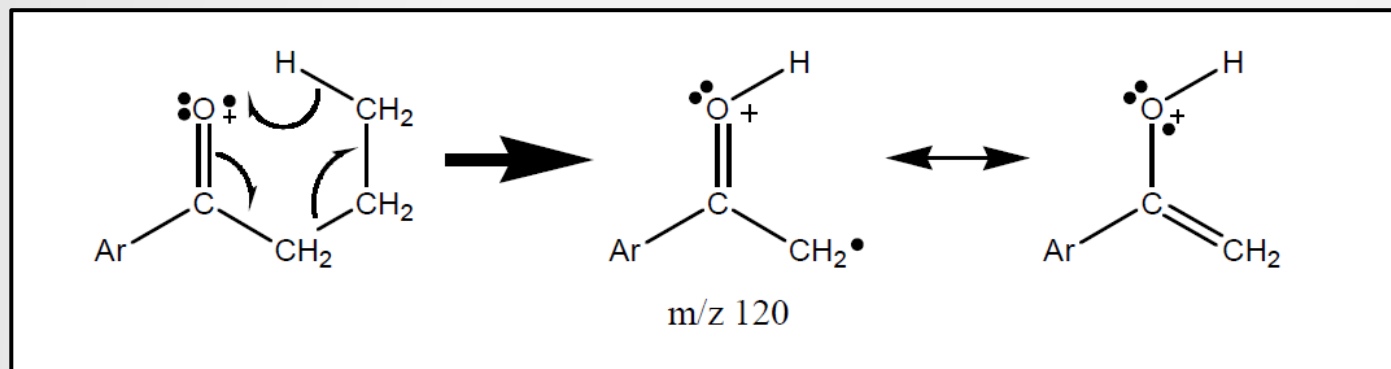
- Mc-Lafferty Rearrangement involve migration of gamma- hydrogen atom in molecule that contain hetero atom, followed by the cleavage of $\alpha - \beta$ bond.
- This rearrangement can occur in aldehyde, ketone ,carboxylic acid, amide and ester
- Elimination of neutral molecules takes place.
- The rearrangement proceeds through a sterically hindered 6 membered transition state.



