

REDUCTION SUMMARY

Name	Reagent	Function
Wolf Kishner Reduction	(i) N_2H_4 / (ii) KOH, Δ	$\text{>C=O} \rightarrow \text{>CH-CH}_3$
Clemenson Reduction	$\text{Zn} - \text{Hg}/\text{HCl}$	$\text{>C=O} \rightarrow \text{>CH-CH}_3$
Mozingo Reduction	$\begin{array}{ c} \text{SH} \\ \text{SH} \end{array}$ Dry HCl followed by Raney Ni	$\text{>C=O} \rightarrow \text{>CH-CH}_3$
Stephen's Reduction	SnCl_2/HCl followed by H_3O^+	$\text{R}-\text{C}\equiv\text{N} \rightarrow \text{R}-\text{CH}=\text{O}$
MPV Reduction	$\text{Al} \left(\text{O}-\text{CH} \begin{array}{l} \text{CH}_3 \\ \text{CH}_3 \end{array} \right)_3 / \text{HO}-\text{CH} \begin{array}{l} \text{CH} \\ \text{CH} \end{array}$	$\text{>C=O} \rightarrow \text{>CH-OH}$
Hydroboration Reduction	(i) B_2H_6 (ii) $\text{AcOH}, \text{H}_2\text{O}$	$\text{>C=C<} \rightarrow \begin{array}{c} \text{>C}-\text{C<} \\ \quad \\ \text{H} \quad \text{H} \end{array}$ $\text{>C=O} \rightarrow \begin{array}{c} \text{>C}-\text{O} \\ \quad \\ \text{H} \quad \text{H} \end{array}$
Bouvault Blank Reduction	Na in EtOH	$\text{R}-\text{COO}-\text{R} \rightarrow \text{RCH}_2\text{OH} + \text{ROH}$
Transfer Hydrogenation	$\text{N}_2\text{H}_4/\text{H}_2\text{O}_2$	$\text{>C=C<} \rightarrow \begin{array}{c} \text{>C}-\text{C<} \\ \quad \\ \text{H} \quad \text{H} \end{array}$
Rosenmund Reduction	$\text{H}_2, \text{Pd} - \text{BaSO}_4$	$\text{R}-\overset{\text{O}}{\parallel}{\text{C}}-\text{Cl} \rightarrow \text{R}-\overset{\text{O}}{\parallel}{\text{C}}-\text{H}$
Birch Reduction	Na in Liq. NH_3	$-\text{C}\equiv\text{C}- \rightarrow \begin{array}{c} \text{H} \\ \\ -\text{C}=\text{C}- \\ \\ \text{H} \end{array}$
Red phosphorus in presence of HI	Red P + HI	$\text{R}-\text{CH}=\text{O} \rightarrow \text{RCH}_3$ $\text{R}-\overset{\text{O}}{\parallel}{\text{C}}-\text{R} \rightarrow \text{RCH}_2\text{R}$ $\text{R}-\overset{\text{O}}{\parallel}{\text{C}}-\text{OH} \rightarrow \text{R}-\text{H}$

OXIDATION

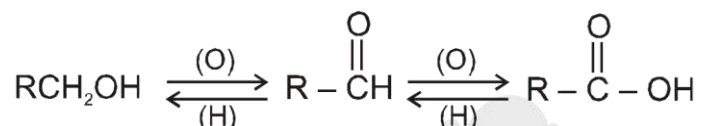
1. OXIDATION

1.1 Introduction

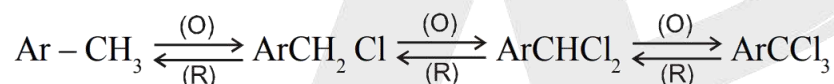
- (i) oxidation is defined as the addition of oxygen (electronegative) element to a substance or removal of hydrogen (electropositive) element from a substance.

or

Oxidation of an organic molecule usually corresponds to increasing its oxygen content or decreasing its hydrogen content.



- (ii) Oxidation of an organic compound may be more broadly defined as a reaction that increases its content of any element more electronegative than carbon. Replacing hydrogen atoms by chlorine atoms is an oxidation

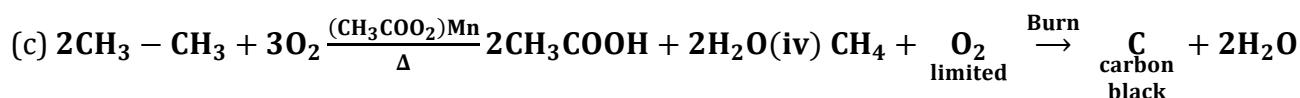
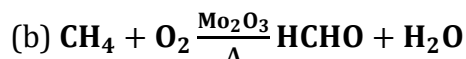
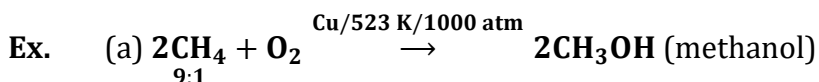
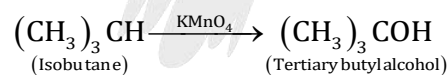


When organic compound is oxidised, oxidising agent used is reduced. When an organic compound is reduced, the reducing agent used must be oxidized.

1.2 Oxidation of Alkanes

Different products are formed by the use of different oxidising agents or different reaction conditions.

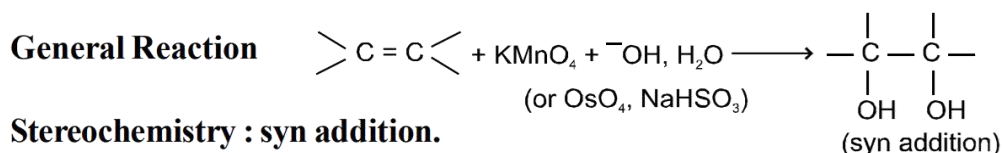
- (i) **By KMnO_4 or $\text{K}_2\text{Cr}_2\text{O}_7$** : Alkanes are usually not affected by oxidising agents like KMnO_4 or $\text{K}_2\text{Cr}_2\text{O}_7$. However, alkanes having tertiary hydrogen are oxidised by these oxidising agents to an alcohol.



1.3 Oxidation of alkenes and alkynes

- (i) Baeyer reagent [cold dilute 1% alkaline KMnO_4 solution] :

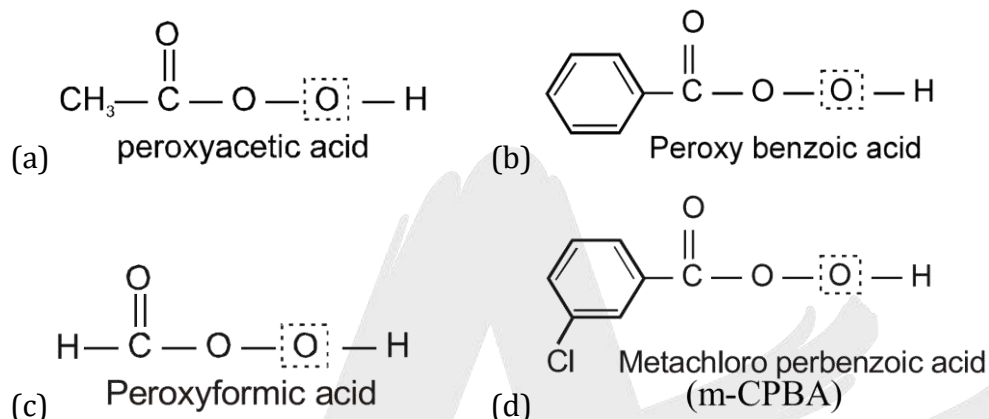
Alkene \rightarrow Vicinal diol; Alkyne \rightarrow Diketone; Aldehyde \rightarrow Acid



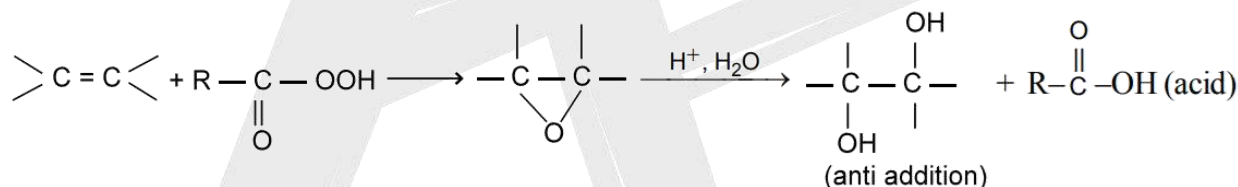
Stereochemistry : syn addition.

(ii) Oxidation with peroxyacids

An alkene is converted to an epoxide by a peroxyacid. [a carboxylic acid that has an extra oxygen atom in a —O—O— (peroxy) linkage]. Some simple peroxyacids (sometimes called peracids) are shown below :

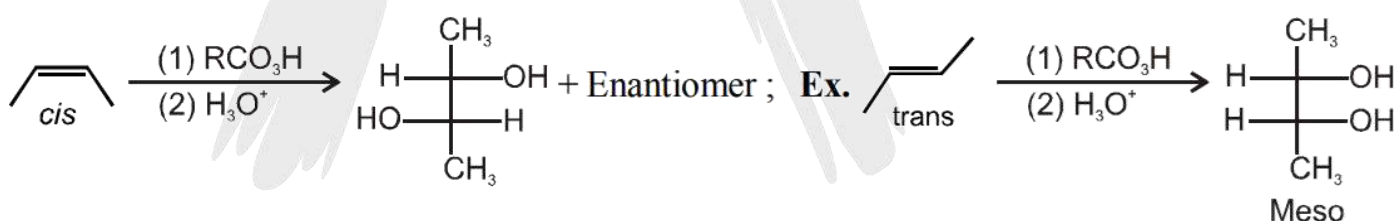


General Reaction

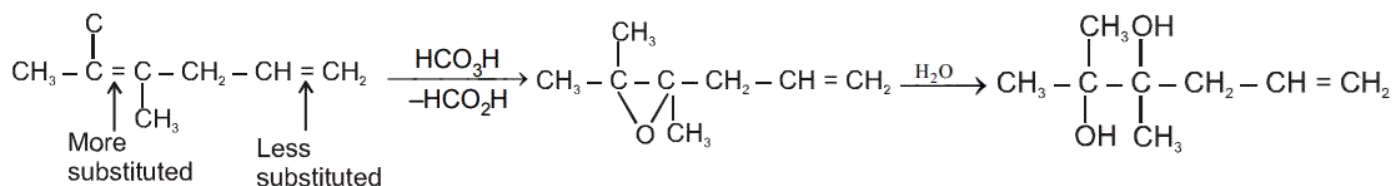


Stereochemistry : anti addition in diol formation.

Ex.



Note : The more highly substituted olefinic bond is more nucleophilic and therefore reacts faster with the peroxyacid than the less substituted double bond.



(iii) Oxidation with acidic KMnO_4 [KMnO_4/H^+]:

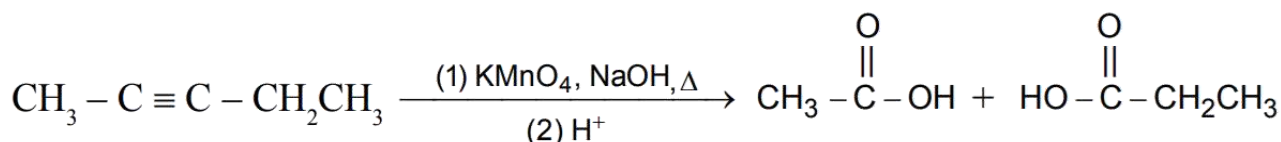
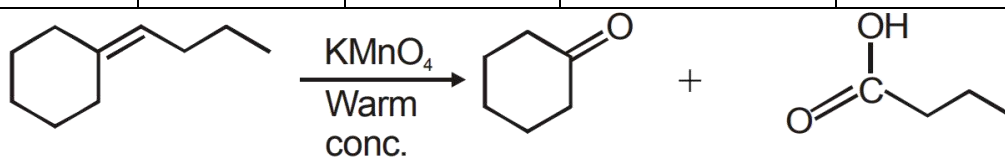
When alkene & alkyne heated with KMnO_4 in acidic or in alkaline medium; following changes takes place.

(ORGANIC CHEMISTRY)

REDUCTION OXIDATION

	KMnO_4/H^+				
Reactant	= CH_2 group	= CHR group	= CR_1R_2 group	$\equiv \text{CH}$ group	$\equiv \text{CR}$ group
Product	CO_2	RCOOH	$\text{O} = \text{CR}_1\text{R}_2$ group	CO_2	RCOOH

Ex.



(iv) Oxidation with ozone (ozonolysis):

Like permanganate ozone cleaves double bonds to give Ketones and aldehydes. However, ozonolysis is milder, and both Ketones and aldehydes can be recovered without further oxidation.

Reductive Ozonolysis:

	$\text{O}_3/\text{Zn}, \text{H}_2\text{O}$				
Reactant	= CH_2 group	= CHR group	= CR_1R_2 group	$\equiv \text{CH}$ group	$\equiv \text{CR}$ group
Product	HCHO	RCHO	$\text{R}_1\text{R}_2\text{C} = \text{O}$	$-\text{CO} - \text{CHO}$	diketone

Reductive Ozonolysis:

	$\text{O}_3/\text{H}_2\text{O}_2$				
Reactant	= CH_2 group	= CHR group	= CR_1R_2 group	$\equiv \text{CH}$ group	$\equiv \text{CR}$ group
Product	CO_2	RCOOH	$\text{R}_1\text{R}_2\text{C} = \text{O}$	CO_2	RCOOH

Type of Oxidising agent \rightarrow	Milder oxidising agent	Mild oxidising agent			Strong oxidising agent			Very Strong oxidising agent
Oxidising agent \rightarrow				CrO_3 in Inert medium	CrO_3 in water or H_2CrO_4	KMnO_4/H^+	$\text{K}_2\text{Cr}_2\text{O}_7/\text{H}^+$	$\text{KMnO}_4/\text{H}^+/\text{Heat}$
Type of Alcohol \downarrow	$\text{Cu}, \Delta(300^\circ\text{C})$	PCC	PDC					

(ORGANIC CHEMISTRY)

REDUCTION OXIDATION

1° alcohol or Primary alcohol	Aldehyde	Aldehyde	Carboxylic acid	Carboxylic acid
2° alcohol or Primary alcohol	Ketone	Ketone	Ketone	Mixture of Carboxylic acid
2° alcohol or Primary alcohol	Dehydrate to Alkene	Not oxidised	Not oxidised	Mixture of Carboxylic acid

1.4 Oxidation Reaction of Alcohols :

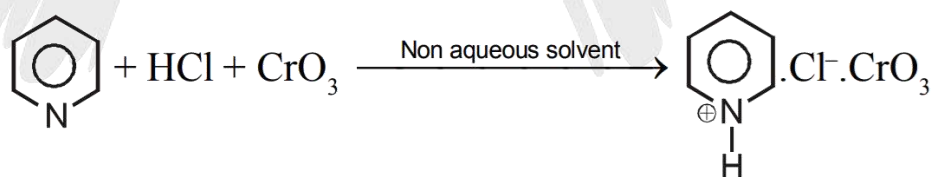
(i) Oxidation of alcohols using Cr(VI) reagents:

For oxidation of alcohols to corresponding carbonyl compounds, generally **Cr(VI)** reagents such as $\text{K}_2\text{Cr}_2\text{O}_7$, Jones reagent, PCC etc. are employed. For the synthesis of aldehydes, the Collins Reaction or use of more modern although more expensive chromium (VI) reagents such as PCC and PDC can be an appropriate choice. Oxidation of alcohols to carbonyl compound occurs via **Cr(VI)** acid monoester. Oxidation of fused aromatic system is generally carried out using **CrO₃** reagent

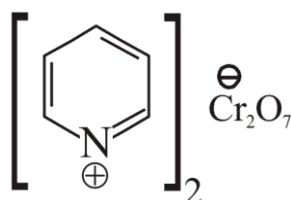
(a) PCC (Pyridinium Chloro Chromate)

It is other efficient reagent used widely for oxidation of primary and secondary alcohols. Reagent can be used in close to stoichiometric amounts with substrate. PCC is slightly acidic but can be buffered with **NaOAc**.

As no water is present in the reaction mixture, no aldehyde hydrate is formed which is oxidized to carboxylic acid in presence of **Cr(VI)**

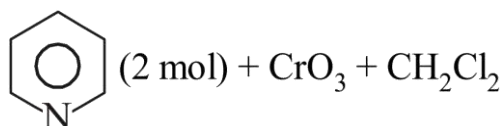


- (b) PDC (Pyridinium Dichromate): Since PDC is less acidic than PCC it is often used to oxidize alcohols that may be sensitive to acids. In methylene chloride solution, PDC oxidizes primary and secondary alcohols in roughly the same fashion as PCC, but much more slowly. Allylic alcohols are oxidized efficiently to conjugated enals and enones respectively.



- (c) **Collins Reagent:** It is the mixture of chromium trioxide with pyridine in dichloromethane. It is used to selectively oxidize primary alcohols to aldehyde, and will tolerate many other functional groups in the molecule.

It can be used as an alternative to Jones reagent and PCC in oxidation of secondary alcohols. Moreover, Collins reagent is especially useful for oxidations of acid sensitive compounds. Collins reagent can be prepared and isolated or generated in situ. This complex is both difficult and dangerous to prepare, as it is very hygroscopic and can in flame during its preparation.



- (d) **Jones Reagent :** It is chromium oxide, sulfuric acid and acetone. A mixture of potassium or sodium dichromate and dilute sulfuric acid can also be used.

It is a powerful oxidizing reagent and exhibits only poor chemoselectivity.

It is used for the oxidation of primary and secondary alcohols to carboxylic acids and ketones, respectively, that do not contain acid sensitive group.

Chromic acid and alcohol then through chromate ester gives carbonyl compound in presence of base (water in this case).

Aldehydes can form hydrates in presence of water and further oxidized to carboxylic acid in presence of **Cr(VI)** reagents. Tertiary alcohols cannot be oxidized by this reagent.

