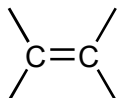


Chapter Outline (Part 2)

- I. Alkene structure & stability
- II. Alkene synthesis: E2 elimination
- III. Alkene synthesis: E1 elimination
 - A) Dehydration of alcohols
- IV. Substitution vs. Elimination
- V. Synthesis strategies

I. Alkene structure (review)

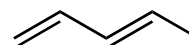
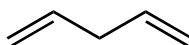
3-D sketch: p orbitals are orthogonal to sp^2 plane



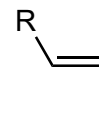
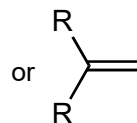
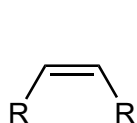
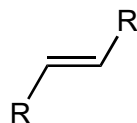
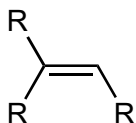
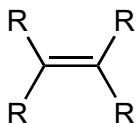
- π bonds are higher energy than σ bonds (more reactive, easier to break)
- π bonds are electron-rich (can react as a nucleophile or a base - see Chapter 8)

Alkene stability

- conjugation increases stability (resonance)



- increasing number of alkyl substituents increases stability



_____ substituted

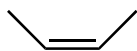
_____ substituted

_____ substituted

_____ substituted

- trans is more stable than cis, except in most rings

*trans possible if ring is >7 carbons
 Shown here is cyclooctene:*



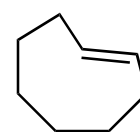
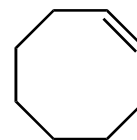
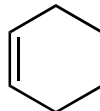
cis
(less stable)



trans
(more stable)

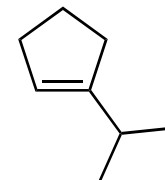
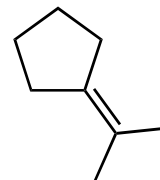
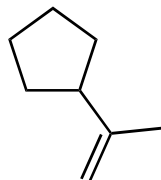
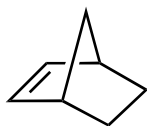


cis only



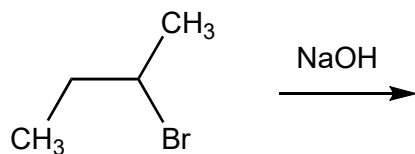
- FYI π bond is unstable at bridgehead carbons (Bredt's rule)

Example: Which alkene is most stable? Least stable?



- one-step mechanism
- needs strong base
- rate = $k [\text{RX}] [\text{base}]$

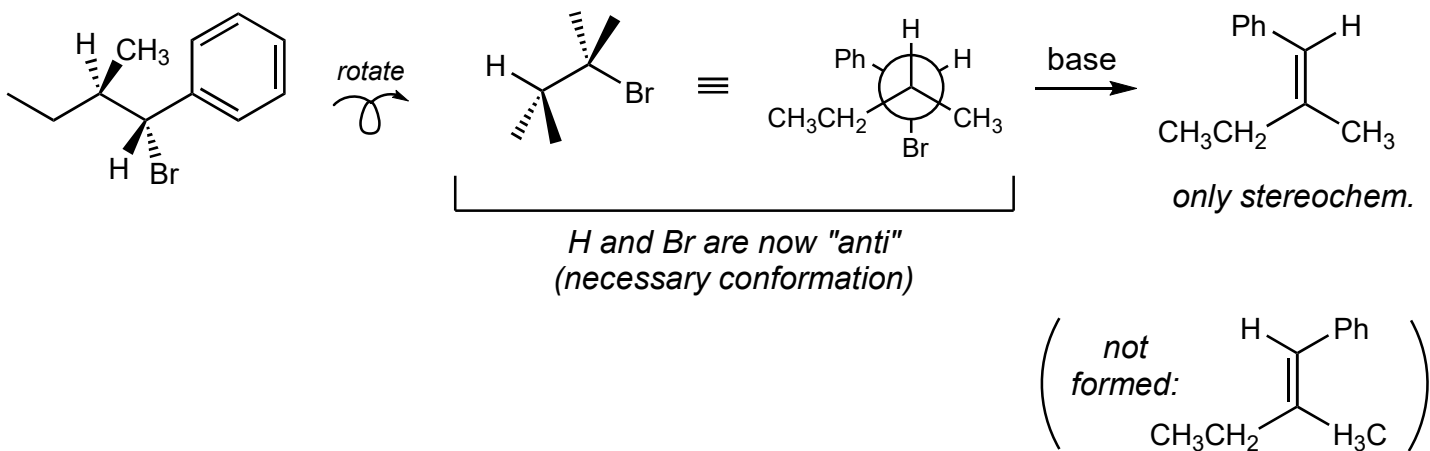
Example:



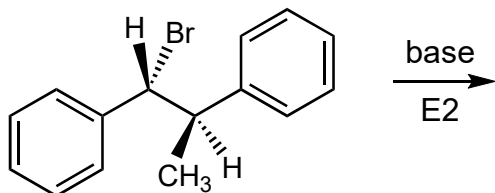
"eliminate" or lose β -hydrogen and LG (loss of HBr is called dehydrohalogenation)

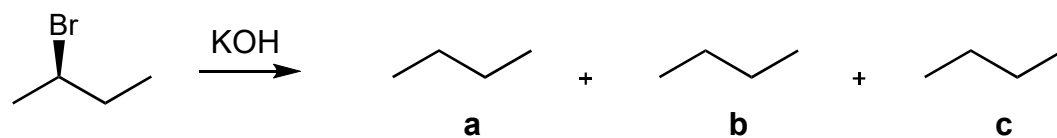
Stereochemistry of E2 mechanism

- β -hydrogen and LG must be anti-coplanar (180°) or anti-periplanar (close to 180°)
- E2 is called "anti elimination"



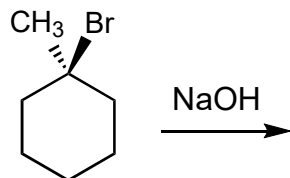
Example:



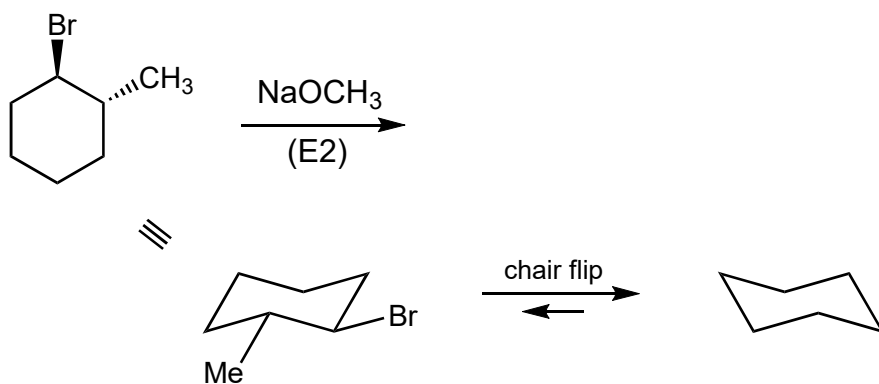


not formed:

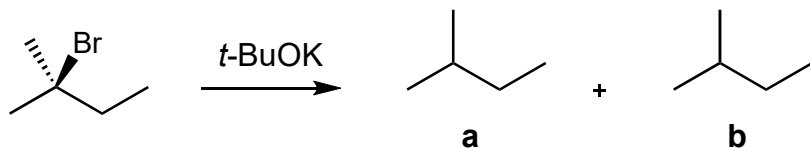
_____ is the major product because it is the most stable alkene (Zaitsev's Rule)



Effect of chair conformation on rate of E2 mechanism.

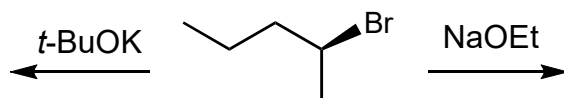


When a sterically hindered "bulky" base is used, then β -hydrogen on *less substituted C* is removed.



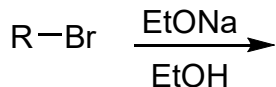
_____ is the major product because it is formed fastest (Hofmann's Rule)

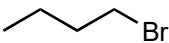
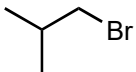

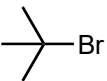
Example: predict the major E2 elimination product for each reaction.



