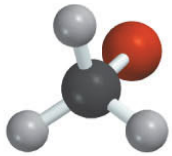
Chapter 7: Part 2: Substitution Reactions – SN1

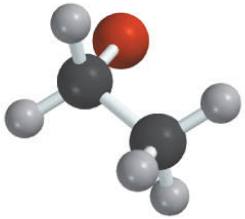
1. The SN1 Mechanism
2. Factors Affecting SN1 Reactions
    1. The Leaving Group
    2. The Nucleophile
    3. Carbocation Intermediate
    4. Steric Hindrance
3. Stereochemistry

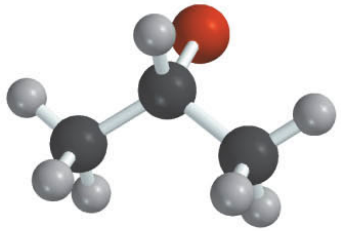
Least crowded–
most reactive

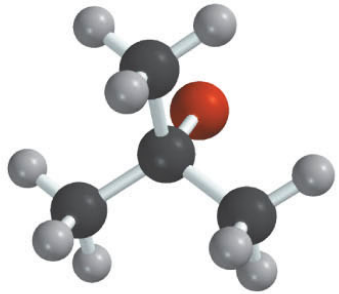
Increasing Reactivity

Most crowded–
least reactive







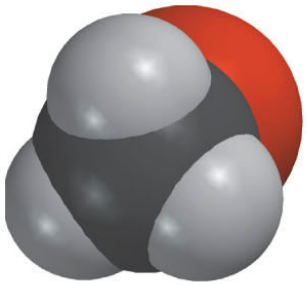


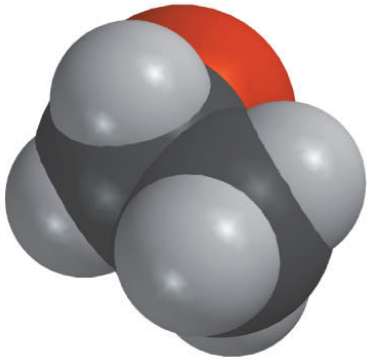
CH_3Br

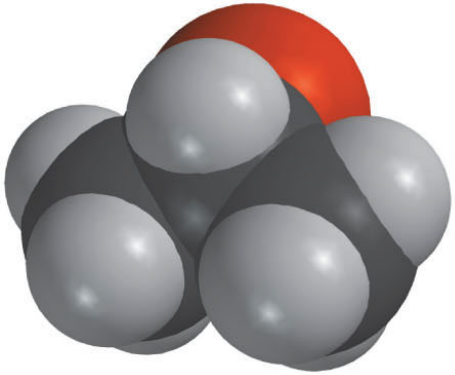
CH_3CH_2Br

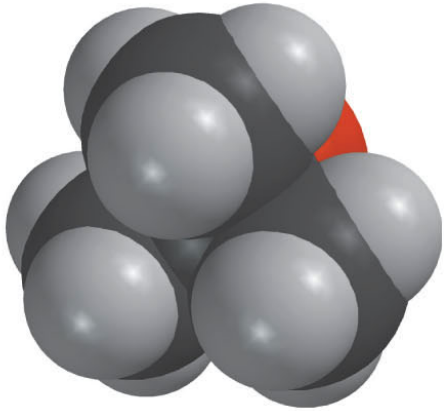
$(CH_3)_2CHBr$

$(CH_3)_3CBr$







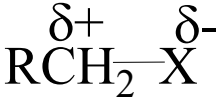


In an SN2 reaction: A bulky substituent in the alkyl halide reduces the reactivity of the alkyl halide: steric hindrance

Summary of SN2

1. Best with 1^{o} alkyls with good leaving groups.
2. Helped by polar aprotic solvents.
3. Using good highly polarized species as nucleophiles helps.
4. Crowding at the carbon that bears the leaving group slows the rate of bimolecular nucleophilic substitution.

Alkyl halides have relatively good leaving groups - How do alkyl halides react?

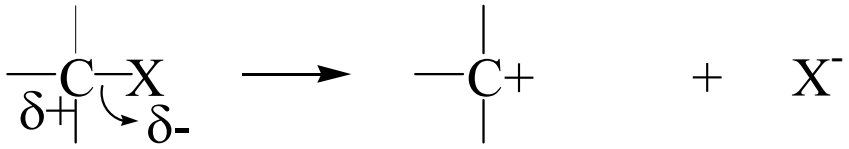


X= F, Cl, Br, I

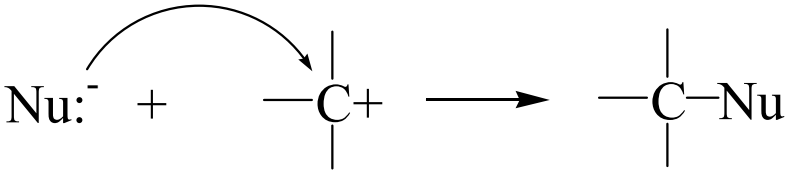
an SN2 reaction….