(ii) **Oxidation using Mn reagents**

- (a) **MnO₂** : It is used widely as oxidant in organic synthesis. It oxidizes allylic alcohols, acetylenicalcohols and benzylic alcohols to corresponding aldehydes or ketones. The configuration of double bond is preserved in the reaction.

- (b) **KMnO₄** : Manganese can function as oxidant when it is in +7 oxidation state. **KMnO₄** is one such oxidant. It is a very strong oxidizing agent.

Alkyl side chain on aromatic rings are oxidized to carboxylic acid group. This method is more generally applied to methyl group, however, longer side chains can also be cleaved. Tertiary alkyl groups are not oxidized and are usually accompanied by ring cleavage. **KMnO₄** is also used to oxidize primary alcohol and aldehyde to corresponding carboxylic acid.

Ex. Write the product of following reaction when **X** is treated with

- (i) Jones reagent (ii) **PCC** (iii) Oppenauer oxidation (iv) **MnO₂** (v) **KMnO₄**



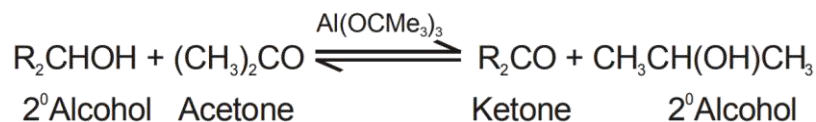
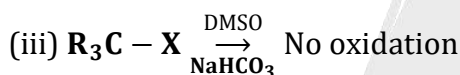
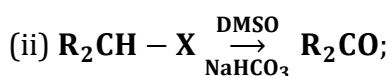
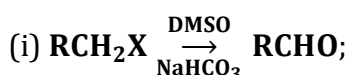
OH

(X)

(c) Oppenauer's oxidation

(i) This reaction involves the oxidation of a secondary alcohol with a ketone and base to the corresponding ketone.

(ii) Commonly used bases are aluminium tert-butoxide.

(d) Kornblum oxidation [(i) DMSO (ii) NaHCO₃]

1.5 Oxidation reaction of Carbonyl Compound

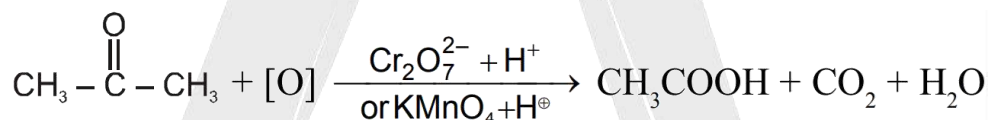
(i) Popoff's rule (Acidic KMnO₄ & K₂Cr₂O₇ as oxidising agent) :

(a) Aldehydes are oxidised to carboxylic acid having same number of C atoms as aldehyde.

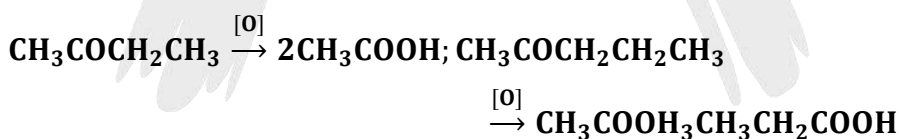


(b) Ketones are oxidised with difficulty.

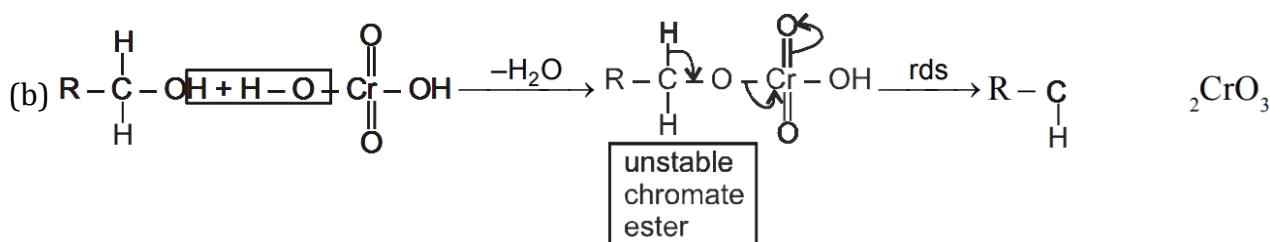
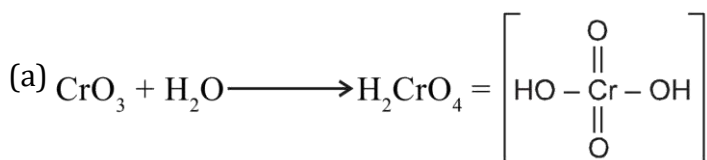
They are oxidised only on heating with a strong oxidising agent.

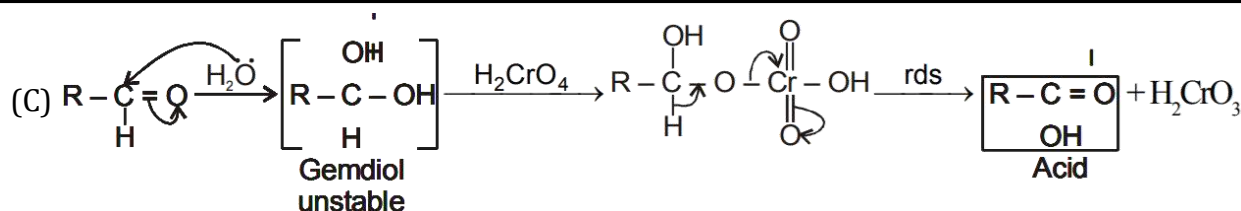


(c) In case of mixed or unsymmetrical ketones the >C=O group remains with the smaller alkyl group.



Mechanism (with Cr⁺⁶ oxidising agents) :



**Remarks :**

Primary alcohol forms a chromate ester with chromic acid.

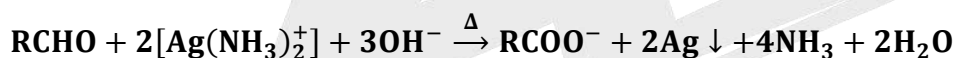
The chromate ester decomposes in 2nd slow step with the elimination of α -hydrogen. So the first oxidation product, an aldehyde is obtained.

In aqueous medium, aldehyde forms a gemdiol (hydrated aldehyde). It is further oxidised to an acid by similar mechanism.

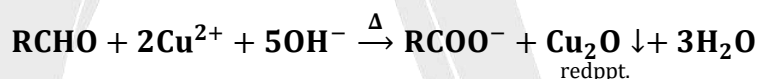
(ii) TOLLEN'S REAGENT :

RCHO (aldehydes) can be easily oxidised to **RCOOH** (except **HCHO** that can be oxidised to **CO₂**) by weak oxidising agents like ammonical **AgNO₃** (Tollen's reagent) hence they are better reducing agents.

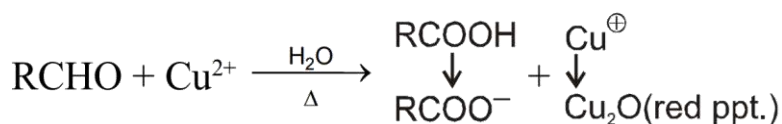
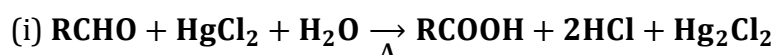
Aldehydes reduce Tollen's reagent to Ag and appears in the form of silver mirror is called silver-mirror test. It is given by all aldehydes and reducing sugars.

**(iii) FEHLING'S SOLUTION :**

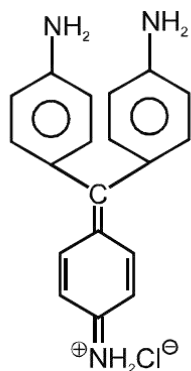
Aldehydes (except benzaldehyde) reduce Fehling's solution (**Cu²⁺** reduced to **Cu⁺**) which is an alkaline solution of cupric (**Cu²⁺**) ion complexed with tartrate ion.

**(iv) BENEDICT'S SOLUTION :**

Aldehydes also reduce Benedict's solution (**Cu²⁺** complexed with citrate ion) to **Cu⁺** Sodium citrate + **NaOH** + **NaHCO₃** + **CuSO₄**

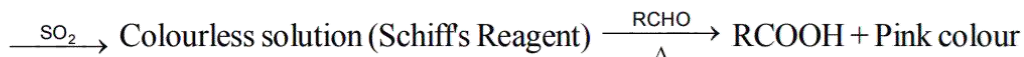
**(v) HgCl₂ and Hg₂Cl₂****(vi) SCHIFF'S REAGENT:**

Schiff's Reagent is aq. solution of following base decolourised by passing **SO₂**. Aldehyde restore pink colour of Schiff's reagent.



p-Rosaniline Hydrochloride

Magenta colour (Fuscin)

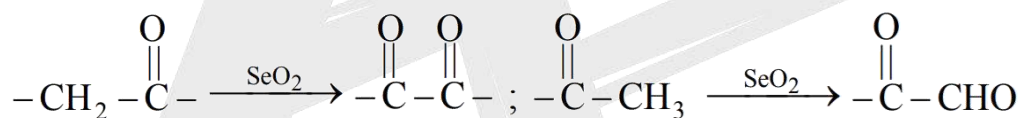


Note: Ketons are not easy to oxidize so they do not give these 5 tests. These five tests can be used to distinguish aldehyde and ketones. Both gives 2, 4 DNP test.

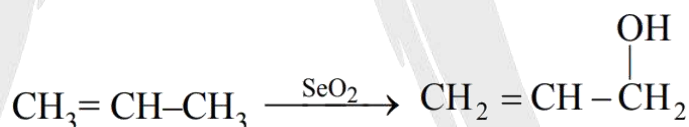
(vii) Oxidation by using SeO_2 : SeO_2 is a selective oxidizing agent with converts $-\text{CH}_2-$ group adjacent

to carbonyl group into carbonyl group. The reagent, in general, oxidises active methylene and methyl

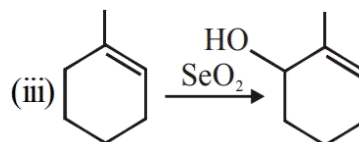
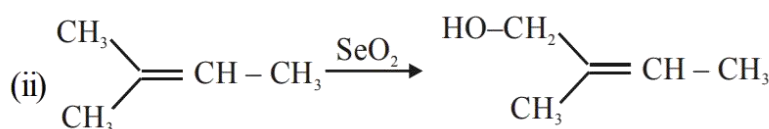
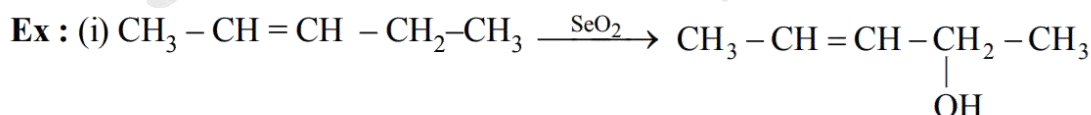
groups to ketonic and aldehydic groups respectively.



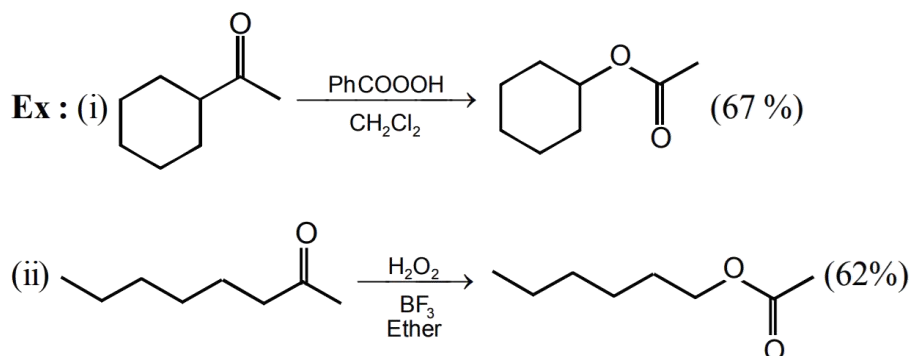
-Double bonds, triple bonds and aromatic rings may also activate the methylene group. The methylene or methyl group α to the most highly substituted end of the double bond is hydroxylated according to the order of preference of oxidation $\text{CH}_2 > \text{CH}_3 > \text{CH}$ groups.



-Rate of reactivity order : $2^\circ \text{C}-\text{H} > 1^\circ \text{C}-\text{H} > 3^\circ \text{C}-\text{H}$



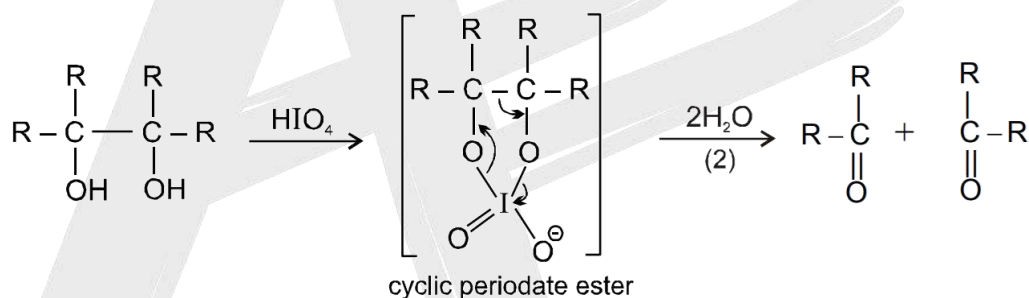
(viii) BAEYER-VILLIGER OXIDATION: It is the oxidative cleavage of a carbon-carbon bond adjacent to a carbonyl which converts ketones to esters and cyclic ketones to lactones. It can be carried out with peracids such as m-CPBA, or with hydrogen peroxide and a lewis acid.



KETONES ARE DIFFICULT TO OXIDIZE : Ketones can be oxidized from their enolic form at high temperature with very strong oxidizing agent. Oxidation of ketones is sometimes governed by Popoff's rule. According to this rule carbonyl group remains with the smaller alkyl group. More electron rich alkene will be easy to oxidized.



(ix) **DIOLS OXIDATION BY HIO_4 :** (Oxidation by lead acetate is similar to HIO_4 oxidation)

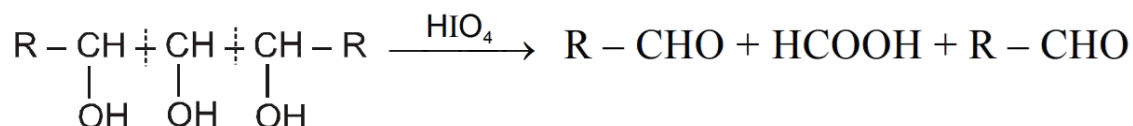


Mechanism:

Remarks :

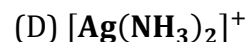
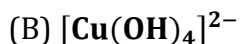
- HIO_4 (periodic acid) oxidises vicinal diols (1, 2-diols).
- It brings about oxidative cleavage of vicinal diol.
- It can also oxidise α -hydroxy carbonyl compound, α -dicarbonyl compound and α hydroxy Imine.
- HIO_4 forms a cyclic periodate ester as an intermediate.

General reaction

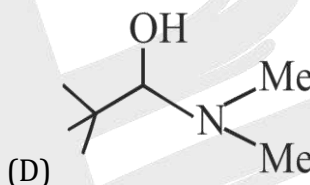
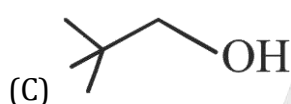
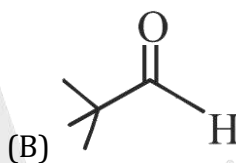
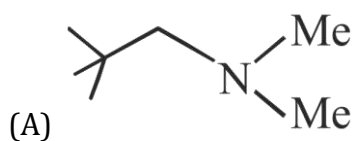
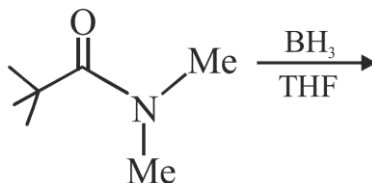


EXERCISE # I

1. Tollen's reagent is



2. Major product of following reaction is:



3. Baeyer's reagent decolourises when reacts with:

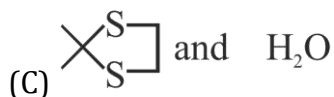
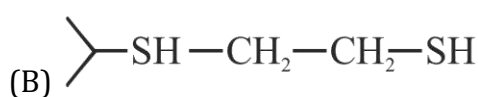
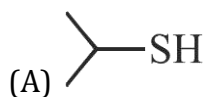
(A) Alkane

(B) Alkene only

(C) Alkene and alkyne both

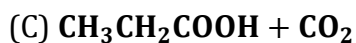
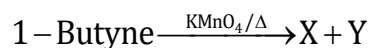
(D) Alkyne only

4. The end products of the reaction are:



(D) Propane

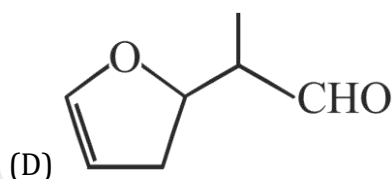
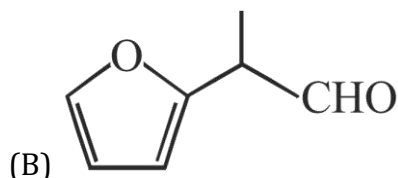
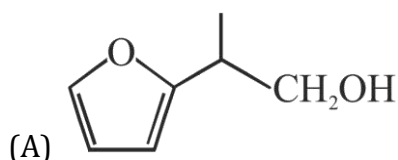
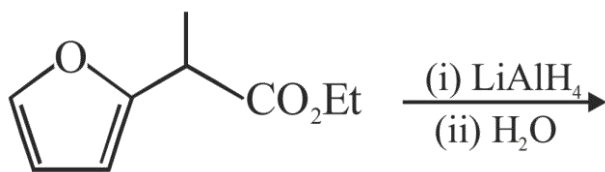
5. X and Y in following reaction is:



(ORGANIC CHEMISTRY)