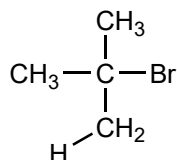
When do they compete? Reactions involving HO⁻ (hydroxide) or RO⁻ (alkoxide).

Compare rates:

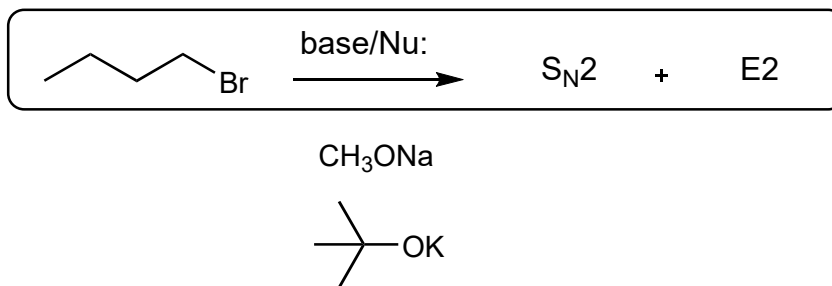


RBr	name	Type	% S _N 2	% E2
CH ₃ Br				
				
				
				
				

Consider *t*-BuBr:



What if we vary base?



t-Butoxide is a very bulky base (also Et₃N, *i*Pr₂NH, DBU, DBN)

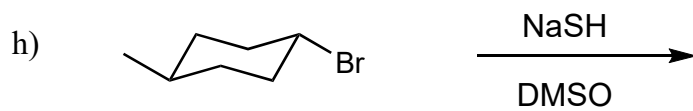
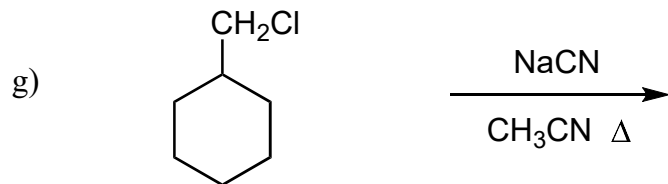
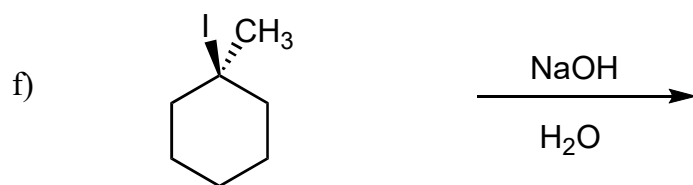
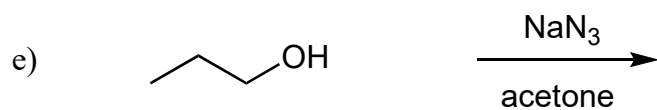
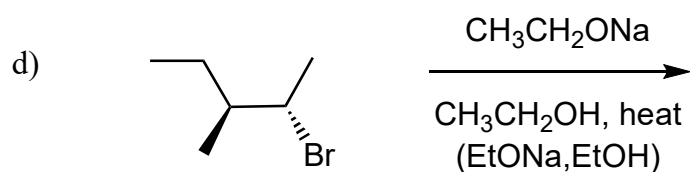
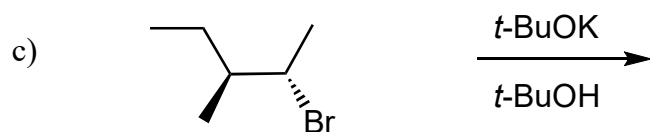
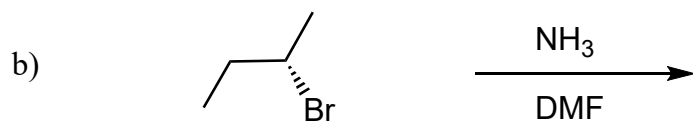
- not good for S_N2

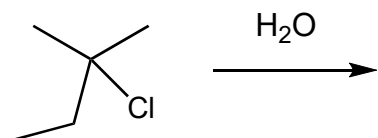
- classic E2 reaction conditions (gives Hofmann product if there is a choice)

Addition of heat also favors elimination (TΔS becomes large)

Preference for E2 over S_N2 (by RX type):

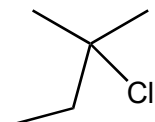
E2 vs. S_N2: Predict the major product(s) expected for each of the following reactions. 7-17
Remember to indicate stereochemistry, when appropriate. If no reaction is expected, write NR.





