

CBCS: B. Sc. (Honours) with CHEMISTRY
CORE COURSE

CHEMISTRY

(Honours)

(4th Semester)

Course No.: **CHEMISTRY-C-402**

(Organic Chemistry)

Contact Hours: 60

Full Marks = 70 [End Semester Exam (56) + Internal Assessment (14)]

B. Sc. 4th Sem Organic Chemistry Syllabus

Unit I: Nitrogen Containing Functional Groups

Preparation and important reactions of nitro and compounds, nitriles and isonitriles

Amines: Effect of substituent and solvent on basicity; Preparation and properties: Gabriel phthalimide synthesis, Carbylamine reaction, Mannich reaction, Hoffmann's exhaustive methylation, Hofmann-elimination reaction; Distinction between 1°, 2° and 3° amines with Hinsberg reagent and nitrous acid.

Diazonium Salts: Preparation and their synthetic applications. Diazomethane & Diazoacetic Ester with synthetic application.

16 Lectures, Marks - 14

Unit II: Polynuclear Aromatic Hydrocarbons

Preparation and structure elucidation & Reactions of Polynuclear hydrocarbons : naphthalene phenanthrene and anthracene , and important derivatives of naphthalene and anthracene;.

12 Lectures, Marks - 12

Unit III:

Heterocyclic Compound-I

Classification and nomenclature, Structure, aromaticity in 5-numbered and 6-membered rings containing one heteroatom; Synthesis, reactions and mechanism of substitution reactions of: Furan, Pyrrole (Paal-Knorr synthesis, Knorr pyrrole synthesis, Hantzsch synthesis), Thiophene,

Derivatives of furan: Furfural and furoic acid.

Heterocyclic Compound-II

Pyridine (Hantzsch synthesis), Pyrimidine, Structure elucidation of indole, Fischer indole synthesis and Madelung synthesis), Structure elucidation of quinoline and isoquinoline, Skraup synthesis, Friedlander's synthesis, Knorr quinoline synthesis, Doebner- Miller synthesis, Bischler-Napieralski reaction, Pictet-Spengler reaction, Pomeranz-Fritsch reaction

20 Lectures, Marks - 18

Unit IV: Alkaloids

Natural occurrence, General structural features, Isolation and their physiological action

Hoffmann's exhaustive methylation, Emde's modification, Structure elucidation and synthesis of Hygrine and Nicotine. Medicinal importance of Nicotine, Hygrine, Quinine, Morphine, Cocaine, and Reserpine.

6 Lectures, Marks - 6

Unit V: Terpenes

Occurrence, classification, isoprene rule; Elucidation of structure and synthesis of Citral, Neral and α -terpineol.

6 Lectures, Marks - 6

References: Organic Chemistry by M. K. Jain
Organic Chemistry by J. Clayden
Organic Chemistry by Bahl and Bahl

We will start with Unit I

This unit will cover the following topics

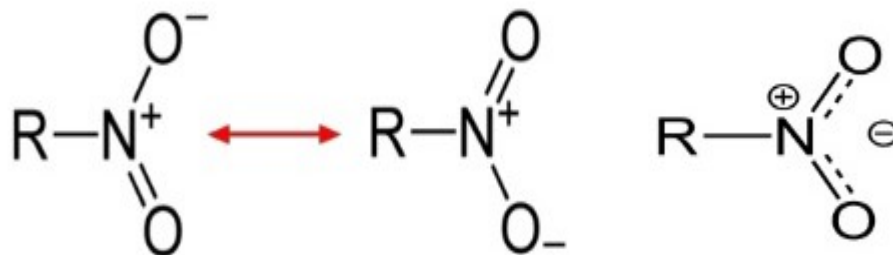
- ❖ Preparation and properties of nitro compounds
- ❖ Preparation and properties of nitriles
- ❖ Preparation and properties of isonitriles
- ❖ Preparation and important properties of amines
 - 1) How does basicity of amine change if the substituent changes
 - 2) Some important name reactions like Gabriel phthalimide synthesis,
 - 3) Carbylamine reaction, Mannich reaction, Hoffmann's exhaustive methylation
 - 4) Chemical test to distinguish 1° , 2° , 3° , amines
- ❖ Preparation and properties of diazonium salts
- ❖ Preparation and properties of Diazomethane
- ❖ Preparation and properties of Diazoacetic ester

Nitro Compounds

****The NO₂ group is called nitro group.**

****It is electron withdrawing group due to its Inductive effect as well as Resonance effect. Its electron withdrawing nature is due to the electronegativity of oxygen and nitrogen.**

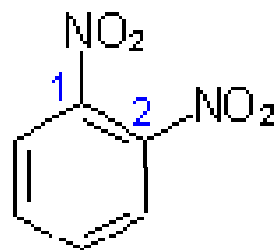
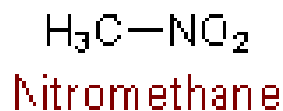
****They are used to make explosive compounds (like bombs)**



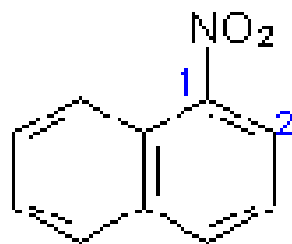
****If the nitro functional group is attached with benzene ring it is called aromatic nitro compound**

****All aromatic nitro compounds are yellow colored which may change to dark brown due to oxidation**

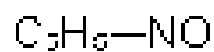
****Examples**



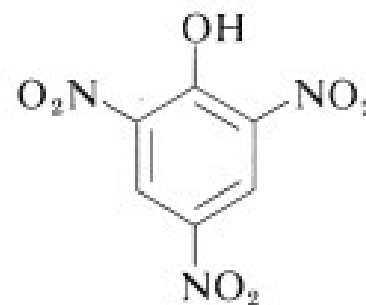
1,2-Dinitrobenzene
(preferred)
 α -Dinitrobenzene



1-Nitronaphthalene



Nitrobenzene

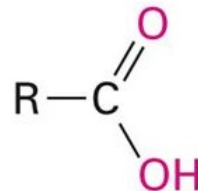
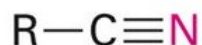


