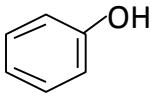
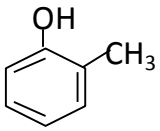
PHENOL (HYDROXYBENZENE), C_6H_5OH

This is a class of compounds in which the hydroxyl group (– OH group) is directly attached to the benzene ring.e.g

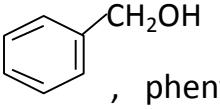


Phenol (hydroxybenzene)

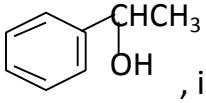


2-methylphenol

NOTE



, phenyl methanol is not a phenol because the hydroxyl group (- OH group) is not directly bonded to the carbon atom of the benzene ring. Therefore it is an aromatic primary alcohol.



, is an aromatic secondary alcohol.

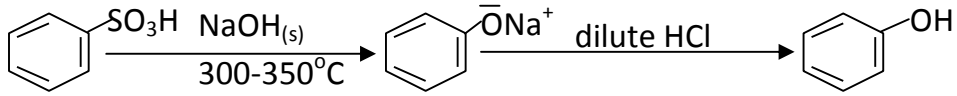
Physical properties of phenol

- It is a colourless crystalline solid which turns pink on exposure to air and light.
- It is sparingly soluble in water but very soluble in organic solvents.

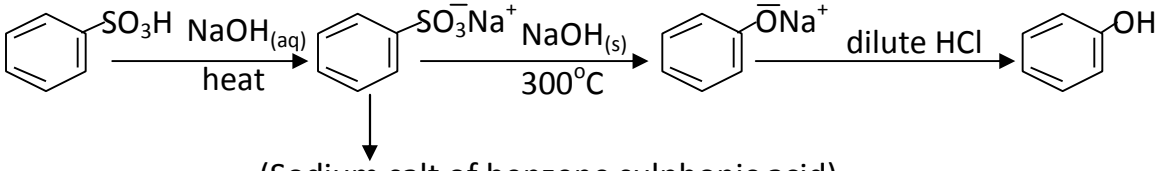
METHODS OF PREPARATION OF PHENOL

1. From benzene sulphonic acid.

   The benzene sulphonic acid is heated with fused sodium hydroxide at a temperature of about 300°C-350°C and at a high pressure of about of about 150 atmospheres to form sodium phenoxide.



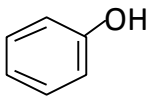
OR



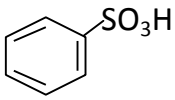
(Sodium salt of benzene sulphonic acid)

Compiled by Mr. Isabirye David. *isabiryedavid152@gmail.com*
0703732102/0784863664

Qn. Show how the following conversion can be made.

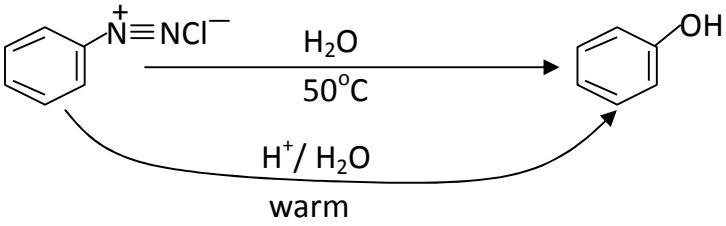


from



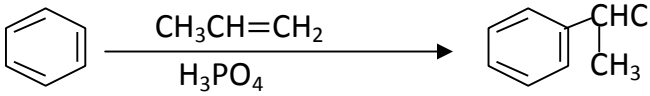
2. From benzene diazonium salt.

Phenol is formed when a diazonium salt is warmed with water at 50°C or warmed with acidified water.



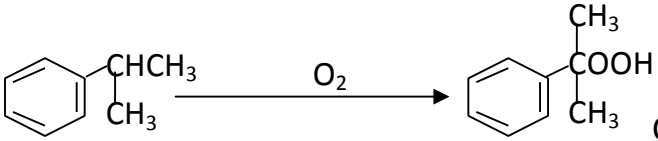
3. By the Cumene process.

Benzene is first alkylated with Propene using Phosphoric acid or aluminium chloride catalyst to form Cumene.