Mc-Lafferty Rearrangement

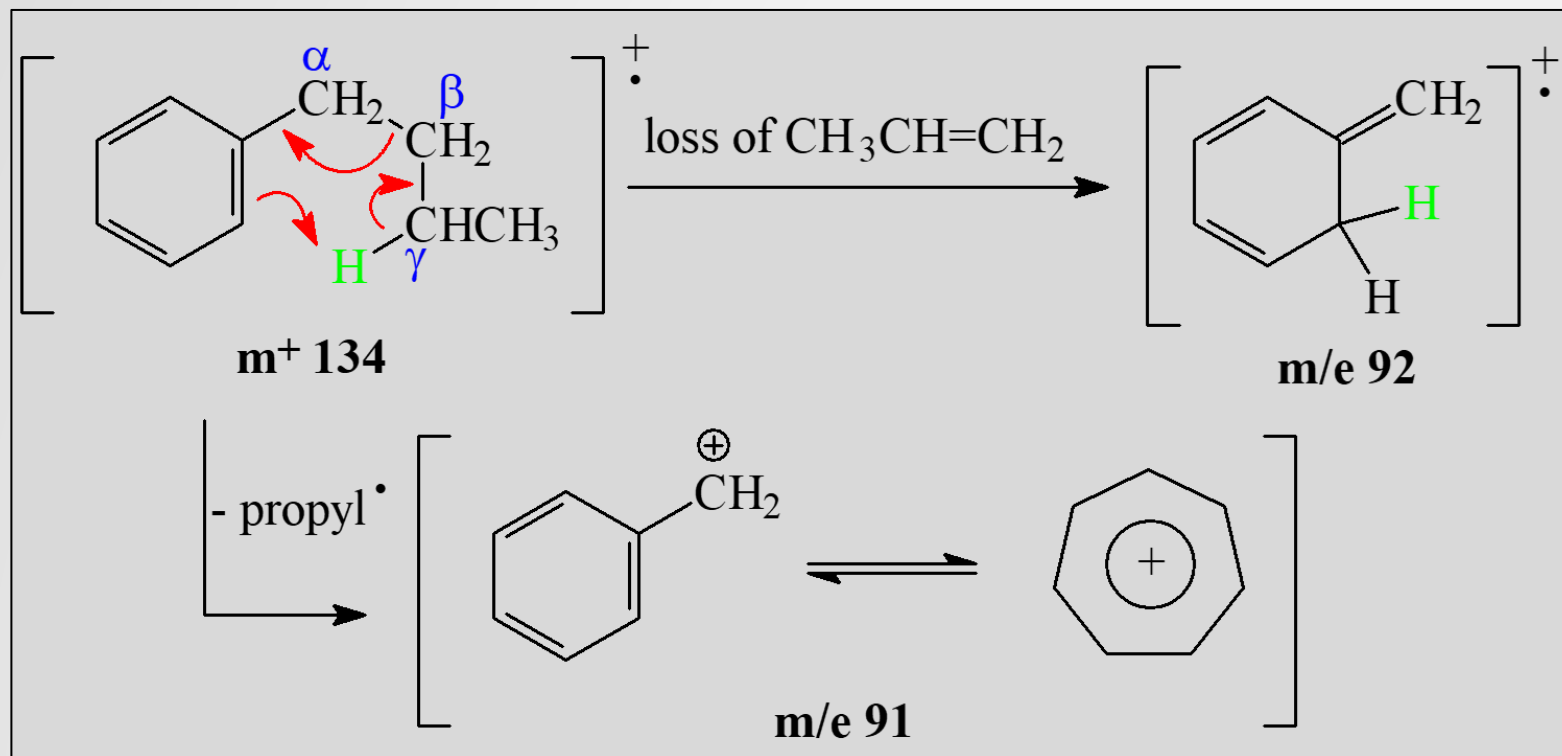


Ketones undergo the typical Mc-Lafferty Rearrangement when contains an abstractable hydrogen atom.



Aromatic ketones undergo the typical Mc-Lafferty rearrangement if the other alkyl component contains an abstractable hydrogen atom.

Mc-Lafferty Rearrangement

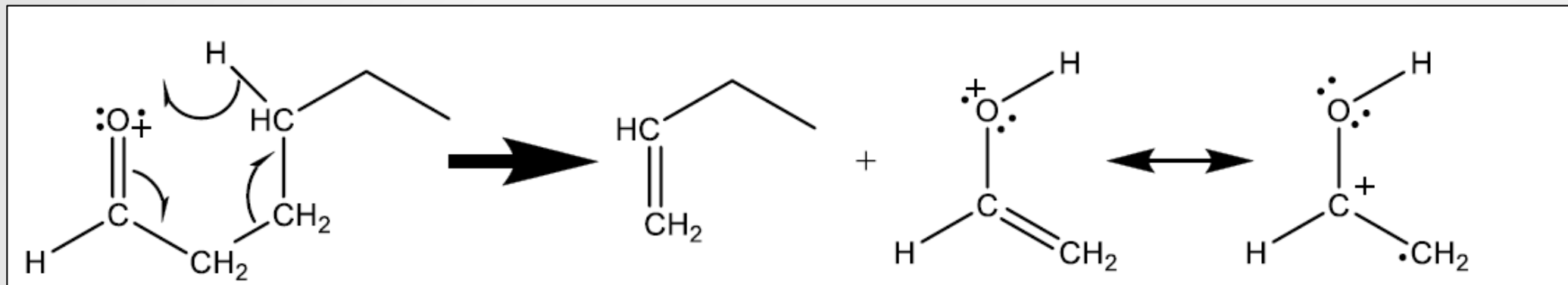


Substituted aromatic compound undergo Mc-Lafferty Rearrangement when alkyl group contains an abstractable hydrogen atom.