2,4,6-trinitrophenol
(picric acid)

Nitriles

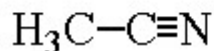
****A nitrile is any organic compound that has a $\text{-C}\equiv\text{N}$ functional group. The prefix cyano- is used interchangeably with the term nitrile in industrial literature.**

****Nitriles exhibit similar chemistry to carboxylic acids because both have a carbon atom with three bonds to an electronegative atom containing π -bonds**

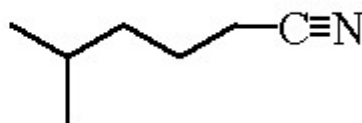


**A nitrile—three
bonds to nitrogen**

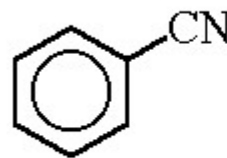
**An acid—three
bonds to two oxygens**



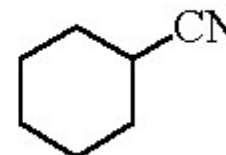
Acetonitrile



5-Methylhexanenitrile



Benzonitrile

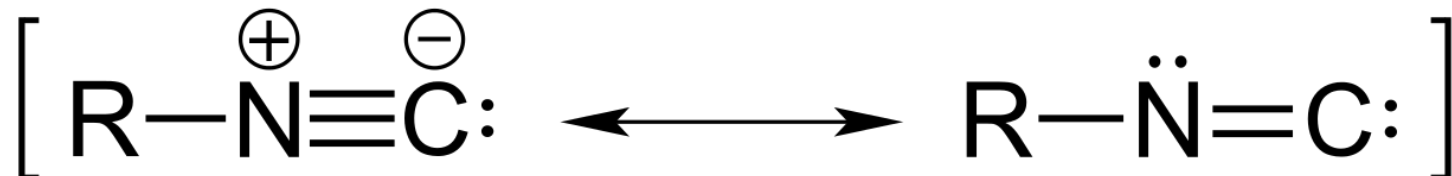


Cyclohexanecarbonitrile

Or Methyl cyanide

Isonitriles

An isocyanide (also called isonitrile or carbylamine) is an organic compound with the functional group $\text{-N}\equiv\text{C}$. It is the isomer of the related nitrile ($\text{-C}\equiv\text{N}$), hence the prefix is *isocyano*



Example



Hydrogen Cyanide



Hydrogen Isocyanide

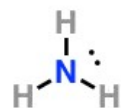
Amines

Classification of Amines

Amines are basic nitrogen-containing compounds that are derivatives of ammonia. Amines are classified as:

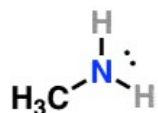
- **Primary** (*the nitrogen atom has one hydrocarbon group directly attached*)
- **Secondary** (*the nitrogen atom has two hydrocarbon groups directly attached*)
- **Tertiary** (*the nitrogen atom has three hydrocarbon groups directly attached*).

Amines: count the number of **carbons** directly attached to the **nitrogen**



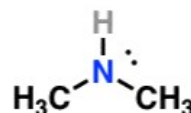
0 carbons

Ammonia
(unique)



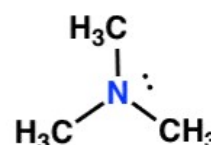
1 carbon
directly
attached

Primary (1°)
amine



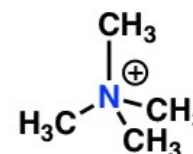
2 carbons

Secondary (2°)
amine



3 carbons

Tertiary (3°)
amine



4 carbons

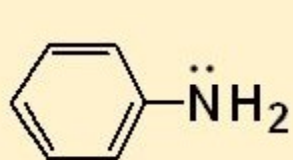
Quaternary (4°)
amine (*ammonium*)

Structure and classification

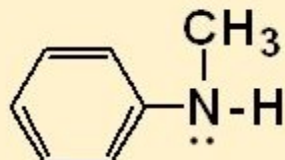
Amines are further divided into aliphatic, aromatic and heterocyclic amines

Aliphatic amines: An amine in which nitrogen is bonded only to alkyl groups

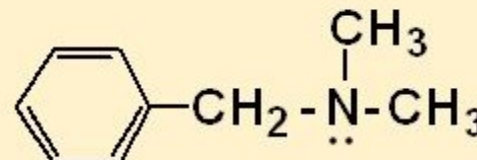
Aromatic amines: An amine in which nitrogen is bonded to one or more aryl groups.



Aniline
(a 1° aromatic amine)



N-Methylaniline
(a 2° aromatic amine)

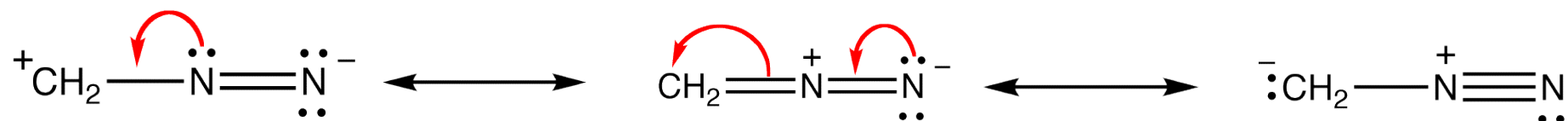
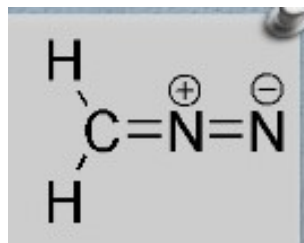


Benzyltrimethylammonium
(a 3° aliphatic amine)