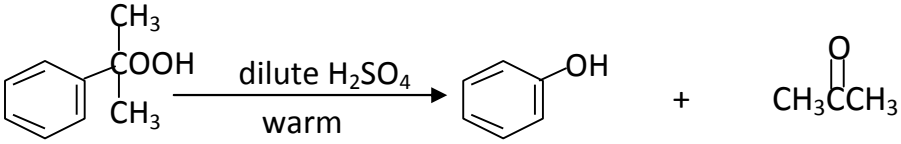
Cumene (1-methylethyl benzene)

Cumene is then oxidised by oxygen to form Cumene hydroperoxide.



Cumene hydroperoxide

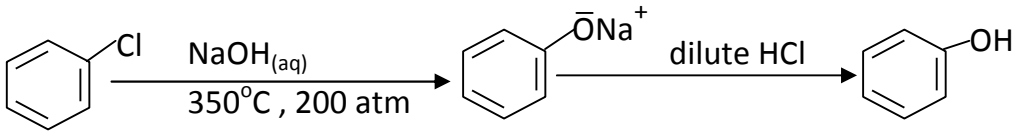
The Cumene hydroxide is the hydrolysed using dilute sulphuric acid to form Phenol and Propanone.



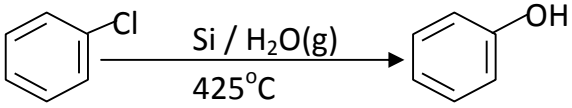
Qn. Using equations only show how Phenol can be prepared from benzene and Propene.

Compiled by Mr. Isabirye David. ***isabiryedavid152@gmail.com***
0703732102/0784863664

4. From aromatic halides i.e

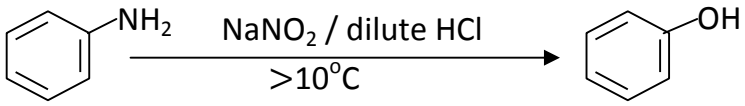
(a) 

Sodium phenoxide

(b) 

5. From Phenylamine

Phenylamine reacts with nitrous acid ($NaNO_2$/HCl) at a temperature above 10^oC to form a Phenol.



REACTIONS OF PHENOL

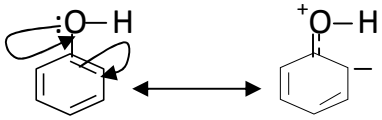
Phenol undergo reactions characteristic of both aromatic and the hydroxyl group.

Reactions due to the hydroxyl group (-OH group)

(i) Acidic character

Qn. Explain why phenol is more acidic than alcohols.

Explaination

This is because in phenol, the hydroxyl group is directly bonded to the benzene ring. Therefore the lone pair of electrons on the oxygen atom interacts with the delocalised pie electrons of the benzene ring. This creates a partial double bond between the oxygen atom and the carbon atom of the benzene ring hence the carbon-hydrogen bond is made stronger while the oxygen-hydrogen bond is weakened and this facilitates the release of a proton (hydrogen ion) into solution hence increasing acidity. i.e. 

In alcohols, the oxygen-hydrogen bond is not weakened and the proton is not easily lost. This is because there is no delocalised electrons to interact with the lone pairs of electrons on the oxygen atom.

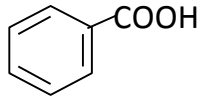
Compiled by Mr. Isabirye David. *isabiryedavid152@gmail.com*
0703732102/0784863664

Distinguishing Phenol from carboxylic acids

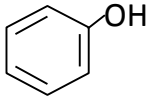
Unlike carboxylic acids, Phenol is not acidic enough to liberate carbon dioxide gas from sodium carbonate solution or sodium hydrogen carbonate solution.

Example.

Qn. Name one reagent that can be used to distinguish between the following pair of compounds. In each case state what is observed when each member of the pair is treated with the named reagent and write the equation of reaction that takes place.



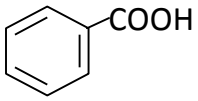
and



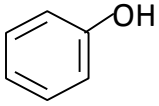
Reagent:

Sodium carbonate solution (or Sodium hydrogen carbonate solution)

Observations:

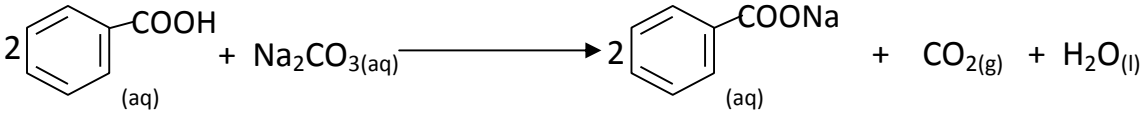


; Effervescence of a colourless gas

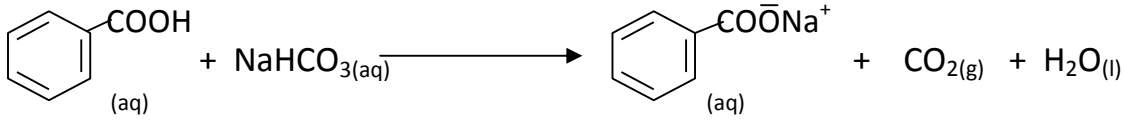


; No observable change

Equation:

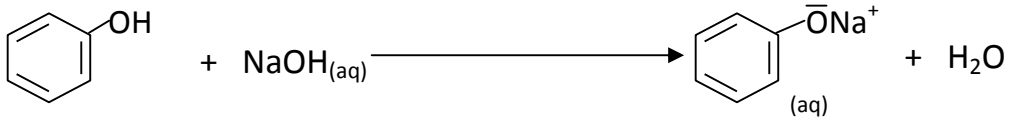


Or



N.B

Because Phenol is acidic, it dissolves in sodium hydroxide solution or potassium hydroxide solution forming sodium phenoxide and water. Alcohols do not dissolve in sodium or potassium hydroxide solution.



Compiled by Mr. Isabirye David. *isabiryedavid152@gmail.com*
0703732102/0784863664

N.B

Sodium carbonate solution or sodium hydrogen carbonate solution is used as a confirmatory test for all carboxylic acids.

Qn. Name a reagent that can be used to distinguish between the following pairs of compounds and in each case state the observation.

(a) CH_3COOH and CH_3CH_2OH

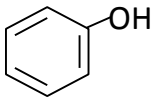
(b) HCOOH and CH_3OH

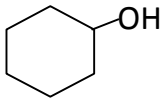
(ii) Reaction with neutral iron (III) chloride solution.

Phenol reacts with neutral iron (III) chloride solution to form **a violet solution or a purple solution.**

This reaction confirms a Phenol and is used to distinguish a phenol from other organic compounds.

Qn. Name a reagent that can be used to distinguish between each of the following pairs of compounds and in each case state what is observed.

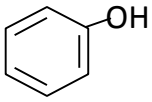


and


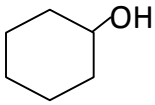
Reagent

Neutral iron (III) chloride solution

Observation

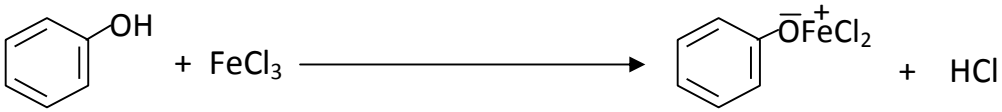


; forms a Purple solution (a violet solution)



; No observable change

Equation

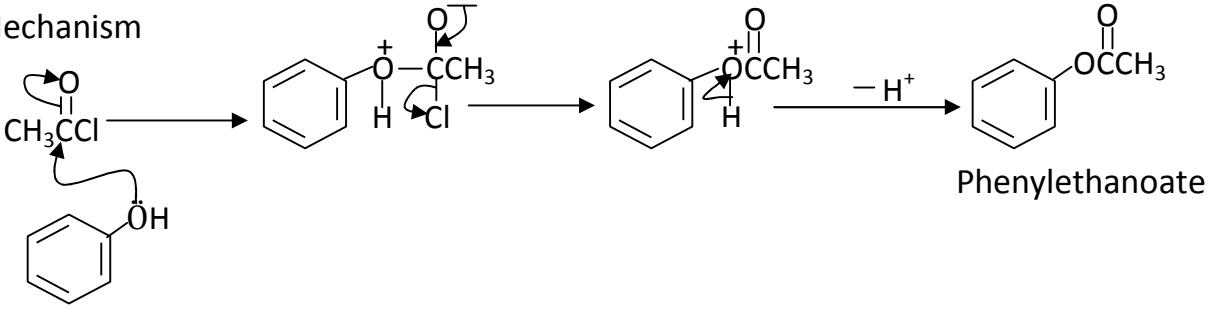


Compiled by Mr. Isabirye David. *isabiryedavid152@gmail.com*
0703732102/0784863664

(iii) Esterification

Like alcohols, Phenol reacts with acid halides to form esters e.g.