Tertiary alkyl halides are very unreactive in SN2 substitutions. Do they undergo nucleophilic substitution at all?

Alternatively …



SN1 Reaction



Experimental Evidence for an S_N1 Reaction

1. The rate of the reaction depends only on the concentration of the alkyl halide.

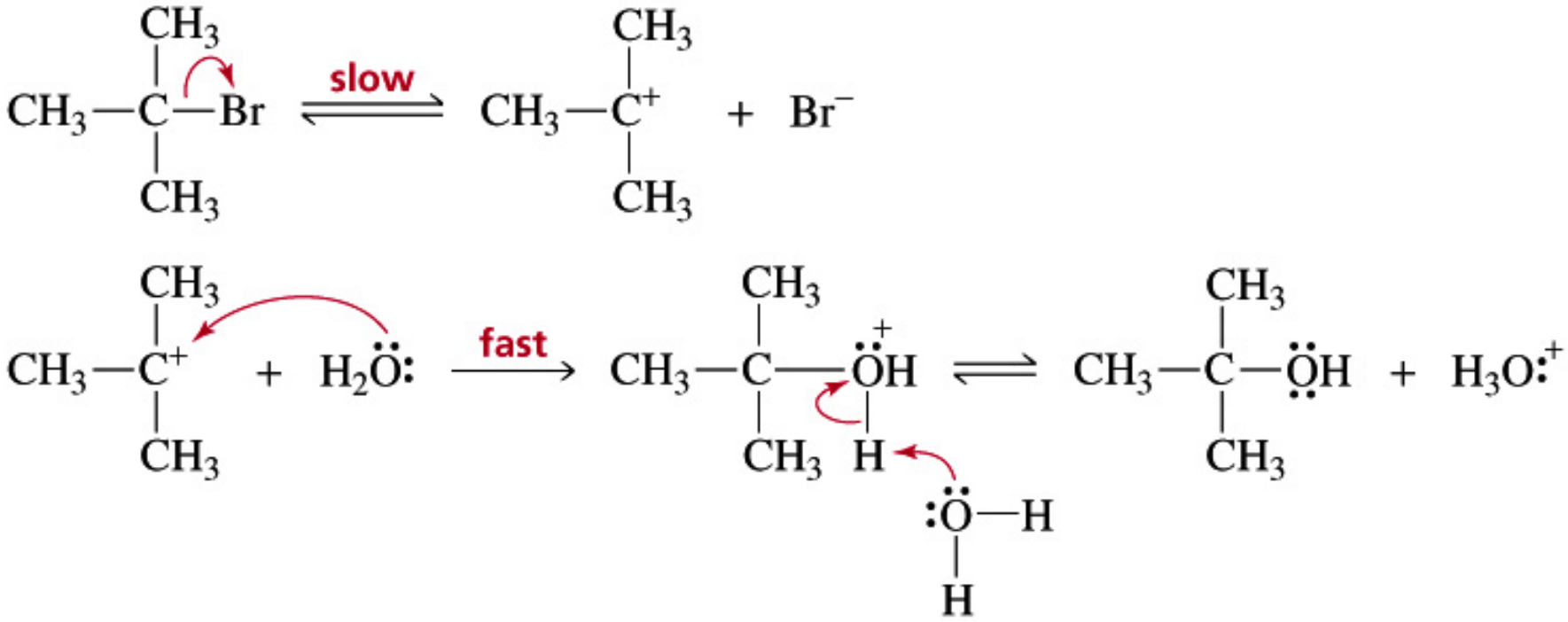
2. The rate of the reaction is favored by the bulkiness of the alkyl substituent.

3. In the substitution of a chiral alkyl halide, a mixture of products is obtained.

The SN1 reaction:

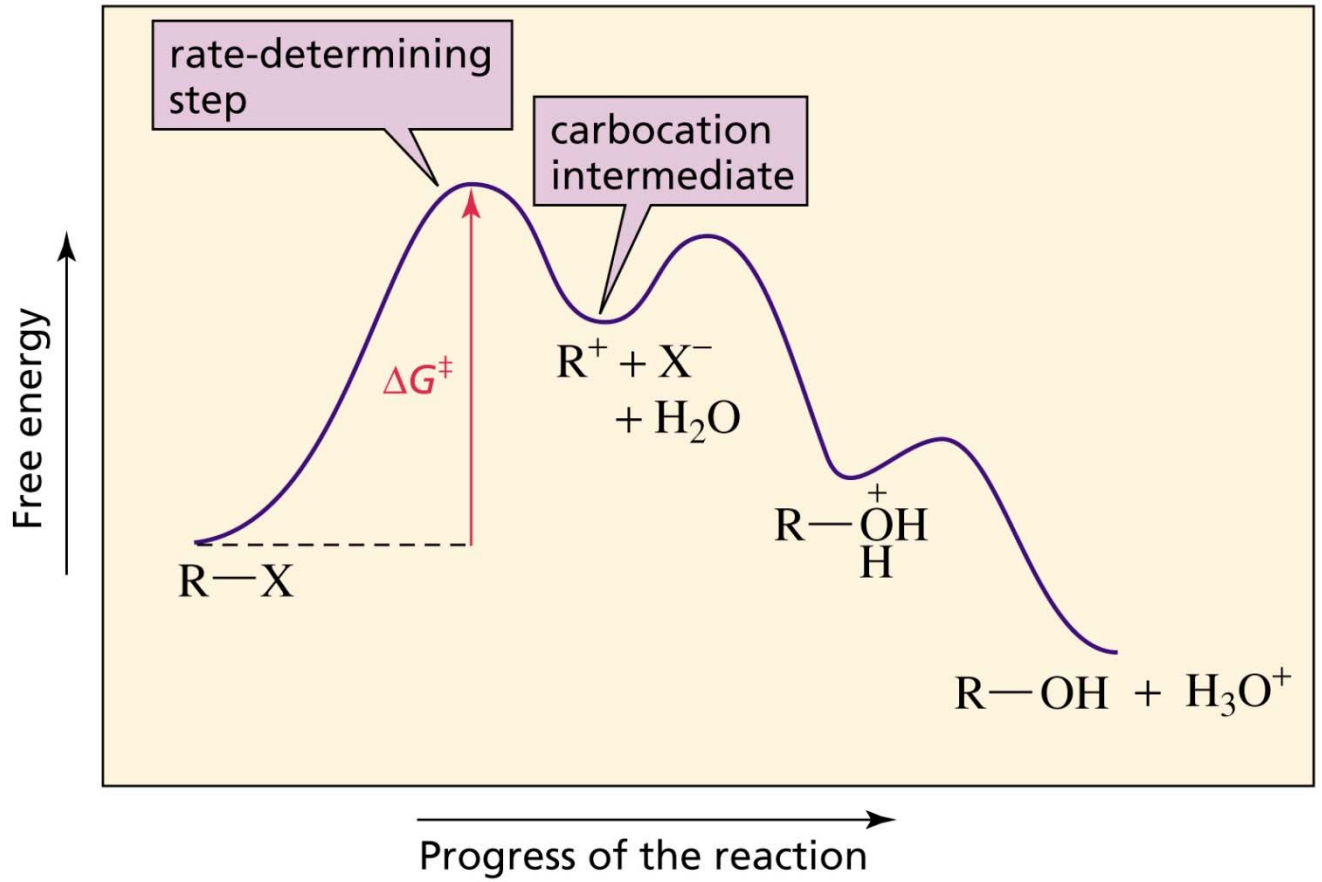
Substitution Nucleophilic *Unimolecular*

The SN1 mechanism proceeds by 2 steps. The first - the rate limiting step - leads to the formation of a carbocation intermediate.



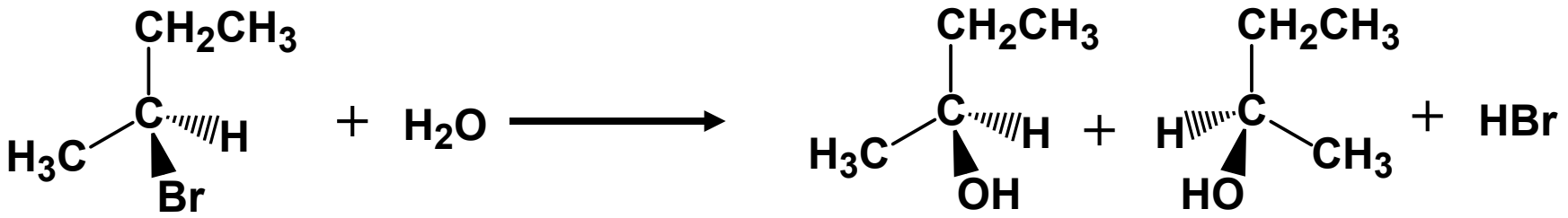
The second is substitution by a nucleophile.