REDUCTION OXIDATION

6. Major product of following reaction is/are:



(C) $\text{CH}_3\text{CH}_2\text{OH}$

7. Bayer's reagent is:

(A) alkaline permanganate solution

(B) acidified permanganate solution

(C) neutral permanganate solution

(D) aqueous bromine solution

8. An alkyne C_7H_{12} when reacted with alkaline KMnO_4 followed by acidification by HCl , yielded a mixture of $\text{CH}_3 - \underset{\text{CH}_3}{\text{CH}} - \text{COOH}$ & $\text{CH}_3\text{CH}_2\text{COOH}$. The alkyne is -

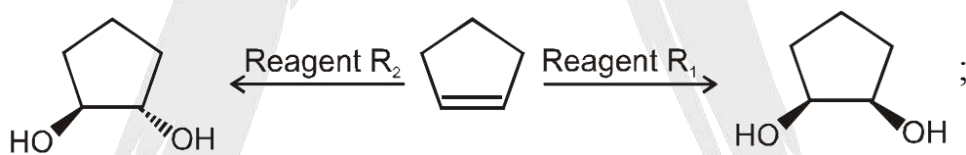
(A) 3-hexyne

(B) 2-methyl-2-hexyne

(C) 2-methyl-3-hexyne

(D) 3-methyl-2-hexyne

9. R_1 and R_2 in following reaction respectively is :



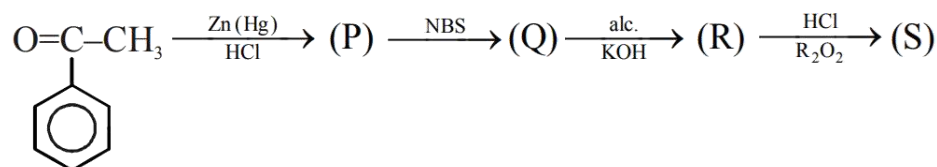
(A) Cold alkaline KMnO_4 , $\text{OsO}_4/\text{H}_2\text{O}_2$

(B) Cold alkaline KMnO_4 , HCO_3H & H_3O^+

(C) Cold alkaline KMnO_4 , $\text{C}_6\text{H}_5\text{CO}_3\text{H}$

(D) $\text{C}_6\text{H}_5\text{CO}_3\text{H}$, HCO_3H

10. Which of the following is/are hydrocarbon?



(A) P

(B) Q

(C) R

(D) S

11. Glucose as well as fructose are oxidized by periodic acid. The number of moles of HCOOH formed from each mole of glucose and fructose are

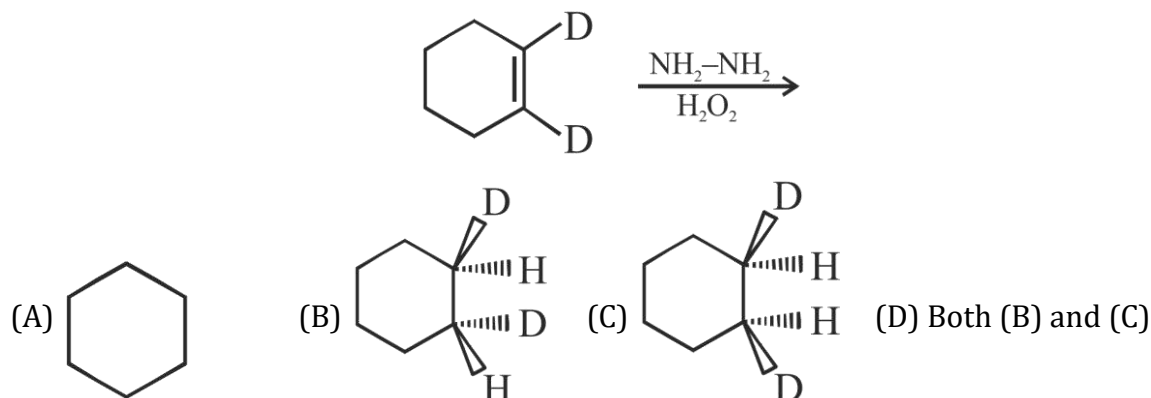
(A) 5 and 5

(B) 5 and 4

(C) 5 and 3

(D) 4 and 312

12. Major products of the given reaction will be:



13. Fehlings solution is

- (A) AgNO_3 solution + NaOH solution + NH_4OH
 (B) Alkaline solution of Cupric ion complexed with citrate ion
 (C) Copper sulphate + sodium potassium tartarate + NaOH
 (D) Copper sulphate solution

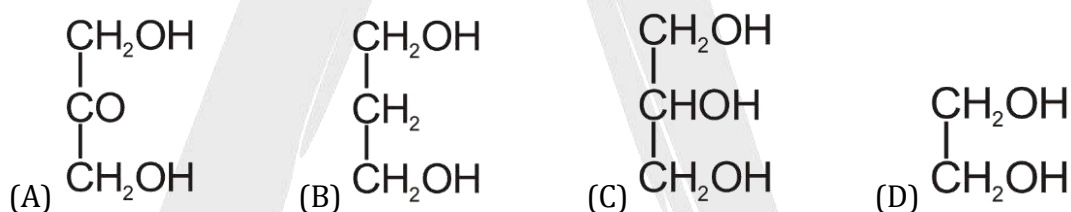
14. Secondary alcohols on heating with copper at 300°C give

- (A) Alkenes (B) Aldehydes (C) Ketones (D) tert-alcohols

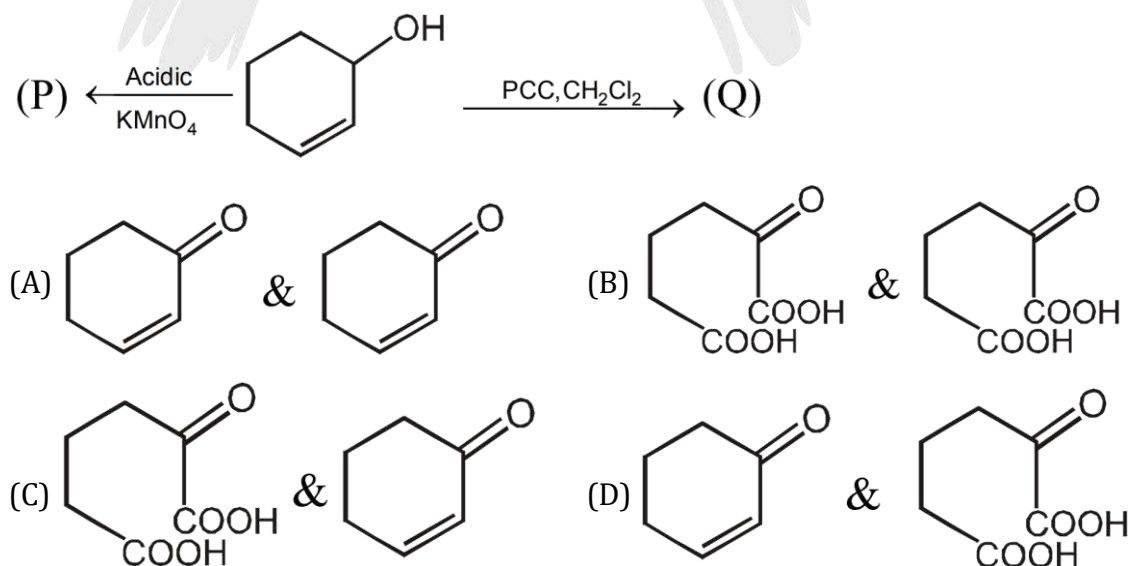
15. The reagent which can react easily with both acetaldehyde and acetone is:

- (A) Tollens reagent (B) Schiff's reagent (C) H_2/Ni (D) Fehling's solution

16. Which of the following compounds is resistant to periodic acid oxidation?



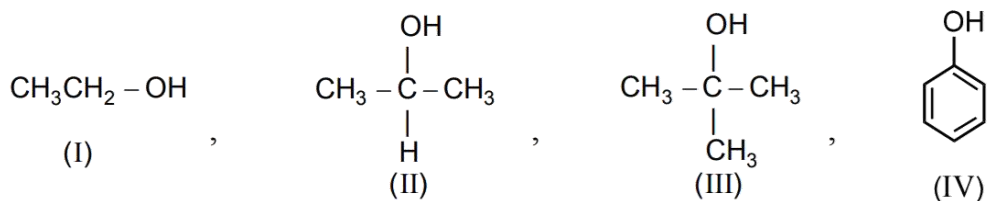
17. Identify (P) and (Q) respectively in the given reaction :



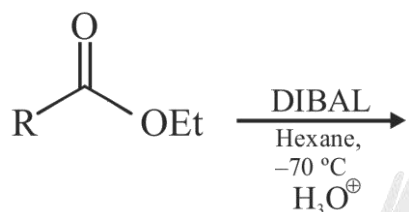
(ORGANIC CHEMISTRY)

REDUCTION OXIDATION

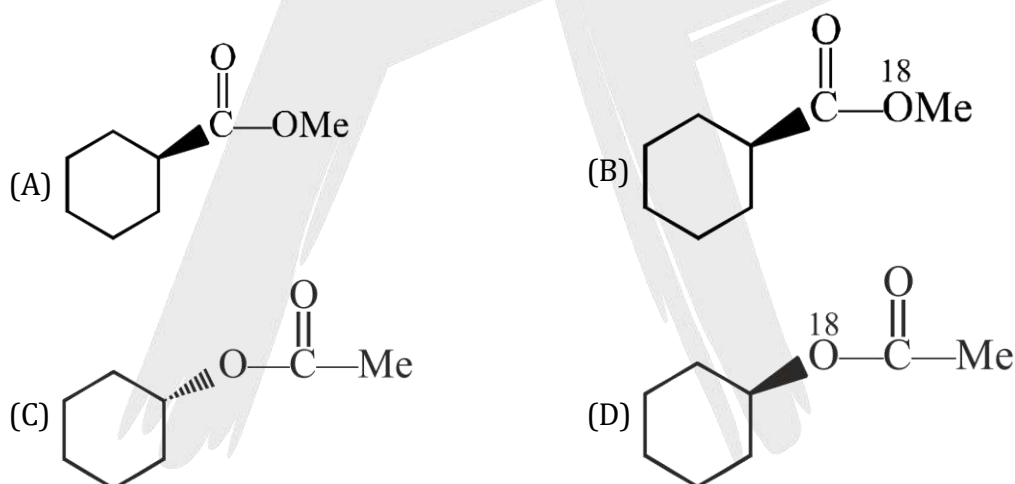
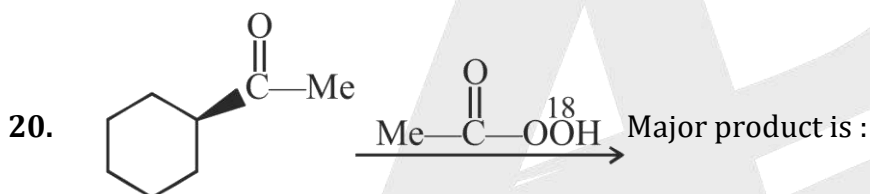
18. Which of the following sets of compounds cannot turn clear orange solution of $\text{CrO}_3/\text{aq. H}_2\text{SO}_4$ to greenish opaque solution



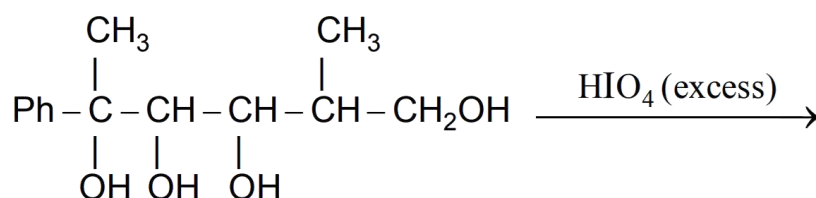
- (A) I, IV (B) II, III (C) I, II (D) III, IV
19. Major product of following reaction is/are:



- (A) $\text{R}-\text{CHO}$ (B) $\text{R}-\text{CH}_2\text{OH}$ (C) $\text{CH}_3\text{CH}_2\text{OH}$ (D) $\text{R}-\text{COOH}$



21. The product which is not formed in the following reaction is:

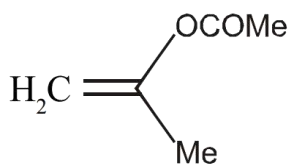


- (A) HCOOH (B) $\text{Ph}-\overset{\text{CH}_3}{\underset{\text{O}}{\parallel}}{\text{C}}-\text{CH}_3$ (C) $\text{OHC}-\overset{\text{CH}_3}{\underset{\text{O}}{\parallel}}{\text{CH}}-\text{CH}_2\text{OH}$ (D) $\text{OHC}-\overset{\text{CH}_3}{\underset{\text{O}}{\parallel}}{\text{CH}}-\text{CHO}$

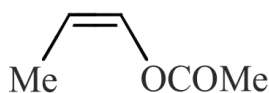
(ORGANIC CHEMISTRY)

REDUCTION OXIDATION

22. The products of acid hydrolysis of **P** and **Q** can be distinguished by:



(P)



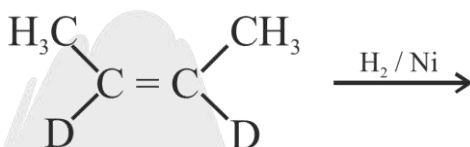
(Q)

- (A) Lucas reagent (B) 2, 4-DNP (C) Fehling's solution (D) NaHSO_3

23. On catalytic reduction with H_2/Pt how many alkenes will give n-butane ?

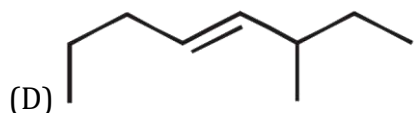
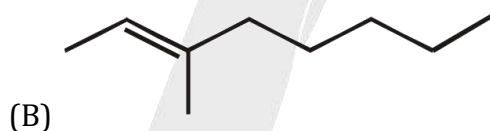
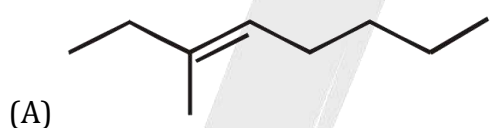
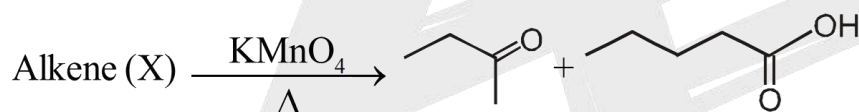
- (A) 1 (B) 2 (C) 3 (D) 4

24. Major products of following reaction will be :

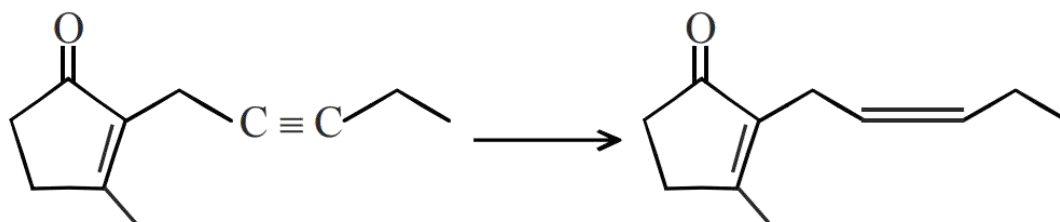


- (A) Racemic mixture (B) Diastereomers
(C) Meso (D) Constitutional isomers

25. Alkene **X** in following reaction is :

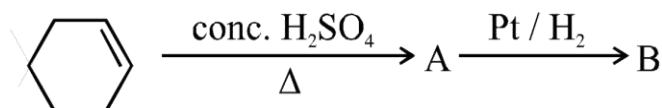


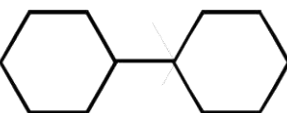
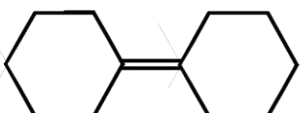
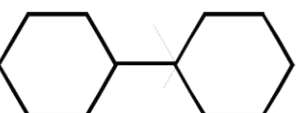
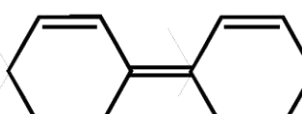
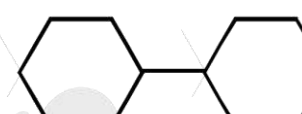
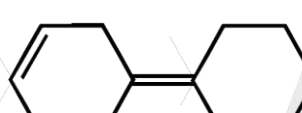
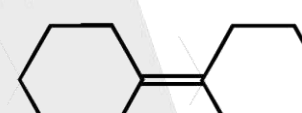
26. Which reagent will be used for the given conversion?



- (A) $\text{Na} / \text{Liq. NH}_3$ (B) $\text{H}_2, \text{Pd} - \text{CaCO}_3$ (C) $\text{Li, Ph} - \text{NH}_2$ (D) H_2, Pt

27. In following reaction A and B respectively are:



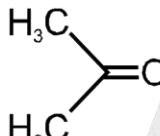

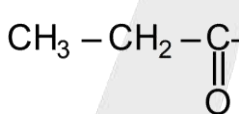
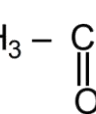
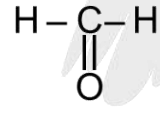
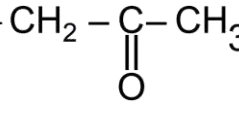
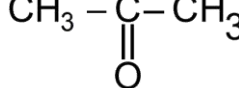

- (A) Both 
- (B)  , 
- (C)  , 
- (D)  , 

28. Which of the following will decolorise alkaline KMnO_4 solution?

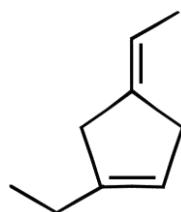
- (A) C_3H_8 (B) CH_4 (C) CCl_4 (D) C_2H_4

29. Product B and C in given reaction are respectively:



- (A)  and 
- (B)  and 
- (C)  and 
- (D)  and 

30. If the following compound is treated with Pd in excess of H_2 gas, how many stereoisomers of the product will be obtained?

