Extra 1

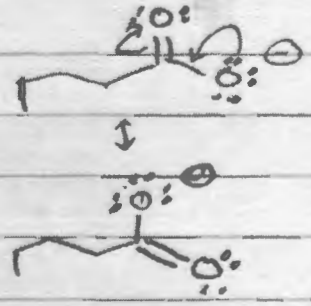
Curved Arrow Conventions in Organic Chemistry

①  ← 2 barbs = 2 e^- movement

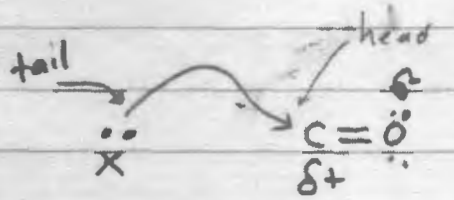
 ← 1 barb

1 e^- moved

Remember Resonance structures



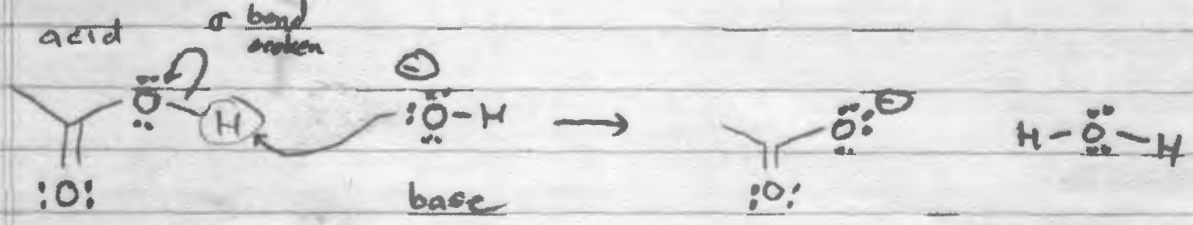
double-barbed arrows used to show movement of e^- pairs

② 

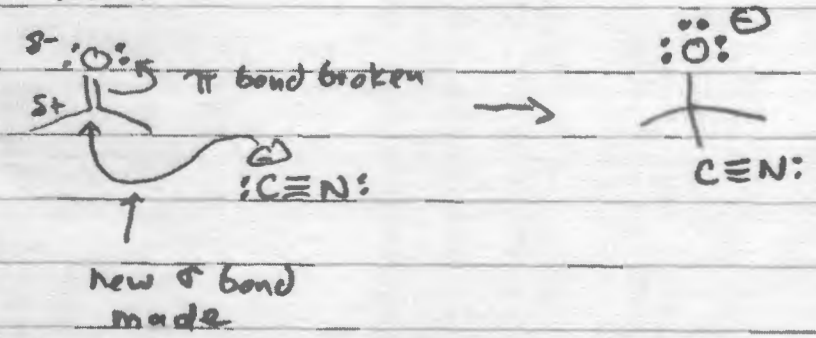
arrow head points to where e^- are going

electron source to electron sink

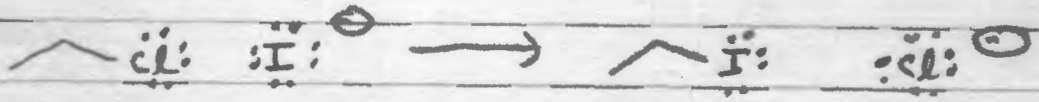
③ If electrons move toward a sink, then an arrow needs to be drawn to show e^- move away. Either a π bond or σ bond is broken in rxn mechanism.



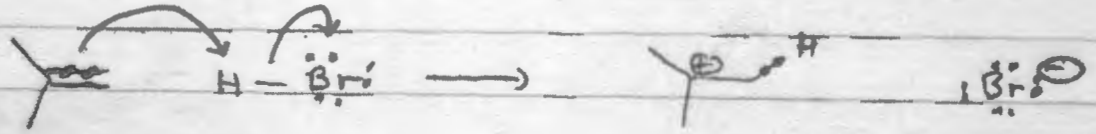
Extra-2



Draw curved arrow to show the mechanism (show the reactants couple)

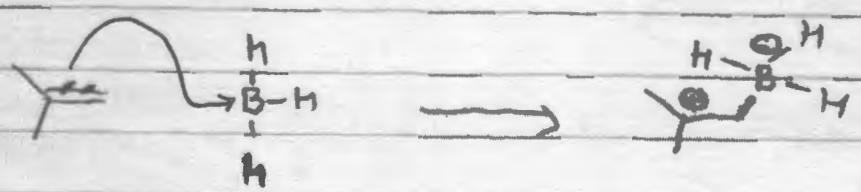


What's happening here?