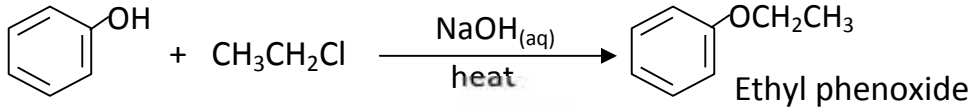
Mechanism



Phenylethanoate

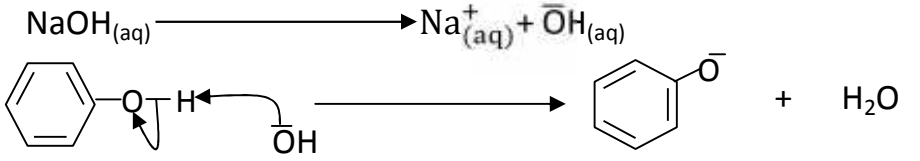
(iv) Formation of ethers.

Phenol reacts with alkyl halides in the presence of alkalis to form ethers.

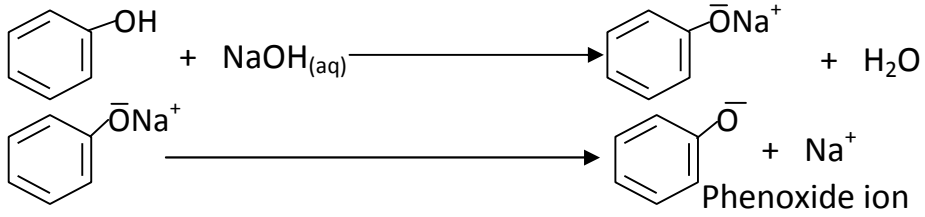


Ethyl phenoxide

Mechanism

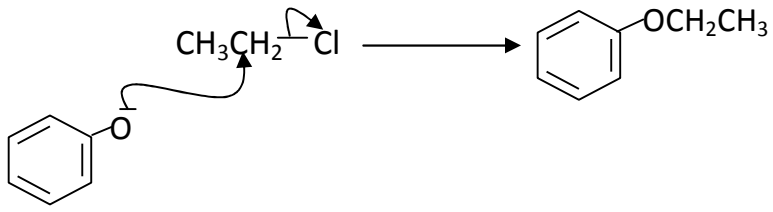


Or



Phenoxide ion

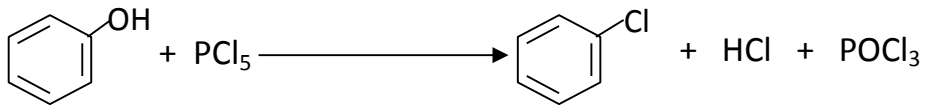
Then



Compiled by Mr. Isabirye David. *isabiryedavid152@gmail.com*
0703732102/0784863664

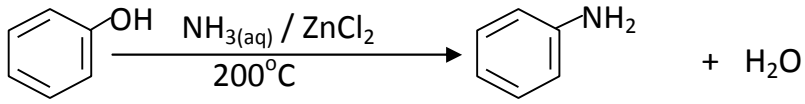
(v) Reaction with phosphorus pentachloride (PCl_5)

Phenol reacts with PCl_5 forming Chlorobenzene.

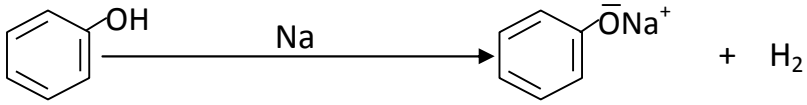


(VI) Reaction with ammonia.

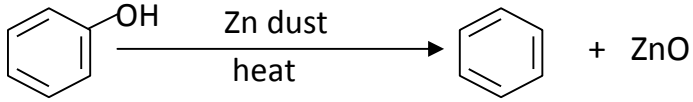
When phenol is heated with ammonia solution at a temperature of about 200°C in the presence of zinc chloride, Phenylamine is formed.



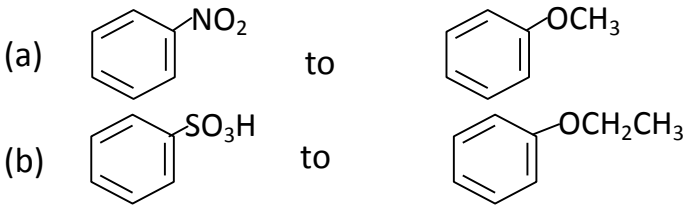
(vii) Phenol reacts with sodium metal to form sodium phenoxide and hydrogen gas.