Reaction Coordinate Diagram for an S_N1 Reaction



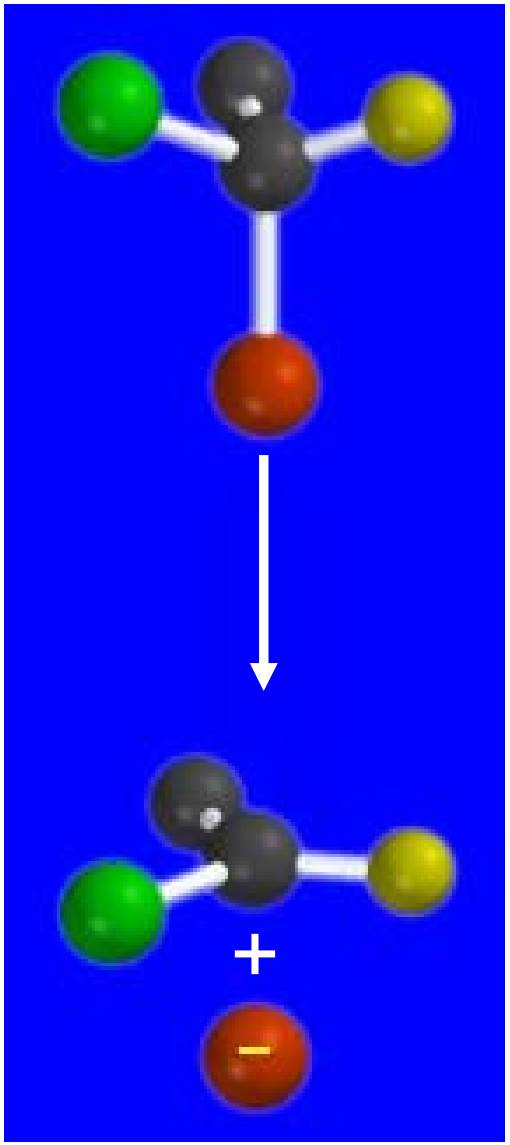
- *The more stable the carbocation, the faster its rate of formation, and the greater the rate of unimolecular nucleophilic substitution*

The Stereochemistry of S_N1 Reactions



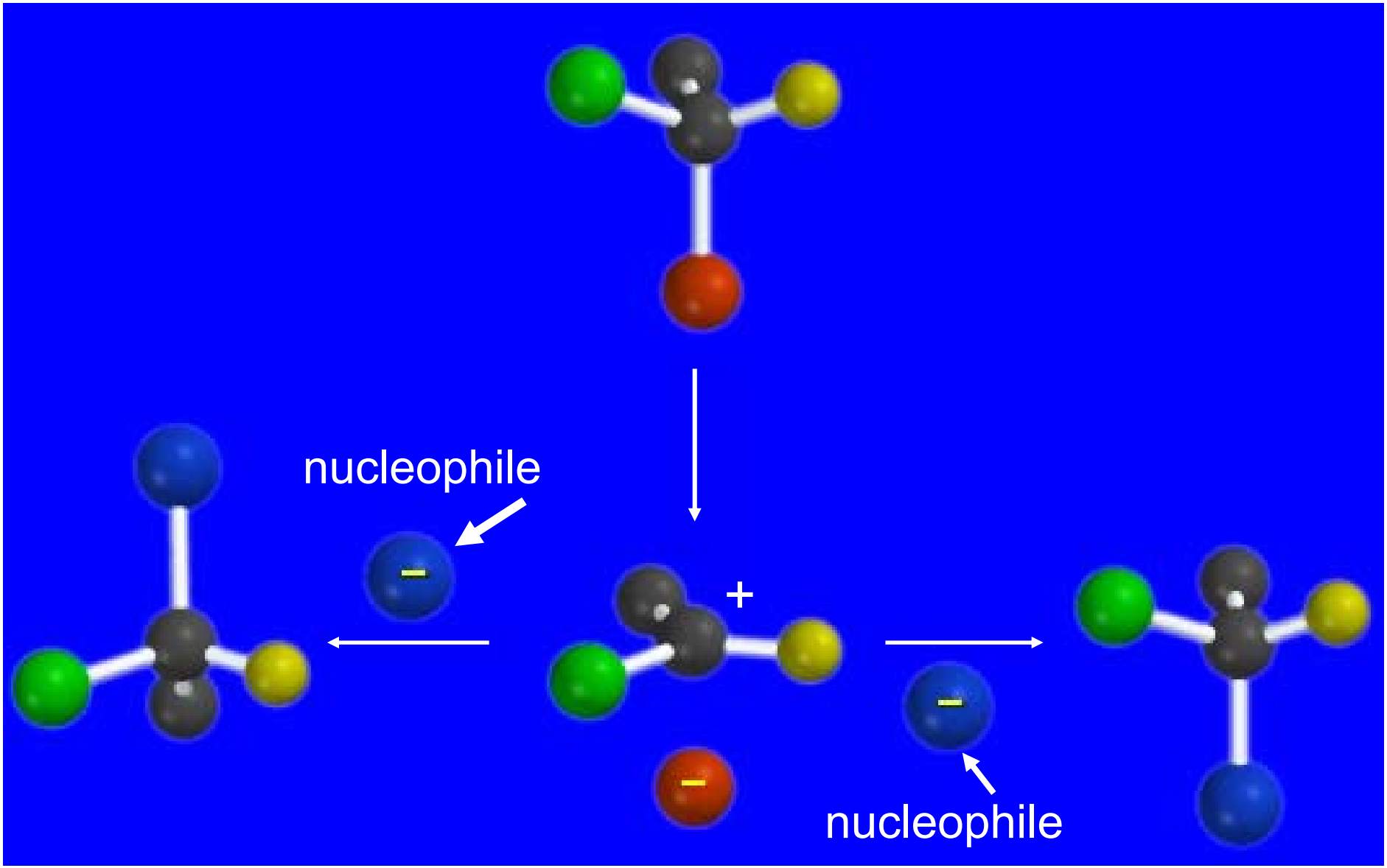
(S)-2-bromobutane (S)-2-butanol (R)-2-butanol