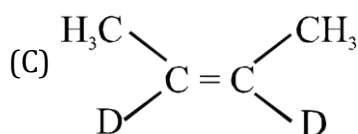
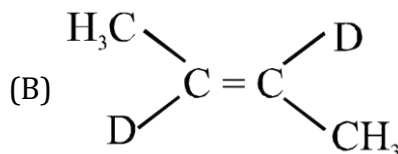
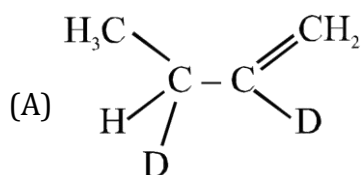
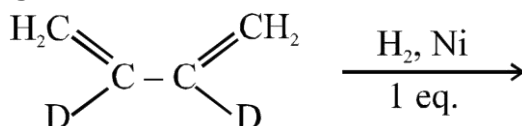


- (A) 1 (B) 2 (C) 3 (D) 4

(ORGANIC CHEMISTRY)

REDUCTION OXIDATION

31. Major product of following reaction is :

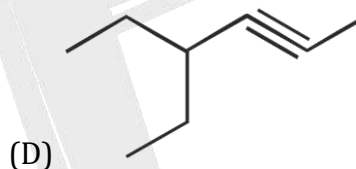
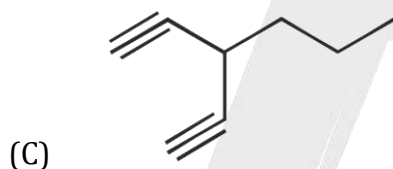
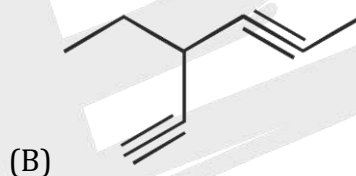
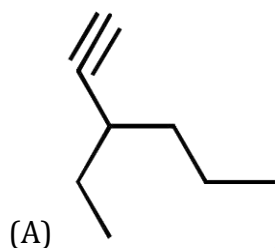


(D) All of these

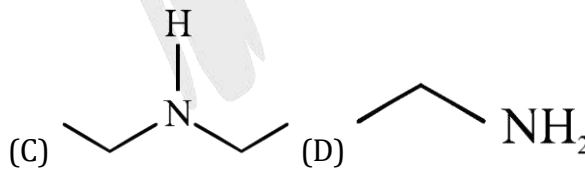
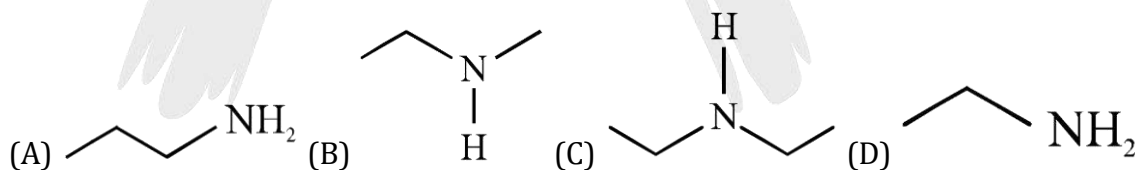
32. Which of the following can not be obtained when alkenes are oxidised with KMnO_4 and then followed by acid hydrolysis?

(A) alkanolic acids (B) alkanols (C) alkanones (D) carbon dioxide

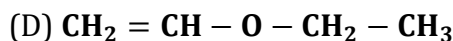
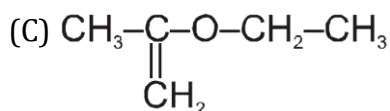
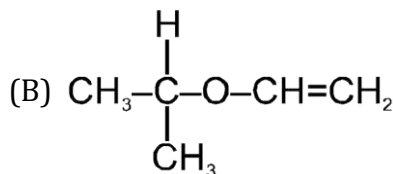
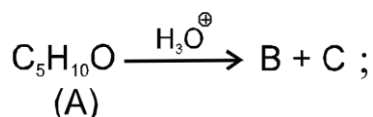
33. Which alkyne gives 3-ethylhexane on catalytic hydrogenation?



34. The final major product (B) in following reaction is :



35. In following reaction if (B) and (C) both give +ve iodoform test then compound (A) can be :



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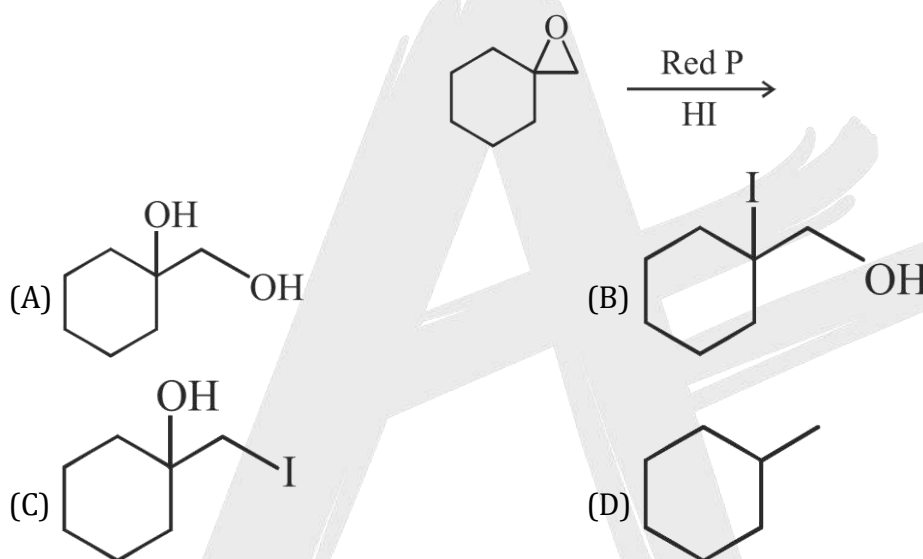
REDUCTION OXIDATION

36. Which of the following can be selectively oxidised by MnO_2/Δ :
- (A) $\text{C}_6\text{H}_5 - \text{CHOH} - \text{CH}_3$ (B) $\text{C}_6\text{H}_5 - \text{CH}_2 - \text{CH}_2 - \text{OH}$
 (C) $\text{CH}_3 - \text{CH} = \text{CH} - \text{CH}_2 - \text{OH}$ (D) $\text{CH}_2 = \text{CH} - \text{CH}_2 - \text{CH}_2 - \text{OH}$
37. Which will give silver mirror test with Tollens reagent :
- (A) $\text{C}_6\text{H}_5\text{CHO}$ (B) $\text{CH}_3 - \text{CHO}$ (C) HCOOH (D) $\text{C}_6\text{H}_5\text{CH}(\text{OH})\text{COC}_6\text{H}_5$
38. Fehling solution gives red precipitate with:

- (A) Aromatic aldehyde (B) Aliphatic aldehyde

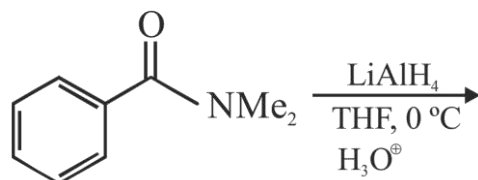


39. Choose the major product of the following reaction.



40. Silver mirror test with Tollens reagent is given by:
- (A) $\text{C}_6\text{H}_5\text{CHO}$ (B) $\text{Ph} - \text{NH} - \text{OH}$
 (C) $\text{C}_6\text{H}_5 - \text{CH}_2 - \text{C}(=\text{O}) - \text{CH}_2\text{OH}$ (D) CH_3CHO

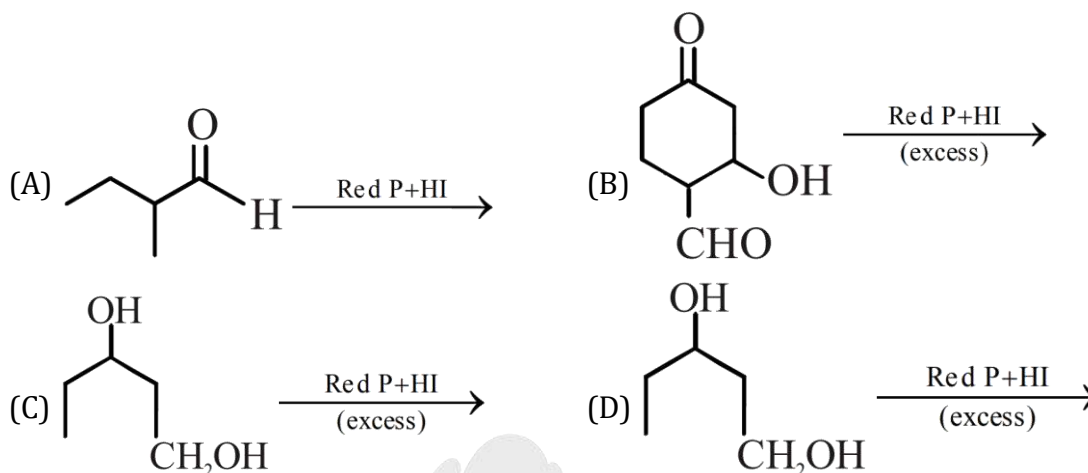
41. Major product of following reaction is:



- (A) $\text{Ph} - \text{CH}_2\text{OH}$ (B) NHMe_2 (C) $\text{Ph} - \text{CH}_2 - \text{NMe}_2$ (D) $\text{Ph} - \text{CHO}$

EXERCISE # II

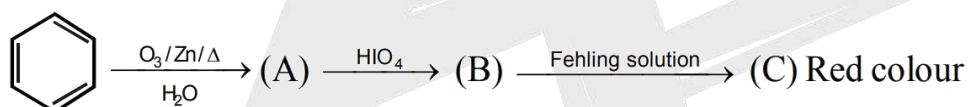
1. In which of the following reactions reactant and product both can show stereoisomerism:



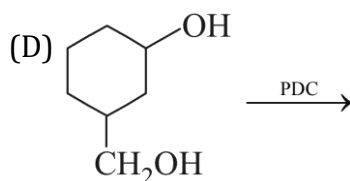
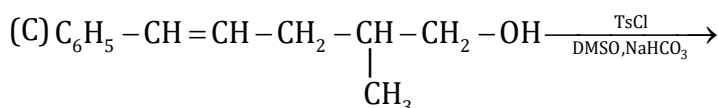
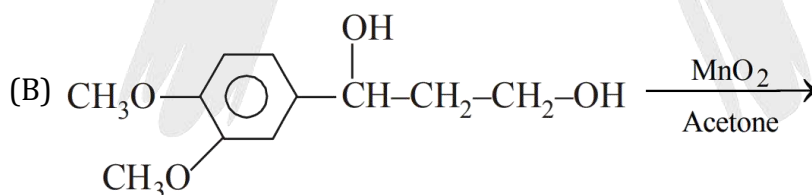
2. Which of the following is an example of oxidation reaction:



3. In following reaction sequence compound B is:



4. Major product of which reaction can show Stereoisomerism?

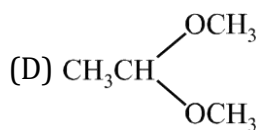
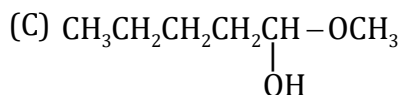
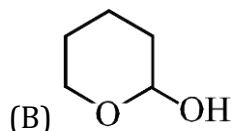


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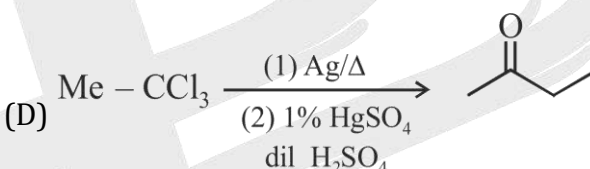
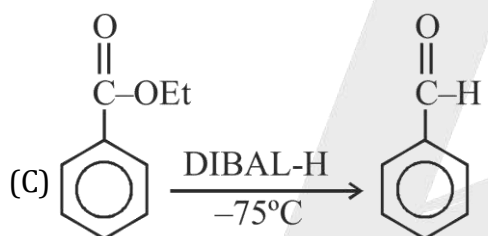
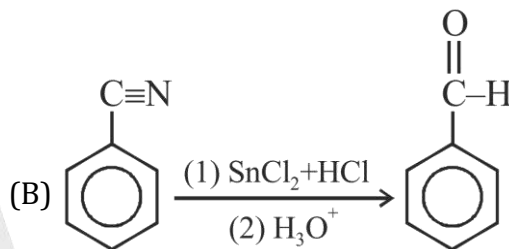
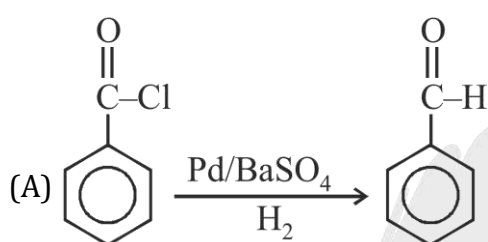
REDUCTION OXIDATION

5. Which of the following compound will give positive Tollens test

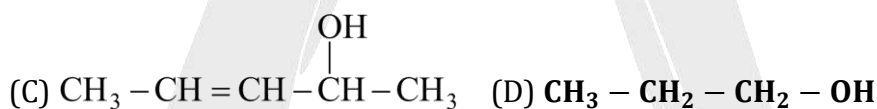
(A) Tartaric acid



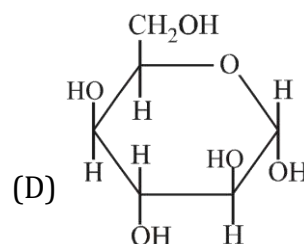
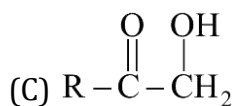
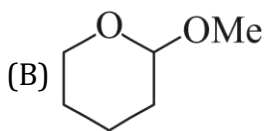
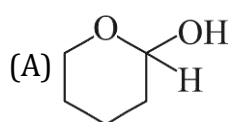
6. Which of the following reactions is/are correctly match with their major products?



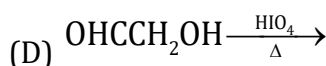
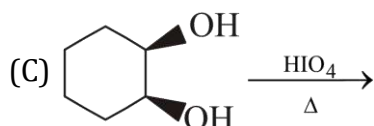
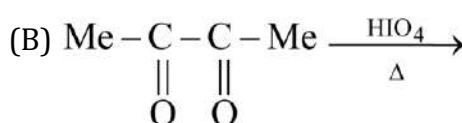
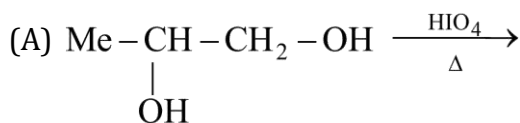
7. Which one of the following alcohols are oxidised by MnO_2 ?



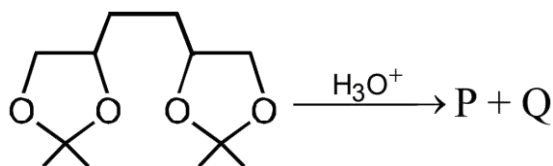
8. Which will give the Tollen test.



9. Major product and reactant of which reactions gives positive tollens test:

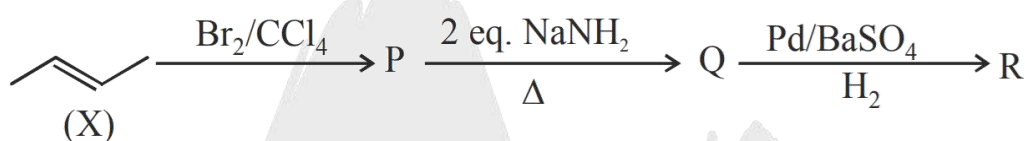


10. In following reaction **P** and **Q** are respectively.



- (A) Acetone and Hexane-1,2,5,6-tetraol.
 (B) Acetaldehyde and Acetone.
 (C) Acetaldehyde and Hexane-1,2,5,6-tetraol.
 (D) Acetone and Formaldehyde.

11. Choose the incorrect option(s) for following sequence.

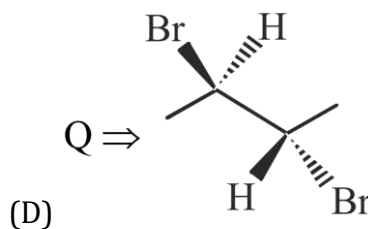
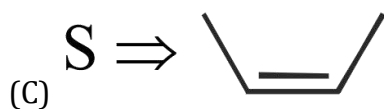
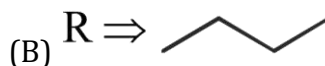
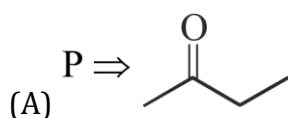
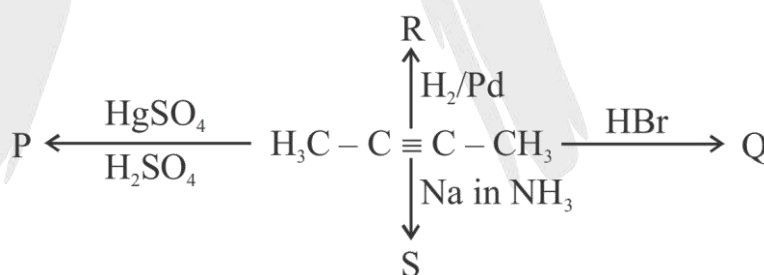


- (A) **P** is a racemic compound
 (B) **Q** is terminal alkyne
 (C) **X** & **R** are positional isomer
 (D) Formation of **R** is redox reaction

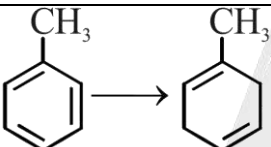
12. Which of the following compounds will consume even number of periodic acid?