Diazomethane

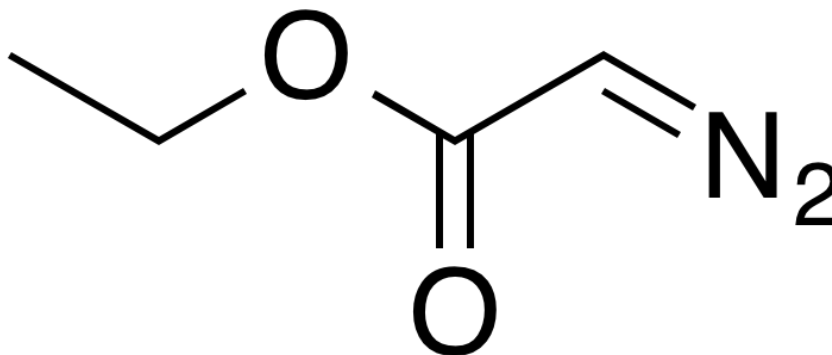
Diazomethane has molecular formula CH₂N₂. It is very difficult to handle in common laboratory conditions and the person handling it must be an expert

It is highly reactive and explosive



Diazoacetic ester

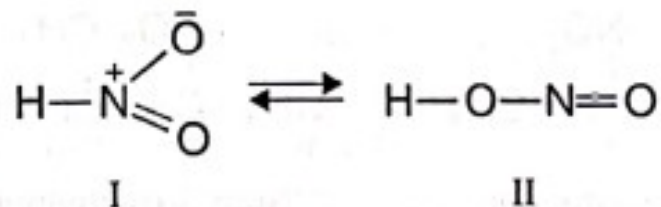
Ethyl diazoacetate ($\text{N}=\text{N}=\text{CHC}(\text{O})\text{OC}_2\text{H}_5$) is a diazo compound and a reagent in organic chemistry



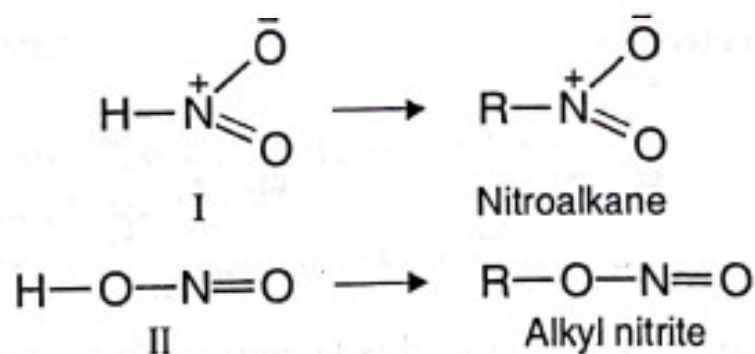
NITROALKANES

Difference between nitro compounds and nitrites (read carefully, it is nitrites and not nitriles)

Nitrous acid (HNO_2) exists in two tautomeric forms

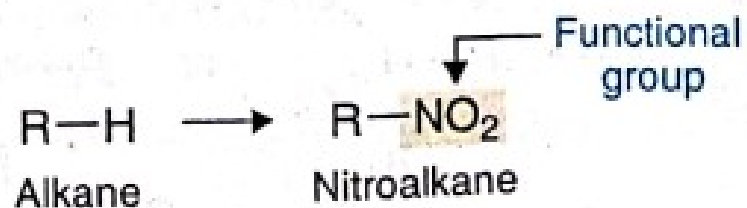


The alkyl derivatives arising from form I are known as **aliphatic nitro compounds**. Those derived from form II are called **alkyl nitrites**, which are, in fact, the esters of nitrous acid.



Definition of Nitro Compounds

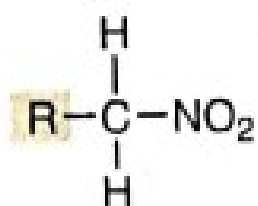
Nitroalkanes are considered as the derivatives of alkanes in which a hydrogen atom is replaced by a nitro group, $-\text{NO}_2$



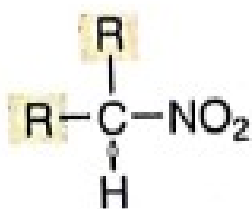
The general formula of nitroalkanes is R-NO_2 where the nitro group ($-\text{NO}_2$) is the functional group.

Classification of aliphatic nitro compounds

**Nitroalkanes are classified depending upon the number of alkyl groups attached to the carbon to which -NO_2 group is attached



1° Nitroalkane



2° Nitroalkane

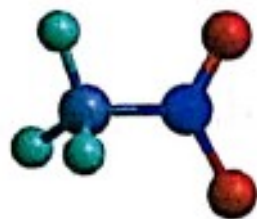


3° Nitroalkane

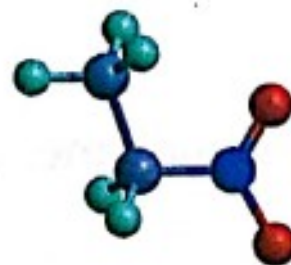
Nomenclature of nitroalkanes

**Aliphatic nitro compounds are named by IUPAC system. The systematic name of a nitro compound is constructed by prefixing “nitro” to the name of the alkane in which the $-\text{NO}_2$ group is substituted. The total name emerges as one word, the position of the $-\text{NO}_2$ group on the carbon chain being indicated by a number

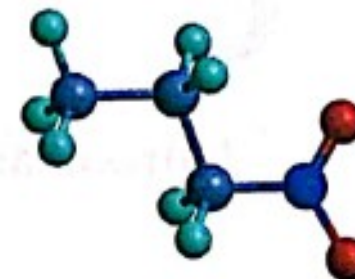
**red ball represents oxygen,
blue ball represents carbon
and light blue ball represents
hydrogen



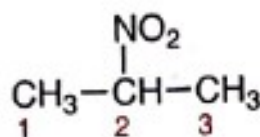
CH_3NO_2
Nitromethane



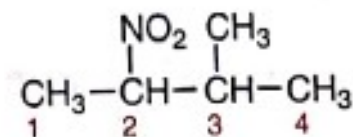
$\text{CH}_3\text{CH}_2\text{NO}_2$
Nitroethane



$\text{CH}_3\text{CH}_2\text{CH}_2\text{NO}_2$
1-Nitropropane



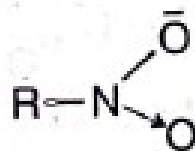
2-Nitropropane



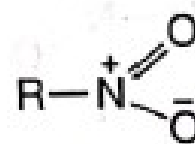
2-Nitro-3-methylbutane

Structure of nitroalkanes

Nitroalkanes are represented as :