- Nucleophilic substitutions that exhibit first-order kinetic behavior are not stereospecific.



Ionization step
gives carbocation; three
bonds to chirality
center become coplanar

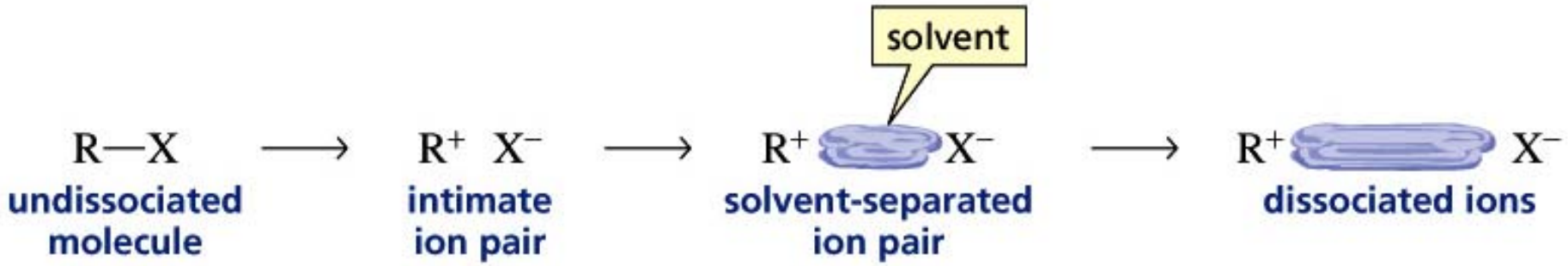
Leaving group shields
one face of carbocation;
nucleophile attacks
faster at opposite face.

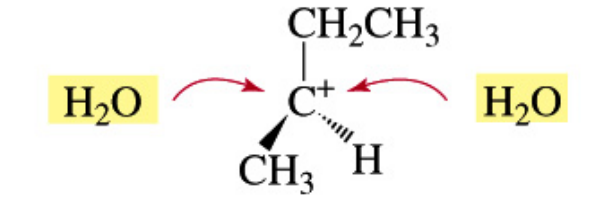


More than 50%

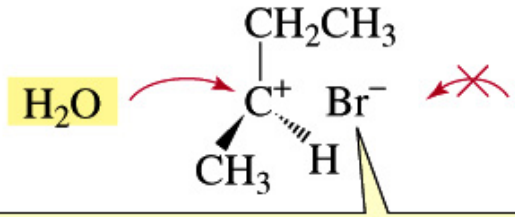
Less than 50%

Sometimes extra inverted product is formed in an S_N1 reaction because …





Br⁻ has diffused away, giving H_2O equal access to both sides of the carbocation



Br⁻ has not diffused away, so it blocks the approach of H_2O to one side of the carbocation