- (A) $\text{HO}-\text{CH}_2-\text{CH}_2-\underset{\text{OH}}{\text{CH}}-\text{CH}_2-\text{OH}$
 (B) $\text{CH}_2-\underset{\text{OH}}{\text{CH}}-\underset{\text{OH}}{\text{CH}}-\underset{\text{OH}}{\text{CH}_2}$
 (C) $\text{H}_2\text{C}-\underset{\text{OH}}{\text{CH}}-\underset{\text{OH}}{\text{CH}}-\underset{\text{OH}}{\text{CH}_3}$
 (D) $\text{Me}-\underset{\text{O}}{\underset{\text{||}}{\text{C}}}-\underset{\text{NH}_2}{\text{CH}}-\text{Me}$

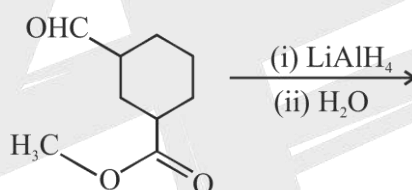
13. Which of the following is correctly matched?



14.

	Column-I (Conversion)		Column-II (Required Reagent)
(A)	$\text{H}_3\text{C}-\text{C}\equiv\text{C}-\text{CH}_3 \longrightarrow \begin{array}{c} \text{CH}_3 \quad \text{CH}_3 \\ \diagdown \quad \diagup \\ \text{C}=\text{C} \\ \diagup \quad \diagdown \\ \text{H} \quad \text{H} \end{array}$	(P)	$\text{H}_2, \text{Pd} - \text{BaSO}_4$
(B)	$\text{H}_3\text{C}-\text{C}\equiv\text{C}-\text{CH}_3 \longrightarrow \begin{array}{c} \text{CH}_3 \quad \text{H} \\ \diagdown \quad \diagup \\ \text{C}=\text{C} \\ \diagup \quad \diagdown \\ \text{H} \quad \text{CH}_3 \end{array}$	(Q)	$\text{Li}, \text{Liq. NH}_3$
(C)	$\text{H}_3\text{C}-\underset{\text{CH}_3}{\text{CH}}=\text{CH}-\text{CH}_3 \longrightarrow \text{H}_3\text{C}-\text{CH}_2-\text{CH}_2-$	(R)	$\text{N}_2\text{H}_4/\text{H}_2\text{O}_2$
(D)		(S)	$\text{B}_2\text{H}_6, \text{CH}_3\text{COOH}$

15. Total number of alcohols obtained in following reaction is:

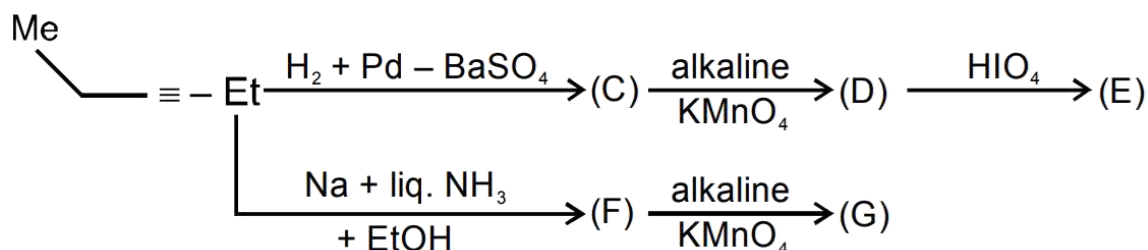


16. Total numbers of reagent that can be used for given conversion.

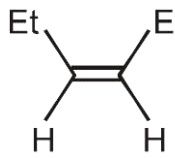
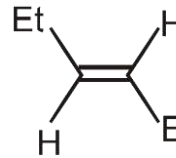


- (a) $\text{Zn} - \text{Hg}/\text{HCl}$ (b) LiAlH_4 (c) LiBH_4 (d) (i) N_2H_4 (ii) $\text{OH}^\ominus, \Delta$
 (e) $\text{LiAl(OEt)}_3\text{H}$ (f) Red P/HI (g) (i) $(\text{CH}_2\text{SH})_2$ (ii) $\text{H}_2, \text{Raney Ni}$

COMPREHENSION TYPE Paragraph for Q. 17 to 21



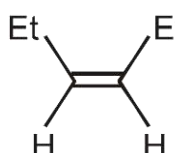
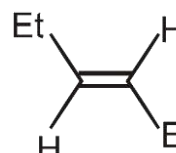
17. The compound (C) is:

- (A)  (B)  (C) $\text{Et}-\text{C}\equiv\text{C}-\text{Et}$ (D) Both (A) and (B)

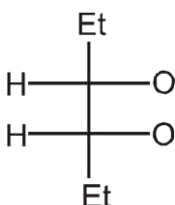
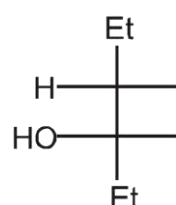
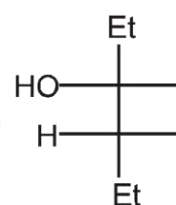
(ORGANIC CHEMISTRY)

REDUCTION OXIDATION

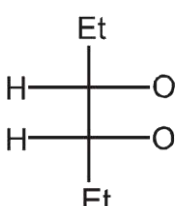
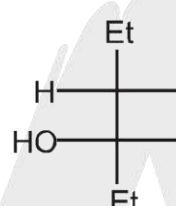
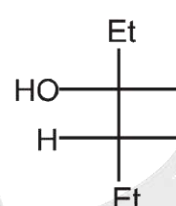
18. The compound (F) is:

- (A)  (B)  (C) $\text{Et}-\equiv-\text{Et}$ (D) Both (A) and (B)

19. The compound (D) is:

- (A)  (B)  (C)  (D) Both (B) and (C)

20. The compound (G) is:

- (A)  (B)  (C)  (D) None of these

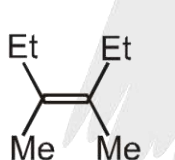
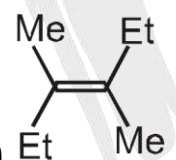
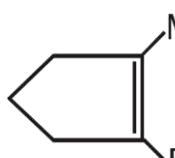
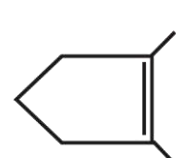
21. The compound (E) is:

- (A) Two moles of $\text{Me}-\text{CH}_2-\text{CHO}$. (B) Two moles of $\text{Me}-\text{CH}_2-\text{COOH}$.
(C) One mole of (A) and one mole of (B) (D) No reaction.

22. Reaction of 2-butanol with Cu, Δ involve

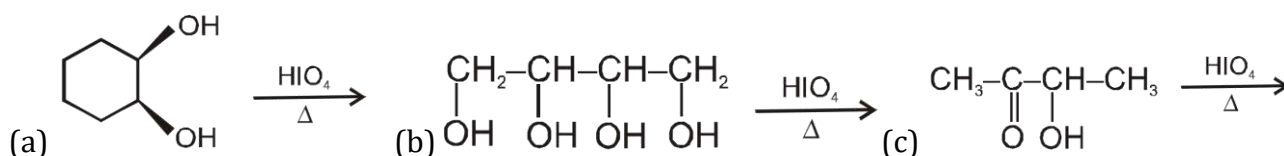
- (A) dehydrogenation (B) elimination
(C) dehydration (D) oxidation

23. Which of the following will give syn addition?

- (A)  $\xrightarrow[\text{(ii) H}_2\text{O/OH}^-]{\text{(i) KMnO}_4}$ (B)  $\xrightarrow[\text{(ii) Na}_2\text{SO}_3]{\text{(i) OsO}_4}$
(C)  $\xrightarrow[\text{(ii) Na}_2\text{SO}_3]{\text{(i) OsO}_4}$ (D)  $\xrightarrow[\text{(ii) H}_3\text{O}^+]{\text{(i) RCOOOH}}$

SUBJECTIVE TYPE

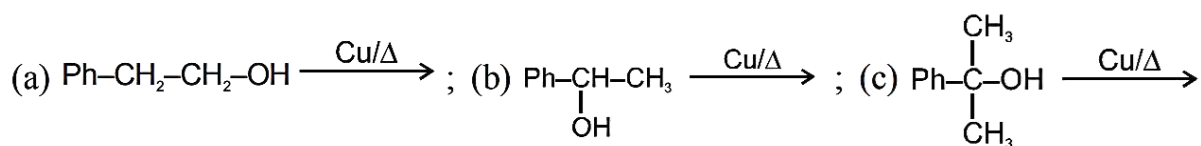
24. Complete the following reactions:



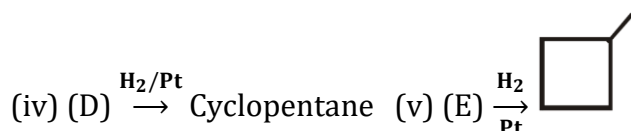
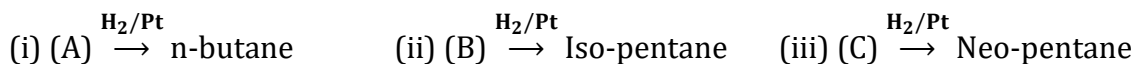
(ORGANIC CHEMISTRY)

REDUCTION OXIDATION

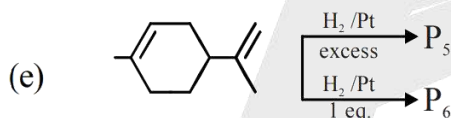
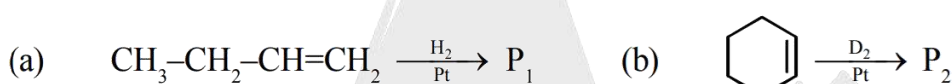
25. Complete the following reactions:



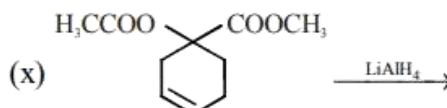
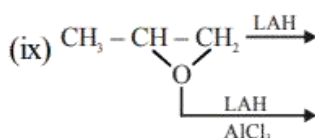
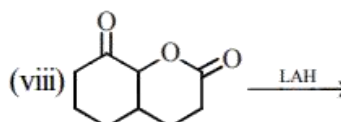
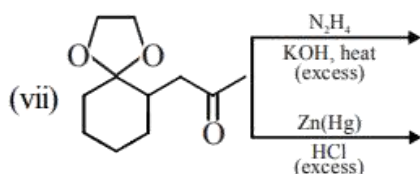
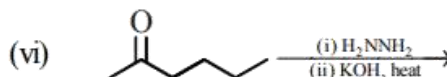
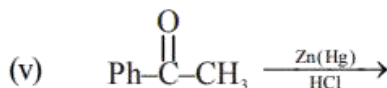
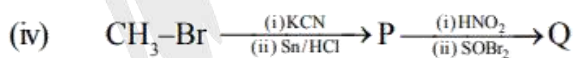
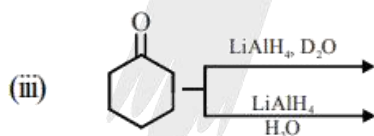
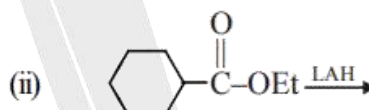
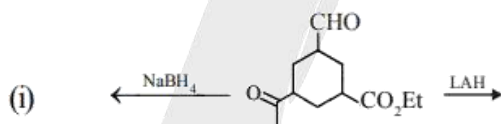
26. How many alkene on catalytic reduction give normal butane as product.



27. Give the expected major product for each reaction, including stereochemistry where applicable.



28. Give product in the following reactions



(ORGANIC CHEMISTRY)

REDUCTION OXIDATION

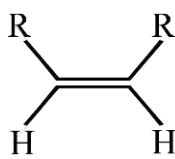
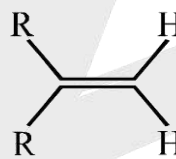
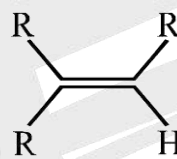
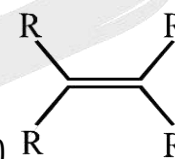
EXERCISE # III (MAIN & ADVANCE)

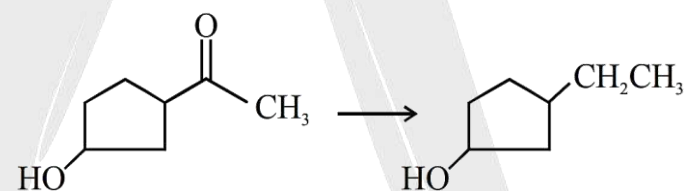
- Hydrogenation of benzoyl chloride in the presence of **Pd** and **BaSO₄** gives: [IIT 1992]
(A) Benzyl alcohol (B) Benzaldehyde (C) Benzoic acid (D) Phenol
- Draw the stereochemical structure of the product in the following reactions. [IIT 1994]

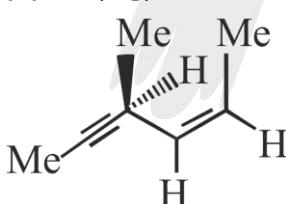
$$\text{R}-\text{C}\equiv\text{C}-\text{R} \xrightarrow[\text{Lindlar catalyst}]{\text{H}_2}$$
- Under Wolff Kishner reduction conditions, the conversions which may be brought about is? [IIT 1995]
(A) Benzaldehyde into Benzyl alcohol (B) Cyclohexanol into Cyclohexane
(C) Cyclohexanone into Cyclohexanol (D) Benzophenone into Diphenylmethane
- In the reaction, **P** is [IIT 1995]

$$\begin{array}{c} \text{CH}_3 \\ \diagdown \\ \text{CO} \\ \diagup \\ \text{CH}_3 \end{array} \xrightarrow{\text{SeO}_2} \text{P} + \text{Se} + \text{H}_2\text{O}$$

(A) **CH₃COCHO** (B) **CH₃COOCH₃** (C) **CH₃COCH₂OH** (D) None
- Which one of the following alkenes will react fastest with **H₂** under catalytic hydrogenation condition [IIT 2000]

(A)  (B)  (C)  (D) 
- The appropriate reagent for the following transformation: [IIT-2000]



(A) **Zn(Hg), HCl** (B) **NH₂NH₂, OH⁻** (C) **H₂/Ni** (D) **NaBH₄**
- 
 Hydrogenation of the above compound in the presence of poisoned palladium catalyst gives- [IIT-2001]

(A) An optically active compound (B) An optically inactive compound
(C) A racemic mixture (D) A diastereomeric mixture
- When **CH₂ = CH - COOH** is reduced with **LiAlH₄**, the compound obtained will be - [AIEEE-2003]

(A) **CH₃ - CH₂ - CH₂OH** (B) **CH₃ - CH₂ - CHO**
(C) **CH₃ - CH₂ - COOH** (D) **CH₂ = CH - CH₂OH**

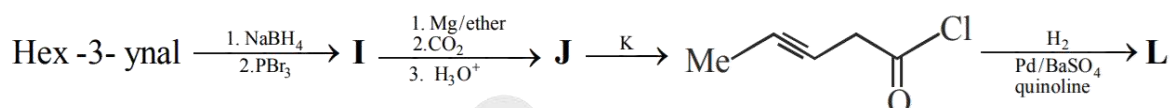
(ORGANIC CHEMISTRY)

REDUCTION OXIDATION

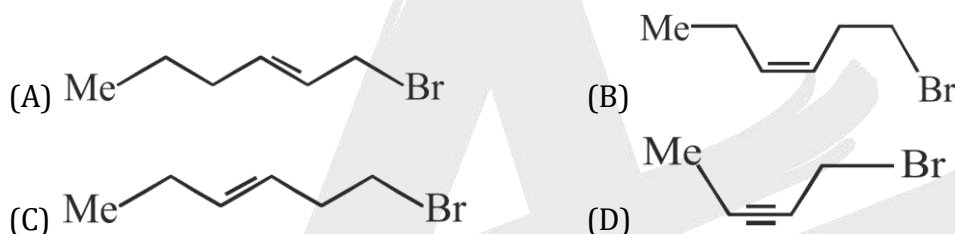
9. 2-hexyne can be converted into trans-2-hexene by the action of: [IIT-2004]
 (A) $\text{H}_2 - \text{Pd} - \text{BaSO}_4$ (B) Li in liq. NH_3
 (C) $\text{H}_2 - \text{PtO}_2$ (D) NaBH_4
10. The best reagent to convert pent-3-en-2-ol into pent-3-en-2-one is [AIEEE 2005]
 (A) Acidic dichromate (B) Acidic permanganate
 (C) Pyridinium chloro-chromate (D) Chromic anhydride in glacial acetic acid

Paragraph for Question No. 11 to 13

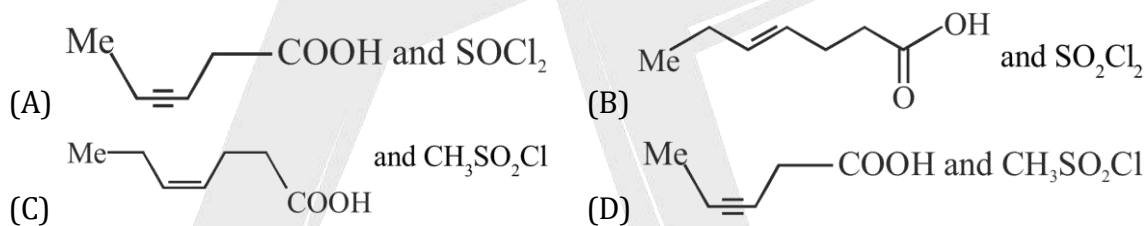
In the following reaction sequence, products I, J and L are formed. K represents a reagent.