E1 Mechanism: 2 steps, via carbocation

1) loss of LG



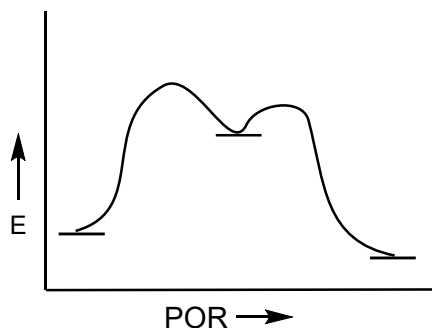
(same slow, rate-determining step as $\text{S}_{\text{N}}1$)

2) loss of β -H

(follows Zaitsev's rule - forms most substituted, most stable alkene)

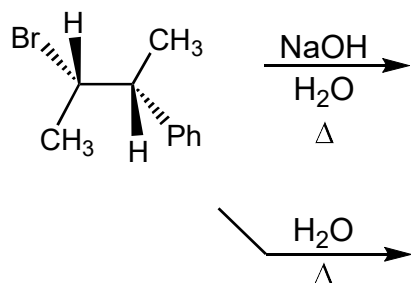
E1 Kinetics Rate = $k[\text{RCl}]$

- unimolecular
- rate not dependent on $[\text{H}_2\text{O}]$ so H_2O is not involved in rate-determining step
- a more stable carbocation will be formed faster (lower E_a) and gives faster E1/ $\text{S}_{\text{N}}1$



Rate (by RX type)

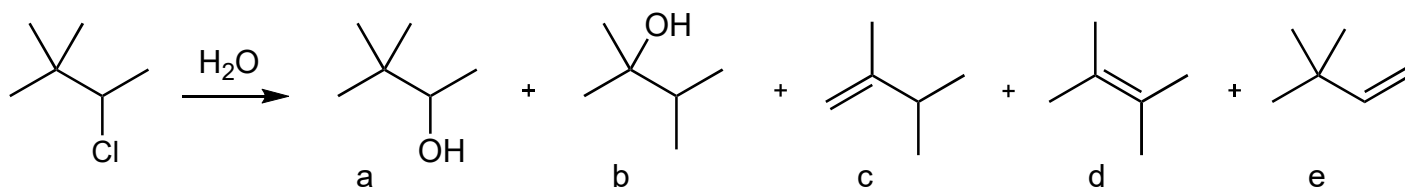
allyl / benzyl / 3° > 2° >> 1° methyl



Carbocation Rearrangements

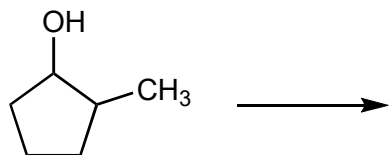
Because of rearrangements, product mixtures are common for reactions involving carbocations.

- 1) Of the elimination products shown below, which is expected to be major?
- 2) What mechanism accounts for the alcohol products? For the alkene products?
- 3) Provide detailed mechanisms to generate all products shown.



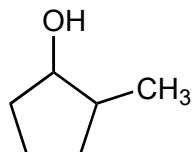
III A. Dehydration of Alcohols

7-20

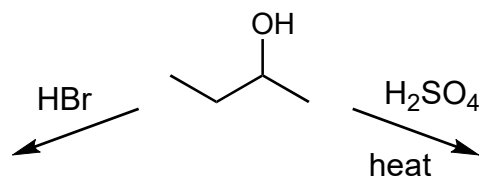
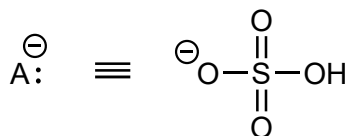
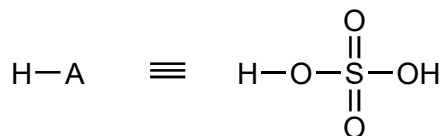


loss of _____ = dehydration

Mechanism? S_N1 S_N2 E1 E2

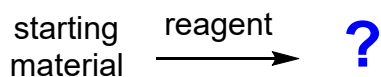
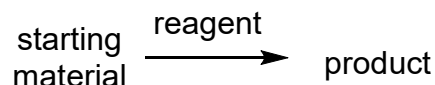