S_N1 Reactivity versus Solvent Polarity

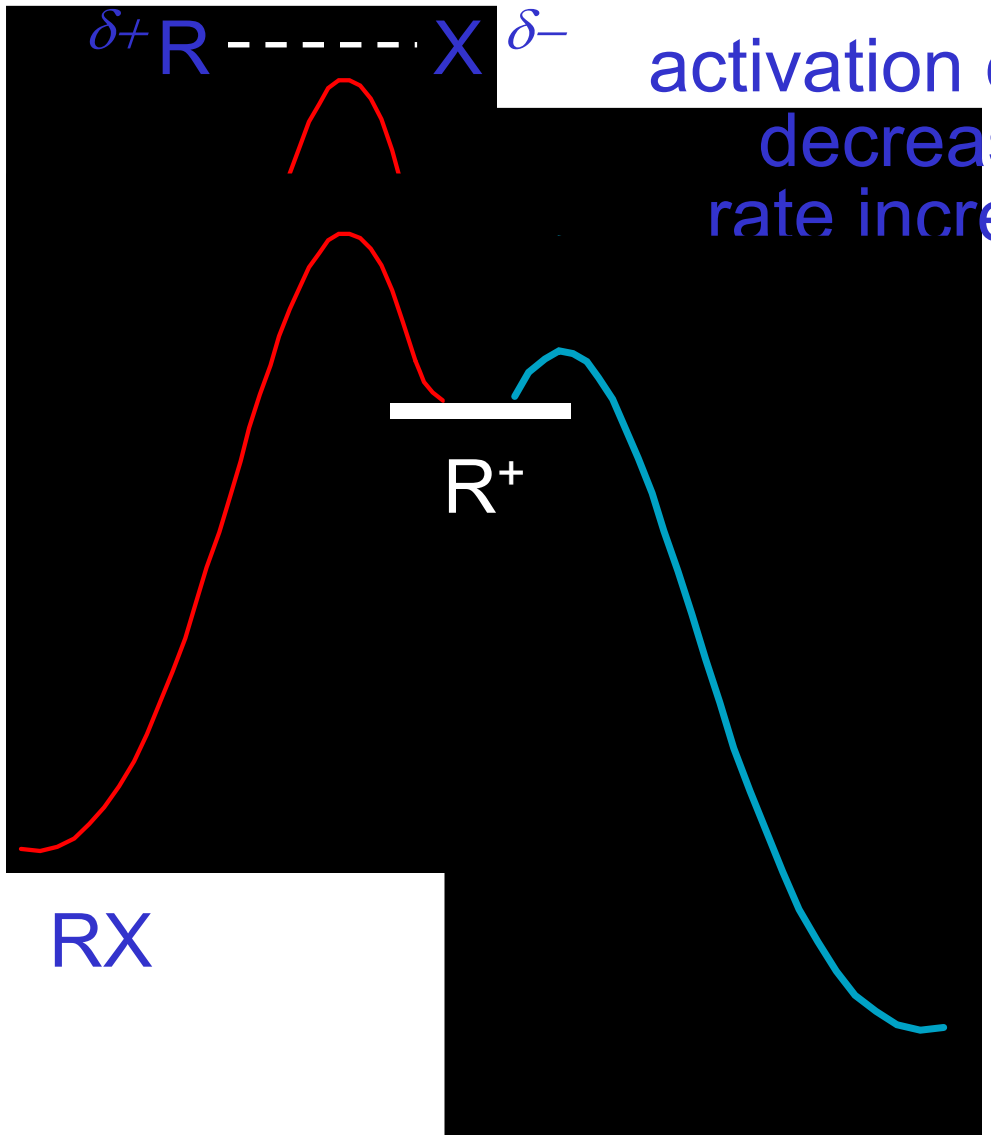
SN1 Reaction Rates Increase in Polar Solvents

Solvent	Dielectric constant	Relative rate
acetic acid	6	1
methanol	33	4
formic acid	58	5,000
water	78	150,000

Most polar

Fastest rate

transition state stabilized by polar solvent



activation energy decreases; rate increases

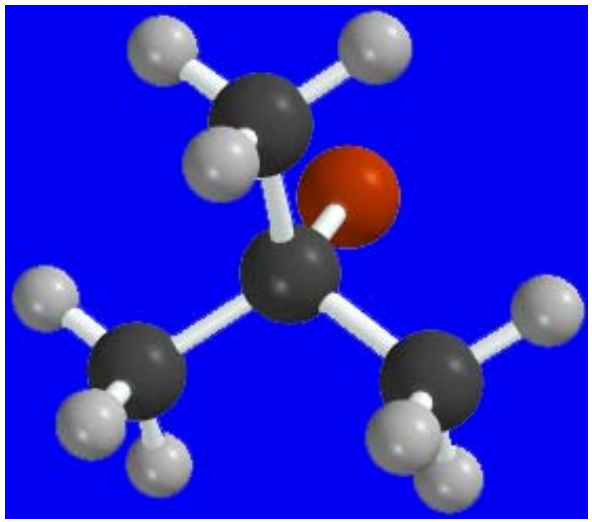
energy of RX not much affected by polarity of solvent

