

Chemistry

B.Sc. Second Sem.

Nucleophilic substitution

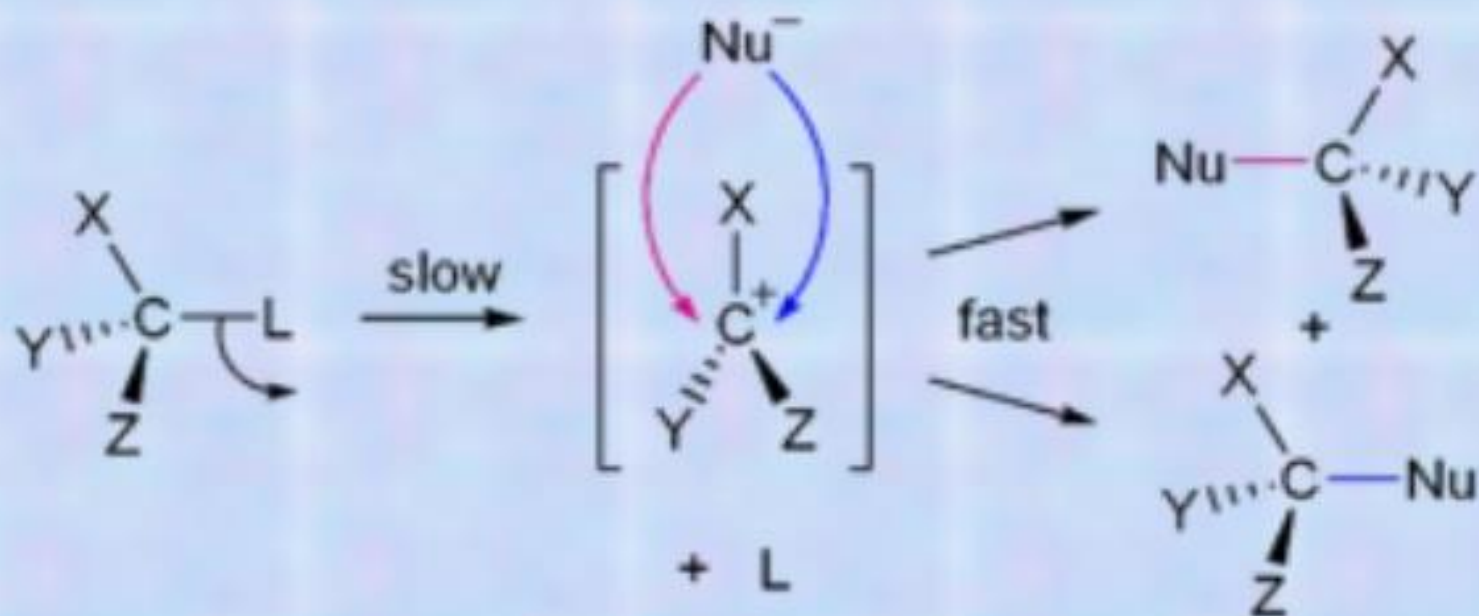
in Alkyl and Aryl Halides

(Unit-2)