Mc-Lafferty Rearrangement

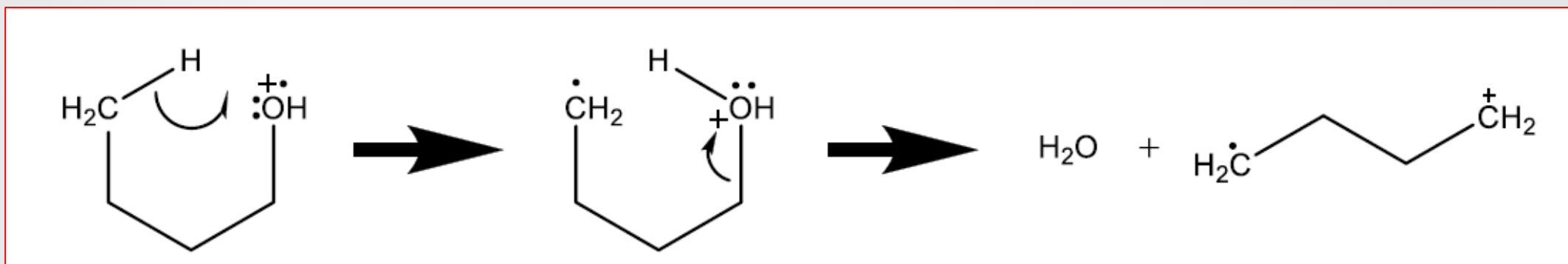
Aldehyde

$m/e=44$

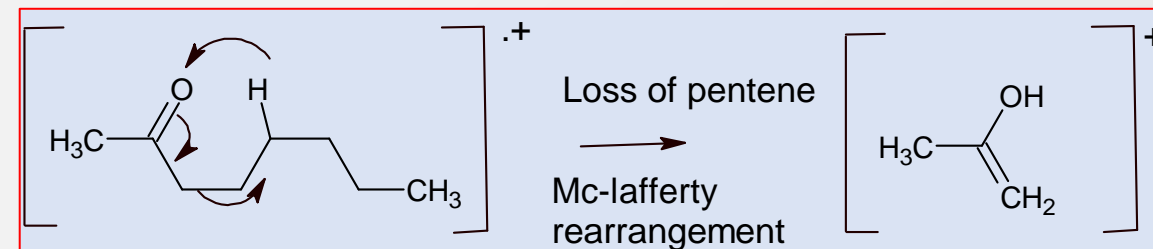
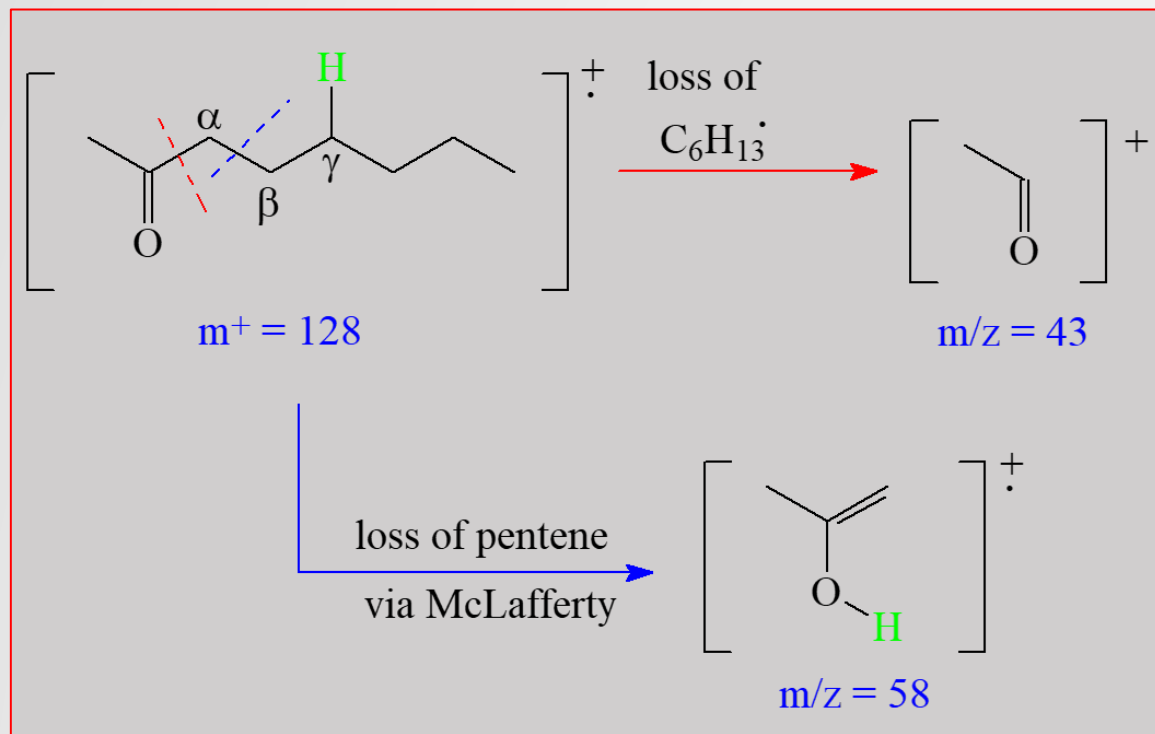