CIRCLE

Acid	Acid	Conj Acid	Conj Acid
Base	Base	Conj Base	Conj Base



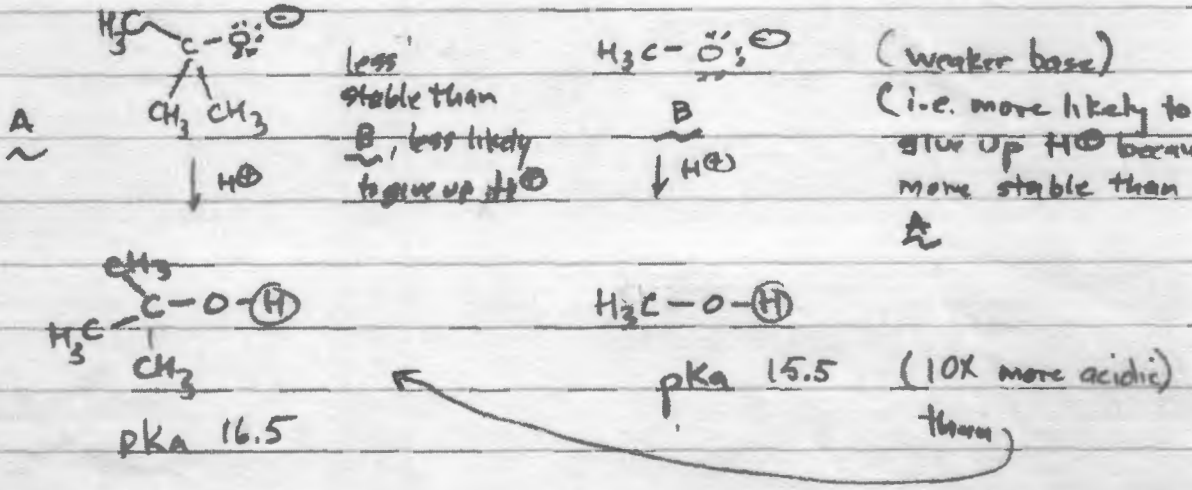
CIRCLE

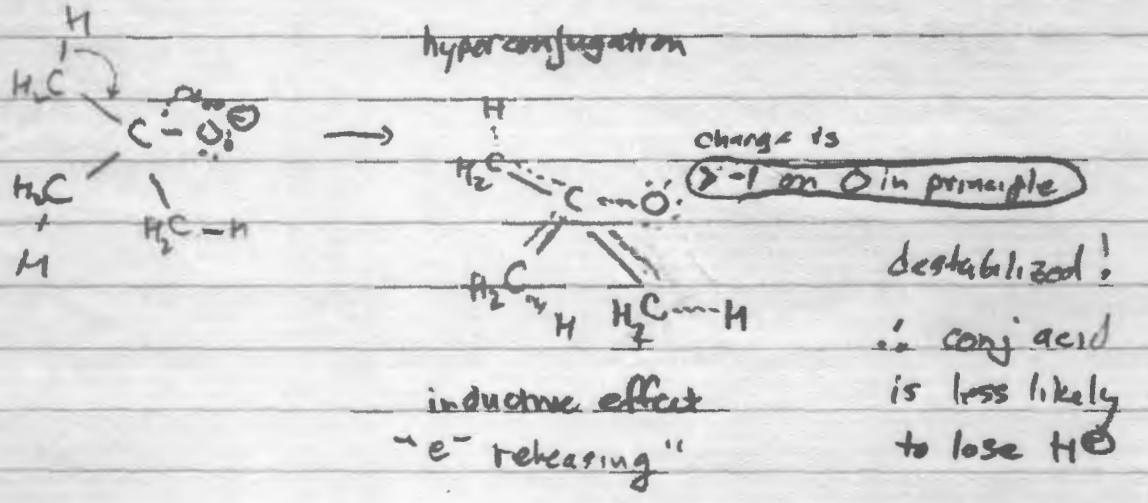
Lewis Acid	Lewis Acid
Lewis Base	Lewis Base

Extra - 3

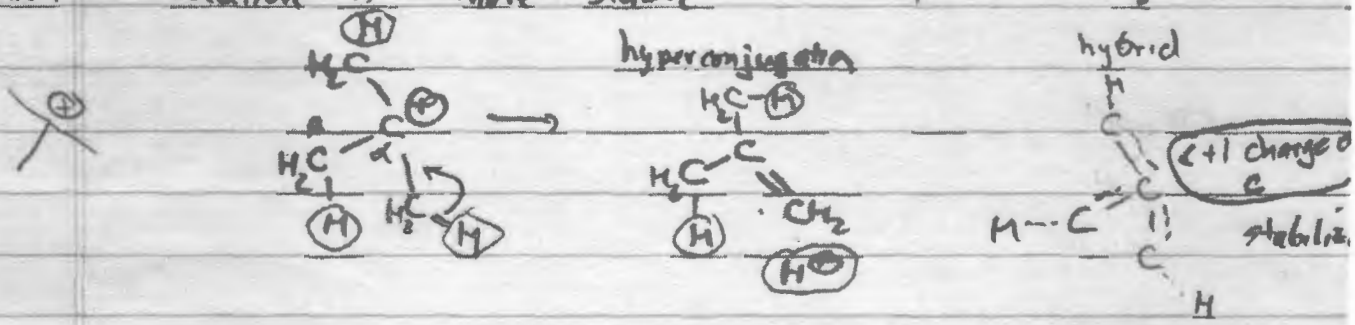
Carbocation Stability

Recall what made A a stronger base than B





Which Carbocation is more stable ⊕ or $H_3C^{\oplus}$

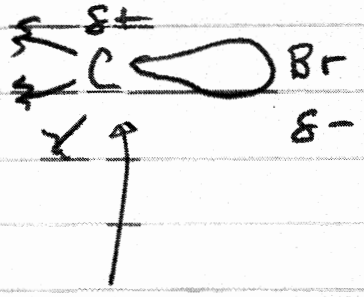


Extra-4

No β carbons can release e^- density to C^+ to stabilize it

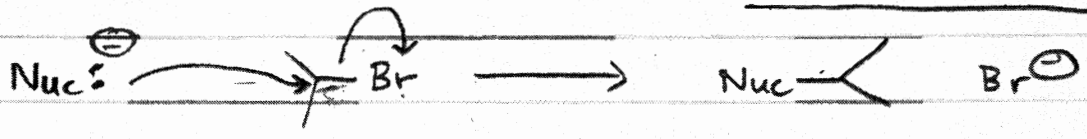
Carbocations: Least stable — 1° C^+ — 2° C^+ — 3° C^+ — More stable

Let's look at "polarity" of C-halide bond.



this is where nucleophiles ("lovers" of (+) charge) will attack.

Curved arrows tell you this happens



This is Nucleophilic substitution!

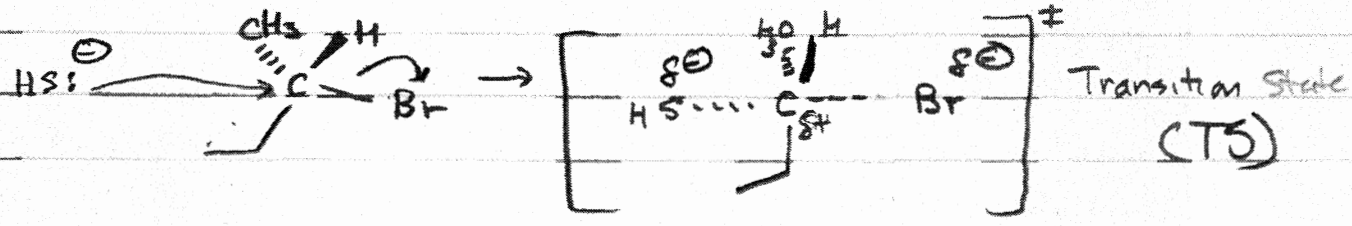
Generally, Br is considered the L.g (leaving group)

S_N2 — Nucleophile

↳ Substitution — bimolecular reaction in rate equation (2 things must collide in a 2nd order reaction during the slowest step)

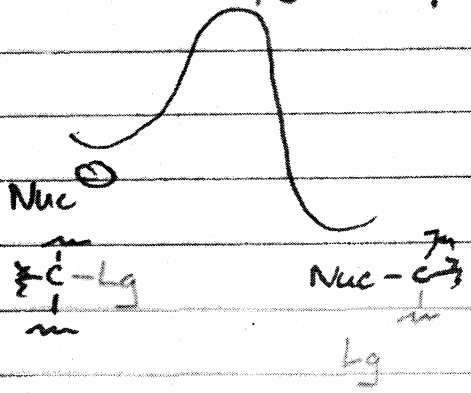
$$\text{rate}_{S_N2} = k[\delta+ C - \text{L.g.}]^1[\text{Nuc}^\ominus]^1$$