Reactivity toward substitution by the S_N1 mechanism

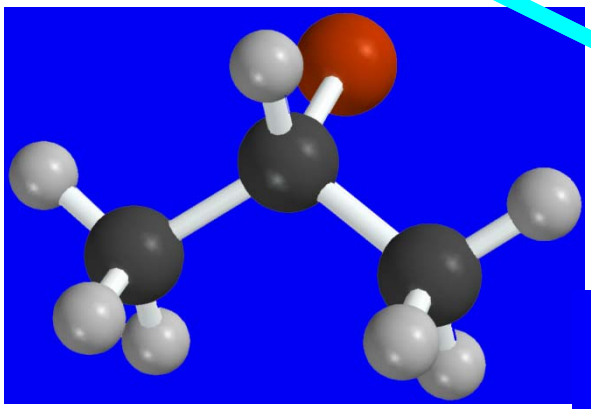
RBr solvolysis in aqueous formic acid

Alkyl bromide	Class	Relative rate
CH_3Br	Methyl	1
CH_3CH_2Br	Primary	2
$(CH_3)_2CHBr$	Secondary	43
$(CH_3)_3CBr$	Tertiary	100,000,000

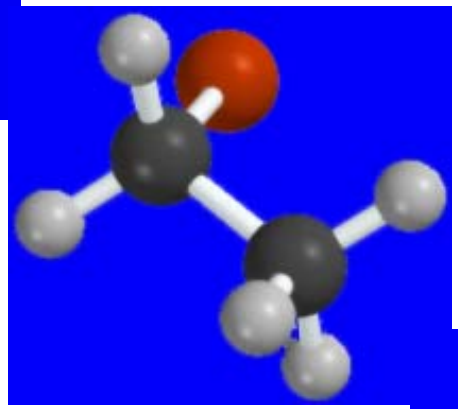
Decreasing S_N1 Reactivity



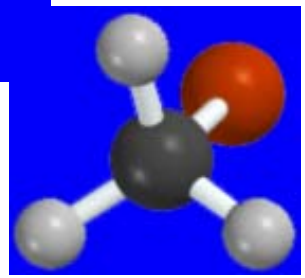
$(CH_3)_3CBr$



$(CH_3)_2CHBr$



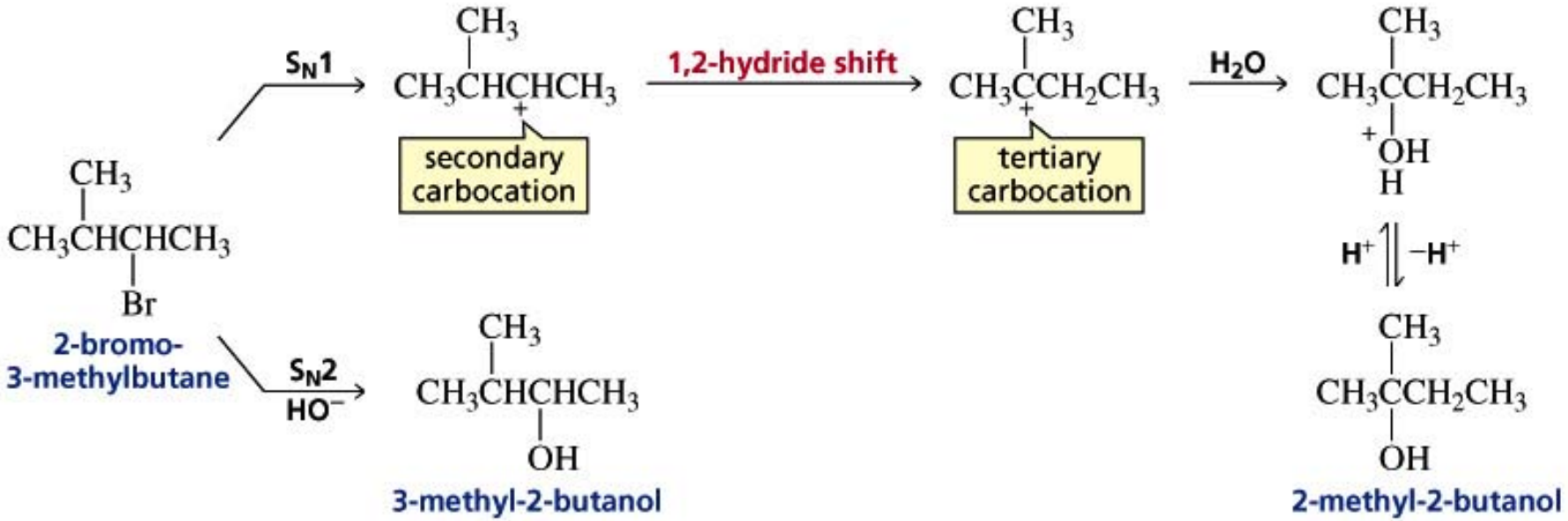
CH_3CH_2Br



CH_3Br

Remember this is the
OPPOSITE from SN2 reactions…..