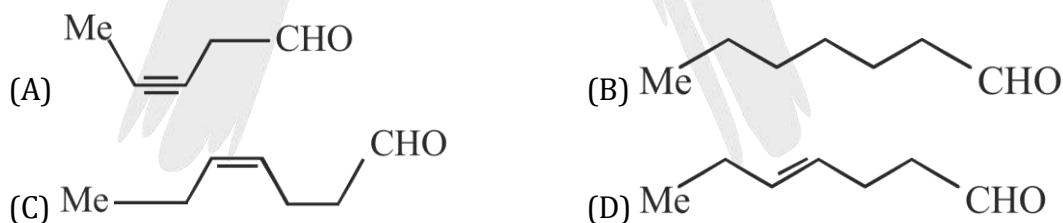
11. The structure of the product I is [JEE-2008]



12. The structures of compounds J and K, respectively, are [JEE-2008]

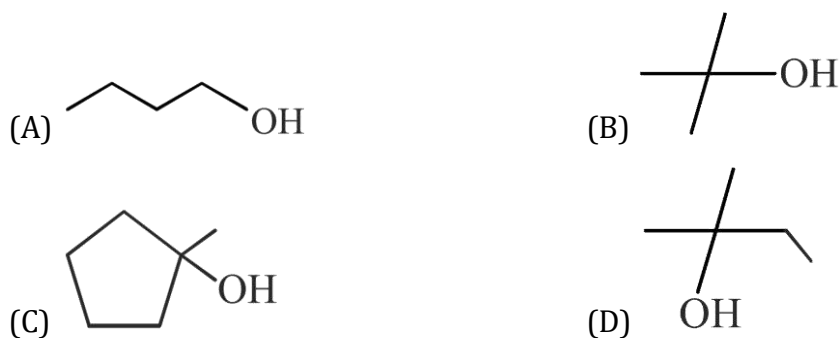


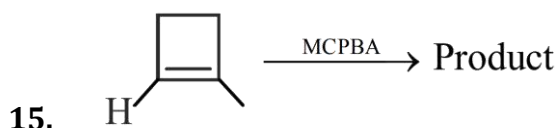
13. The structure of product L is [JEE-2008]



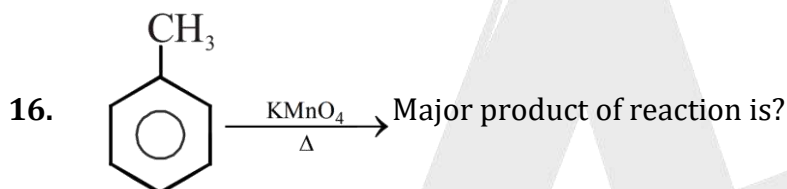
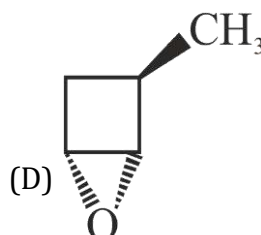
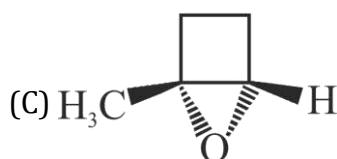
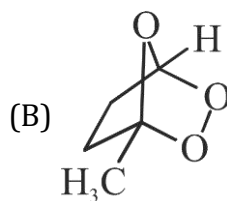
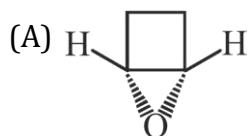
14. Which of the following will change the colour of acidic dichromate solution.

[JEE Mains-2013]

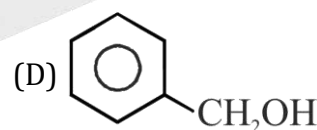
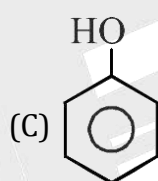
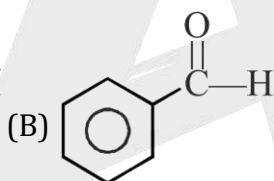
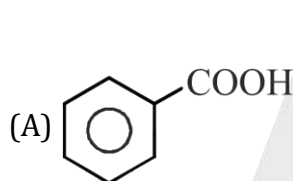




[JEE Mains-2013]



[JEE Mains-2013]



17. The most suitable reagent for the conversion of $R-CH_2-OH \rightarrow R-CHO$ is

[JEE Mains 2014]

(A) CrO_3

(B) PCC (Pyridinium chlorochromate)

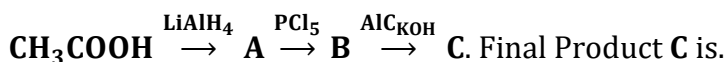
(C) $KMnO_4$ (D) $K_2Cr_2O_7$

18. Consider all possible isomeric ketones including stereoisomers of $MW = 100$, All these isomers are independently reacted with $NaBH_4$ (NOTE : stereoisomers are also reacted separately) The total number of ketones that give a racemic product(s) is/are.

[JEE-2014]

19. In the reaction

[JEE-2014]

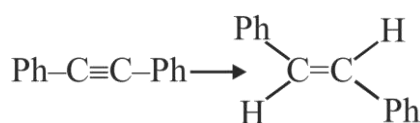
(A) H_2 / Lindlar Cat.

(B) Cat. hydrogenation

(C) $LiAlH_4$ (D) Li/NH_3

20. The reagent needed for converting is:

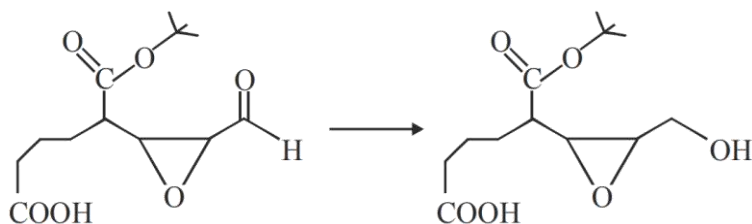
[JEE-2014]

(A) H_2 / Lindlar Cat.

(B) Cat. hydrogenation

(C) $LiAlH_4$ (D) Li/NH_3

21. Reagent(s) which can be used to bring about the following transformation is(are): [JEE-2016]



(A) LiAlH_4 in $(\text{C}_2\text{H}_5)_2\text{O}$

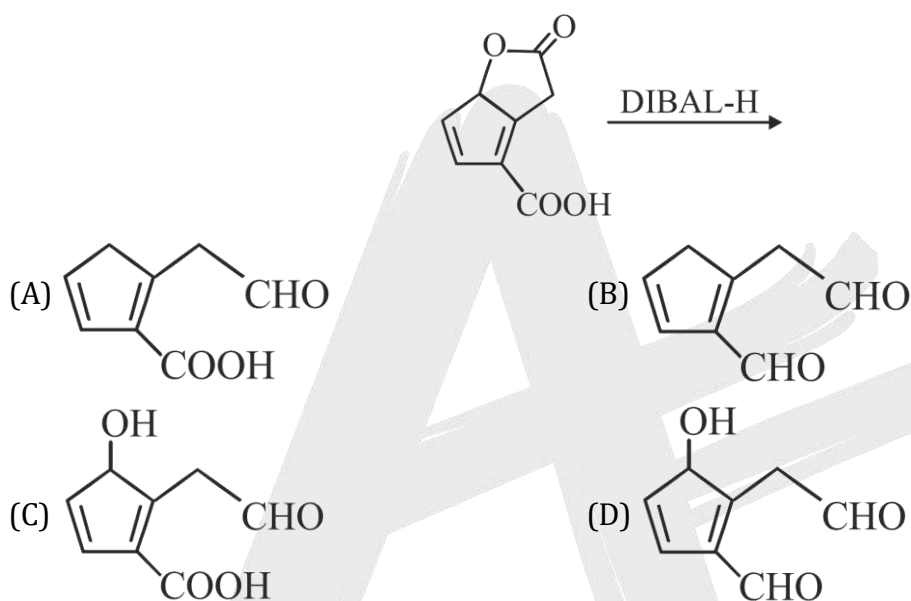
(B) BH_3 in THF

(C) NaBH_4 in $\text{C}_2\text{H}_5\text{OH}$

(D) Raney Ni/H_2 in THF

22. The major product obtained in the following reaction is:

[JEE MAINS-2017]



23. The major product of following reaction is : $\text{R}-\text{C}\equiv\text{N} \xrightarrow[(2)\text{H}_2\text{O}]{(1)\text{AlH}(\text{i-Bu})_2} \text{[JEE MAIN-2019]}$

(A) RCHO

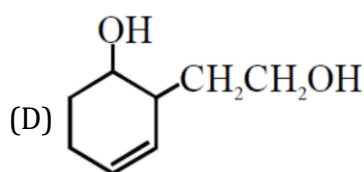
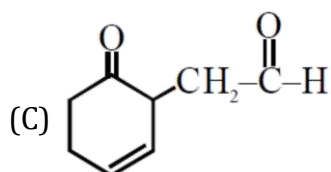
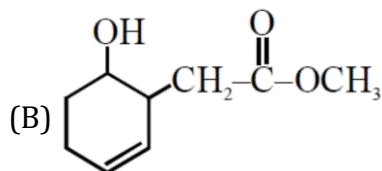
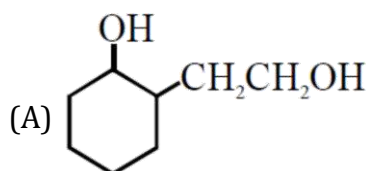
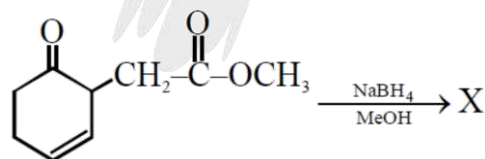
(B) RCOOH

(C) RCH_2NH_2

(D) RCONH_2

24. The major product 'X' formed in the following reaction is:

[JEE MAIN-2019]

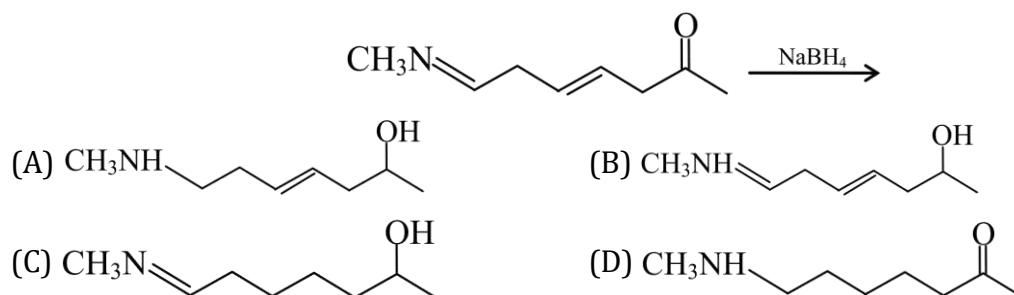


(ORGANIC CHEMISTRY)

REDUCTION OXIDATION

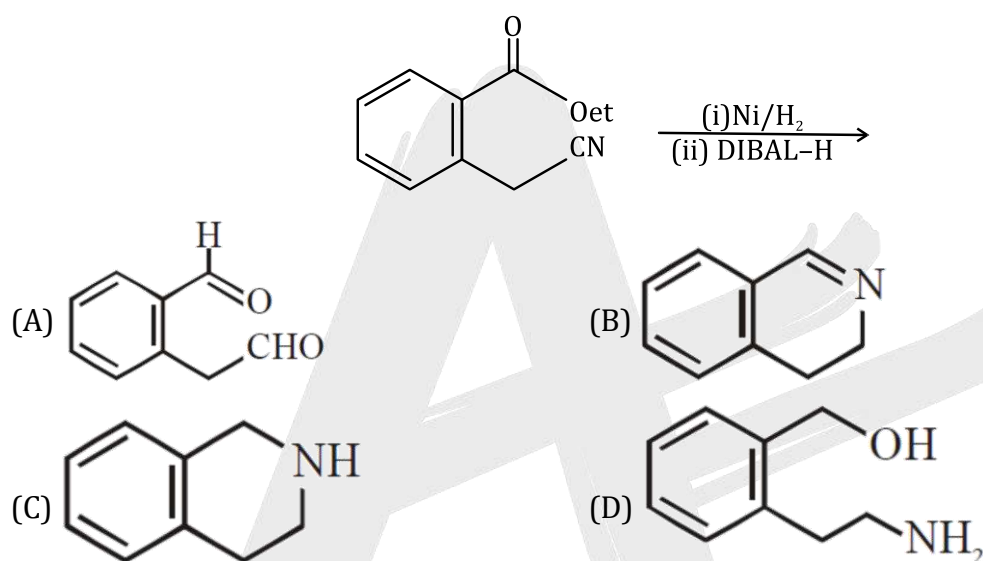
25. The product of the following reaction is:

[JEE MAIN-2019]



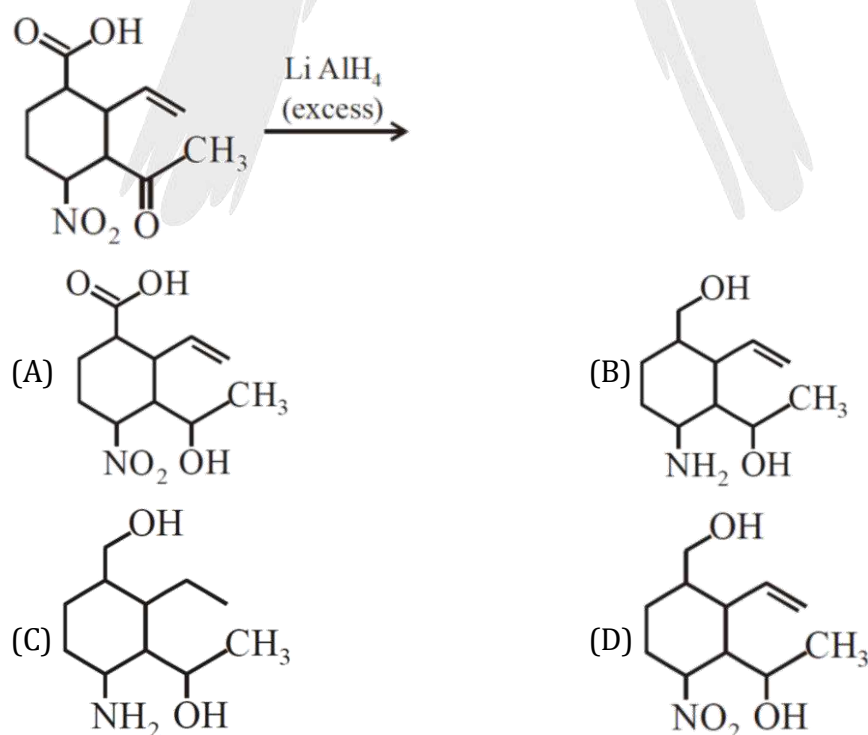
26. The major product of the following reaction is:

[JEE MAIN-2019]



27. The major product obtained in the following reaction is:

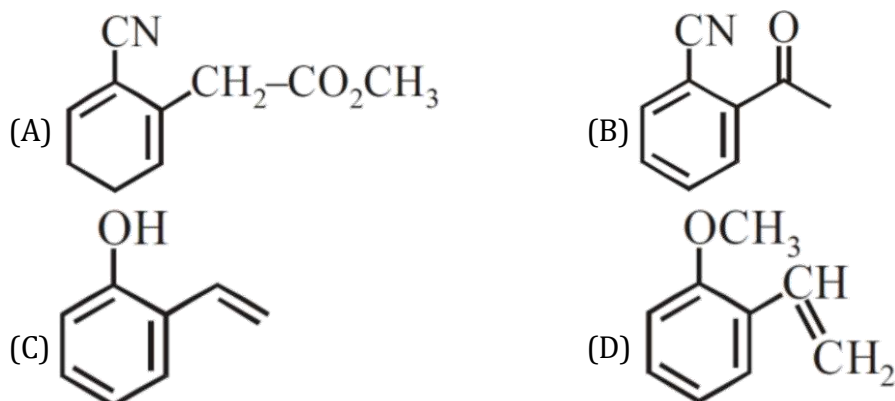
[JEE MAIN-2019]



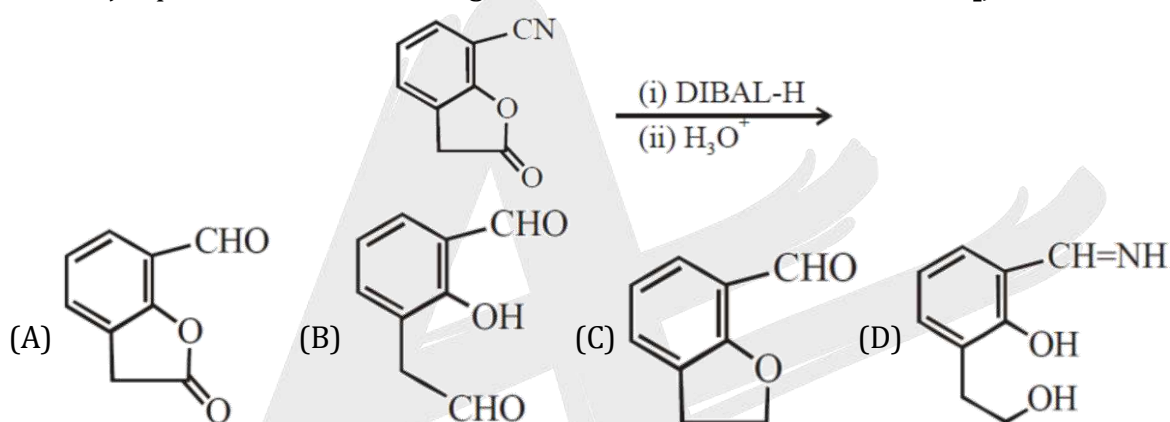
(ORGANIC CHEMISTRY)

