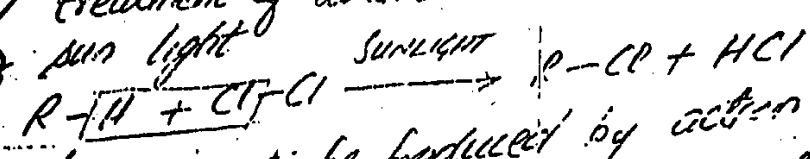


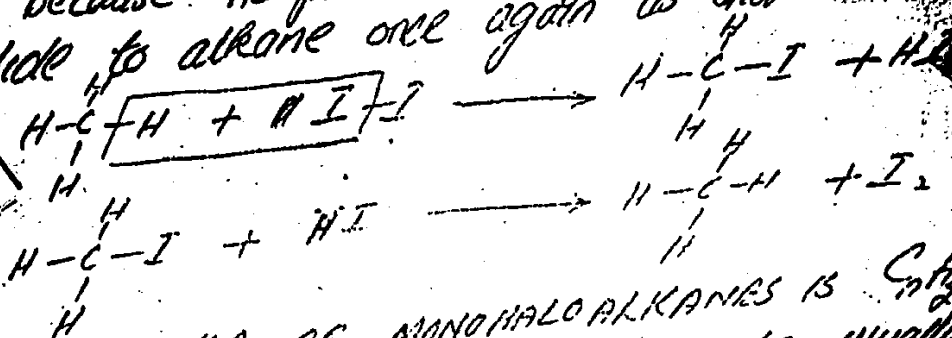
"ALKYL HALIDES"

CHAPTER NO 10

DEFINITION:- Monohaloderivatives of alkanes are called Alkyl halides. The chloro and bromo derivatives are formed by treatment of alkane with chlorine and bromine in presence of sun light.



The iodo derivative cannot be produced by action of I_2 on alkane because HI produced in first step reduces alkyl iodide to alkane once again as shown below.



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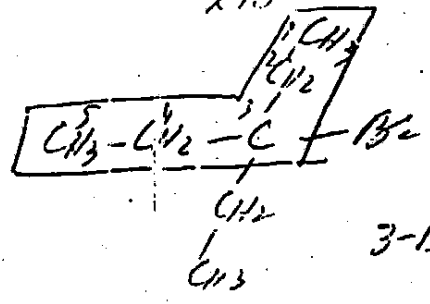
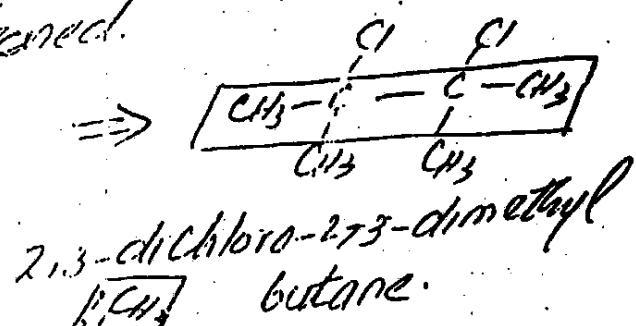
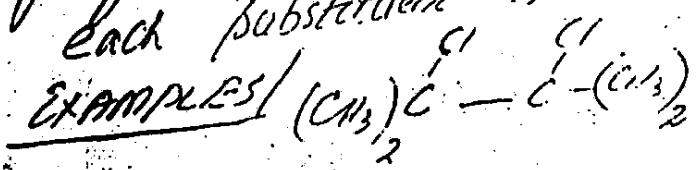
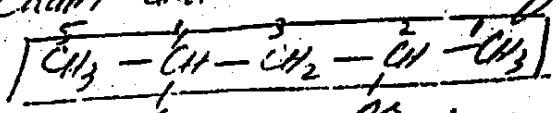
GENERAL FORMULA OF MONOHALOALKANES is $C_nH_{2n+1}X$, in which "X" stands for halogen atom. These are usually written as $R-X$.

"CLASSIFICATION:-"

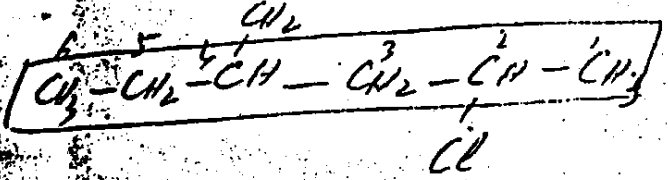
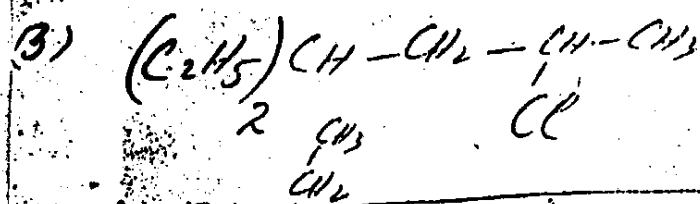
- depending upon number of halogen atoms alkyl halides are classified as follows
- (i) MONOHALOALKANES for example CH_3Cl
 - (ii) DIHALOALKANES for example CH_2Cl-CH_2Cl
 - (iii) TRIHALOALKANES are produced by replacement of three hydrogen atoms by halogen. Depending upon the α -carbon alkyl halides are classified as follows.
 - (i) Primary Alkyl halides:- When α -carbon is directly attached with one carbon it is called α -carbon and alkyl halide is called α -Alkyl halide. For example CH_3-CH_2-Cl
 - (ii) SEC-ALKYL HALIDE when α -carbon is directly attached with two other carbons it is called sec-carbon and alkyl halide is called sec. Alkyl halide. For example $CH_3-CH(Cl)-CH_3$ sec. Propyl bromide
 - (iii) TER-ALKYL HALIDES:- An α -carbon directly attached with three other carbons is called ter. carbon and alkyl halide is ter. Alkyl halide. For example $CH_3-C(Cl)(Br)-CH_3$ 2-bromo-2-halopropane

I.U.P.A.C RULES OF NOMENCLATURE :-

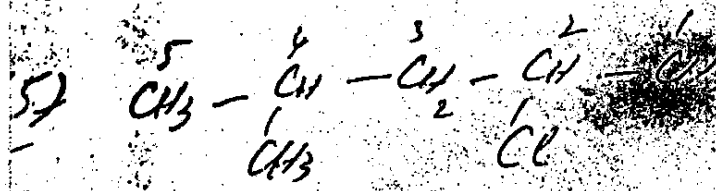
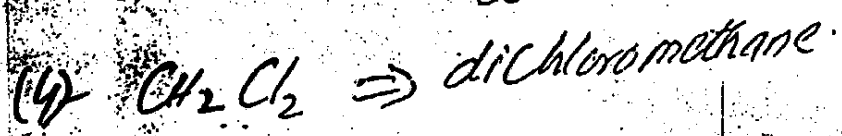
- 1- Select longest carbon chain and write name of parent hydrocarbon.
- 2- Number the carbon chain such that carbon bearing halogen atom gets minimum possible number.
- 3- The position of substituent and halogen atoms is mentioned by writing number of carbon atom to which substituent is attached. Above example 2-bromo-4-methyl pentane
- 4- If there are two or more identical substituents prefix "di" "tri" or "tetra" are used. The position of each substituent is mentioned.



3-bromo-3-ethylpentane.



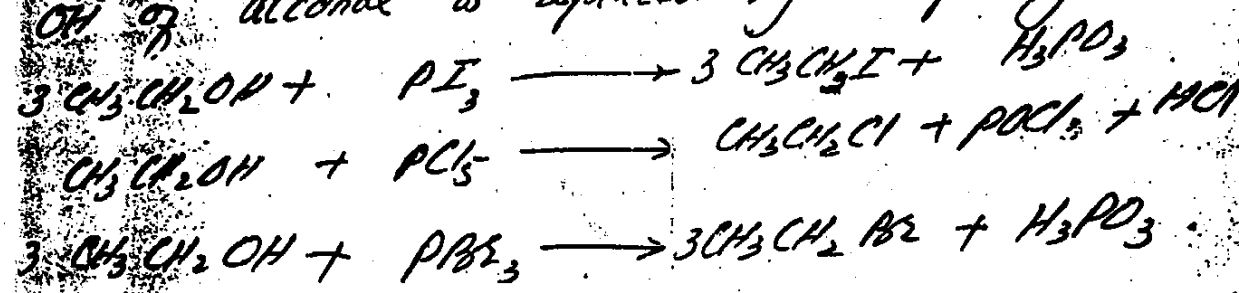
2-chloro-4-ethylhexane.