- produces most stable alkene possible (Zaitsev / Hofmann)
- carbocation can rearrange
- recall what is needed to make OH a good leaving group: _____

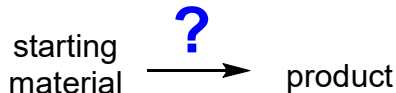


- strong / weak base
- non-nucleophilic, so no S_N1 competition
- A^- is like a spectator ion (N/R)

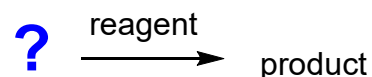
Start building up a set of flashcards to study O-Chem reactions and organize material (essential in Chapter 8!!). From any new reaction we learn in class, you can create **THREE** flashcards:



predict the product

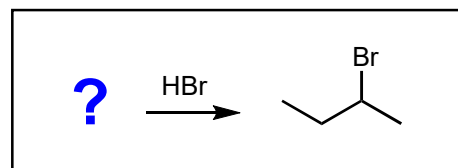
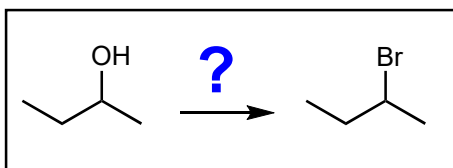
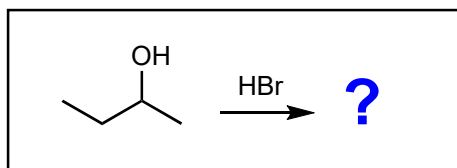
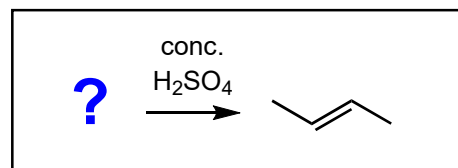
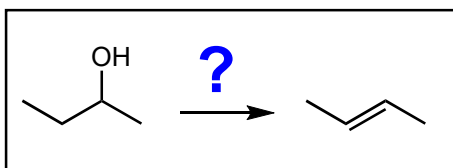
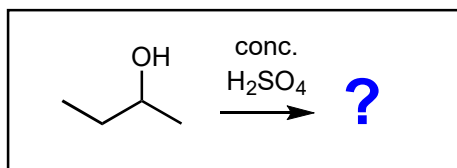


transform problem*



retrosynthesis*

Useful for preparing for final, reviewing material in 2nd semester and *planning a synthesis.



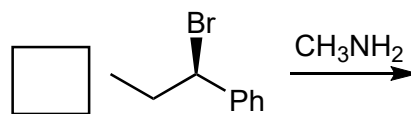
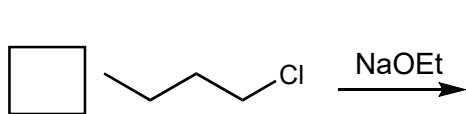
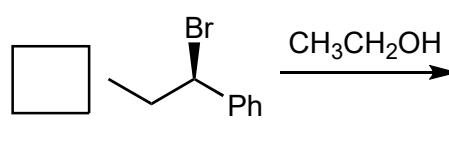
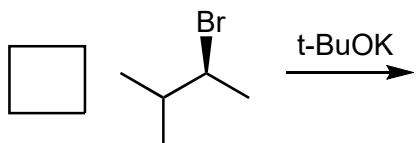
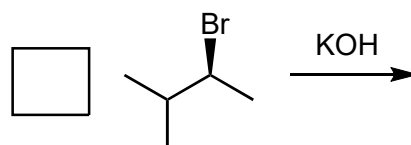
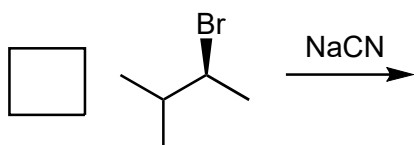
IV. Substitution vs. Elimination