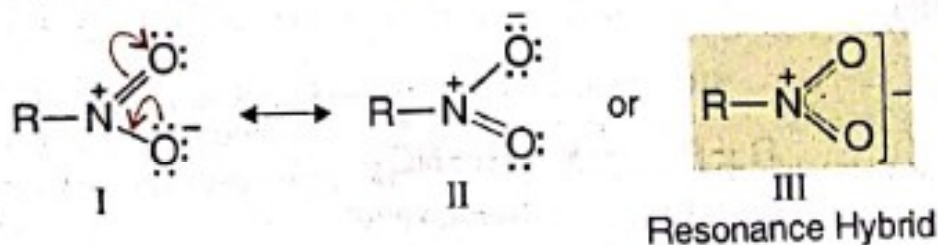


(Classical)



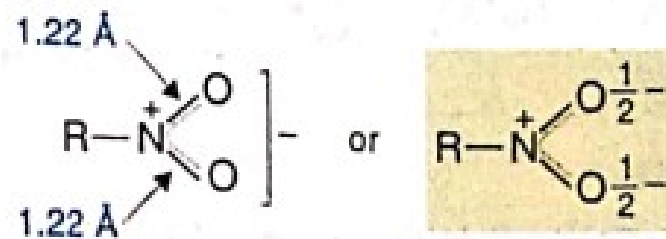
(Polar)

The polar structure is supported by a large dipole moment of the nitro group. Thus nitroalkane is represented as a resonance hybrid of the canonical forms I and II



The hybrid structure III suggests the equivalence of the two nitrogen-oxygen bonds. The spectroscopic and diffraction studies of nitroalkanes have shown that the bond length for each of

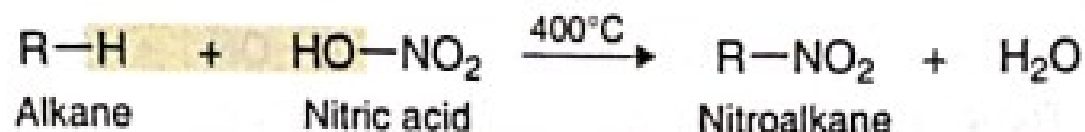
the N-O bonds is 1.22 Å, which is less than N-O single bond (1.36 Å) and N=O double bond (1.15 Å). This confirms the structure and distribution of charge in nitroalkane molecule.



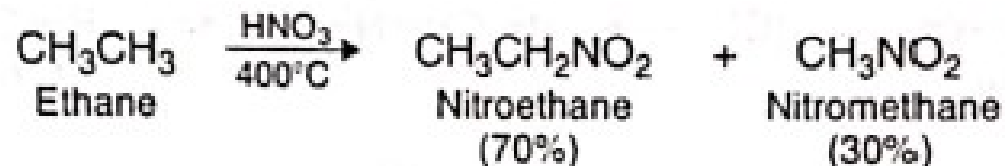
Preparation of Nitroalkanes

1) Vapor Phase Nitration of Alkanes

(1) Vapor Phase Nitration of Alkanes. Nitroalkanes are made industrially by passing a gaseous mixture of an alkane and nitric acid through a narrow metal tube at about 400°C.

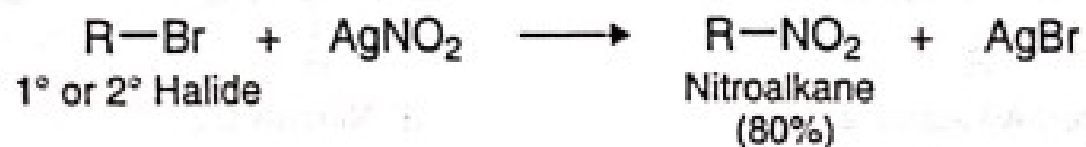


With alkanes other than methane, a mixture of nitroalkanes is obtained which can be separated by fractional distillation.



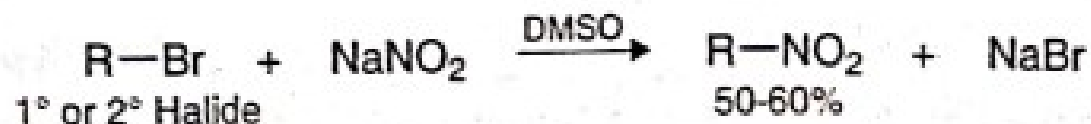
2) By action of alkyl halides with Metal nitrites

(2) Action of Alkyl halides with Metal nitrites. Nitroalkanes are obtained in the laboratory by the action of primary or secondary alkyl halides (bromides or iodides) on silver nitrite in ethanol.



The product consists of 80 percent nitroalkane along with 20 percent of the isomeric alkyl nitrite (RO-N=O), which is also produced in the reaction. The components of the mixture can be easily separated by fractional distillation as the nitroalkane boils at a much higher temperature than the alkyl nitrite.

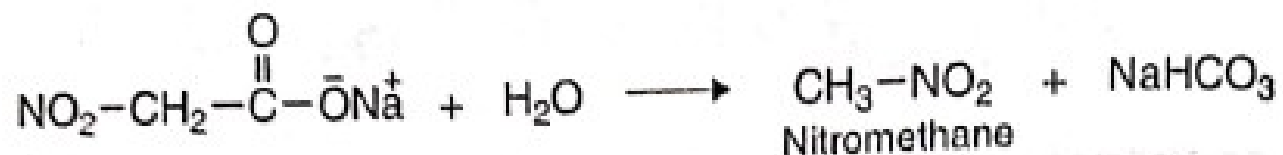
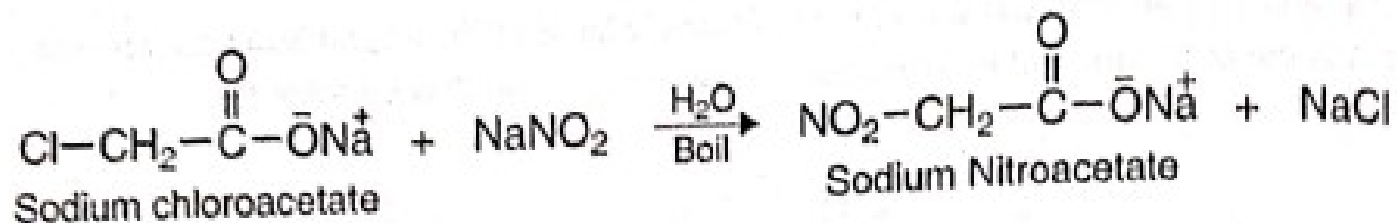
Silver nitrate is an expensive reagent. By using sodium or potassium nitrite in a suitable solvent (dimethyl sulfoxide) nitroalkane may be obtained in 50-60 percent yield.