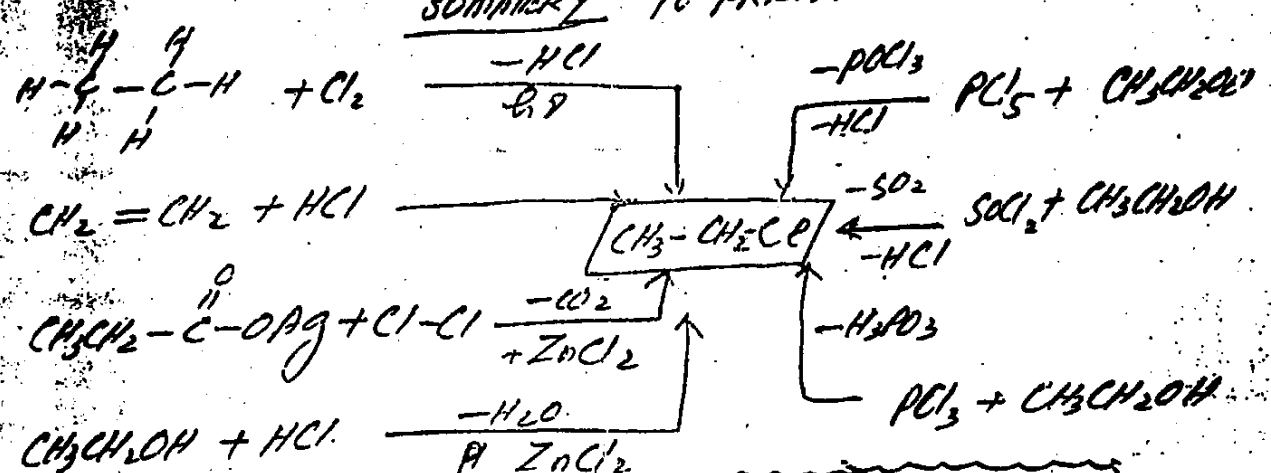
2-chloro-4-methylpentane.

4

REACTION OF ALCOHOL WITH PCl_3 & PCl_5
 Phosphorus trichloride and phosphorus pentachloride react with alcohol to form alkyl halide. The OH of alcohol is replaced by corresponding halogen.



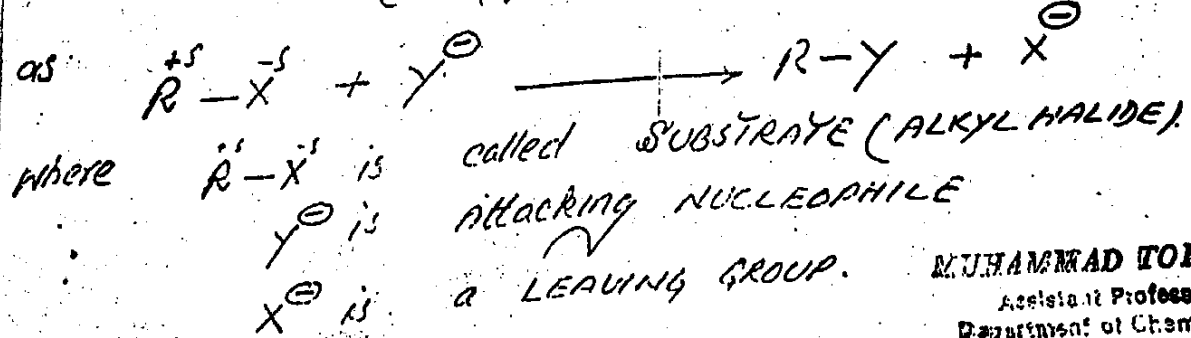
SUMMARY TO PREPARE ETHYLCHLORIDE



(NUCLEOPHILIC SUBSTITUTION REACTIONS)

Q:- What are S_N Reactions? Assign S_N Reactivity to various alkyl halides?

Ans:- Nucleophilic substitution reactions are called S_N reactions. In these reactions one nucleophile replaces another nucleophile. The general S_N reaction can be written as

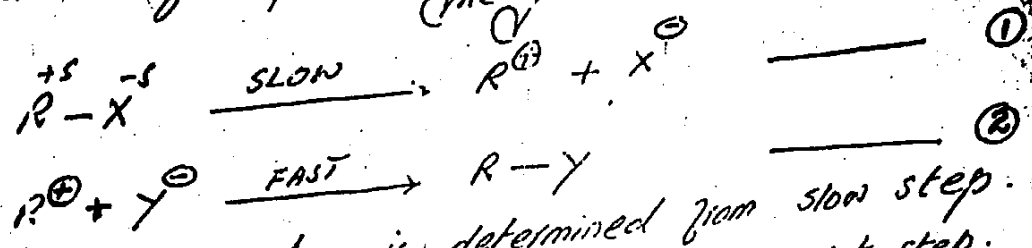


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 Assistant Professor,
 Department of Chemistry
 Govt. College, Sargodha.

NUCLEOPHILE is nucleus loving specie. These are electron rich ions or molecules & mostly negatively charged.

The attacking nucleophile is mostly negatively charged or it may be a neutral molecule with a lone pair of electron. These reactions are further divided into two categories (i) S_N1 - REACTIONS. (ii) S_N2 - REACTIONS.

S_N1 - REACTIONS :- Nucleophilic substitution unimolecular reactions are called S_N1 - REACTIONS. These are two step reactions. In first step leaving group leaves and carbocation ion is formed. In second step attacking nucleophile attacks to form product.

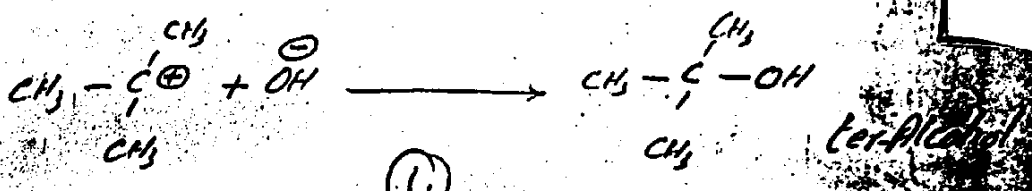
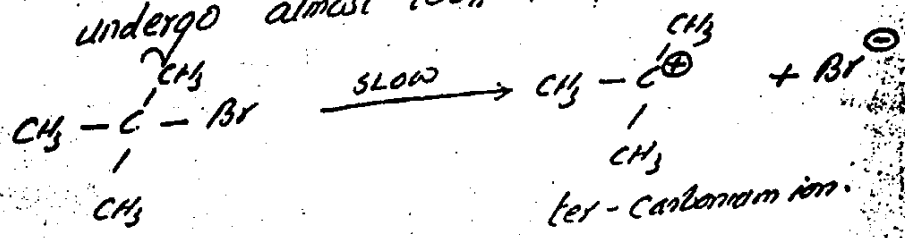


The rate of reaction is determined from slow step. According to Law of mass action from 1st step.

Rate $\propto [R-X]$
 Rate = $k[R-X]$

The rate expression involves only one molecule so it is called unimolecular reaction (first order reaction). The rate of S_N1 reaction depends upon following factors.

EFFECT OF SUBSTRATE :- S_N1 reactions proceed through formation of carbocation ion. The greater the stability of carbocation ion the greater are chances of S_N1 reactions. Ter-alkyl halides produce ter-carbonium ion, which is most stable carbocation ion. So ter-alkyl halides undergo almost 100% S_N1 reactions.



Sec. carbonium ion is less stable than ter. carbonium ion but more stable than p. carbonium ion. So sec-alkyl halides undergo 50% SN₁ reactions. Primary carbonium ion is least stable, so p-alkyl halides generally don't undergo SN₁ - REACTIONS.

KINETIC OF SN₁ REACTIONS - (Conc. Effect.)

The rate of SN₁ reaction is given by

Rate \propto [R-X]
Rate = k[R-X]

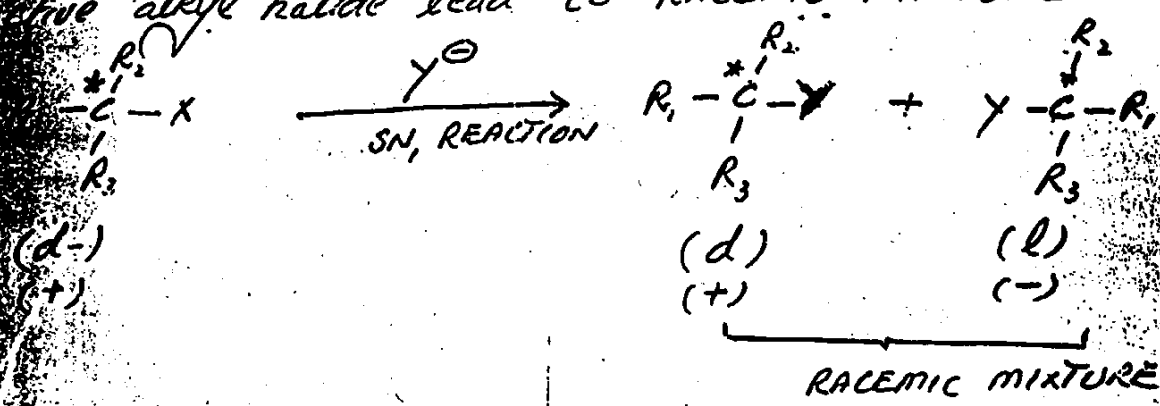
So rate of reaction only depends upon concentration of substrate only. The rate of reaction is independent of concentration of attacking nucleophile. The rate of SN₁ reaction is not effected by an increase or decrease in concentration of attacking nucleophile.

SOLVENT EFFECT

The SN₁ reactions proceed through formation of charged intermediate (CARBONIUM ION). The carbonium ion is more stable in polar solvent. Thus SN₁ reactions are favoured in polar solvents.

For example sec. Alkyl halides undergo more than 50% SN₁ reaction mechanism in polar solvent but more than 50% SN₂ reaction mechanism in Non polar solvent.