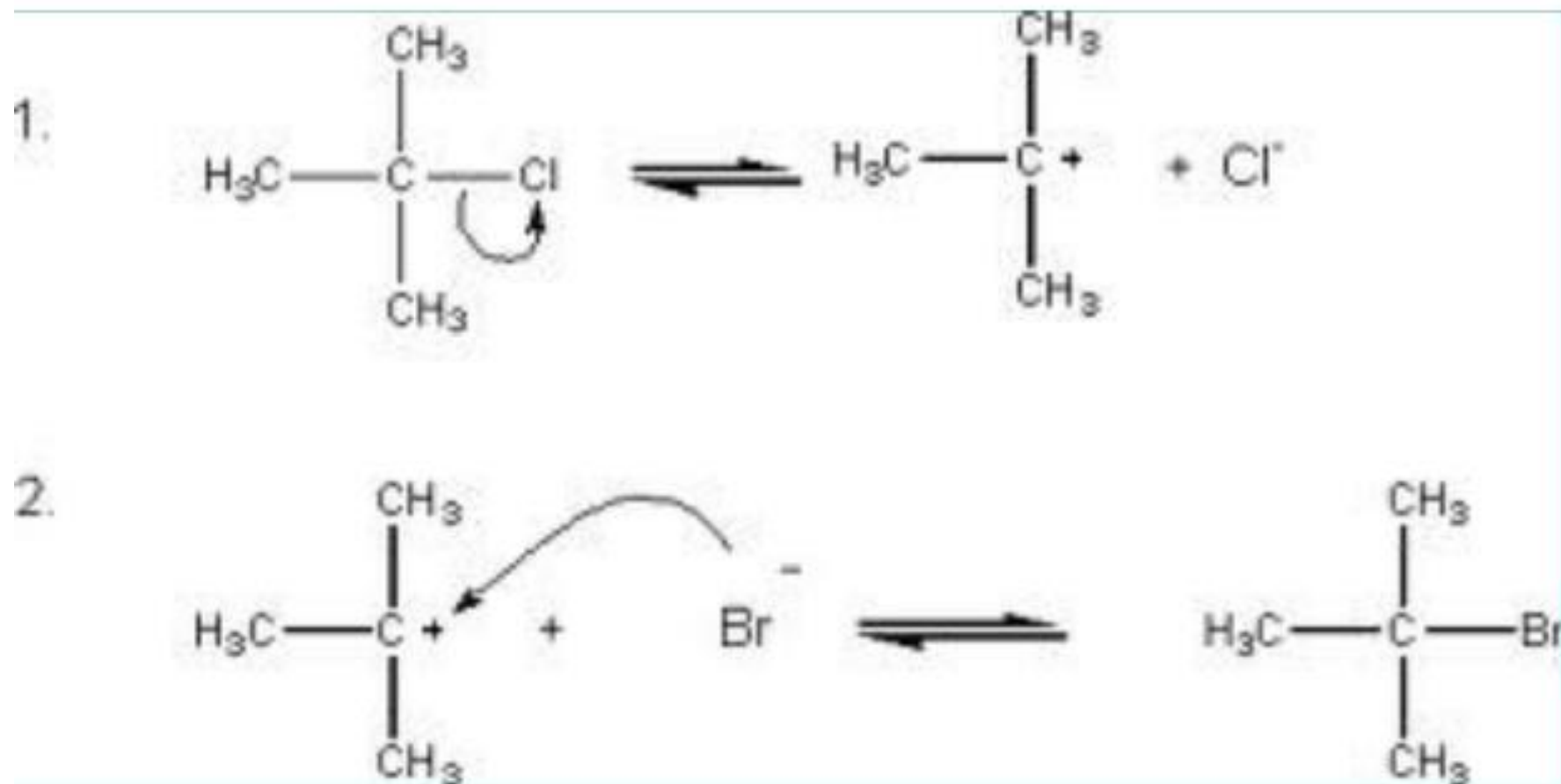
Lecture -2

Nucleophilic substitution at carbon atom

SN¹ Mechanism



S_N1 : Mechanism



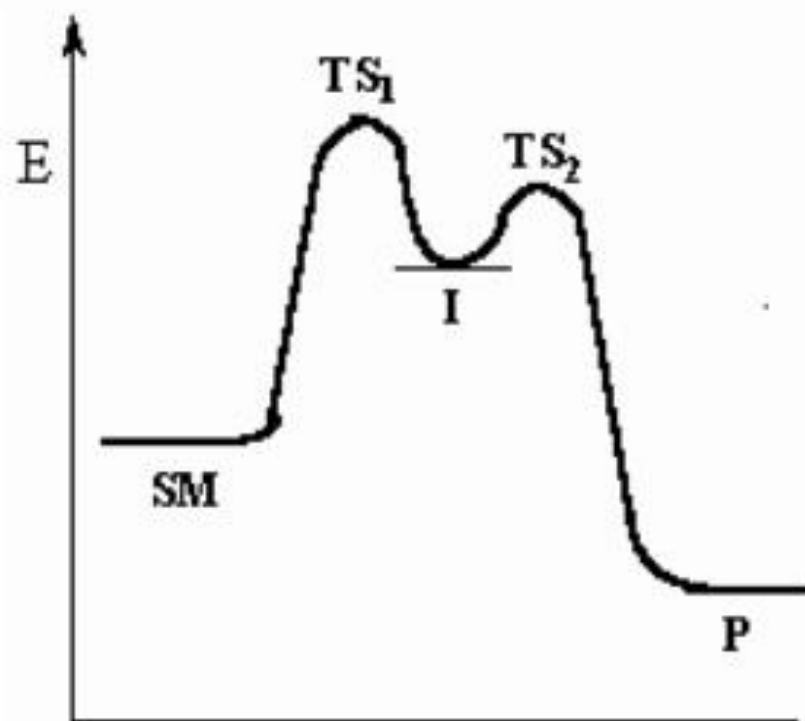
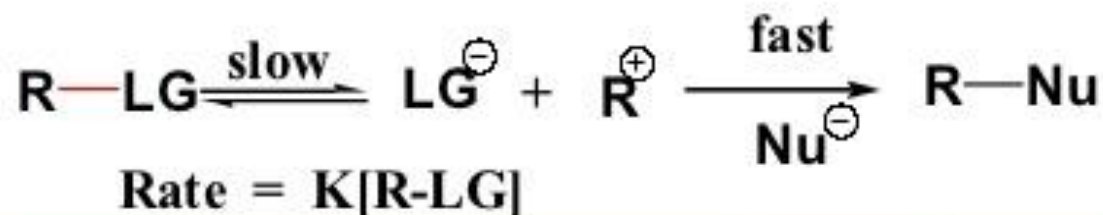
1935: Hughes & Ingold

Kinetics

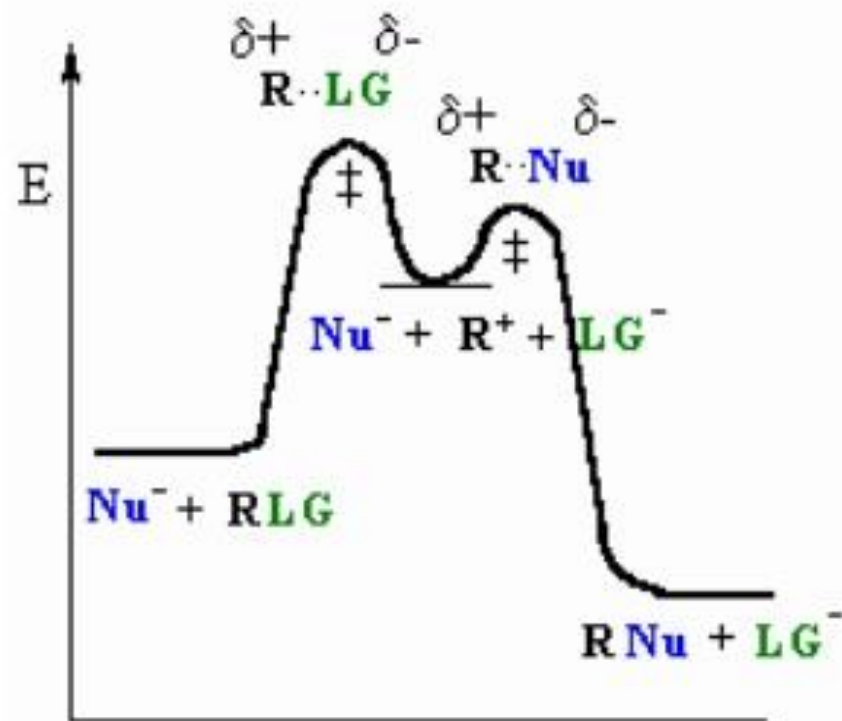
S_N1 Reaction: kinetics

- The reaction follows first order (unimolecular) kinetics
- $\text{Rate} = k [\text{R-Br}]^1$
 - The rate of an S_N1 reaction depends upon 3 factors:
 1. The nature of the substrate (the alkyl halide)
 2. The ability of the leaving group to leave
 3. The nature of the solvent
 - The rate is independent of the power of the nucleophile.