These 2 reactants must collide

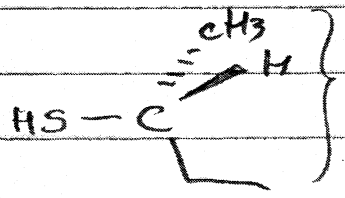


Ch9-3

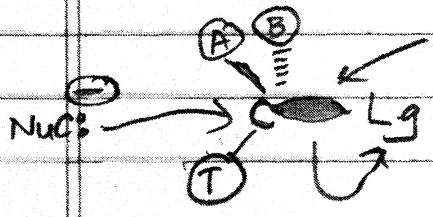
TS (see previous page)



S_N2 (one-step reaction)



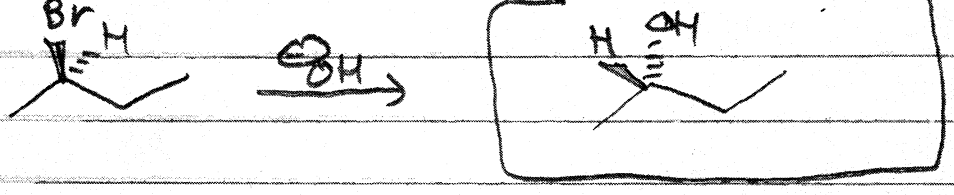
NOTE how everything on 'C' got inverted the other way.



e^- density makes it hard for Nuc:$^\ominus$ to attack from this side.

∴ Nuc attacks from opposite side of Lg.

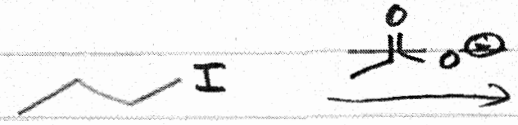
"Backside" Attack



S_N2 product

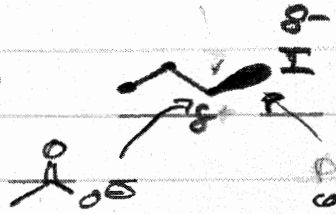
Ch 9-3

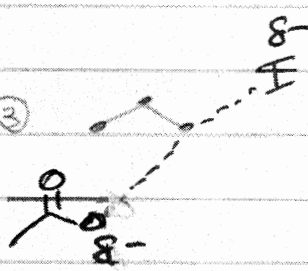
S_N2 reactions



① What is the nucleophile? 

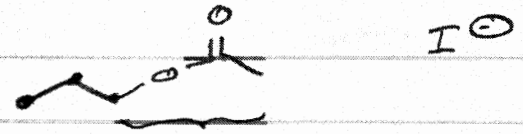
② Where will this nucleophile attack?



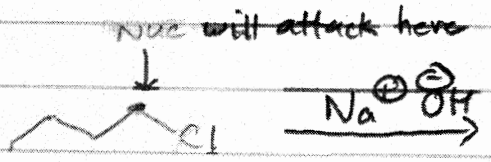
③ 

Account for carbons!

There are 3 C and the leaving group is $I^{\ominus}$

④ 

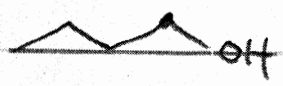
Nucleophile replaces 'I'



① What is the nucleophile? $^{\ominus}OH$

② Where will Nuc attack? (see arrowed C above)

③ Account for all atoms in structure, and do substⁿ.



Ch 9-4

S_N2 Rxns

① What makes a good nucleophile?

Localized Negative charge – not affected by resonance

Nuc:⊖

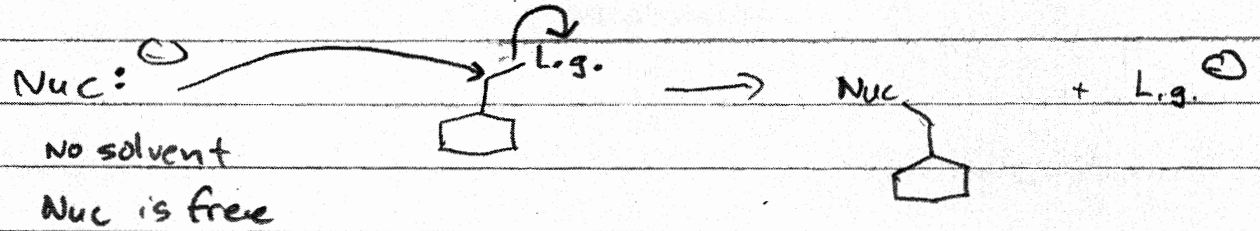
Good nucleophiles	
I^- Br^- Cl^-	HS^- HO^- HO^- $^-:N{\equiv}C:$ RS^- RO^- RO^-

NOTICE (−) charges

redrawn for clarity.

② How does solvent affect Nucleophilic Rxn rate in S_N2?

ⓐ Solvents that can H-bond to Nuc:⊖ will hinder/slow ability of Nuc to attack!



No solvent

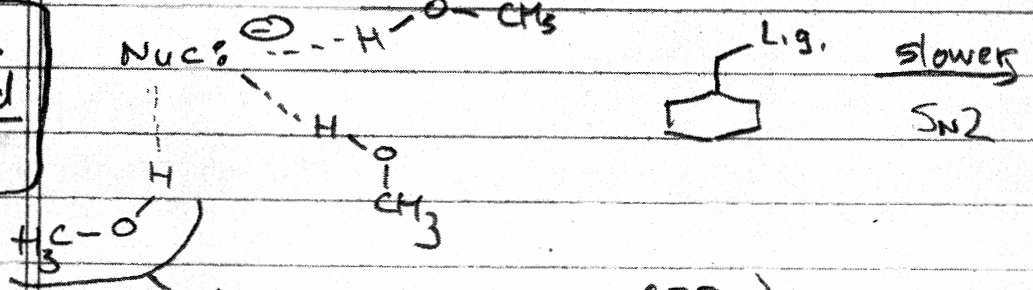
Nuc is free to attack

(PPS)

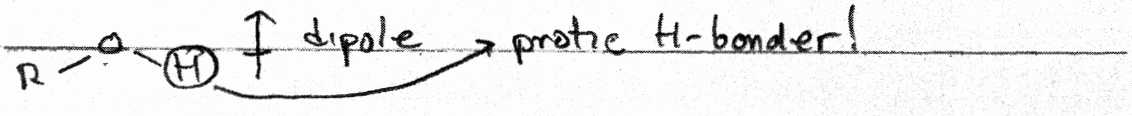
A polar protic solvent, can H-bond w/ Nuc:⊖

∴ S_N2 rxn is slowed down

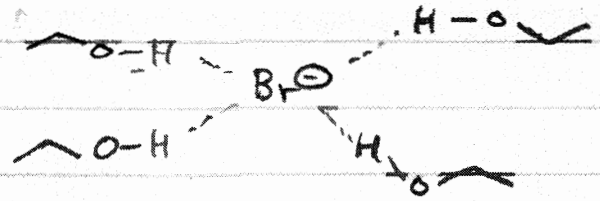
Nuc is blocked by PPS



polar protic solvent (PPS)



Ch 9-5



a PPS stabilizes (−) chrg of Nucleophile making it less likely to attack the δ+ of a polar covalent bond attached to L.g.