Alcohol

$m/e=56$

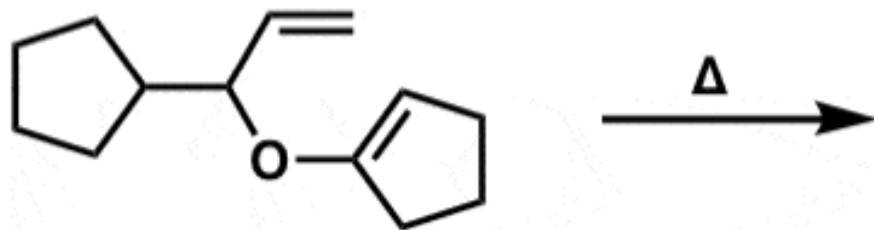


Mc-Lafferty Rearrangement

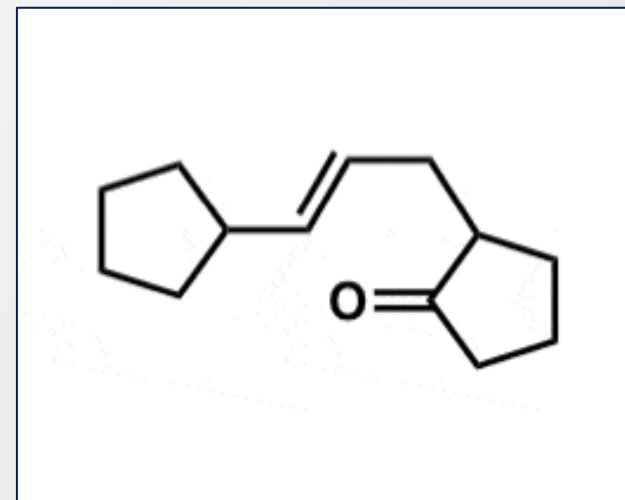
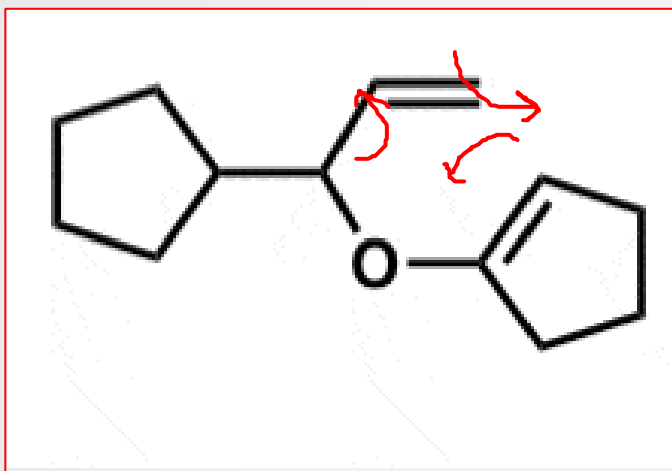