Tertiary halides react with metal nitrites to form chiefly alkyl nitrites and alkenes, and are therefore not used.

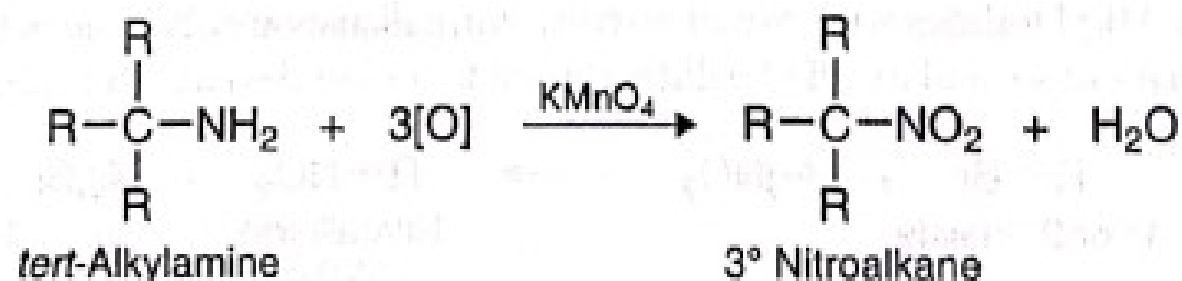
3) Action of Sodium nitrite with α -Halogen acid salts

(3) Action of Sodium nitrite with α -Halogeno acid salts. A useful method for preparing lower nitroalkanes is to boil an aqueous solution of sodium nitrite with sodium salt of α -halocarboxylic acid. Sodium nitrocarboxylate produced in the first instance decarboxylates to form the nitroalkane.



5) Oxidation of *tert*-Alkylamines

(6) Oxidation of *tert*-Alkylamines. Tertiary nitroalkanes are best prepared by oxidizing *tert*-alkylamines with aqueous potassium permanganate.



Physical and Chemical Properties of Nitroalkanes

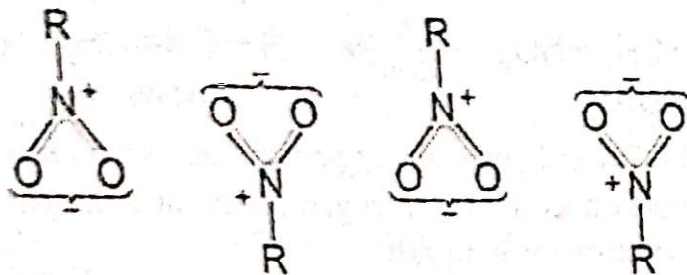
Physical Properties of Nitroalkanes

- (1) The lower nitroalkanes are colorless pleasant smelling liquids at ordinary temperature.
- (2) Nitromethane is about 10 percent soluble in water but the higher alkanes are practically insoluble. This shows that they are less able than alcohols to form hydrogen bonds.
- (3) Since they are polar molecules, nitroalkanes are useful solvents for polar and ionic compounds.
- (4) They have abnormally high boiling points.

	bp°C		bp°C
Nitromethane, $\text{CH}_3\text{-NO}_2$	101	1-Nitropropane, $\text{CH}_3\text{CH}_2\text{CH}_2\text{-NO}_2$	112
Nitroethane, $\text{CH}_3\text{CH}_2\text{-NO}_2$	115	2-Nitropropane, $(\text{CH}_3)_2\text{CH-NO}_2$	120

Physical Properties of Nitroalkanes

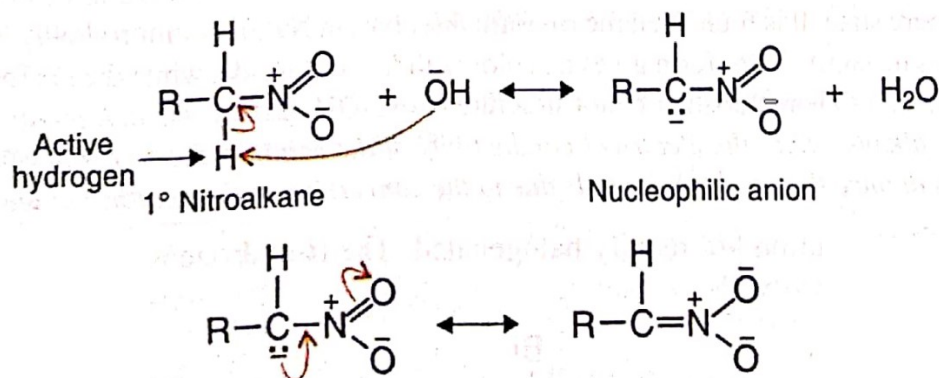
This is explained by the fact that nitroalkanes are highly polar compounds as shown by their high dipole moments (3.6 D). Due to the appreciable electrostatic attraction between the polar molecules, they need a larger amount of energy (heat) in order to separate them.



Chemical Properties of Nitroalkanes

Question: Why do primary and secondary nitroalkanes undergo nucleophilic substitution reaction?