PPS (Slows S_N2 attack since rate is dependent on [Nuc:⊖])

(b) S_N2 reactions prefer polar Aprotic Solvent

non H-bonding

PPS

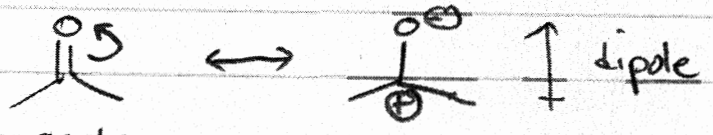
Protic solvents	Polar aprotic solvents
Water, Methanol, Ethanol, Ammonia, Acetic acid	Acetone, Dimethylformamide (DMF), Hexamethylphosphoramide (HMPA), Dimethylsulfoxide (DMSO), $H_3C-C\equiv N$ Acetonitrile

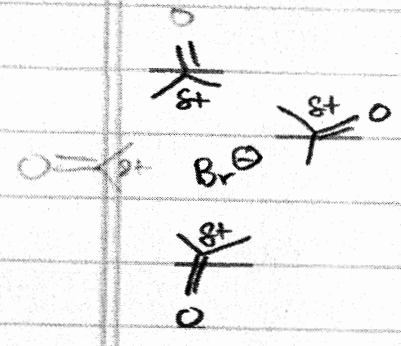
PAS or PAPS

Do not have H bonded to N, O, S

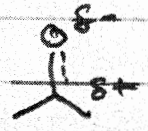
these compounds are polar but not protic!

Resonance reveals this





Resonance Hybrid =



δ+ charge don't stablize

$Br^{\ominus}$ like H-bonds ∴ $Br^{\ominus}$ Nucleophilicity is free to attack!

Ch 9-6

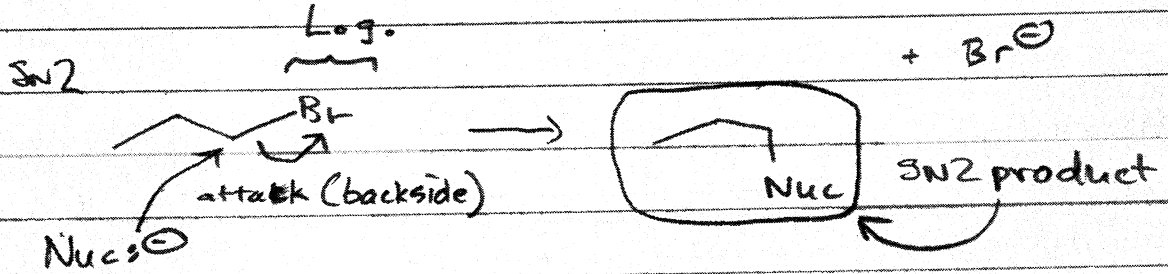
S_N2 rxns like

① good Nuc:$^{\ominus}$ (neg charge) nucleophile

② polar aprotic solvent

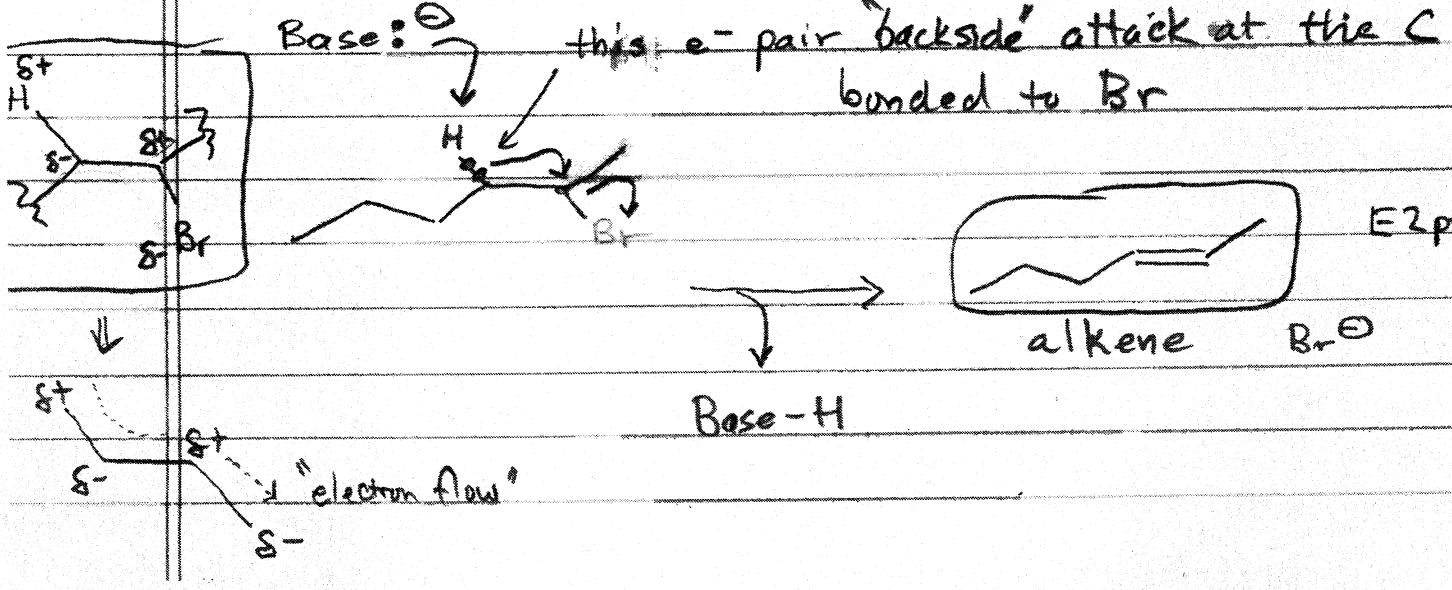
Elimination Rxns E2

In my view S_N2 and E2 rxns are fundamentally identical.



from source external to reactant containing L.g.

E2 : For E2 the Nuc:$^{\ominus}$ is NOW a Base



Ch 9-7

E2 rxn rate = k [alkyl halide]^{1}[Base]^{1} 1+1 = 2 bimolecular

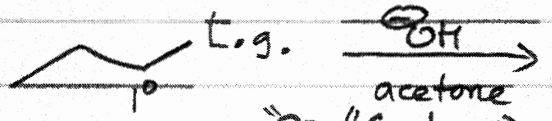
elimination bimolecular

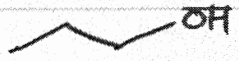
looks similar to SN2 rate

k = [alkyl halide][Nuc] SN2

WHY? 1° (primary) vs 3° (tertiary)

L.g. on 1° C



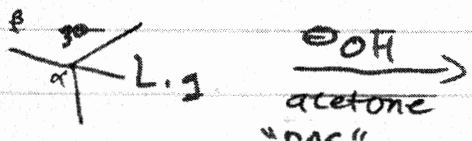


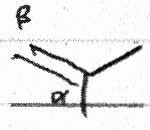
SN2

"PAS" (solvent) see pg Ch7-6

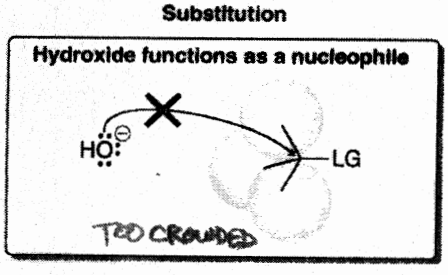
but...