REDUCTION OXIDATION

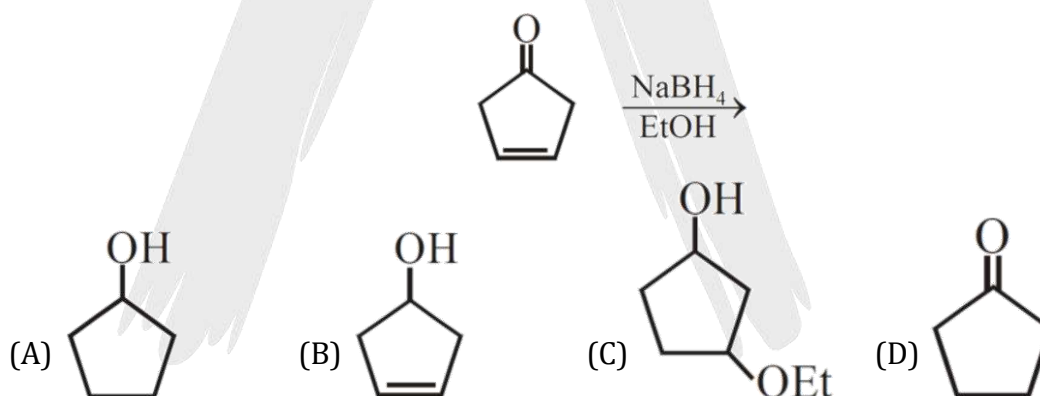
28. Which of the following compounds reacts with ethylmagnesium bromide and also decolourizes bromine water solution [JEE MAIN-2019]



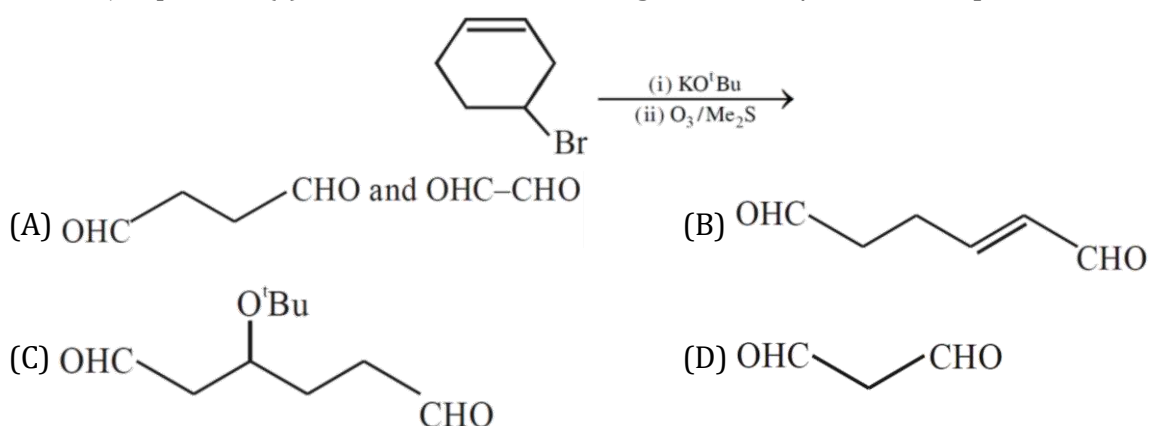
29. The major product of the following reaction is: [JEE MAIN-2019]



30. The major product of the following reaction is: [JEE MAIN-2019]



31. The major product(s) obtained in the following reaction is/are: [JEE MAIN-2019]

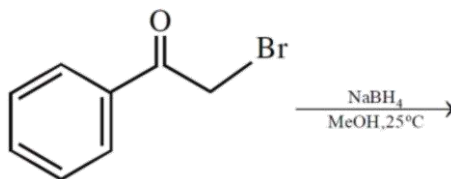


(ORGANIC CHEMISTRY)

REDUCTION OXIDATION

32. The major product of the following reaction is:

[JEE MAIN-2019]



- (A)
- (B)
- (C)
- (D)

33. The major product of the following reaction is:

[JEE MAIN-2019]



- (A) $\text{CH}_3\text{CH}_2\text{CH}_2\text{CHO}$ (B) $\text{CH}_3\text{CH}_2\text{CH}_2\text{CO}_2\text{CH}_3$
 (C) $\text{CH}_3\text{CH}=\text{CHCH}_2\text{OH}$ (D) $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$

34. Which of the following is NOT a correct method of the preparation of benzylamine from cyanobenzene?

[JEE MAIN-2019]

- (A) H_2/Ni (B) (i) $\text{HCl}/\text{H}_2\text{O}$ (ii) NaBH_4
 (C) (i) LiAlH_4 (ii) H_3O^+ (D) (i) $\text{SnCl}_2 + \text{HCl}$ (gas) (ii) NaBH_4

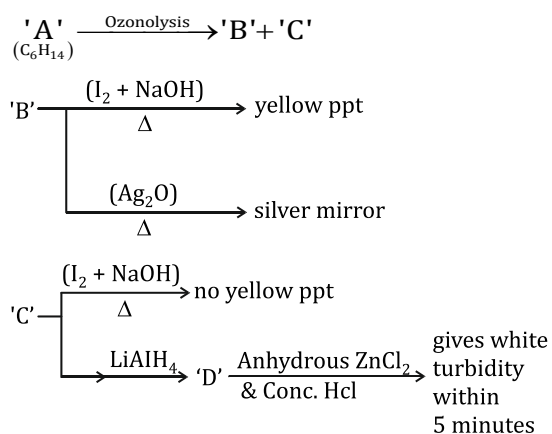
35. Hex-3-ynal $\xrightarrow{(1)\text{NaBH}_4} \xrightarrow{(2)\text{PBr}_3} \xrightarrow{(3)\text{Mg}/\text{Ether}} \xrightarrow{(4)\text{CO}_2} \xrightarrow{(5)\text{H}^+} (\text{X})$, formed product X will be:

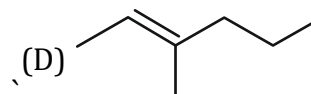
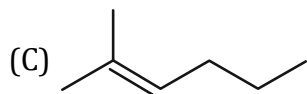
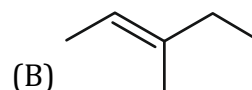
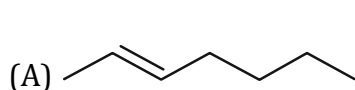
[JEE MAIN 2020]

- (A)
- (B)
- (C)
- (D)

36. Consider the following reactions

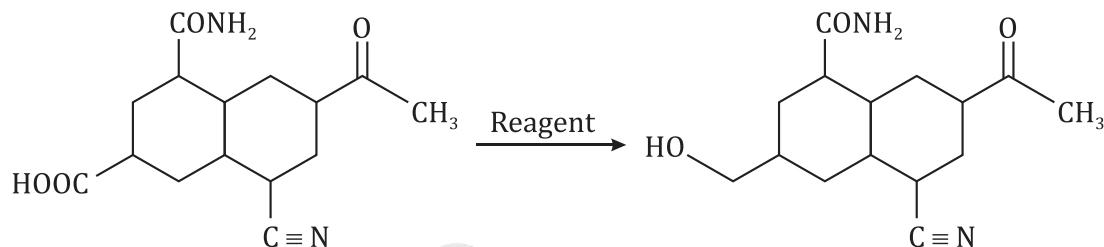
[JEE MAIN 2020]





37. Reagent used for the given conversion is:

[JEE-MAIN 2020]



(A) H_2, Pd

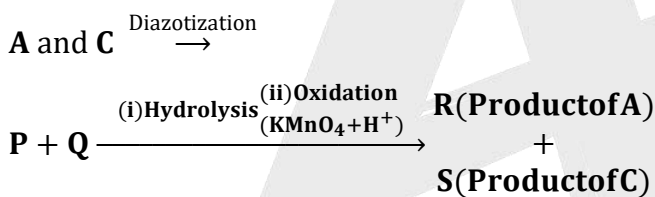
(B) B_2H_6

(C) NaBH_4

(D) LiAlH_4

38. Three isomers A, B and C (mol. formula $\text{C}_8\text{H}_{11}\text{N}$) give the following results

[JEE-MAIN 2020]



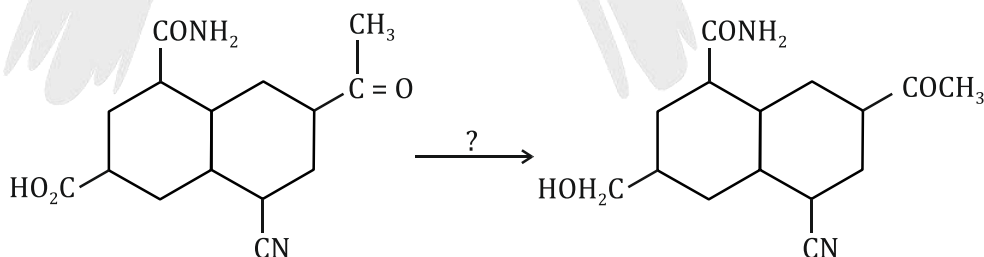
R has lower boiling point than S

B $\xrightarrow{\text{C}_6\text{H}_5\text{SO}_2\text{Cl}}$ alkali-insoluble product

A, B and C, respectively are

39. The most suitable reagent for the given conversion is:

(JEE MAIN 2020)



(A) H_2, Pd

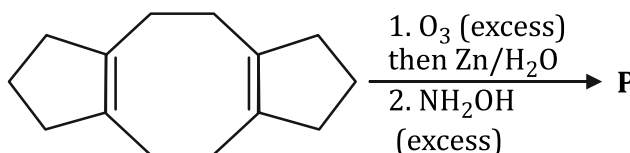
(B) B_2H_6

(C) NaBH_4

(D) LiAlH_4

40. In the reaction given below, the total number of atoms having sp^2 hybridization in the major product P is ____.

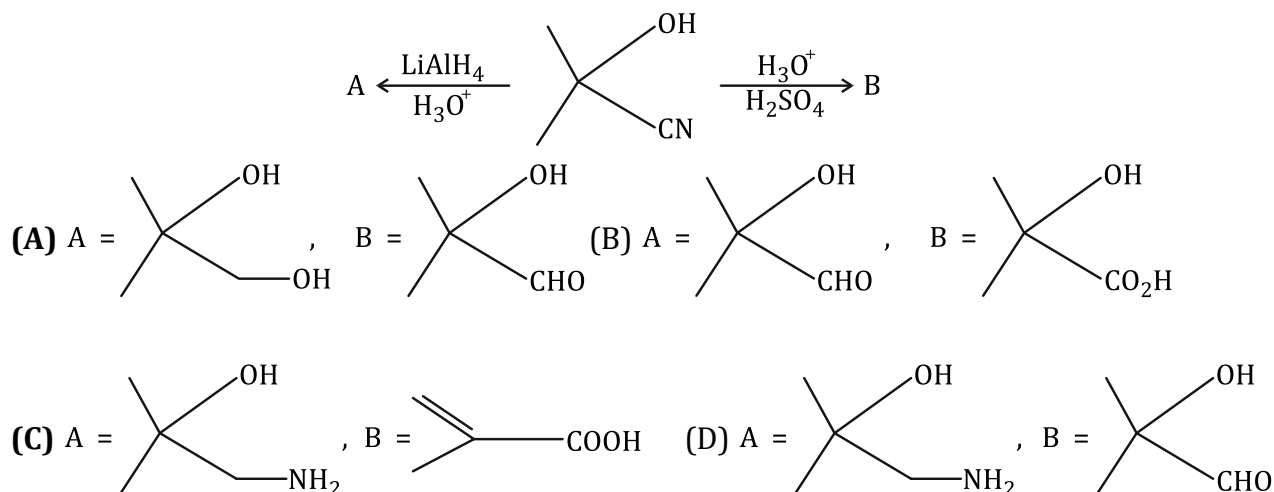
[JEE Adv -2021]



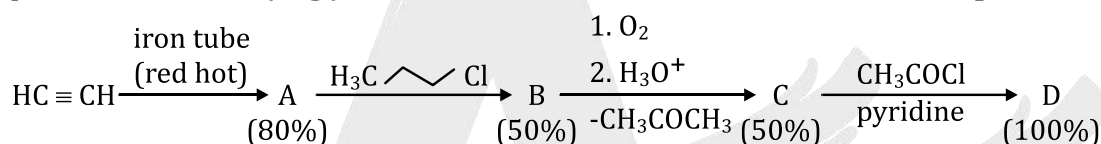
(ORGANIC CHEMISTRY)

REDUCTION OXIDATION

- 41 The major products A and B in the following set of reactions are: [JEE-MAINS 2021]



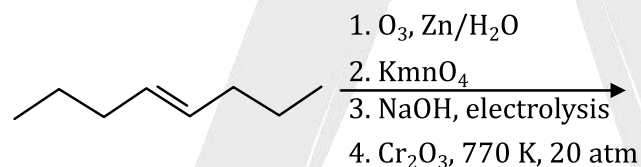
42. If the reaction sequence given below is carried out with 15 moles of acetylene, the amount of the product D formed (in g) is _____. [JEE Adv -2022]



The yields of A,B,C and D are given in parentheses.

[Given: Atomic mass of H = 1, C = 12, O = 16, Cl = 35]

43. The number of $-\text{CH}_2-$ (methylene) groups in the product formed from the following reaction sequence is _____. [JEE Adv -2022]



44. The major products obtained from the reactions in List-II are the reactants for the named reactions mentioned in List-I. Match List-I with List-II and choose the correct option. [JEE Adv-2023]

List-I

(P) Etard reaction

(Q) Gattermann reaction

(R) Gattermann-Koch reaction

(S) Rosenmund reduction

List-II

(1) Acetophenone $\xrightarrow{\text{Zn-Hg, HCl}}$

(2) Toluene $\xrightarrow[\text{(ii) SOCl}_2]{\text{(i) KMnO}_4, \text{KOH}, \Delta}$

(3) Benzene $\xrightarrow[\text{anhyd. AlCl}_3]{\text{CH}_3\text{Cl}}$

(4) Aniline $\xrightarrow[273-278 \text{ K}]{\text{NaNO}_2/\text{HCl}}$

(5) Phenol $\xrightarrow{\text{Zn}, \Delta}$

(A) P \rightarrow 2; Q \rightarrow 4; R \rightarrow 1; S \rightarrow 3

(C) P \rightarrow 3; Q \rightarrow 2; R \rightarrow 1; S \rightarrow 4

(B) P \rightarrow 1; Q \rightarrow 3; R \rightarrow 5; S \rightarrow 2

(D) P \rightarrow 3; Q \rightarrow 4; R \rightarrow 5; S \rightarrow 2

ANSWER KEY

EXERCISE # I

- | | | | | | | |
|--------|----------|--------|-------|----------|-------|--------|
| 1. D | 2. A | 3. C | 4. D | 5. C | 6. AC | 7. A |
| 8. C | 9. B | 10. AC | 11. C | 12. C | 13. C | 14. C |
| 15. C | 16. B | 17. C | 18. D | 19. AC | 20. D | 21. D |
| 22. C | 23. C | 24. C | 25. A | 26. B | 27. B | 28. D |
| 29. A | 30. C | 31. C | 32. B | 33. ABCD | 34. B | 35. BC |
| 36. AC | 37. ABCD | 38. BD | 39. D | 40. ABCD | 41. C | |

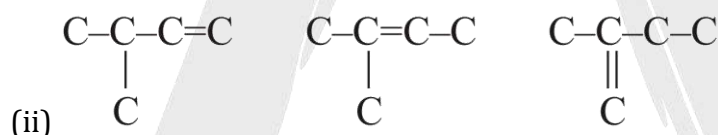
EXERCISE # II

- | | | | | | | |
|--------------------------------------|---------|-------|---------|--------|---------|-------|
| 1. C | 2. CD | 3. D | 4. ACD | 5. ABC | 6. ABCD | 7. C |
| 8. ACD | 9. D | 10. A | 11. ABC | 12. C | 13. AB | |
| 14. (A)→P,R,S; (B)→Q; (C)→R,S; (D)→Q | | | | | | |
| 15. 4 | 16. 4 | 17. A | 18. B | 19. A | 20. BC | 21. A |
| 22. ABD | 23. ABC | | | | | |

24. (a) ; (b) $2\text{CH}_2 = \text{O} + 2\text{HCOOH}$; (c) $\text{CH}_3\text{-CHO} + \text{CH}_3\text{-COOH}$

25. (a) $\text{Ph-CH}_2\text{-CHO}$; (b) $\text{Ph}-\overset{\text{O}}{\parallel}{\text{C}}-\text{CH}_3$; (c) $\text{Ph}-\text{C} \begin{matrix} \nearrow \text{CH}_2 \\ \searrow \text{CH}_3 \end{matrix}$

26. (i) Cis & trans 2-butene & 1-butene;

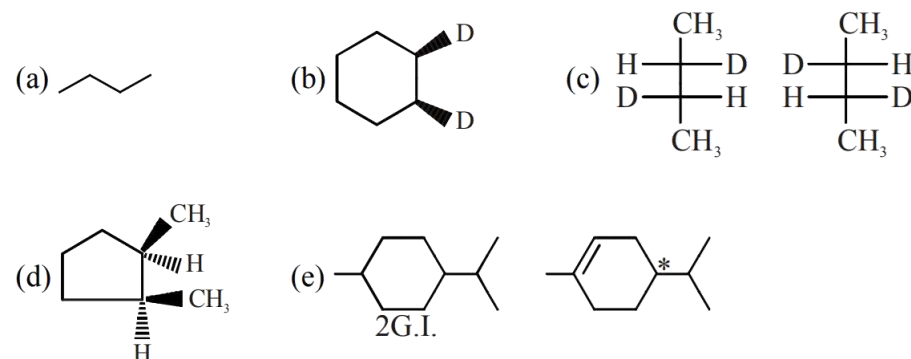


- (iii) Zero (Neo-pentane cannot be prepared by catalytic hydrogenation of alkene);

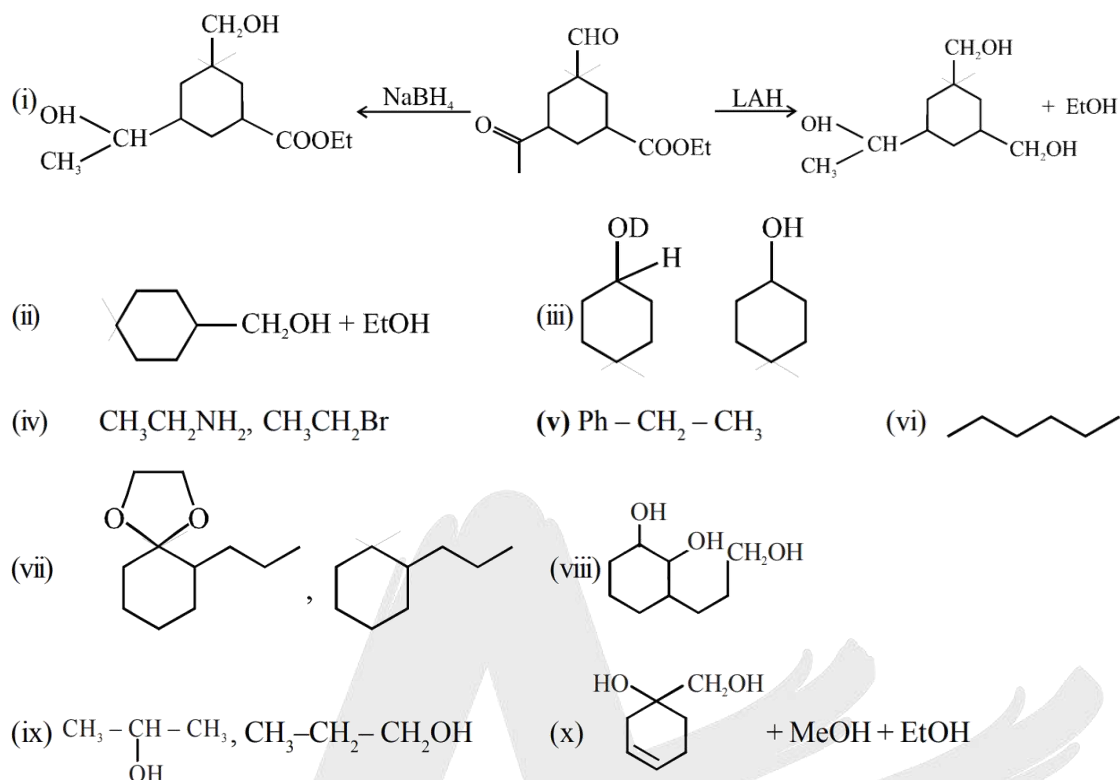
- (iv) One

- (v) Including optical = 4 , Excluding optical = 3

27.