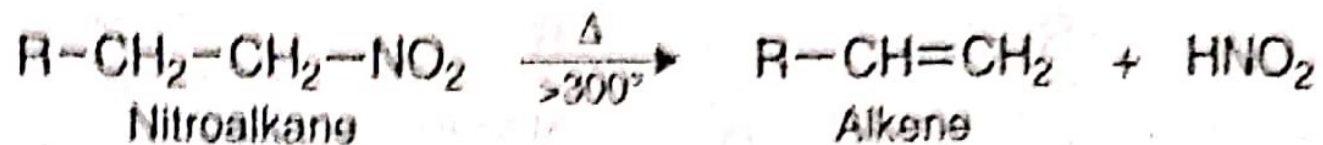
The structure of nitro group indicates a positive charge on the nitrogen atom. Hence, it is strongly electron withdrawing and thus has a strong inductive effect (-I) and mesomeric effect (-M). Because of this electron withdrawal effect primary and secondary nitroalkanes possess active hydrogen atoms on carbon adjacent to NO₂ group. In the presence of a base the hydrogen atom is removed and a nucleophilic anion result. The nucleophilic anion thus produced is resonance stabilized. Thus primary and secondary nitroalkanes can undergo nucleophilic substitution reaction



Chemical Properties of Nitroalkanes

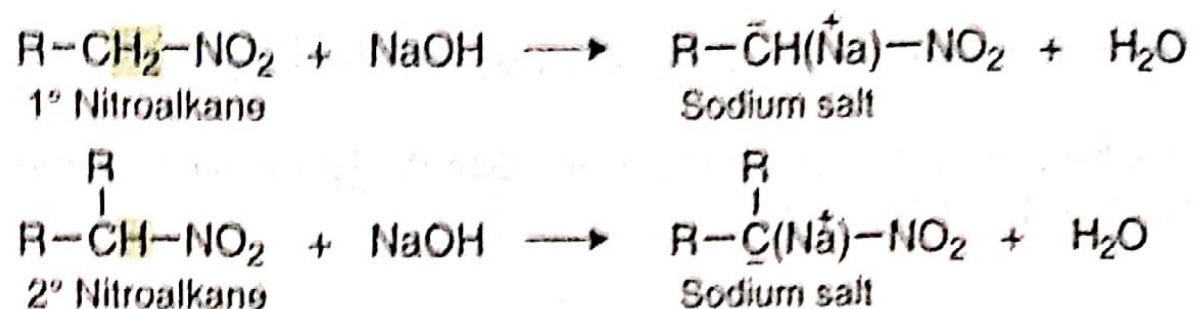
1) Action of heat on nitroalkanes

Nitroalkanes are decomposed on heating beyond 300 °C and this results in the formation of alkenes

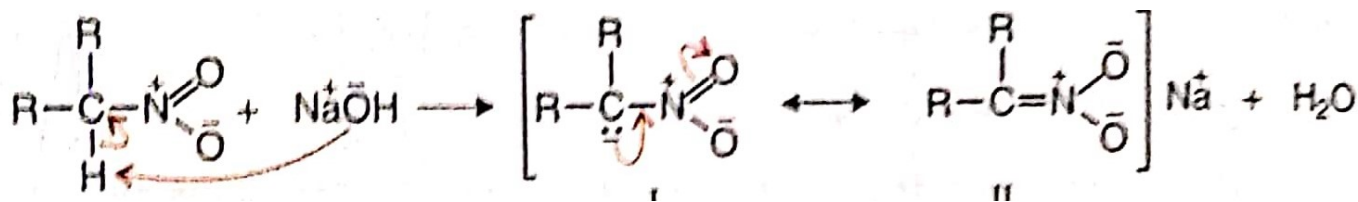


2) Formation of Salts

The alpha hydrogens of primary and secondary nitroalkanes are acidic in nature. Thus they dissolve in NaOH or KOH solution forming salts.

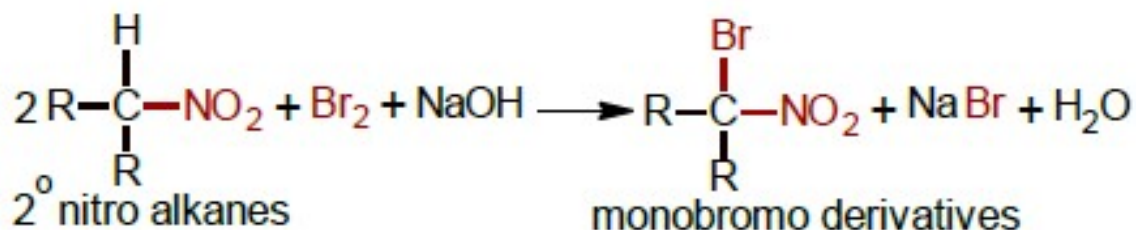
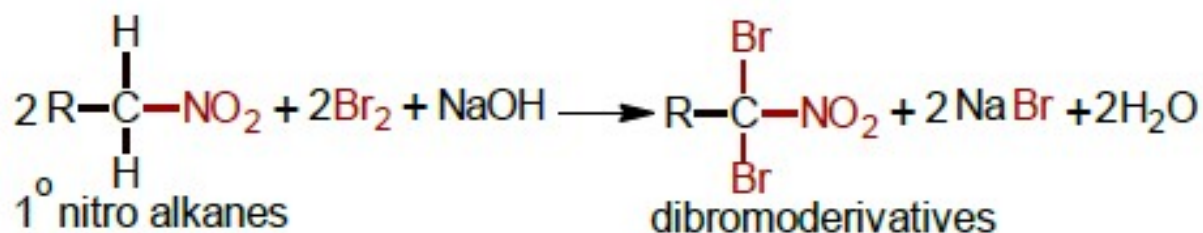


The acidic nature of nitroalkanes is due to the strong electron withdrawing effect of nitro group and also the carbanion formed by removal of alpha hydrogen is resonance stabilized as shown below.



3) Halogenation of Nitroalkanes

Primary and secondary nitroalkanes are easily halogenated in presence of Br_2 and NaOH . The reaction depends on the number of alpha hydrogens. As tertiary Nitroalkanes do not have alpha hydrogens, hence they do not undergo this reaction. This reaction can be used as a test to distinguish nitroalkanes.