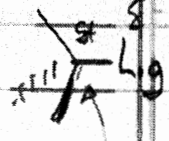
L.g. on 3° C





E2





ideal 5° for SN2, but crowded!

SN2: Difficult for $HO^{\ominus}$ to backside attack sterically hindered C attached to L.g.

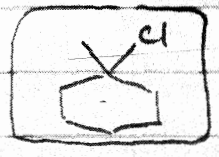
E2: $HO^{\ominus}$ functions as a base and pulls off accessible β-H

Note: C_α is attached to L.g.
C_β is attached to C_α

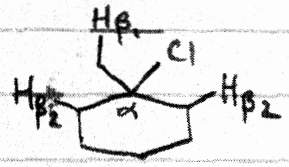
Ch 9-8

Examples

Draw the most abundant E2 product(s)



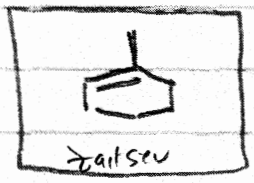
starting material



① Alkyl halide is 3°
② I.D Cα and unique Cβ
③ Base ~~H~~ $(CH_3O^{\ominus})$ ∴ Zaitsev product
E2/SN2

$NaO^{\ominus}CH_3$

① Conditions E2/SN2
② Alkyl halide 3°
③ ∴ E2



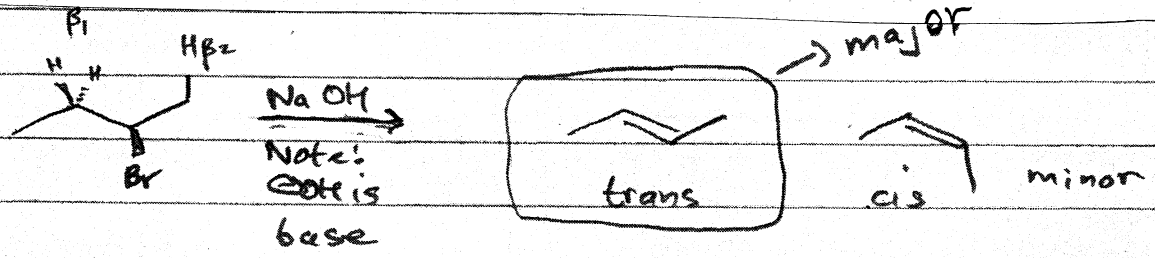
Zaitsev

same

$H\beta_2$ /Cl elimination

$C_\alpha = C_{\beta_2}$

so dont include this as 2nd product

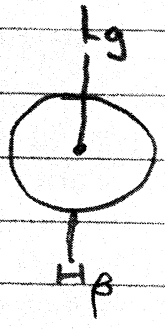


Major E2 product

Zaitzev

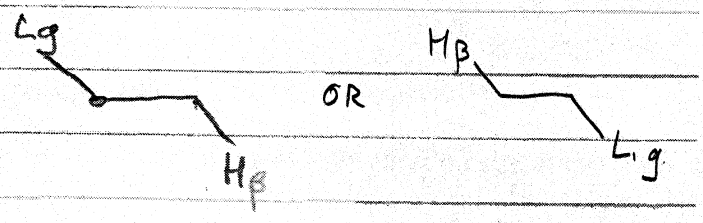
Stereospecificity

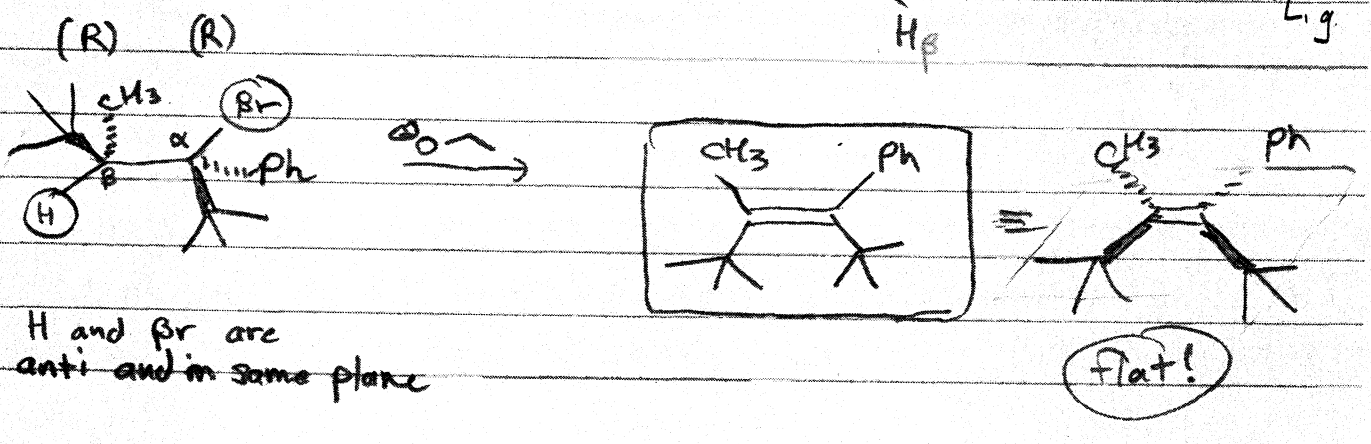
How must Hβ and L.g. be oriented for E2 rxn?



anti and line up (antiperiplanar)

from side

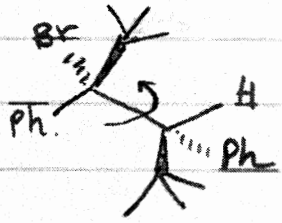


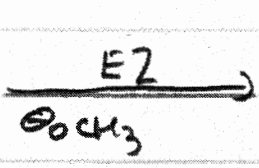


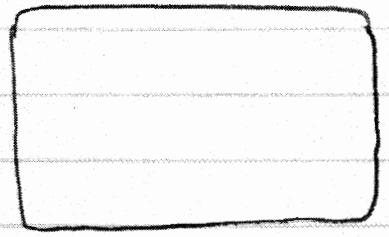
H and Br are anti and in same plane

Ch9-10

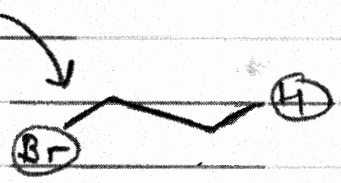
What if drawn as follows, show E2 product