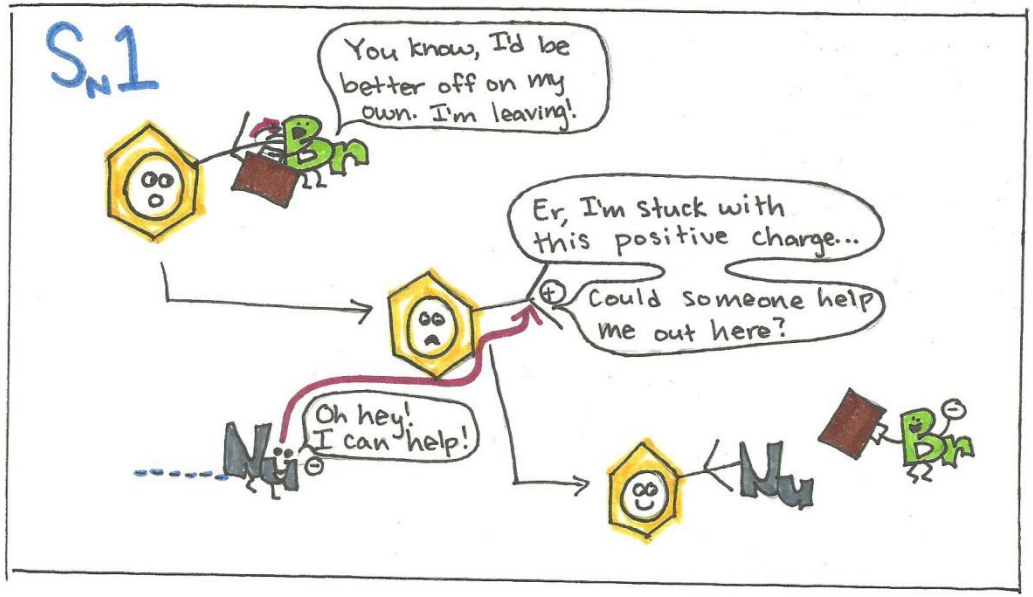
Finally,
When a reaction forms a carbocation intermediate, always check for the possibility of a ***carbocation rearrangement …..***

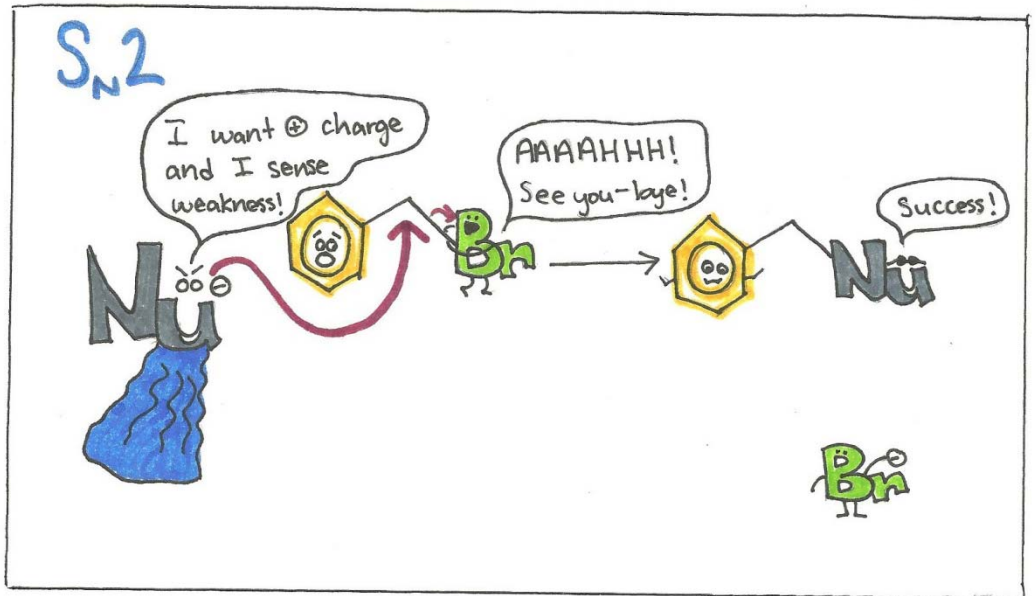


Characteristics of the S_N1 mechanism

- first order kinetics: rate = k[RX]
  - –unimolecular rate-determining step
- carbocation intermediate
  - –rate follows carbocation stability
  - –rearrangements sometimes observed
- reaction is not stereospecific
  - –much racemization in reactions of optically active alkyl halides

S_N1 vs. S_N2: The Daily Adventures of the Average Nucleophile





Megan Jackson 2011

For Next Time….

Suggested Homework Problems Chapter 7

#1,14,2126, 31, 36,38,41,44,50,52,53,59,64,65