28.



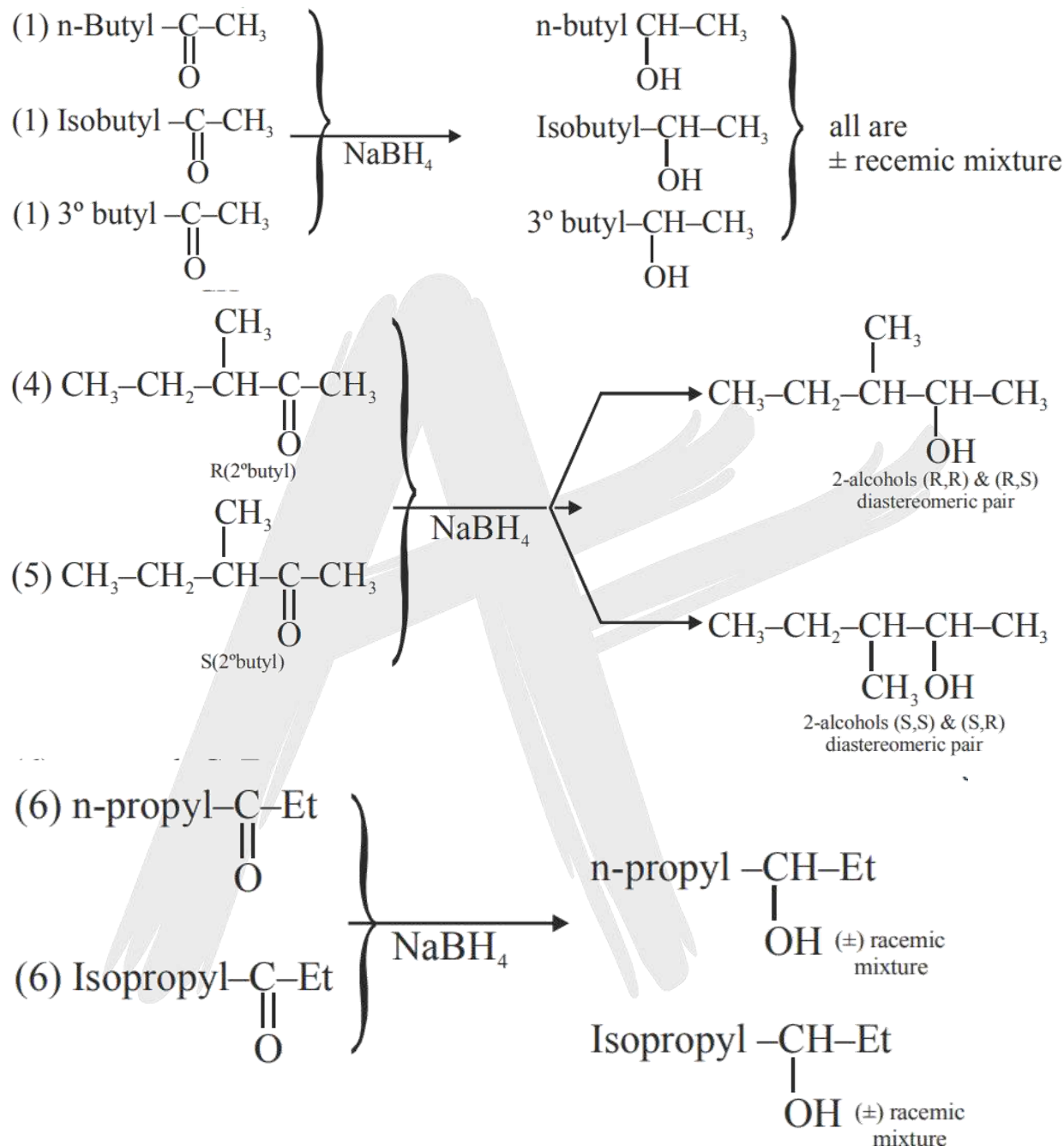
EXERCISE # III (MAIN & ADVANCE)

1.	A	2.		3.	D	4.	A	5.	A	6.	B
7.	B	8.	D	9.	B	10.	D	11.	D	12.	A
13.	C	14.	A	15.	C	16.	A	17.	B	18.	5
19.	A	20.	D	21.	CD	22.	C	23.	A	24.	B
25.	A	26.	B	27.	B	28.	C	29.	B	30.	B
31.	A	32.	B	33.	C	34.	B	35.	A	36.	B
37.	B	38.	D	39.	B	40.	12	41.	0	42.	136
43.	0	44.									

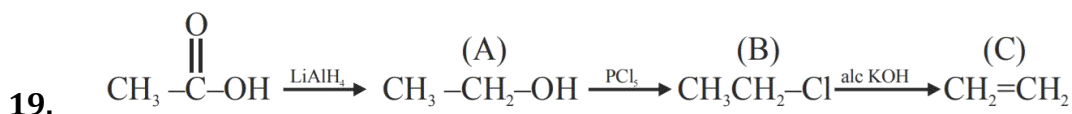
SOLUTION

EXERCISE # III (MAIN & ADVANCE)

18. M. wt 100 of ketone

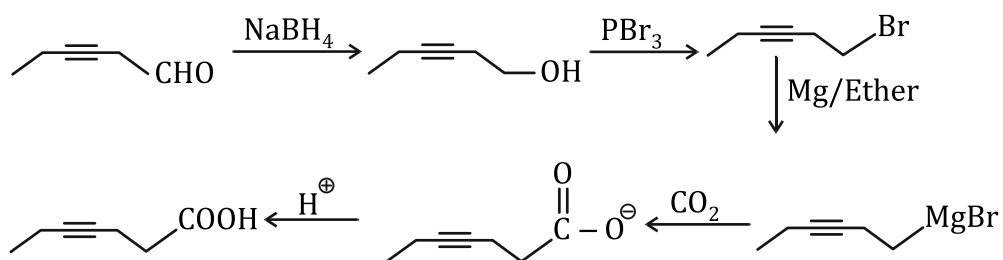
So m, formula = $C_6H_{12}O$ 

(1 : 2 : 3 : 6 : 7)

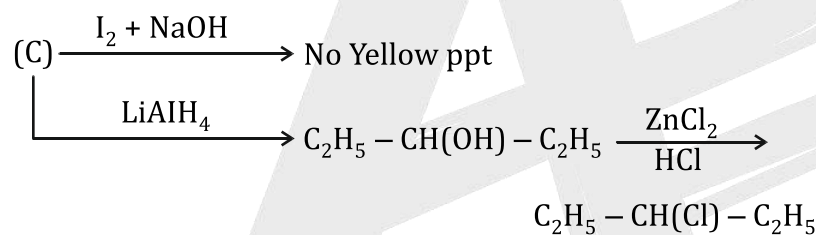
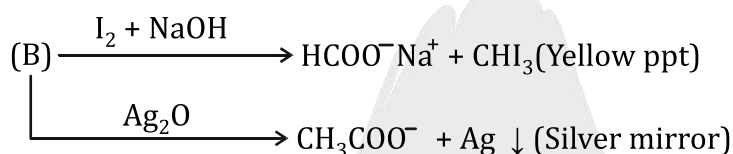
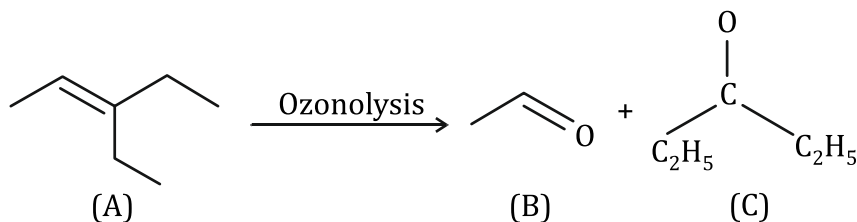


Reduction of CH_3COOH will produce $\text{CH}_3\text{---CH}_2\text{---OH}$ (A) Now reaction of $\text{CH}_3\text{---CH}_2\text{---OH}$ (A) with PCl_5 will produce $\text{CH}_3\text{---CH}_2\text{---Cl}$ (B). Now alcoholic KOH with Et-Cl will produce $\text{CH}_2=\text{CH}_2$ (C) Ethylene by E_2 elimination. Thus Ans. is (1) Ethylene.

35.

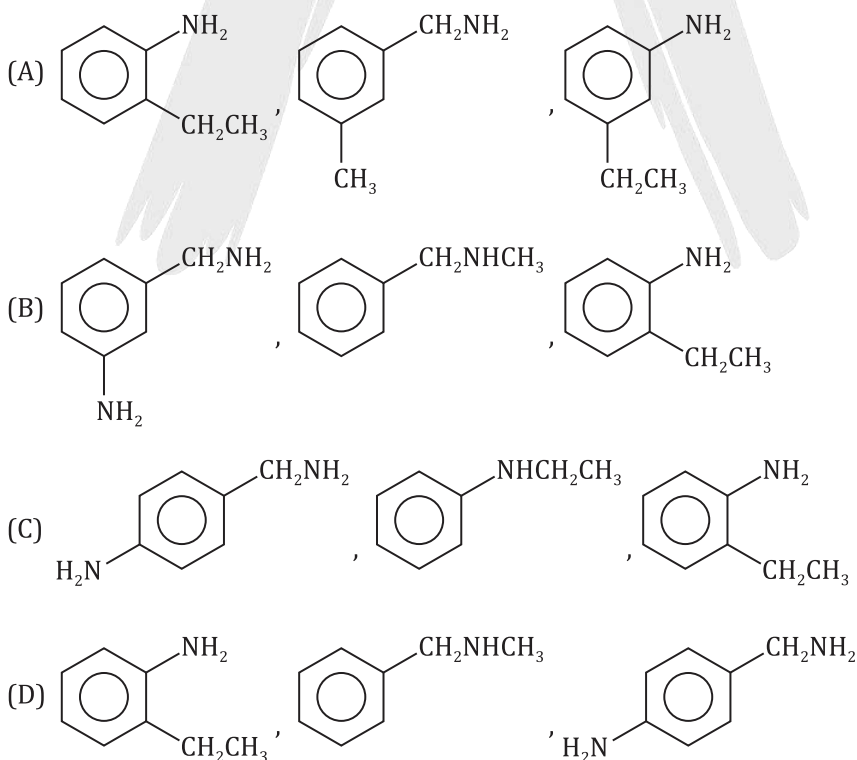


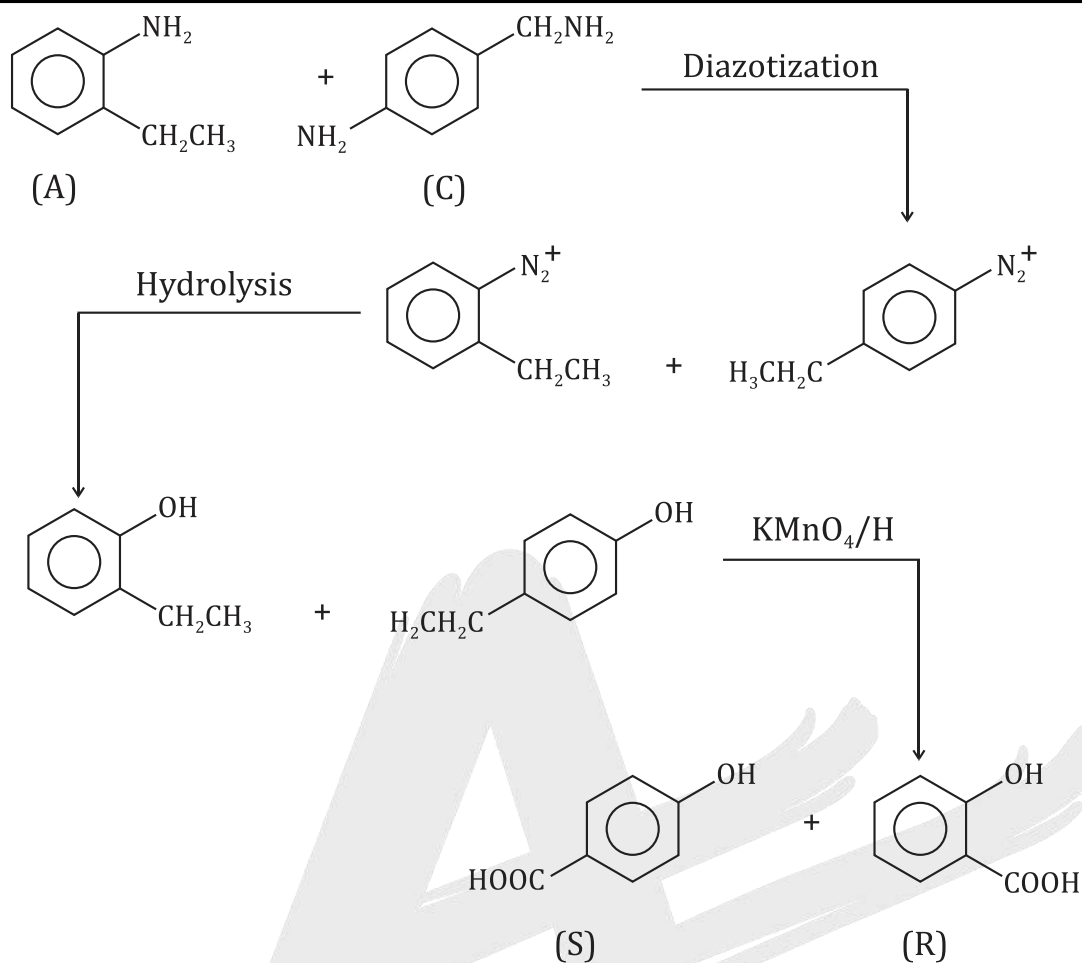
36.



37. B_2H_6 is very selective and usually used to reduce acid to alcohol

38.

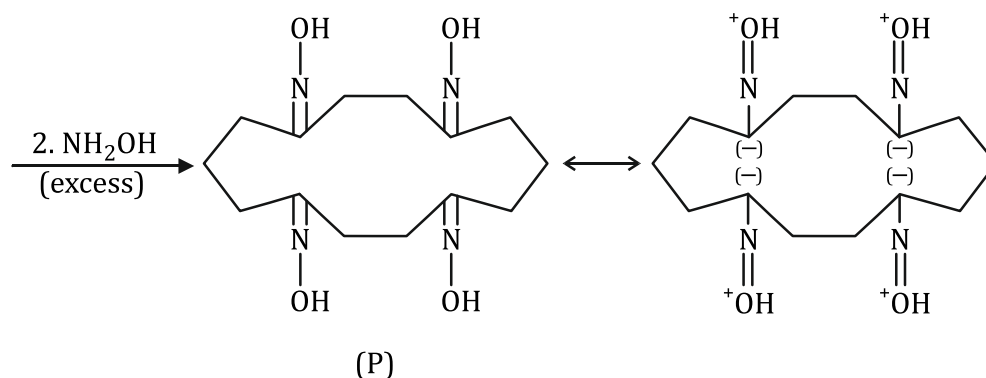
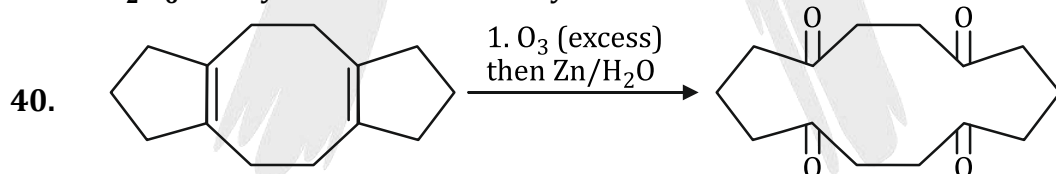




(B) gives insoluble product with $\text{C}_6\text{H}_5\text{SO}_2\text{Cl}$.



39. B_2H_6 is very selective and usually used to reduce acid to alcohol.



The total number of atoms having sp^2 hybridization in the major product (P) = 12
This includes 4 C-atoms, 4 N-atoms and 4 O-atoms.

(ORGANIC CHEMISTRY)

REDUCTION OXIDATION