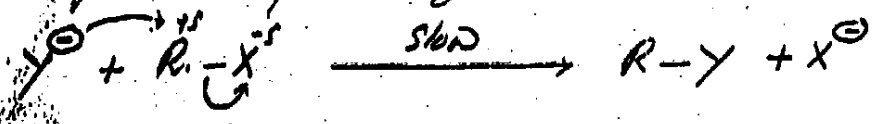
STEREOCHEMICAL EVIDENCE:- The SN₁ reaction of an optically active alkyl halide lead to RACEMIC MIXTURE.



SN₂ - REACTIONS:-

Nucleophilic substitution bimolecular reactions are called SN₂ - REACTIONS. These are one step REACTIONS.

A general expression for S_N2 - reaction is



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GOVT. DEGREE COLLEGE,
SO S.B. BARGODHA.

These are one step reactions which is slow and rate determining step. Rate of reaction according to Law of mass action could be written as

$$\text{Rate} \propto [R-X][Y^{\ominus}]$$

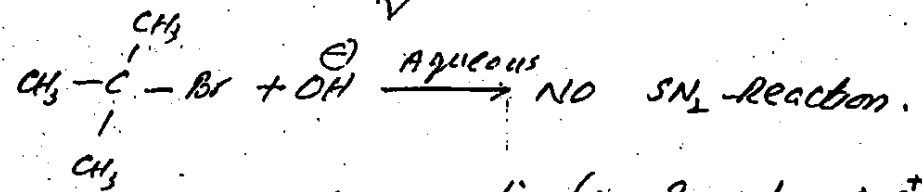
$$\text{Rate} = k[R-X][Y^{\ominus}]$$

The rate expression involves molar concentration of two molecules i.e substrate and attacking nucleophile. So it is a bimolecular reaction.

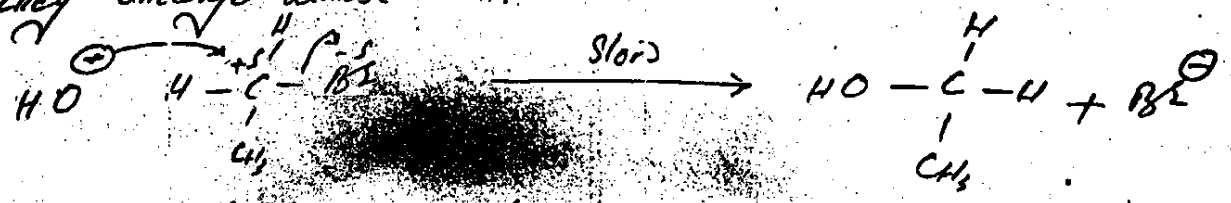
KINETIC EVIDENCE:- The rate of S_N2 reaction is effected both by concentration of attacking nucleophile and substrate. Rate of reaction increases by increasing conc. of substrate and attacking nucleophile. The rate of S_N2 reaction is independent of conc. of attacking nucleophile.

SUBSTRATE EFFECT:- In S_N2 reactions attacking nucleophile always attacks from backside. So reaction is affected by steric hindrance on backside.

Ter. alkyl halides have maximum steric hindrance on back side due to bulky groups. So ter. alkyl halides don't undergo S_N2 - reaction.



These alkyl halide undergo S_N1 - reaction (via formation of C^{\oplus} ion).
p-alkyl halides have least steric hindrance so they undergo almost 100% S_N2 - reaction.



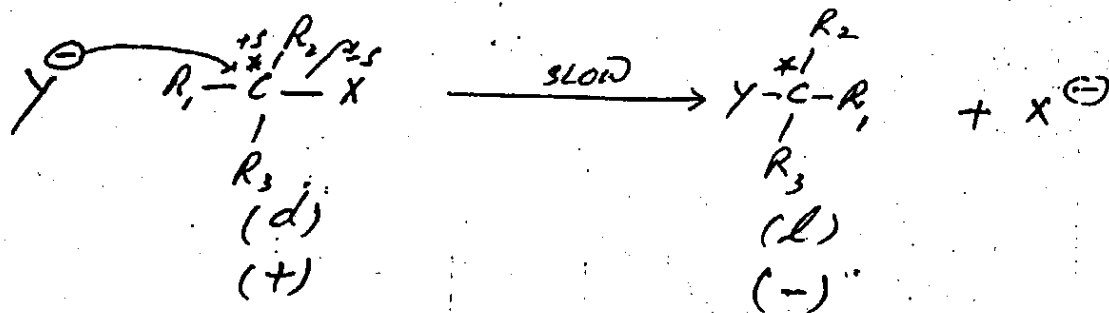
Sec. alkyl halides undergo almost 50% S_N2 reaction due to moderate steric hindrance (less than ter- but more than p-alkyl halides).

SOLVENT EFFECT

S_N2 -reaction does not involve formation of charged intermediate (carbonium ion) so these reactions are favoured in NON-POLAR SOLVENTS, ~~the~~ which inhibit formation of carbonium ion. These reactions are carried out in NON-POLAR SOLVENTS like cyclohexane, n-Hexane, ethers etc.

STEREOCHEMICAL EVIDENCE

If an optically active alkyl halide is used, S_N2 -reactions lead to Inversion of configuration. This is called WALDON INVERSION.



Compare S_N1 & S_N2 reactions.

Nucleophilic substitution reactions are called S_N -REACTIONS.

These are of two types. S_N1 & S_N2 reactions.

S_N1 -REACTIONS

1. These are nucleophilic substitution unimolecular reactions.
2. These are completed in TWO STEPS.
3. The general reaction is
$$\begin{array}{l} \text{Y}^- + \text{R}-\text{X} \xrightarrow{\text{SLOW}} \text{R}^+ + \text{X}^- \\ \text{R}^+ + \text{Y}^- \xrightarrow{\text{FAST}} \text{R}-\text{Y} \end{array}$$
4. Rate expression is first order unimolecular
Rate = $k[\text{R}-\text{X}]$
5. Reaction rate is not effected by conc. of attacking nucleophile.
6. Reaction proceeds through formation of carbonium ion.

S_N2 -REACTIONS

1. These are nucleophilic substitution bimolecular reactions.
2. These are completed in ONE STEP.
3. The general reaction is written as
$$\text{R}-\text{X} + \text{Y}^- \xrightarrow{\text{SLOW}} \text{R}-\text{Y} + \text{X}^-$$
4. Rate expression is bimolecular second order
Rate = $k[\text{R}-\text{X}][\text{Y}^-]$
5. Reaction rate is effected by conc. of attacking nucleophile.
6. No carbonium ion is formed.

SN₁ REACTIONS.

The order of SN₁ reactivity of alkyl halides is $ter > sec > pri$. SN₁ reactions are favoured in polar solvents.

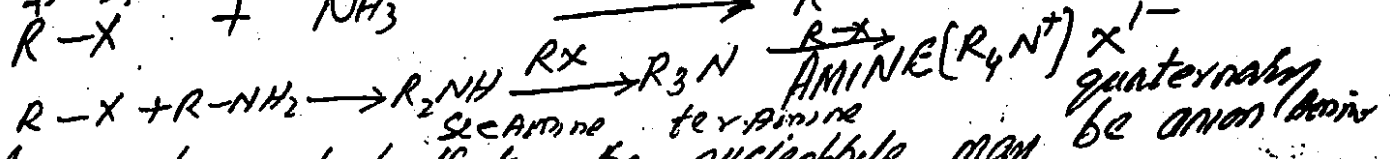
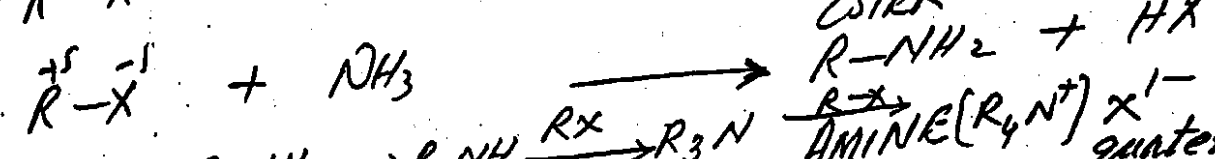
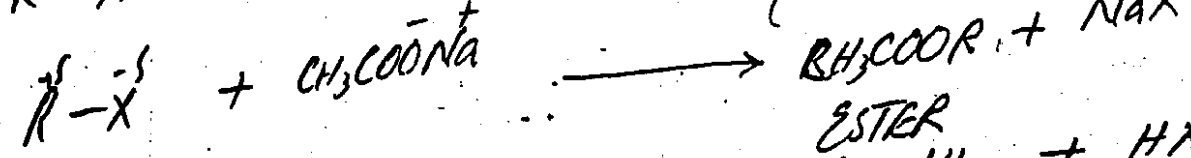
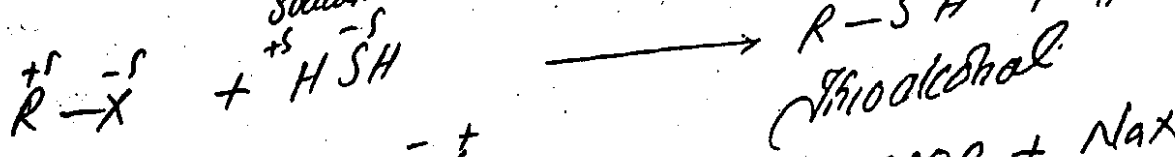
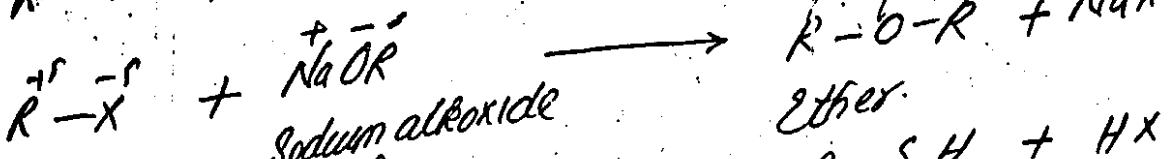
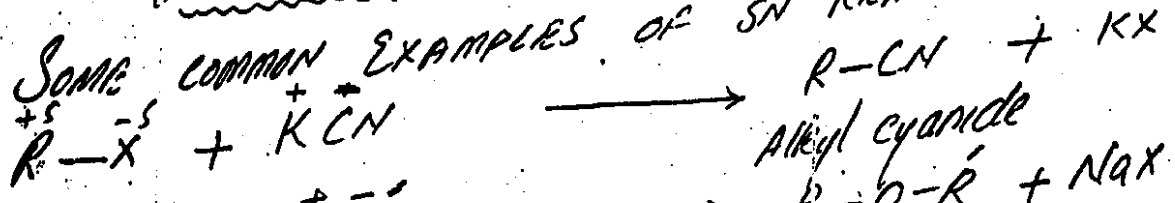
When an optically active alkyl halide undergoes SN₁ reaction it produces RACEMIC MIXTURE. SN₁ reactions require good leaving groups, but a powerful nucleophile is not required for reaction.