Predict the product

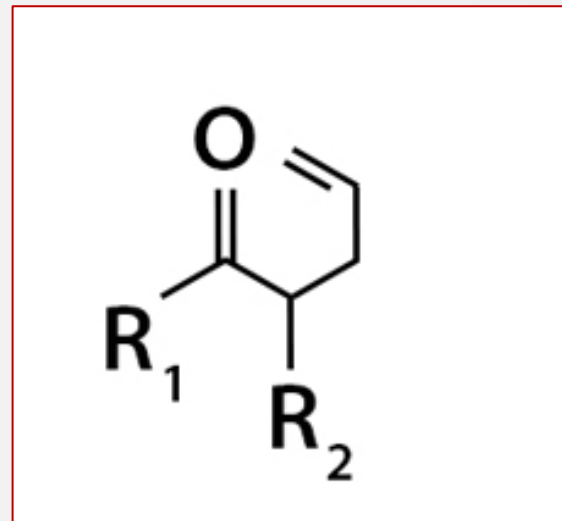
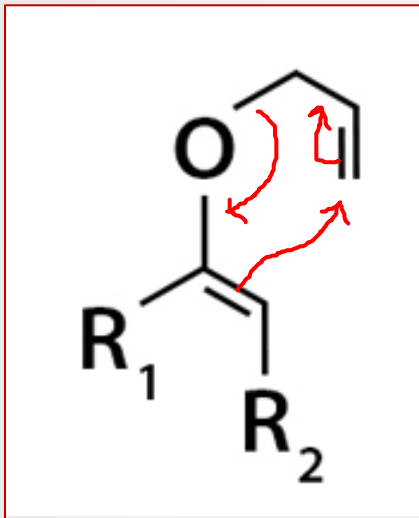
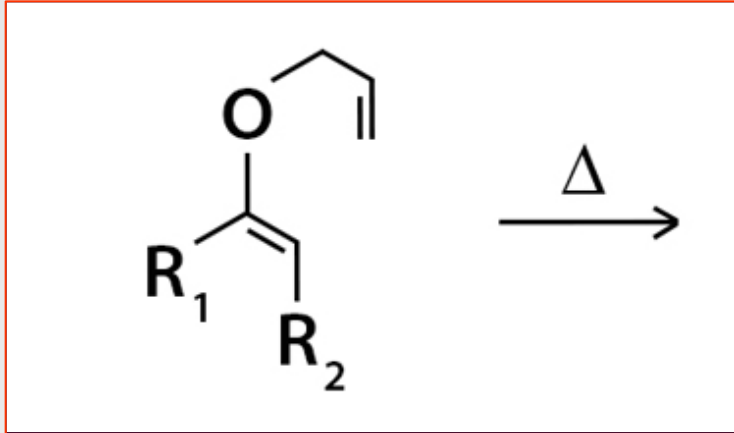
Predict the product of the following Claisen rearrangement:



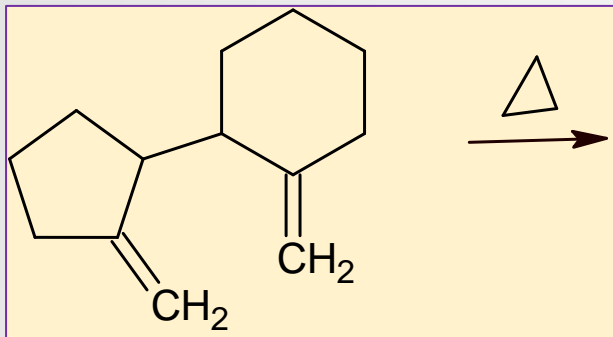
Claisen
Rearrangement



Predict the product



Predict the product



Cope rearrangement