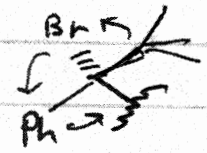


① Need to rotate molecule until H and Br are anti and in same plane Goal



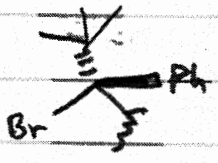
② Add other groups to each C using wedges ◣ and ||||| bonds

original

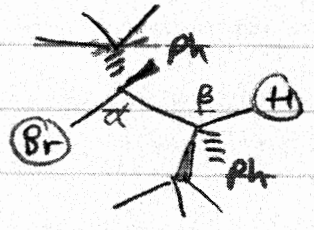


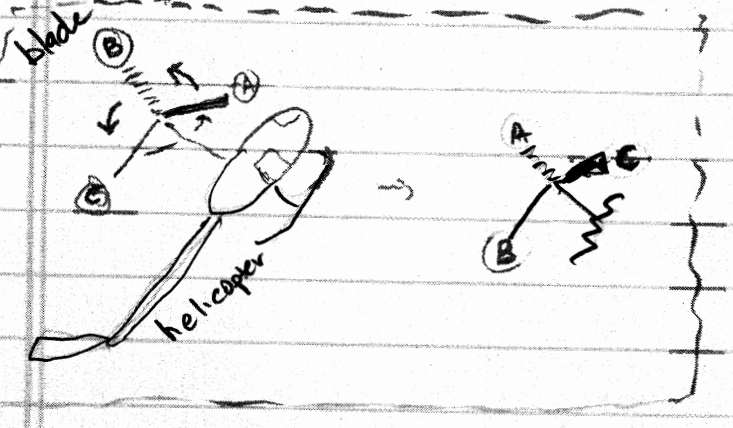
rot 60° CCW

rotated

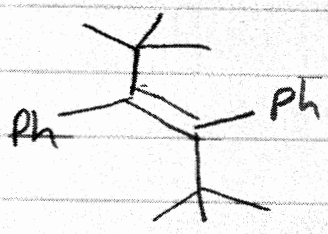


now join to other half





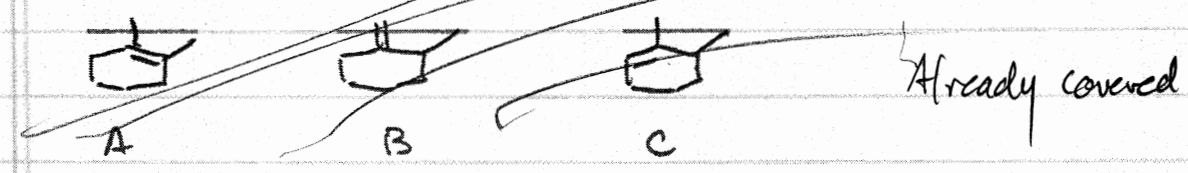
↓ E2 $C_\alpha = C_\beta$



STOP HERE

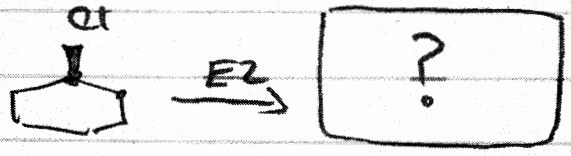
Ch 9-11

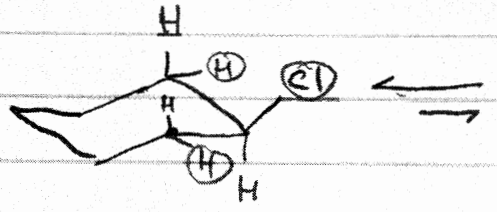
Arrange in order of stability

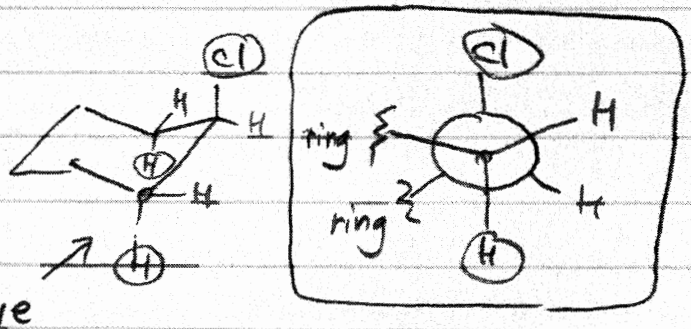


Already covered

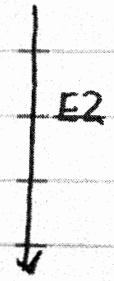
Stereospecificity of E2 rxn w/ substituted Cyclohexanes



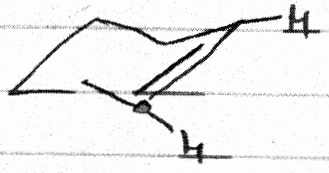




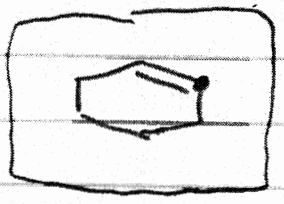
Eye



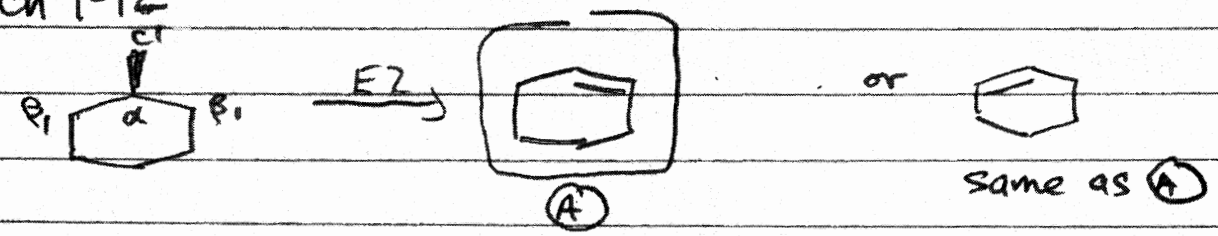
Anti-periplanar arrangement, set for E2! when Cl and H are axial



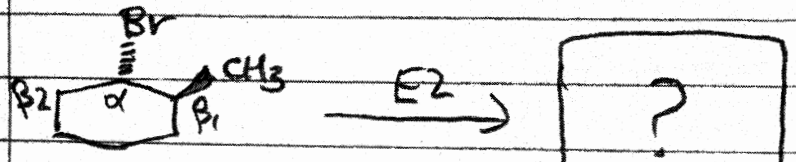
III



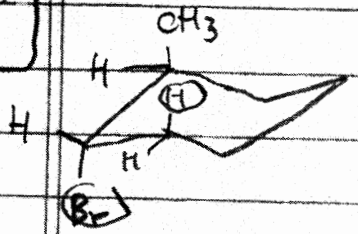
Ch 9-12



(A)