Reaction profile for S_N1 reaction



Reaction Coordinate

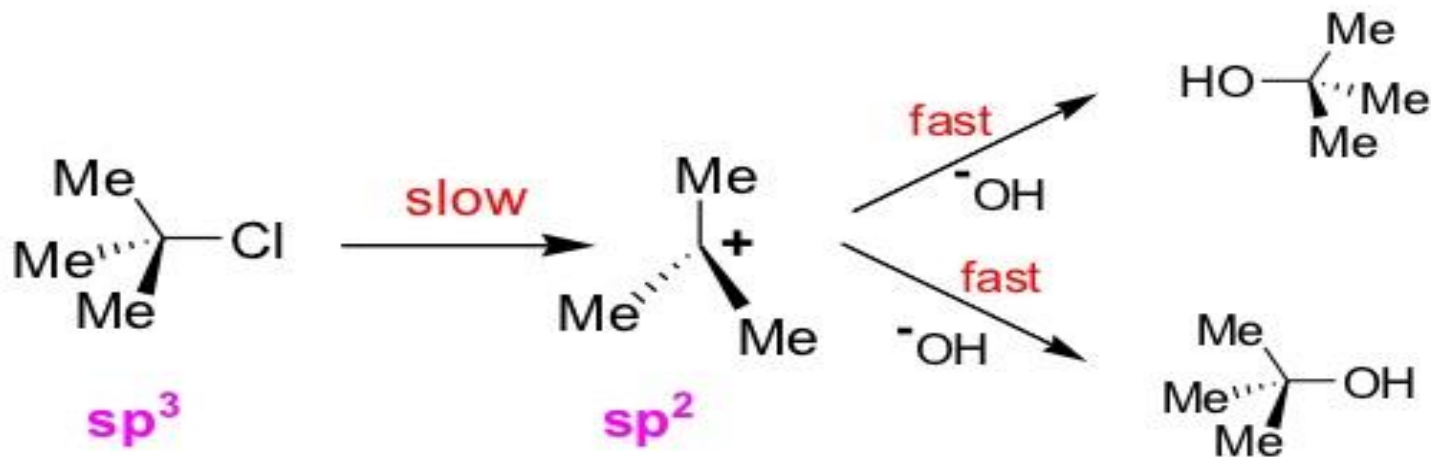


Reaction Coordinate

Stereochemistry

S_N1: Hydrolysis of *t*-butyl chloride by base proceed according to

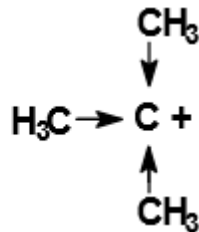
Rate = $k_1[t\text{-BuCl}]$ or independent of $[\text{OH}^-]$



1. Halide undergoes slow ionization to yield the ion pair R^+ and Cl^- followed by first attack by OH^- or solvent or nucleophile.
2. The energy necessary to effect the initial ionization is largely recovered from the energy evolved through solvation of the resultant ion-pair.