Bimolecular reactions (1-step mechanism)

- $\text{S}_{\text{N}}2$ • requires good Nu: (X^- , NH_3 , RNH_2 , CN^- , N_3^- , RO^- , HO^-)
- steric hinderance slows $\text{S}_{\text{N}}2$: CH_3 (fastest) $>$ $1^\circ >$ $2^\circ \gg 3^\circ$ (tertiary, slowest)
- $\text{E}2$ • requires a strong base (RO^- , HO^- , NOT H_2O , ROH)

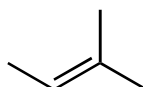
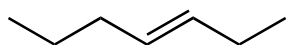
Unimolecular reactions (stepwise mechanism, via carbocation)

- $\text{S}_{\text{N}}1$ and $\text{E}1$ • requires NO strong base/Nu: (usually H_2O , ROH – called solvolysis)
- more stable carbocation, faster reaction: benzyl/allyl, $3^\circ >$ $2^\circ \gg 1^\circ$, methyl



V. Synthesis strategies

Provide suitable starting materials to synthesize the following target molecules (TM).



**Organic Chemistry I, CHM 3140, Dr. Laurie S. Starkey, Cal Poly Pomona
Elimination Reactions & Alkenes Summary (Ch 7 Part 2)**

- I. Review the pi (π) bond & Alkene stability
 - i) more alkyl groups, more stable
 - ii) trans is more stable than cis (except in rings)
 - iii) pi bond unstable at bridgehead carbon (Bredt's Rule)
 - iv) alkene is more stable if conjugated with another pi bond
- II. Alkene synthesis: E2 mechanism (one-step)
 - i) requires strong base (HO^- , RO^- , R_2N^-)
 - ii) stereochemistry: anti-elimination of β -hydrogen and LG
 - iii) regiochemistry: depends on base choice
 - a. usually gives the most stable alkene (Zaitsev with NaOH, MeONa, EtONa)
 - b. bulky base gives less substituted alkene (Hofmann with t-BuOK)
 - iv) often in competition with $\text{S}_{\text{N}}2$ (E2 favored unless primary RX)
- III. Alkene synthesis: E1 mechanism
 - i) two steps, via carbocation (rearrangement can occur)
 - ii) proceeds with loss of stereochemistry (both *E* and *Z* alkenes formed; E favored)
 - iii) regiochemistry: gives the most stable alkene (Zaitsev)
 - iv) usually in competition with $\text{S}_{\text{N}}1$ (E1 favored with heat)
 - v) dehydration of alcohols (conc. H_3PO_4 or conc. H_2SO_4 + heat)
- IV. Predicting Products: Substitution vs. Elimination
 - i) Bimolecular (strong base/nu:): $\text{S}_{\text{N}}2$ vs. E2 (see below)
 - ii) Unimolecular (carbocation): $\text{S}_{\text{N}}1$ vs. E1 (see below)
- V. Synthesis Strategies

Bimolecular reactions (1-step mechanism)

- $\text{S}_{\text{N}}2$ • requires good Nu: (X^- , NH_3 , RNH_2 , CN^- , N_3^- , RO^- , HO^-)
- steric hinderance slows $\text{S}_{\text{N}}2$: CH_3 (fastest) > 1° > 2° >> 3° (tertiary, slowest)
- E2 • requires a strong base (RO^- , HO^- , NOT H_2O , ROH)

Unimolecular reactions (stepwise mechanism, via carbocation)

- $\text{S}_{\text{N}}1$ and E1 • requires NO strong base/Nu: (usually H_2O , ROH – called solvolysis)
- more stable carbocation, faster reaction: benzyl/allyl, 3° > 2° >> 1° , methyl

Alkyl Group (RX)	$\text{S}_{\text{N}}1$, E1, E2	$\text{S}_{\text{N}}2$
3° (tertiary)	common	rare
2° (secondary)	sometimes	sometimes
1° (primary)	rare	common
CH_3 (methyl)	rare	common