Approach 1



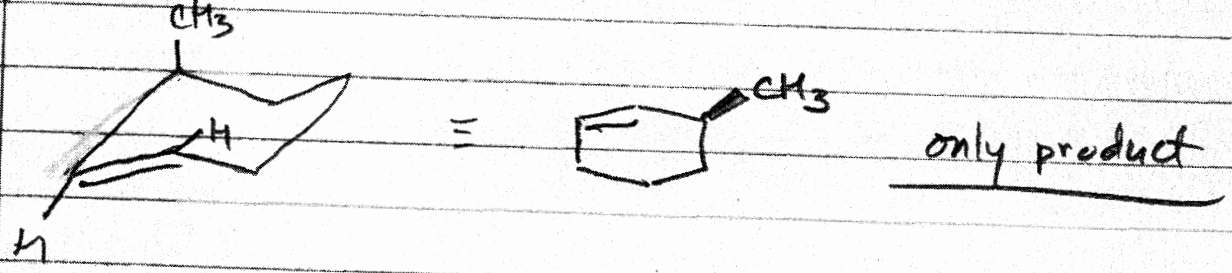
① Choose position on chair where Br (L.g.) is axial down ("down" because that is how it's draw in perspective drawing.

② Determine if β carbons are different (i.e. unique)

③ Determine if β-C have β-H

④ If β-H can it be axial and anti to the Br (or L.g.)?

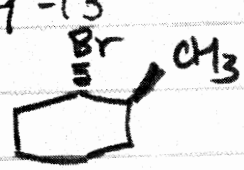
⑤ If anti AND axial E2 can occur there



only product

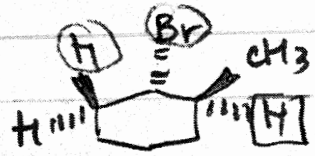
Approach 2

Ch 9 - 13



E2 → ?

① Draw β-H on wedged (▬) or dashed (≡) bond



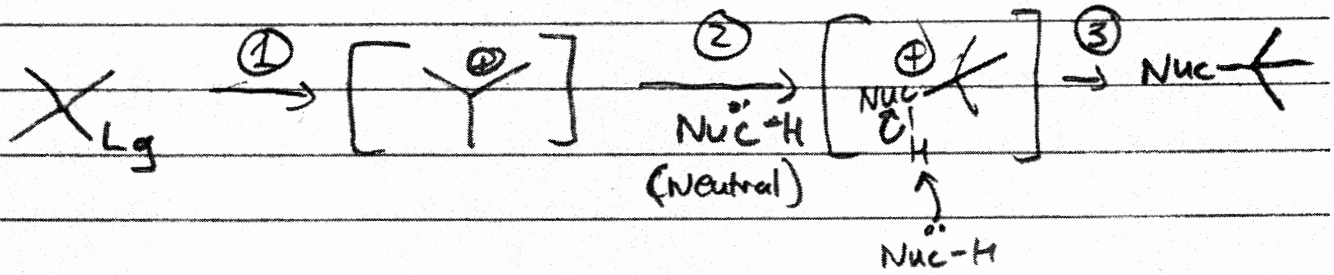
② Note: (Br) and circled (H) are on opposite sides of the ring -- they are "anti"/trans

the (Br) and boxed [H] are on same side of ring -- they are "syn"/cis and ∴ cannot be E2 eliminated

ONLY (Br) and (H) can be eliminated via E2

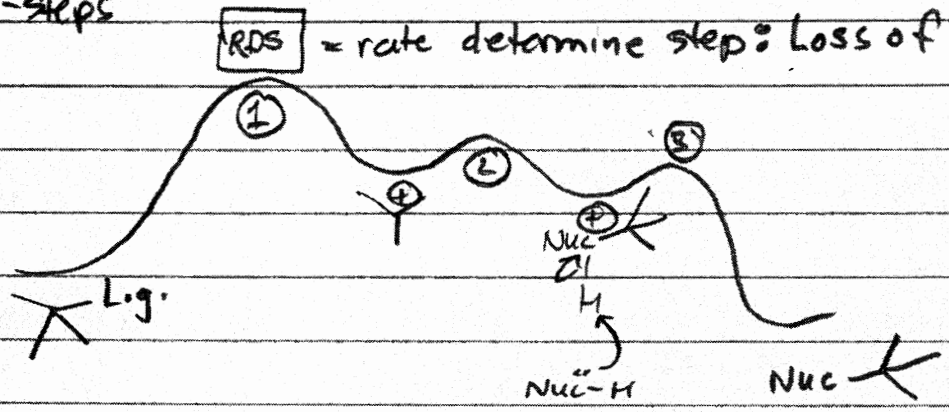
Ch 9 - 14

Sn1 (unimolecular) nucleophilic substitution



3-steps

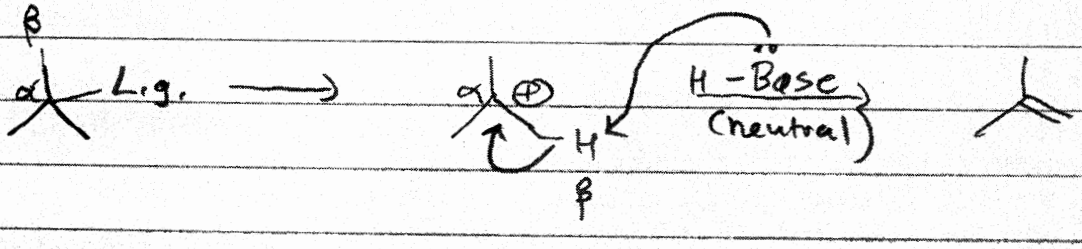
RDS = rate determine step: Loss of L.g.