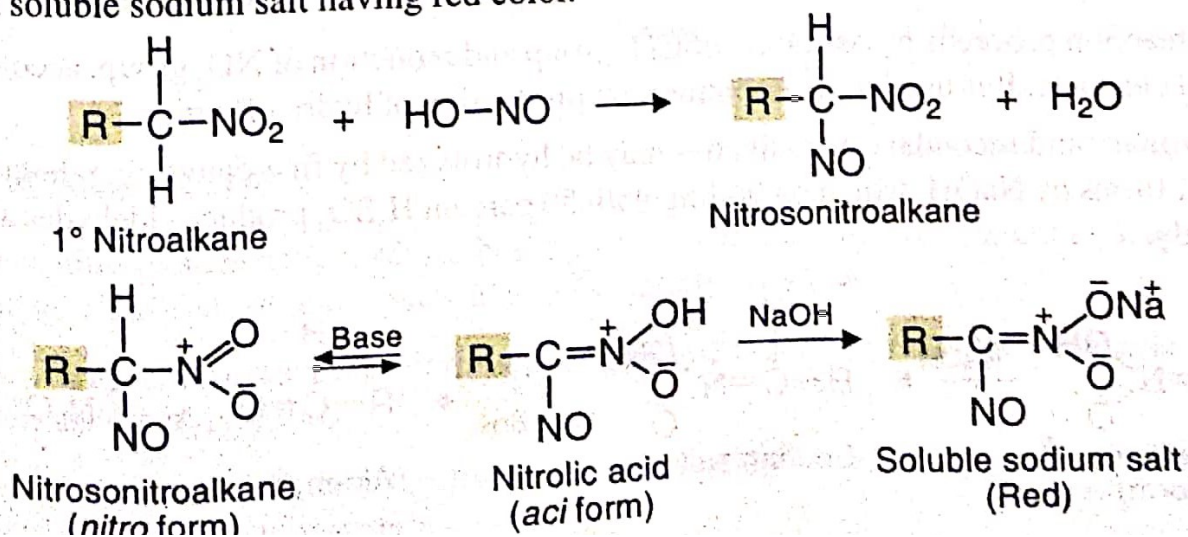
Chloropicin is an important insecticide $\text{CH}_3 - \text{NO}_2 \xrightarrow[\text{NaOH}]{\text{Cl}_2} \text{CCl}_3\text{NO}_2$
Chloropicin or nitrochloroform (insecticide)

4) Reaction with nitrous acid

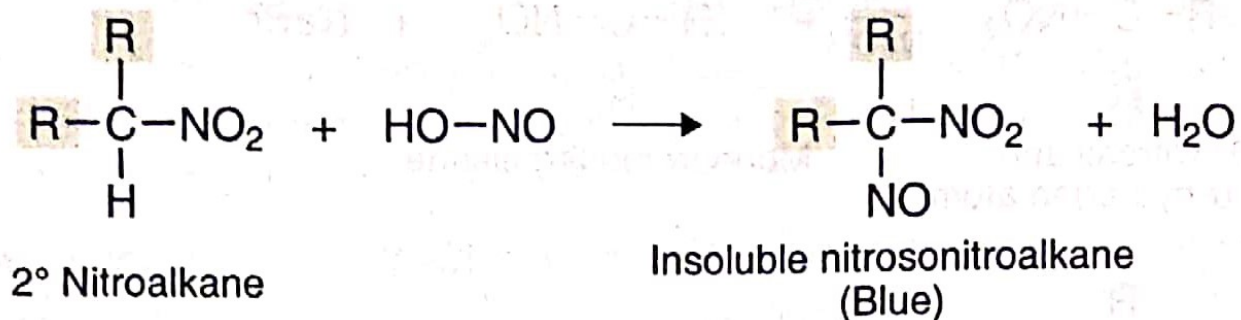
This is a test used to distinguish primary, secondary and tertiary nitroalkanes. The reaction depends on the presence of alpha hydrogen atom in nitroalkanes

Reaction.

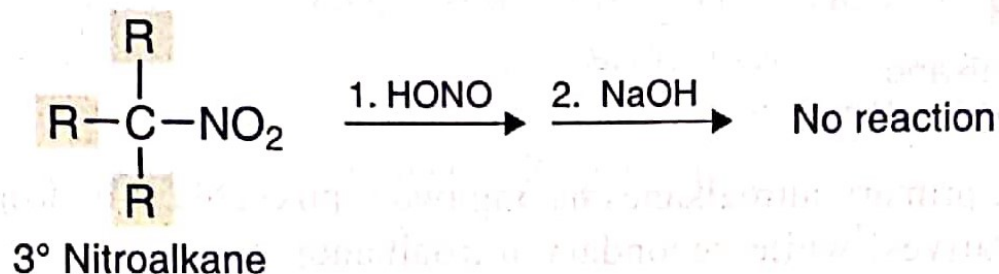
(a) A primary nitroalkane gives a blue nitrosnitroalkane, which in the presence of NaOH solution produces a soluble sodium salt having red color.



(b) A secondary nitroalkane gives a blue nitroso derivative, which no more contains a replaceable H-atom and is, therefore, insoluble.

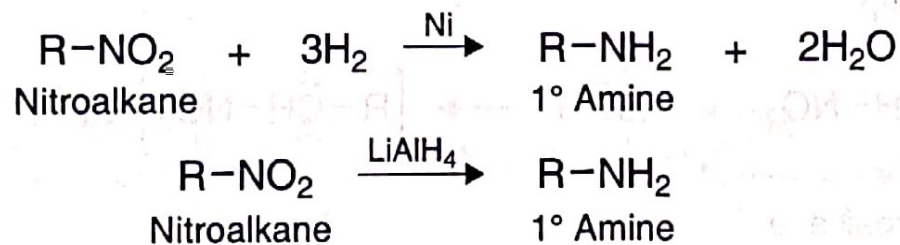


(c) A tertiary amine does not react since it has no reactive hydrogen on the α -carbon.