SN₂ REACTIONS

The order of SN₂ reactivity of alkyl halides is $p > sec > ter$. SN₂ reactions are favoured in non-polar solvents.

Optically active alkyl halide undergoes Walden Inversion of configuration. SN₂ reactions require a powerful attacking nucleophile but good leaving group is not required.

SOME COMMON EXAMPLES OF SN REACTIONS ARE GIVEN.



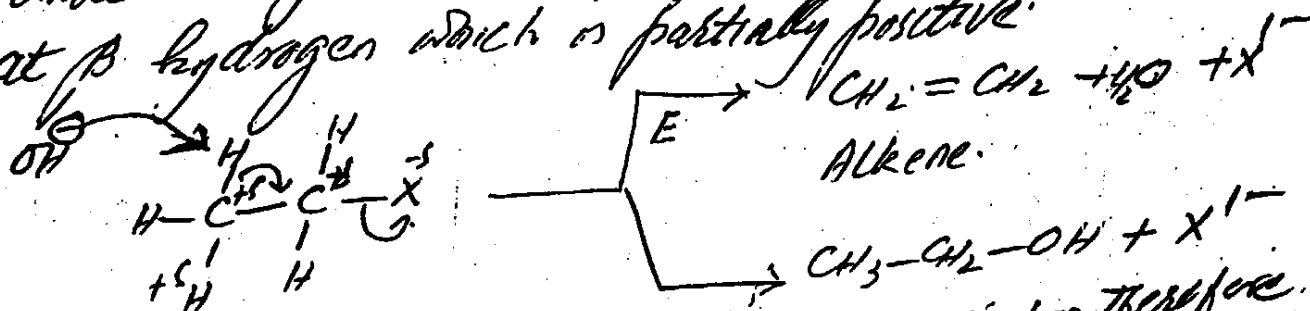
It may be noted that the nucleophile may be anion like OH^- , CN^- or it may be a neutral group bearing a lone pair of electron like NH_3 . Reactions of sec alkyl halides may be SN₁ or SN₂ depending upon nature of solvent in which the reaction is carried out and structure of reactants.

(See more examples for Text Book P-274)

WRITE A NOTE ON ELIMINATION REACTIONS. (10)

The reactions in which atoms or group of atoms are removed from two adjacent carbons are called elimination reactions. These reactions take place simultaneously with SN reactions and very often compete with SN reactions.

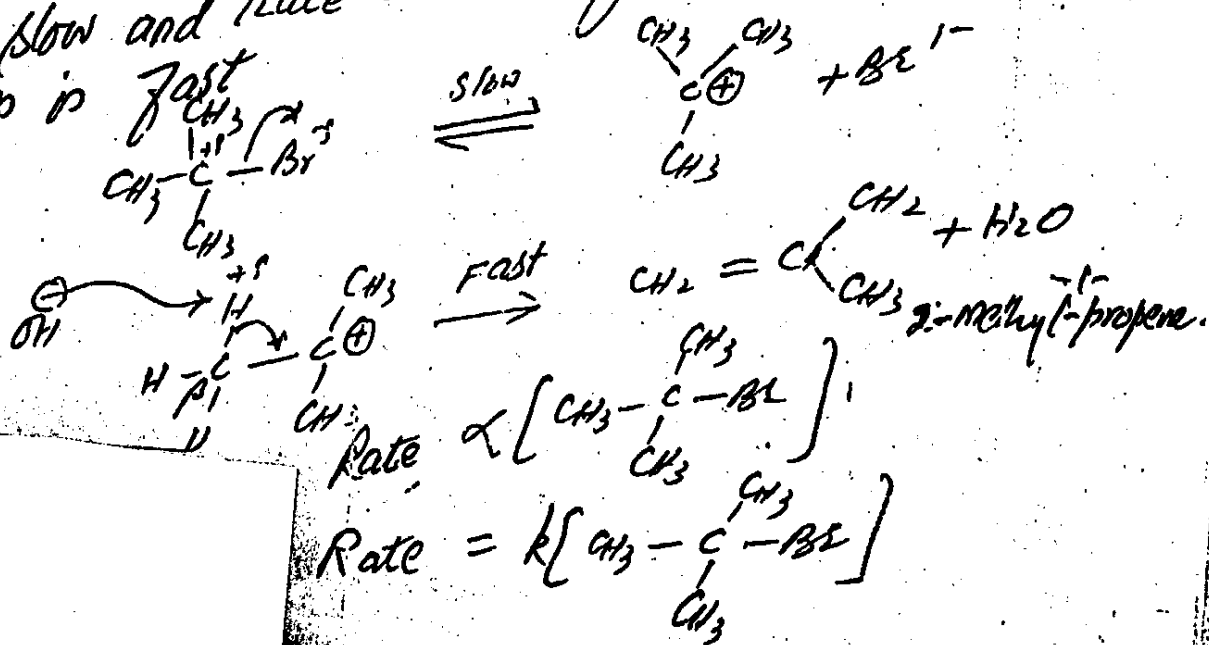
The major point of difference between SN reactions and Elimination reactions is that the attack of nucleophile takes place at α -Carbon during SN reaction while during Elimination reactions nucleophile attacks at β hydrogen which is partially positive.



Since hydrogen is always removed from β -Carbon therefore these reactions are also called β -Eliminations. These reactions are also divided into two types -

(i) E_1 - REACTIONS

E_1 - REACTIONS: These are elimination unimolecular reactions. These are completed in two steps. The first step is slow and rate determining step. The second step is fast.

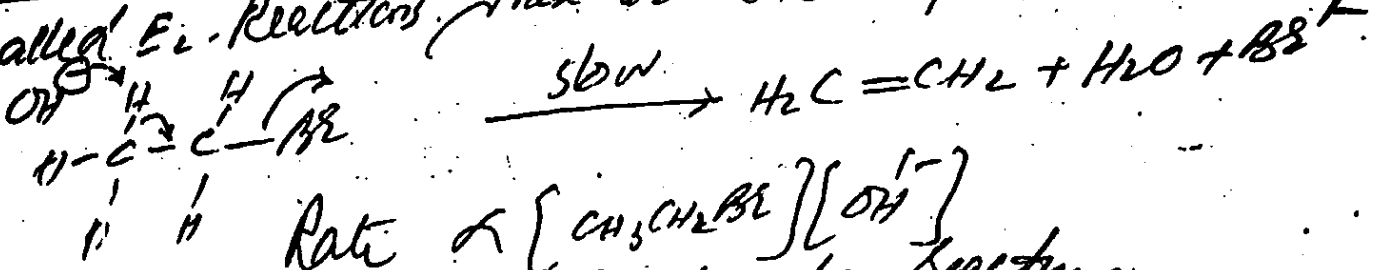


Since rate expression contains molec. conc. of one reactant raise to power 1 so it is unimolecular first order reaction.

FACTORS AFFECTING E_1 MECHANISM:- ter. Alkyl halides undergo E_1 reactions, because E_1 reactions proceed through formation of carbocation ion-ter. Alkyl halides produce most stable ter. carbocation ion. sec Alkyl halides can undergo 50% E_1 reaction and pr -alkyl halides generally don't undergo E_1 elimination.

SOLVENT EFFECT: E_1 eliminations are generally favored in polar solvents because ions are stabilized in polar solvents only.

E_2 -REACTIONS / Elimination bimolecular reactions are called E_2 -Reactions. These are one step reactions.



Rate $\propto [\text{CH}_3\text{CH}_2\text{BR}][\text{OH}^-]$

These are bimolecular second order reactions.

Order of reactivity of alkyl halides towards E_2 eliminations are $pr > sec > ter$ - these are favoured in non-polar solvents.

One major difference between base and a nucleophile is that base attack at β -hydrogen and remove it as proton, while nucleophile can attack α -carbon having δ^+ charge and favours S_N reactions.