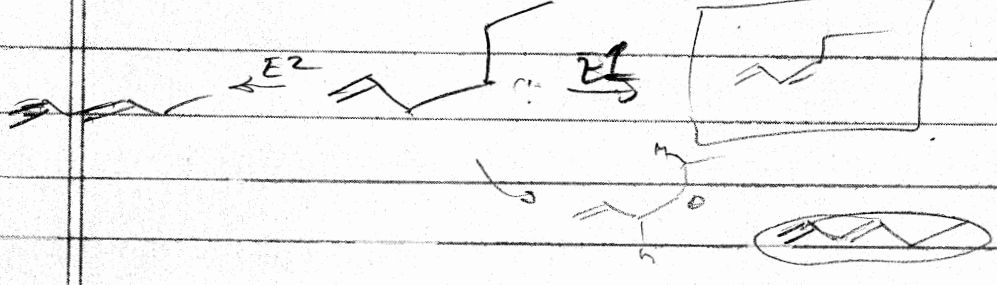


E① is very similar to Sn1 mechanism

(unimolecular)

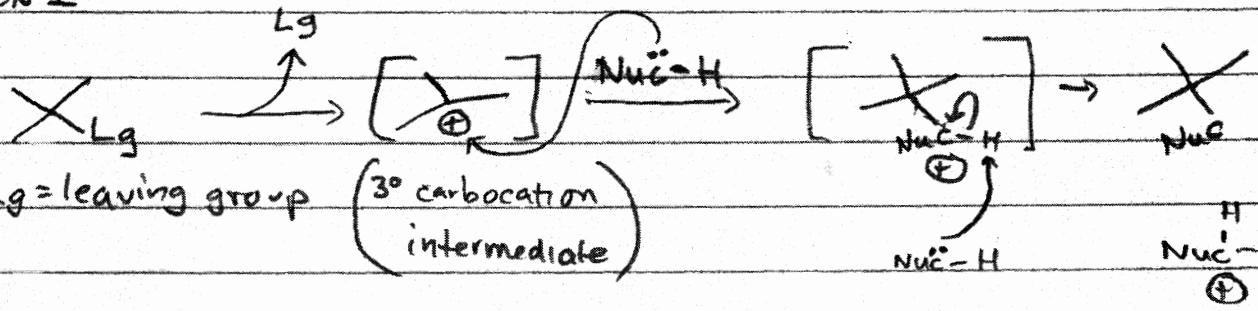
→ Elimination

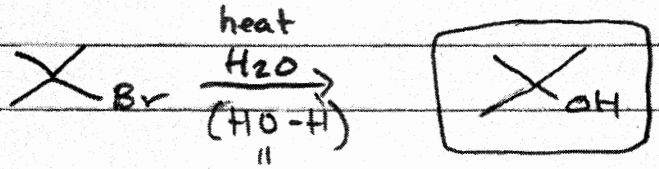




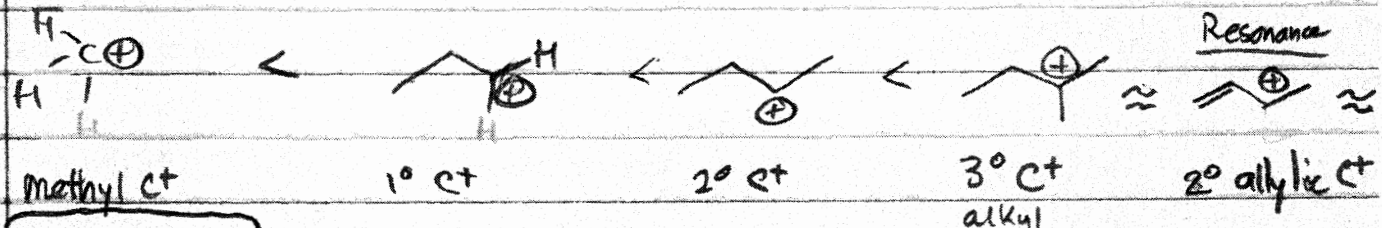
Ch 9 - 15

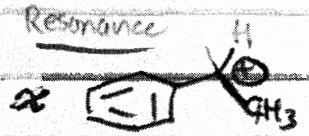
SN1





Carbocation Stability

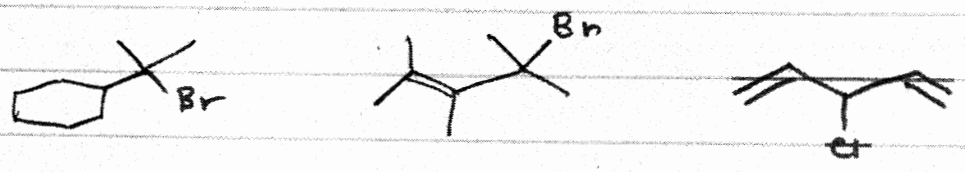




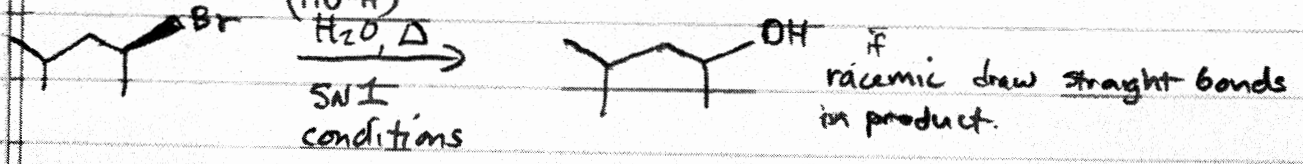
Since SN1 reactions form C+, SN1 rxn rates favor the formation of stable C⊕, such as 3°C⊕, allylic C⊕, benzylic C⊕

Ch 9 - 16

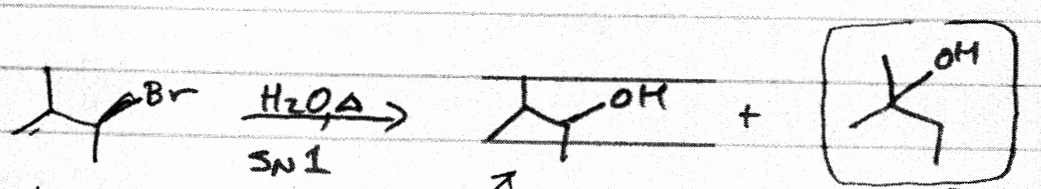
Draw the carbocation made after the L.g. leaves.
If resonance structure stablizes ⊕ charge, draw 1 resonance structure



S_N1 (Nuc-H) (HO-H)



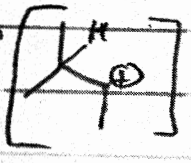
if racemic draw straight bonds in product.



How?

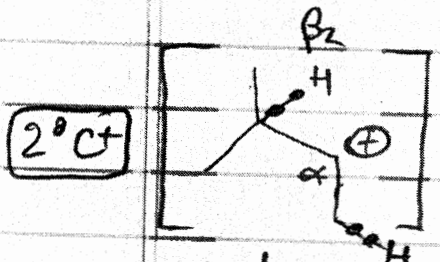
① Draw ⊕ S_N1

Direct HOH attack



② Identify ⊕ substitution

1°, 2°, 3° ?



2° C⊕

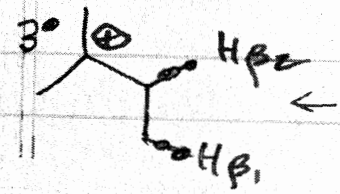
Ⓐ The ⊕ is α C I.D. unique C_β.

Ⓑ Does C_β have a CH_3 or H attached?

Ⓒ Move $:CH_3$ or :H w/ both e⁻ to form new bond where ⊕ is

Ⓓ Is New ⊕ more stable than original ⊕? If yes, migration is possible.

H_{β_2} migrath



3° C⊕ more stable

← results from H_{β_2} migration