(viii) When Phenol is heated with zinc dust, it is reduced to benzene.



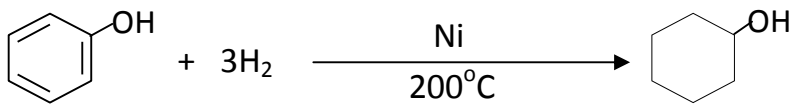
Qn. Write equations to show how the following conversions can be effected**.**



Reactions of Phenol due to the aromatic ring

1. Reduction

Phenol is reduced to cyclohexanol by hydrogen in presence of nickel catalyst heated at 200°C.



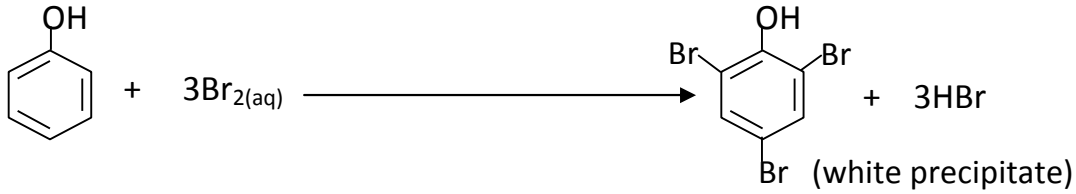
Compiled by Mr. Isabirye David. *isabiryedavid152@gmail.com*
0703732102/0784863664

2. Electrophilic substitution reaction

Phenol is very reactive towards electrophilic reagents and the hydroxyl group in it is 2-(ortho) and 4-(para) directing.

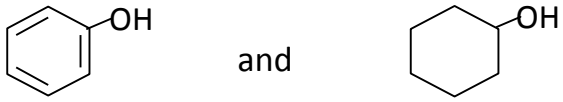
(a) Reaction with bromine.

Phenol reacts with bromine in aqueous solution to form **a white precipitate** of 2,4,6-tribromophenol.



This reaction is also used to distinguish a phenol from other organic compounds.e.g

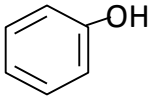
Qn. Name a reagent that can be used to distinguish between the following pair of compounds and in each state the observation.



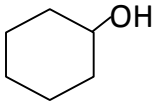
Reagent

Bromine solution (Bromine water)

Observation

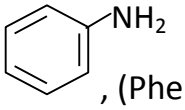


; forms a white precipitate

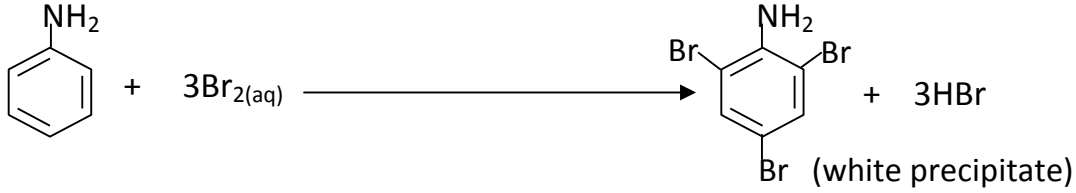


; No observable change

NOTE

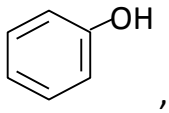
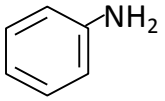
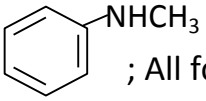


, (Phenylamine) also reacts with bromine in aqueous solution to form **a white precipitate** of 2,4,6-tribromophenylamine.



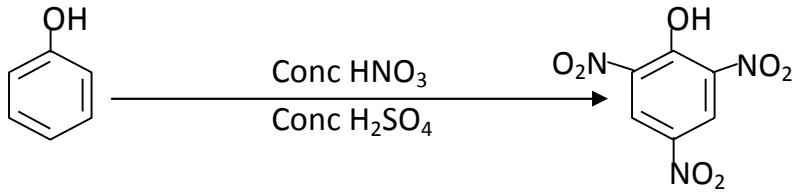
Compiled by Mr. Isabirye David. *isabiryedavid152@gmail.com*
0703732102/0784863664

Summery

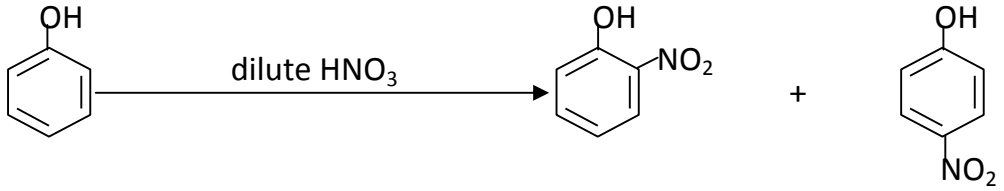


and  ; All form a white precipitate when reacted with Bromine solution (Bromine water)

(b) Nitration reaction.