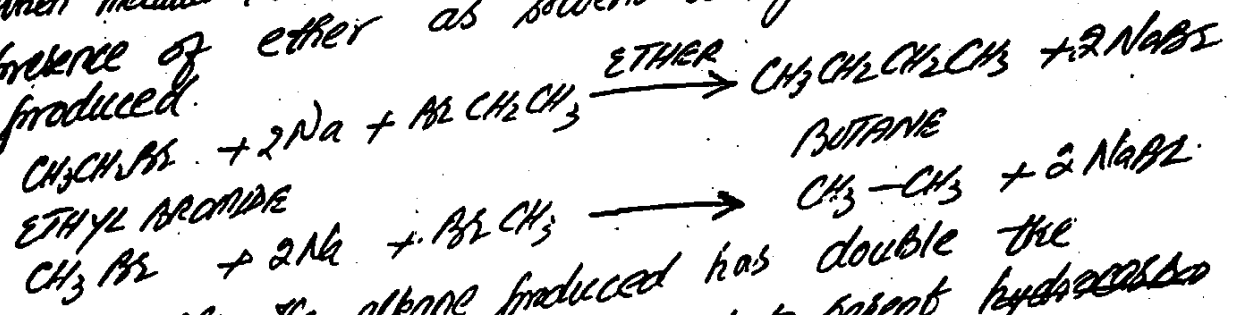
v. imp.

SHOW THAT ALKYL HALIDES ARE MOST IMPORTANT COMPOUNDS IN SYNTHETIC CHEMISTRY?

Alkyl halides are used to produce a large number of other organic compounds. These are an important synthetic tool in the hands of synthetic chemist. The following reactions show that alkyl halides are very important compounds in synthetic chemistry.

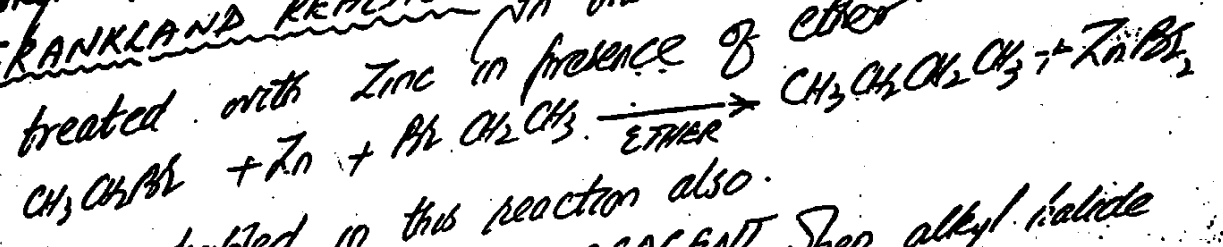
PREPARATION OF ALKANE Alkyl halides can be used to produce a variety of alkanes by following reactions

1. WURTZ REACTION (ACTION OF SODIUM METAL) When metallic sodium is heated with an alkyl halide in presence of ether as solvent a higher alkane is produced.



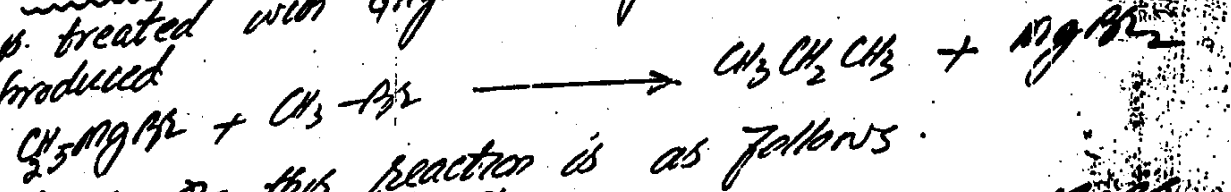
ADVANTAGE: The alkane produced has double the number of carbon atoms as compared to parent hydrocarbon alkyl halide.

2. FRANKLAND REACTION In this reaction alkyl halide is treated with Zinc in presence of ether.

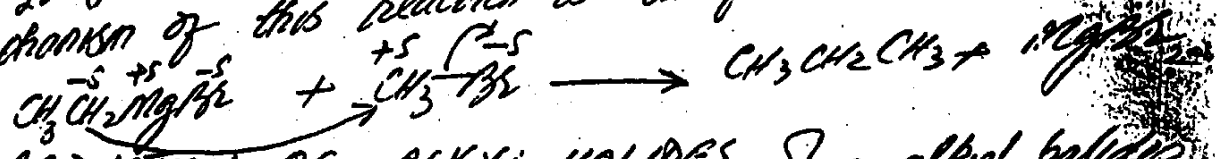


Chain is doubled in this reaction also.

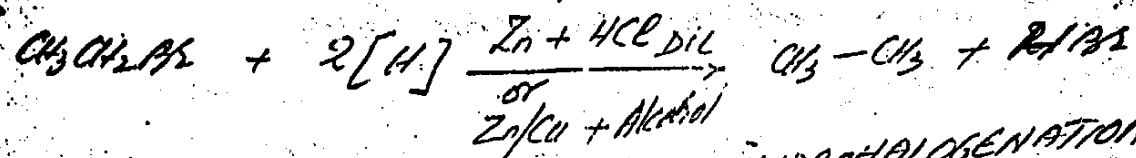
3. REACTION WITH GRIGNARD REAGENT When alkyl halide is treated with Grignard Reagent an alkane is produced.



Mechanism of this reaction is as follows.

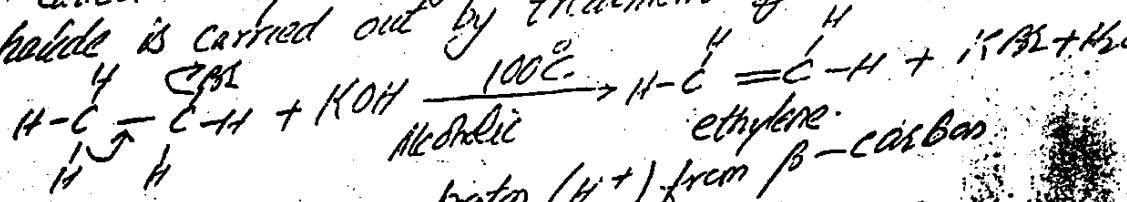


4. REDUCTION OF ALKYL HALIDES When alkyl halides are treated with Zinc and HCl or Zinc-copper couple and an alcohol, these are reduced to corresponding alkane.

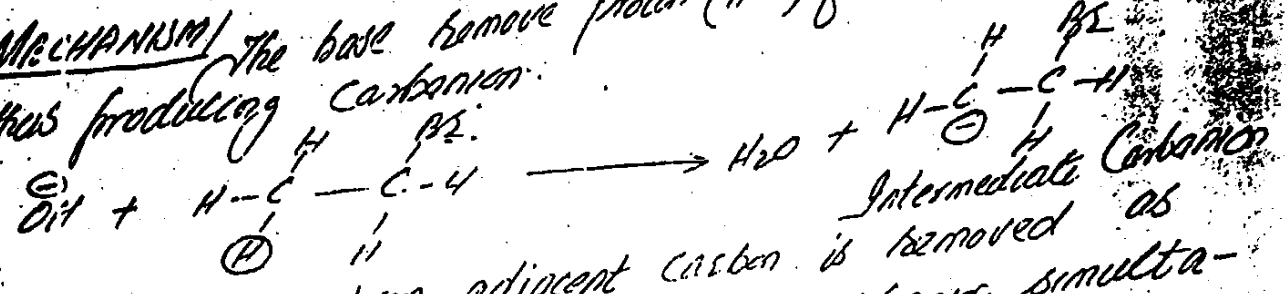


5 PREPARATION OF ALKENES (DEHYDROHALOGENATION)

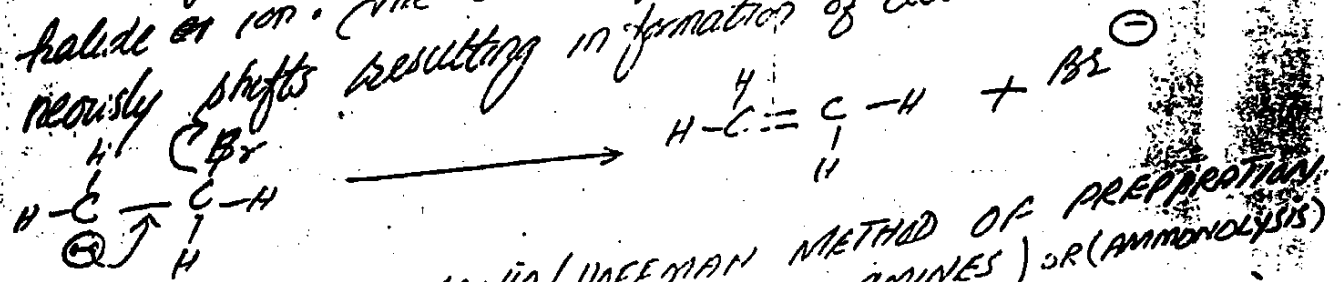
The elimination of hydrogen and halogen from two adjacent carbon atoms is called dehydrohalogenation. Dehydrohalogenation of alkyl halide is carried out by treatment of with Alk. KOH at 100°C



Mechanism The base remove proton (H+) from β-carbon thus producing carbanion.