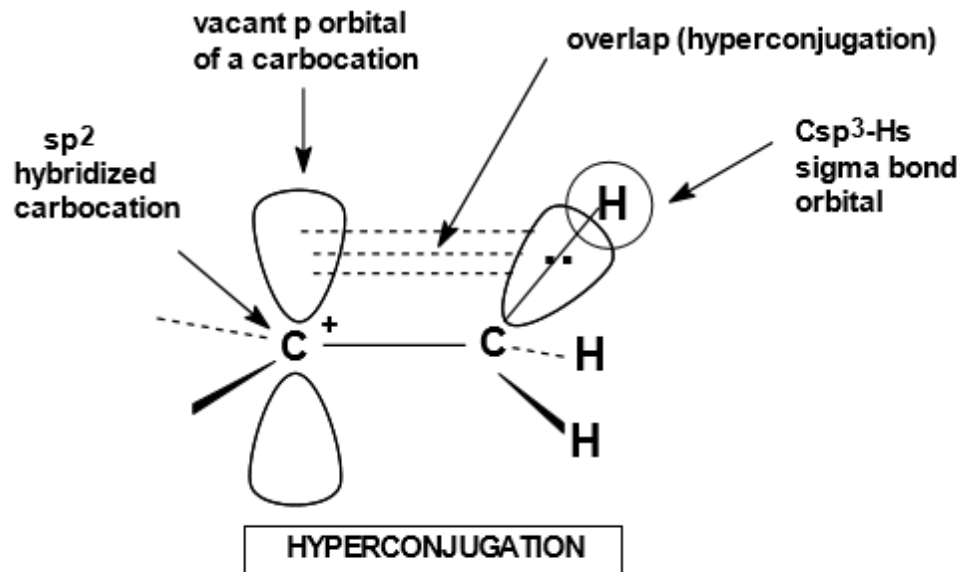
Stability of Carbocations

- Alkyl groups are weak electron donors.
- They stabilize carbocations by donating electron density by induction (through σ bonds)



Inductive effects:
Alkyl groups donate (shift) electron density through sigma bonds to electron deficient atoms.
This stabilizes the carbocation.

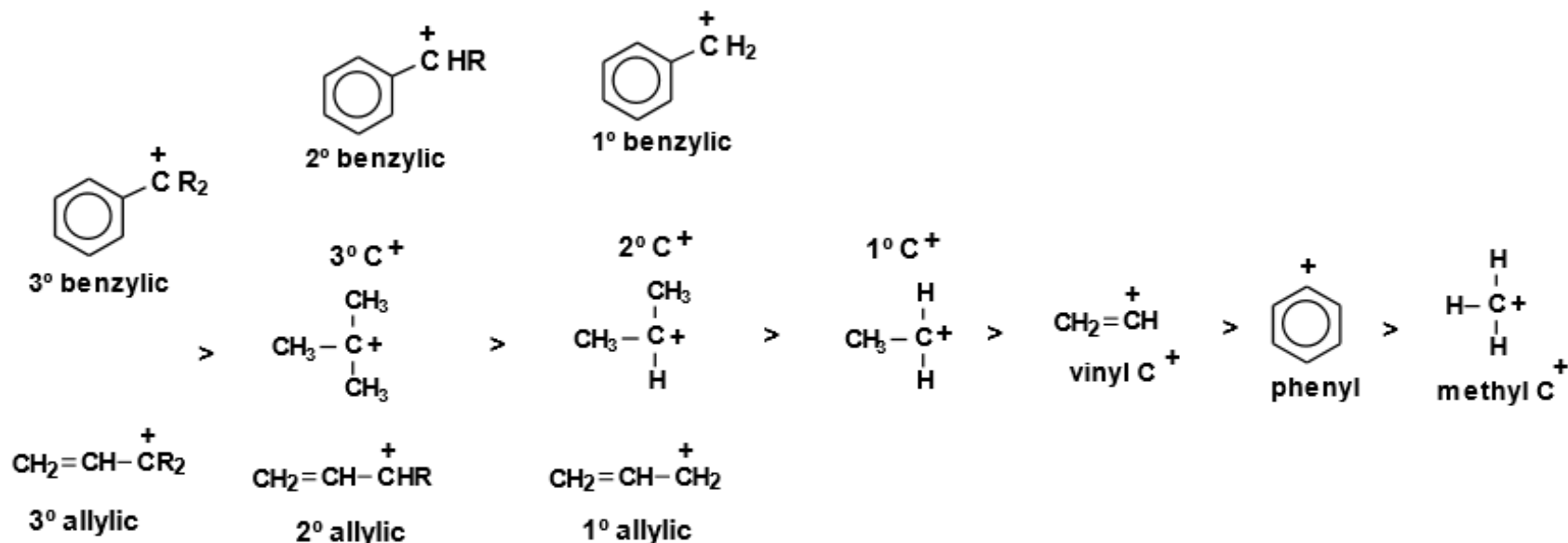
- They stabilize carbocations by hyperconjugation (by partial overlap of the alkyl C-to-H bonds with the empty p-orbital of the carbocation).





Relative Stability of All Types of Carbocations

Increasing C⁺ stability and rate of S_N1 reaction



Note that 1° allylic and 1° benzylic C⁺s are about as stable as 2° alkyl C⁺s.

Note that 2° allylic and 2° benzylic C⁺s are about as stable as 3° alkyl C⁺s.

Note that 3° allylic and 3° benzylic C⁺s are more stable than 3° alkyl C⁺s.