(i) Reaction with concentrated nitric acid and concentrated sulphuric acid form 2,4,6-trinitrophenol (Picric acid).



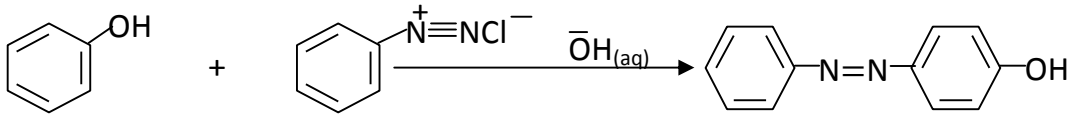
(ii) Reaction with dilute nitric acid forms a mixture of 2-nitrophenol and 4-nitrophenol.



3. Coupling reaction.

An alkaline solution of phenol reacts with benzene diazonium chloride to form **bright yellow precipitate** of 4-hydroxyphenylazobenzene.

This reaction occurs at the para position.



A bright yellow precipitate

Uses of Phenol

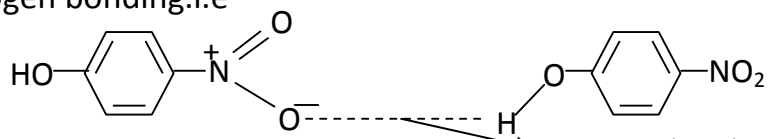
- Used in the manufacture of Phenol-methanal plastics e.g Bakelite
- Used as a starting material for the production cyclohexanol, which is used in the manufacture of nylon.
- Used to manufacture weed killers.e.g 2,4-dichlorophenoxyethanoic acid
- Used to manufacture antiseptics. e.g 2,4-dichloro-3,5-dimethylphenol (Dettol)

Compiled by Mr. Isabirye David. ***isabiryedavid152@gmail.com***
0703732102/0784863664

Qn. Explain why the boiling point of 4-nitrophenol is higher than that of 2-nitrophenol.

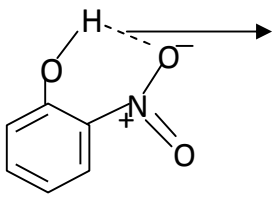
Explaination

In 4-nitrophenol molecule, the two functional groups i.e. the hydroxyl group and the nitro group are far apart and thus the molecules associate via inter molecular hydrogen bonding.i.e



Inter molecular hydrogen bond

While in 2-nitrophenol molecule, the hydroxyl group and nitro group are closer and this causes the hydrogen atom on the hydroxyl group and the oxygen atom on the nitro group to associate via intra molecular hydrogen bond. i.e.



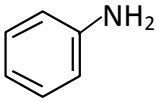
Intra molecular hydrogen bond

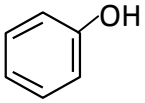
Therefore 2-nitrophenol molecules associate via weak vanderwaals forces of attraction which are easier to break than the intermolecular hydrogen bonds in the 4-nitrophenol molecules. Therefore the boiling point of 4-nitrophenol is higher than that of 2-nitrophenol.

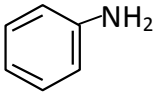
N.B

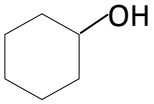
The same explaination is given when explaining why the melting point of 4-nitrophenol is higher than that of 2-nitrophenol.

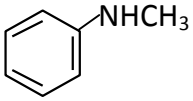
Qn. Name a reagent that can be used to distinguish between the following pairs of compounds and in each case state the observation.

(a) 

and 

(b) 

and 

(c) 

and CH_3NHCH_3

Compiled by Mr. Isabirye David. *isabiryedavid152@gmail.com*
0703732102/0784863664

CARBONYL COMPOUNDS

Compiled by Mr. Isabirye David. *isabiryedavid152@gmail.com*
0703732102/0784863664