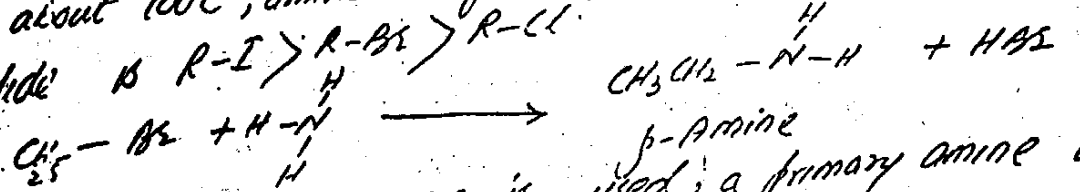


Then halogen atom from adjacent carbon is removed as halide or ion. The electron pair of carbanion shifts towards the carbon atom resulting in formation of double bond.

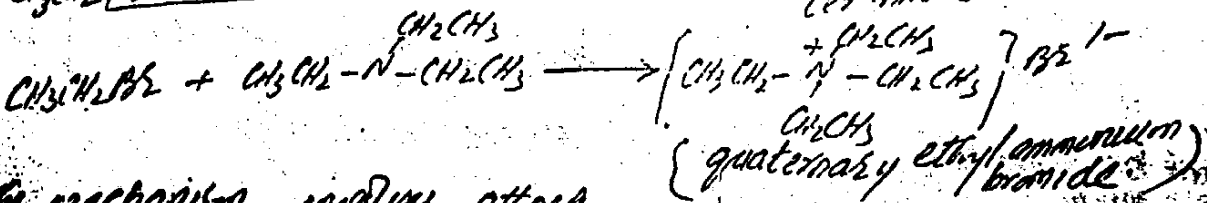
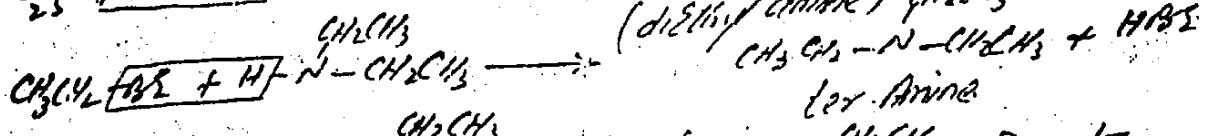
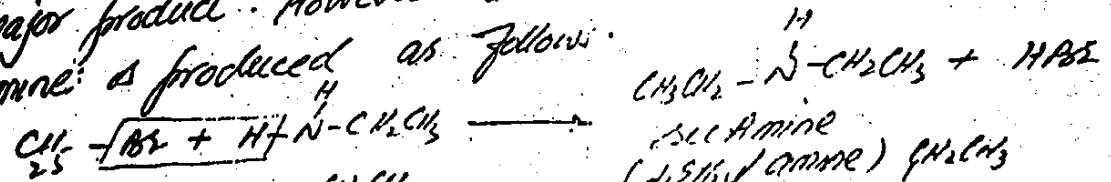


6 ACTION OF AMMONIA (HOFFMAN METHOD OF PREPARATION OF ALKYL AMINES) OR (AMMONOLYSIS)

When an alkyl halide is heated with aqueous solution of ammonia at about 100°C, amines are formed. The order of reactivity of alkyl halide is R-I > R-Br > R-Cl.

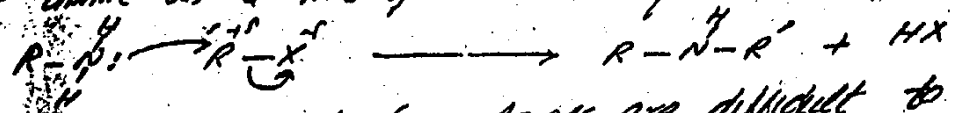


When an excess of ammonia is used, a primary amine is the major product. However, under conditions, a mixture of amines is produced as follows.



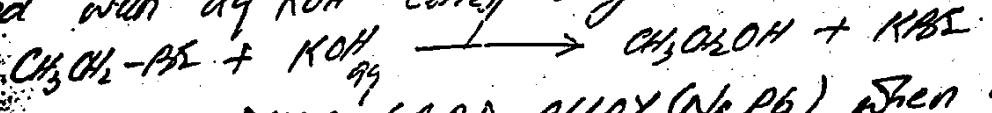
The mechanism involves attack

of name as a nucleophile on alkyl halide

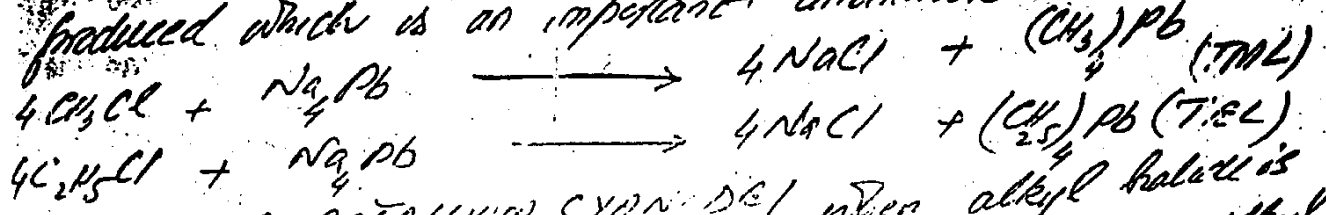


Since 1^o, sec. and ter. Amines are difficult to separate so it is not an attractive method of prep. of Amines.

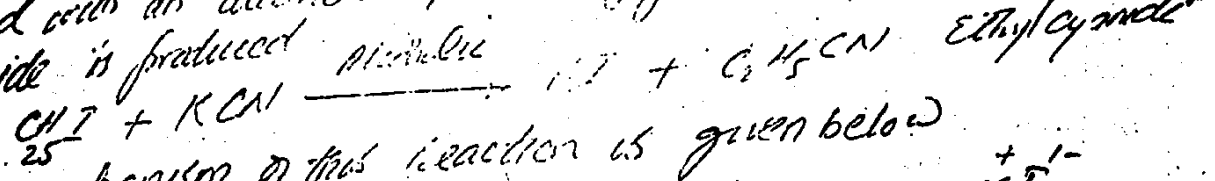
7. REACTION WITH AQUEOUS KOH When an alkyl halide is treated with aq KOH corresponding alcohol is produced.



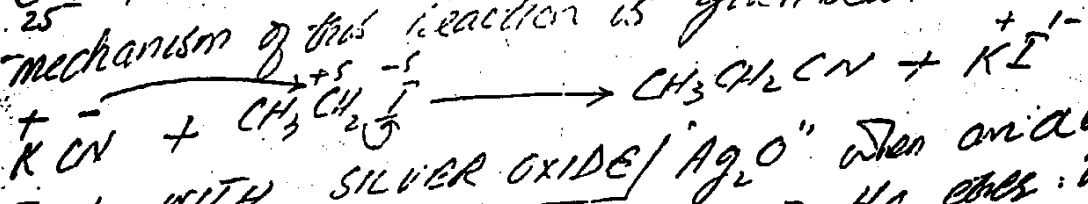
3. ACTION OF SODIUM LEAD ALLOY (Na₂Pb) When alkyl halides are treated with sodium lead alloy tetra alkyl lead is produced which is an important antiknock



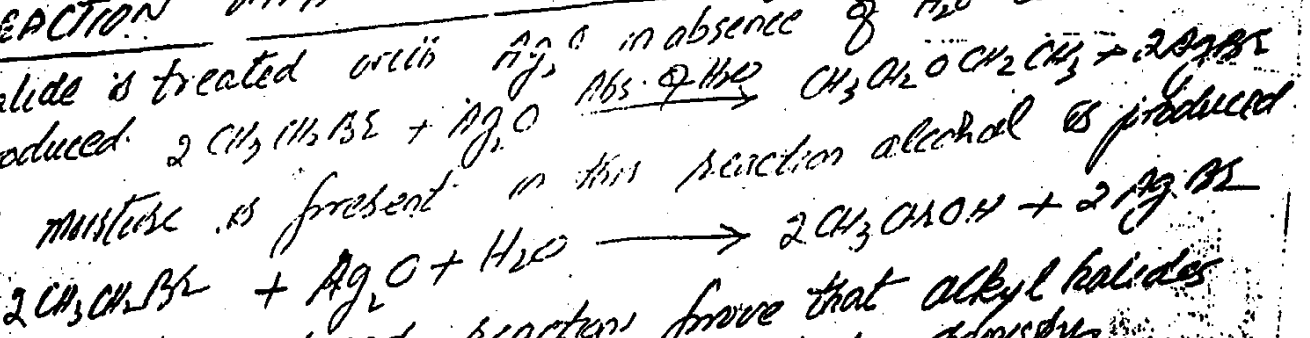
3. ACTION OF POTASSIUM CYANIDE When alkyl halide is boiled with an alcoholic solution of potassium cyanide an alkyl cyanide is produced



The mechanism of this reaction is given below



7. REACTION WITH SILVER OXIDE (Ag₂O) When an alkyl halide is treated with Ag₂O in absence of H₂O ether is produced.



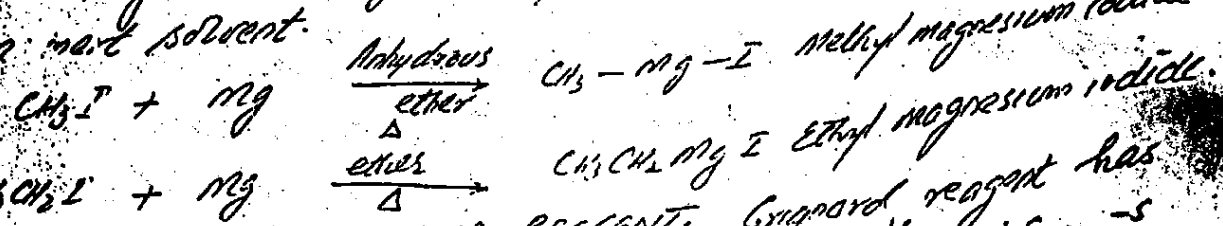
The above mentioned reactions prove that alkyl halides are very important compounds in synthetic chemistry.