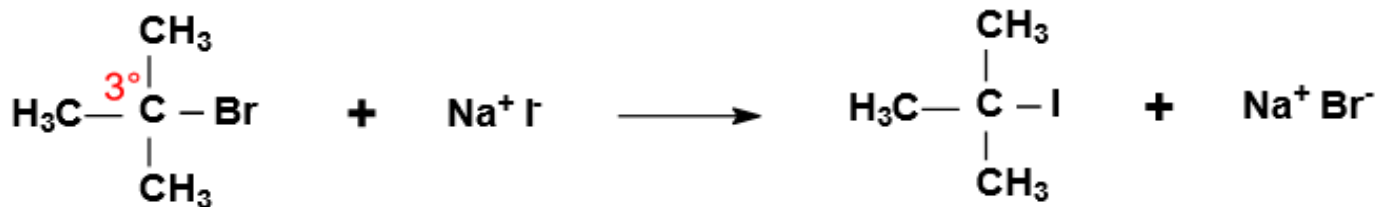
Note that phenyl and vinyl C⁺s are unstable. Phenyl and vinyl halides do not usually react by S_N1 or S_N2 reactions.

Factors Influencing S_N1 Reaction

Effect of the nucleophile on rate of S_N1 reactions:

- Consider the nature of the Nucleophile:

- Recall again that the nature of the nucleophile has no effect on the rate of S_N1 reactions because the slowest (rate-determining) step of an S_N1 reaction is the dissociation of the leaving group and formation of the carbocation.
- All carbocations are very good electrophiles (electron acceptors) and even weak nucleophiles, like H₂O and methanol, will react quickly with them.
- The two S_N1 reactions will proceed at essentially the same rate since the only difference is the nucleophile.



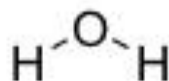
Effect of the solvent on rate of S_N1 reactions:

- 3. Consider the nature of the solvent:

- For S_N1 reactions, the solvent affects the rate only if it influences the stability of the charged transition state, i.e., the C^+ . The Nu^- is not involved in the rate determining step so solvent effects on the Nu^- do not affect the rate of S_N1 reactions.
- Polar solvents, both protic and aprotic, will solvate and stabilize the charged transition state (C^+ intermediate), lowering the activation energy and accelerating S_N1 reactions.
- Nonpolar solvents do not lower the activation energy and thus make S_N1 reactions relatively slower

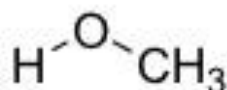
A protic solvent acts as both a solvent and nucleophile in S_N1 reactions - solvolysis:

Water



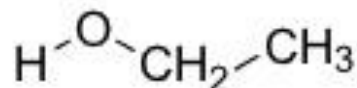
abbreviations

Methanol



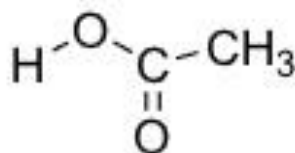
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Ethanol



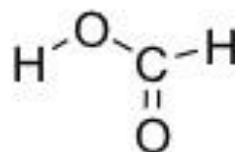
HOEt

Acetic acid



HOAc

Formic acid



Effect of nature of the leaving group on rate of S_N1 reactions:

- **2. Consider the nature of the leaving group:**
- The nature of the leaving group has the same effect on both S_N1 and S_N2 reactions.
- The better the leaving group, the faster a C^+ can form and hence the faster will be the S_N1 reaction.
- The leaving group usually has a negative charge
- Groups which best stabilize a negative charge are the best leaving groups, i.e., the weakest bases are stable as anions and are the best leaving groups.
- Weak bases are readily identified. They have high pK_b values.

Leaving groups

- Leaving groups are the same as in S_N2 reactions:



S_N2 or S_N1 ?

- Primary or methyl
- Strong nucleophile
- Polar aprotic solvent
- Rate = k [halide] [Nuc]
- Inversion
- No rearrangements
- Tertiary
- Weak nucleophile (may also be solvent)
- Polar protic solvent, silver salts
- Rate = k [halide]
- Racemization
- Rearranged products

=>

End
of
Lecture- 2