5) Reduction of nitroalkanes

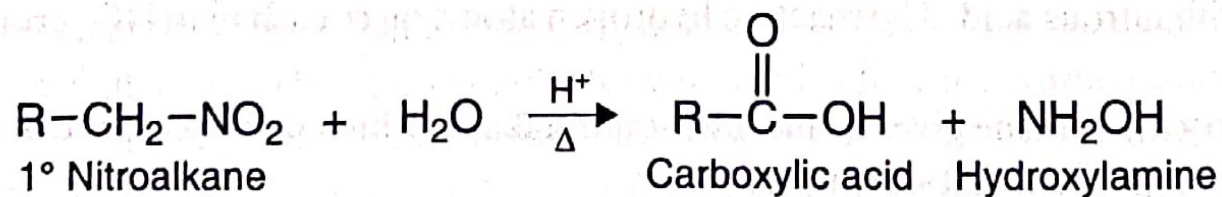
(5) **Reduction.** Nitroalkanes are reduced to a primary amine with hydrogen on Raney nickel, and with lithium aluminium hydride.



This reaction can also be carried out by using a mixture of iron and hydrochloric acid

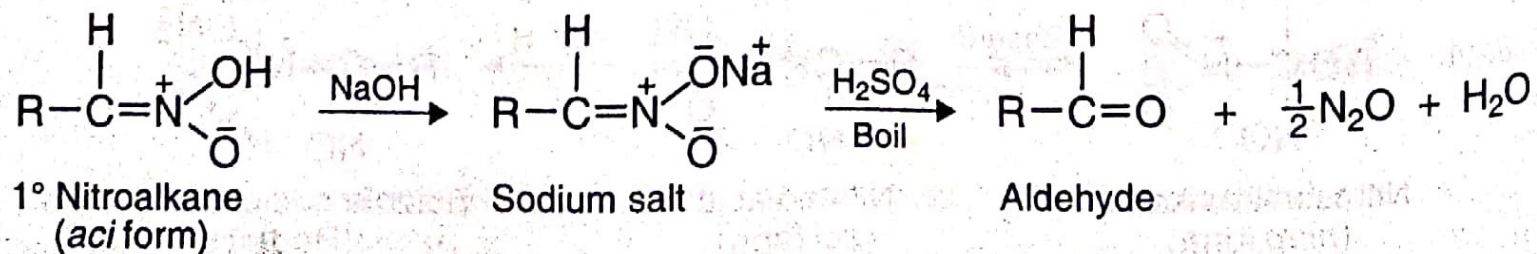
6) Hydrolysis of nitroalkanes

(6) **Hydrolysis.** (a) Primary nitroalkanes on boiling with concentrated hydrochloric acid or sulfuric acid, are hydrolyzed to form a carboxylic acid and hydroxylamine.



This reaction proceeds by oxidation of CH_2 group and reduction of NO_2 group, accompanied by C-N bond cleavage. It is used for the commercial production of hydroxylamine.

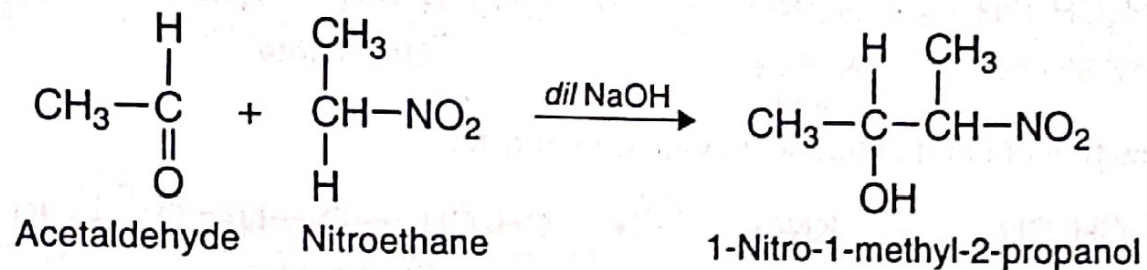
(b) Primary and secondary nitroalkanes may be hydrolyzed by first converting them to the salts of their *aci* forms by NaOH, which on boiling with 50 percent H₂SO₄ produce aldehydes and ketones respectively.



This reaction is known as Nef reaction

7) Condensation with aldehydes and ketones

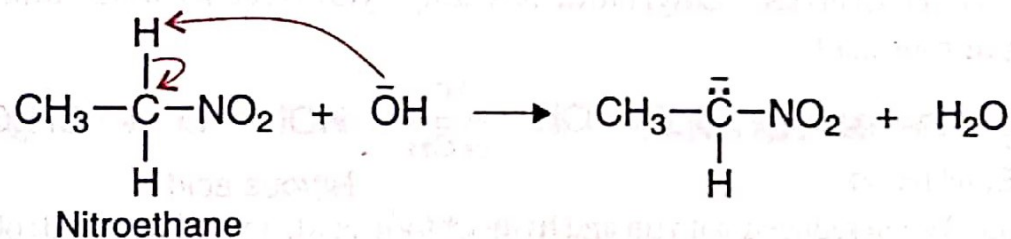
Primary and secondary nitroalkanes react with aldehydes and ketones in presence of dilute alkali. This reaction which yields nitroalcohols is quite similar to Aldol condensation



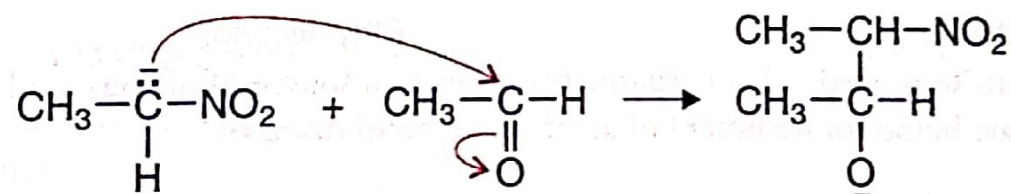
Mechanism is shown in next slide

MECHANISM. Following steps are involved :

Step 1. Formation of carbanion.



Step 2. Carbanion attacks the carbonyl carbon.



Step 3. Protonation.