Imp. Q.: WHAT IS GRIGNARD REAGENT? DISCUSS ITS PREPARATION, STRUCTURE AND APPLICATIONS.

Ans:- Alkyl magnesium halide (RMgX) is commonly called Grignard Reagent. It was discovered by Victor Grignard in 1901. It is an organometallic compound widely used in synthetic chemistry.

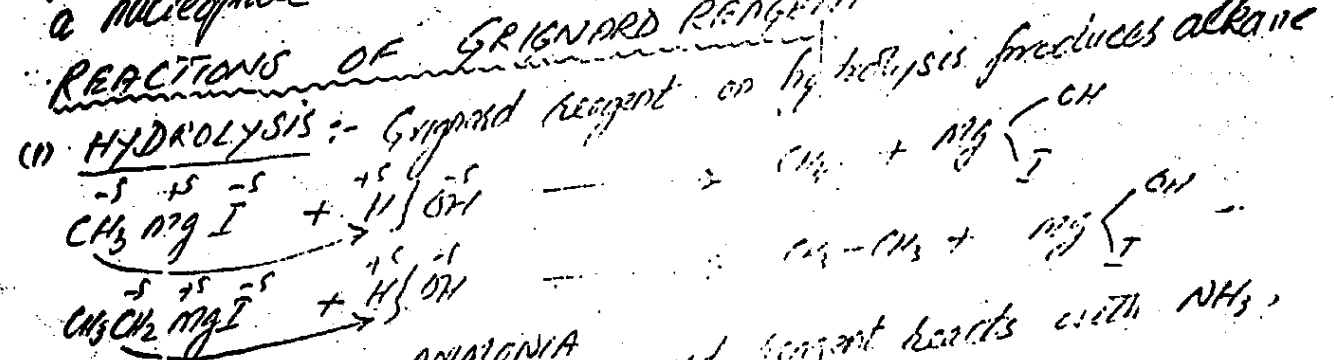
PREPARATION OF GRIGNARD REAGENT

Grignard reagent was prepared by reaction of methyl iodide with fresh magnesium turnings in anhydrous ether. The ether acts as an inert solvent.

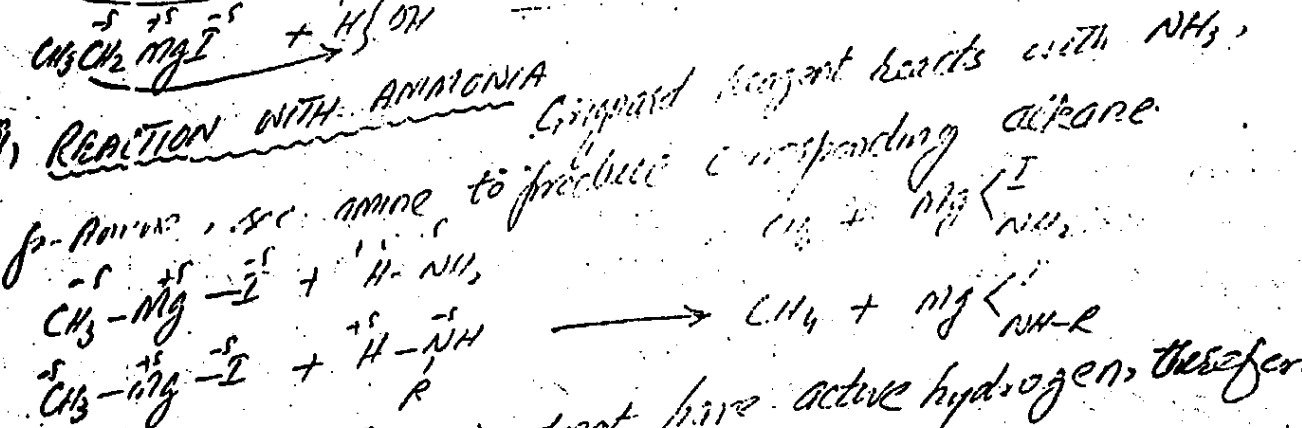


STRUCTURE OF GRIGNARD REAGENT: Grignard reagent has a slightly polar structure as shown below $\overset{\delta-}{C} - \overset{\delta+}{Mg} - I$. Carbon attached to an electropositive element, "magnesium" acquires partial negative charge, thus carbon acts as a nucleophile. All reactions of Grignard reagent are attacks of alkyl group on $\delta+$ charged centre. Thus Grignard reagent acts as a nucleophile.

REACTIONS OF GRIGNARD REAGENT

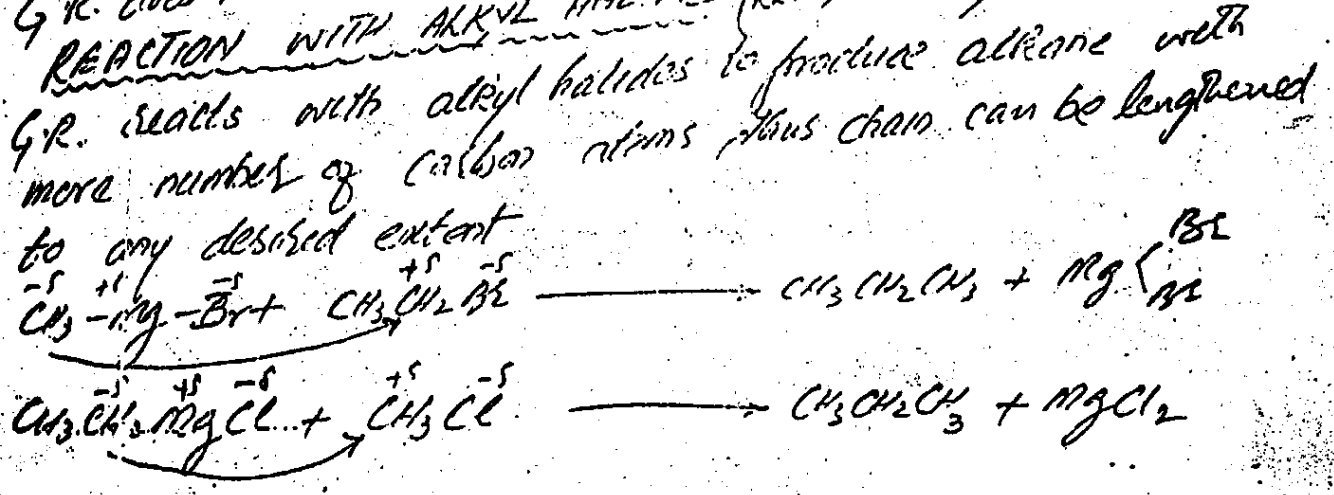


(ii) REACTION WITH AMMONIA



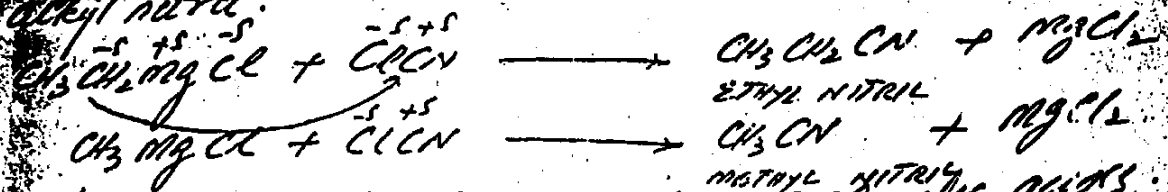
Since ter -Amines (R_3N) do not have active hydrogen, therefore Grignard reagent does not react with ter -Amines.

REACTION WITH ALKYL HALIDES (LENGTHENING OF C-CHAIN)

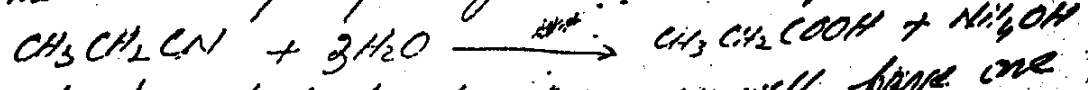


REACTION WITH CYANOGEN CHLORIDE (CClN) 16.13

Grignard reagent reacts with cyanogen chloride to produce alkyl nitrile.



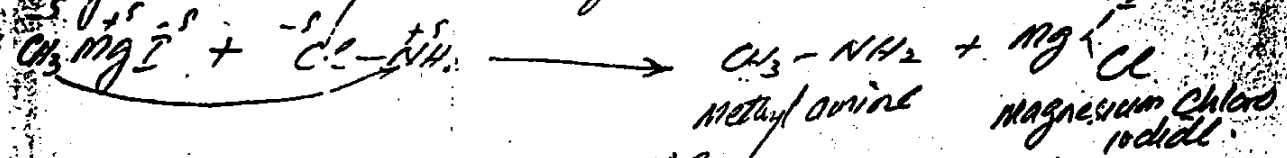
Alkyl nitrile on hydrolysis produce carboxylic acids.



The carboxylic acid produced in this way will have one carbon more than that of alkyl halide used for G.R.

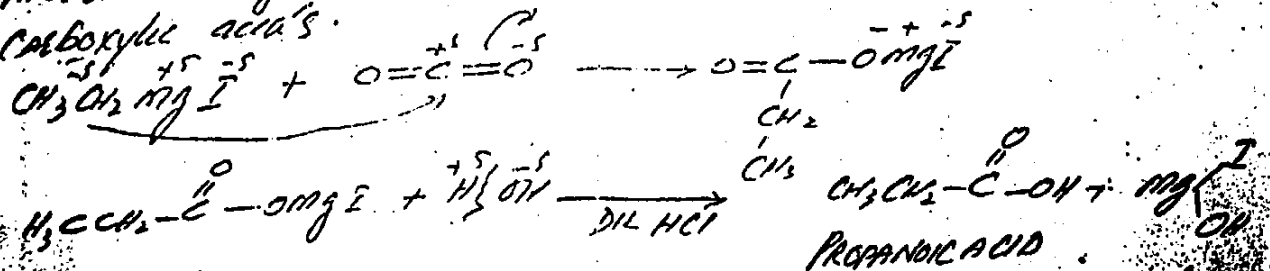
REACTION WITH CHLOROAMINES primary amines can

be produced by action of G.R. with chloroamine ClNH_2



REACTION WITH CARBON DIOXIDE

Dry carbon dioxide is passed through G.R. in presence of ether solvent. The intermediate product is decomposed with dil HCl to carboxylic acids.

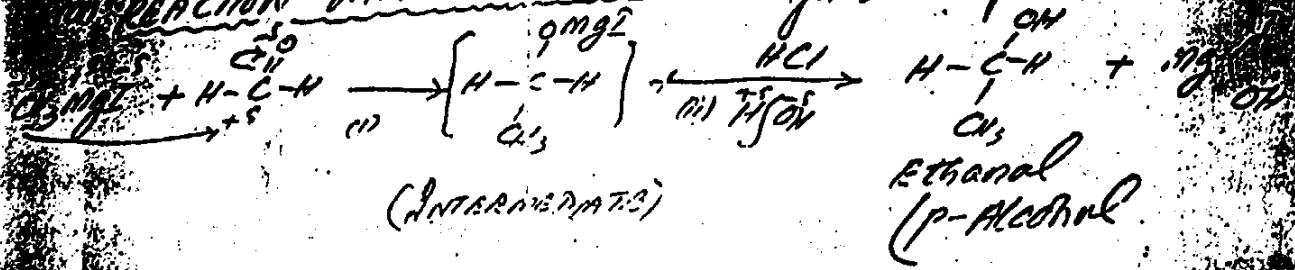


Inorganic carbon of CO_2 is converted into organic carbon of carboxylic acids. The carboxylic acid has one carbon more than that of parent alkyl halide used for prep. of Grignard reagent.

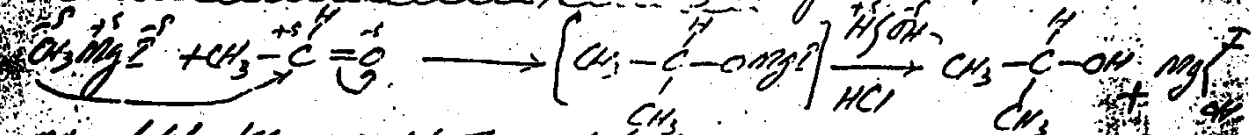
REACTION WITH CARBONYL COMPOUNDS (ALDEHYDES AND KETONES)

Grignard reagent adds to carbonyl group of aldehydes and ketones to produce addition product. This addition product on acid hydrolysis produces different Alcohols.

REACTION WITH FORMALDEHYDE produces p-Alcohol

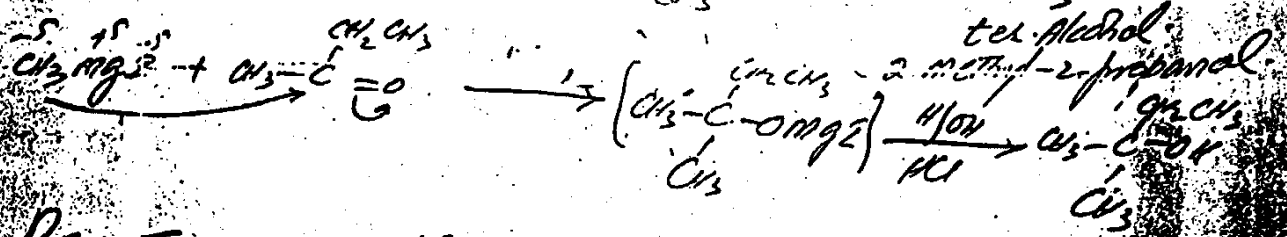
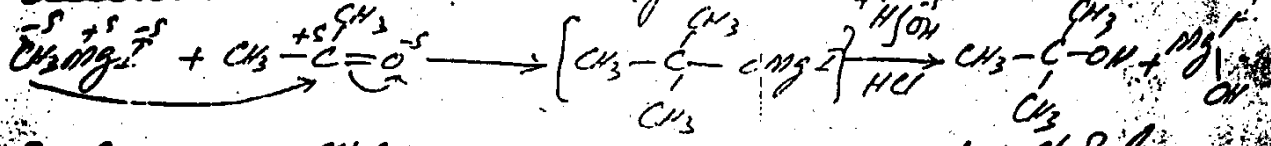


REACTION WITH ACETALDEHYDE: " CH_3CHO " produces sec. Alcohol.



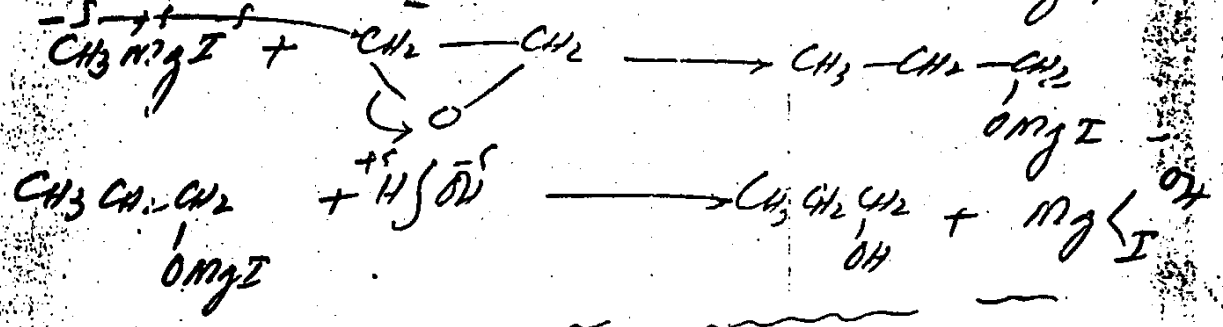
All aldehydes except formaldehyde produce sec. Alcohol. (2-Propanol (Sec. Alcohol))

REACTION WITH KETONES produces ter. Alcohols



REACTION WITH EPOXIDE:

Grignard Reagent reaction with epoxide produces an alcohol with two carbon more than that of G.R.



DEFINE NUCLEOPHILE:

Nucleophile means nucleus loving. The nucleophile may be $-\text{ve}$ ion or it may have a lone pair of electron. In most of cases a nucleophile can also act as a base if it donates electron pair to a proton. e.g. OH^- , $\text{C}_2\text{H}_5\text{O}^-$, HS^- , NH_3 , SCN^- , NH_2^- , Br^- , Cl^- etc

ELECTROPHILE:

The electron loving specie is called an electrophile. It may be positively charged or neutral. The α -Carbon of Alkyl halide has δ^+ ve charge. It is electrophile or electrophilic centre. Carbocation also acts as an electrophile.

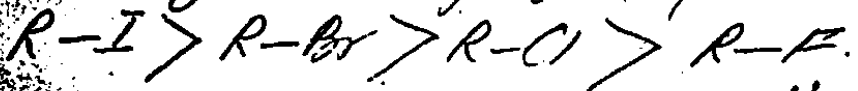
DISCUSS FACTORS AFFECTING REACTIVITY OF ALKYL HALIDES

Alkyl halides are polar molecules with partial positive charge on carbon and partial negative charge on halogen. There are two factors which affect their reactivity.

- (1) C-X BOND ENERGY (2) C-X bond polarity.

BOND ENERGY | The bond energy of a bond depends upon difference of E.N. between two bonded atoms. Thus

order of bond energy is $C-F > C-Cl > C-Br > C-I$.
This order of reactivity of alkyl halide should be



In fact C-F is so strong that alkyl fluorides do not react under normal conditions.

BOND POLARITY | The polarity of bond depends upon difference of E.N. The carbon bonded to fluorine should acquire max. positive charge and as if an e^- nucleophile attacks carbon, it should attack alkyl fluorides most readily. Thus Alkyl fluorides should be most reactive and iodides should be least reactive.

Experiments have shown that iodides are most reactive thus bond energy is main factor which control reactivity of alkyl halides. Thus overall reactivity of alkyl halides for particular alkyl group is $R-I > R-Br > R-Cl > R-F$