Module 3, Lecture 8

Structure and Reactions of Organic Molecules

Introduction to reaction mechanisms
Substitution and Elimination

James **Crowley**

jcrowley@chemistry.otago.ac.nz

Dr. *Bill* Hawkins
bhawkins@chemistry.otago.ac.nz

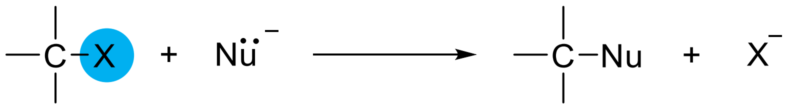
References to Brown *et al* text shown in BLUE

Learning Objectives:

- **to be able to identify what factors are required for a good leaving group**
- **to have an understanding of elimination reactions**
- **to be able to identify what factors are required fro a good leaving group**
- **to have an understanding of E1 elimination mechanism**

Textbook: **Chapter 27, sections 27.5-27.7, Brown**

What determines whether a reaction goes via S_N1 or S_N2?



Require **good** leaving group -departs in rate controlling step

S_N2:

- Nu:⁻ binds as leaving group departs
- Strong Nu:⁻ can make up for poor leaving group

S_N1:

- Only change occurring in slow step is cleavage of C-X bond
- Good leaving group **essential**.

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What determines whether a reaction goes via S_N1 or S_N2?

Relative rates of C-X cleavage

Longer, weaker bonds

X	***Relative Rate***
I:⁻	150
Br:⁻	50
Cl:⁻	1
F:⁻	2×10^{-2}
HO:⁻	5×10^{-8}
RO:⁻	5×10^{-9}

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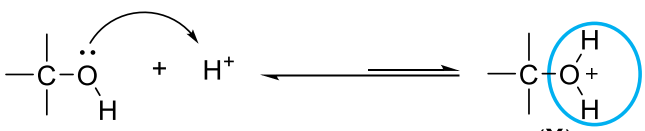
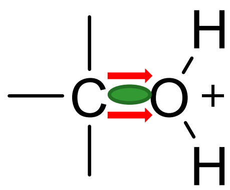
HO:⁻ and RO:⁻ can be converted into better leaving groups under strongly acidic conditions (protonation).



(**X**)

Leaving group becomes water

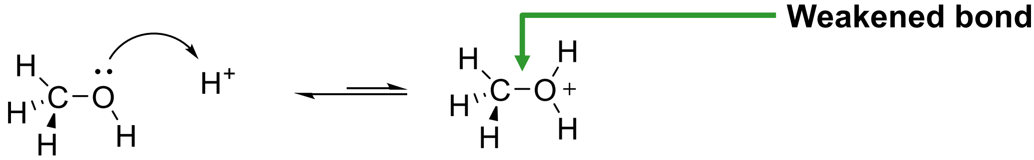
In (**X**), electrons in C-O bond is drawn closer to +ve charge O.

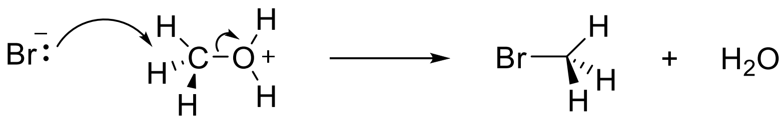


Example:

CH_3OH + NaBr ——> No reaction

CH_3OH + HBr ——> CH_3Br + H_2O





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Nucleophiles

S$_N$1:

- Nu:⁻ not involved in slow step
- Carbocation reacts readily with any nucleophile

S$_N$2:

- Good nucleophile essential

Nucleophilicity:
measure of affinity towards electrophilic $C^{\delta+}$

-ve HO:⁻ good

H_2O weak neutral

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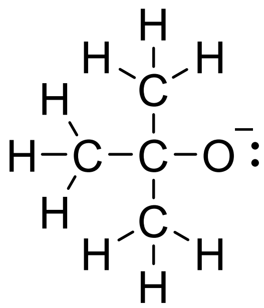
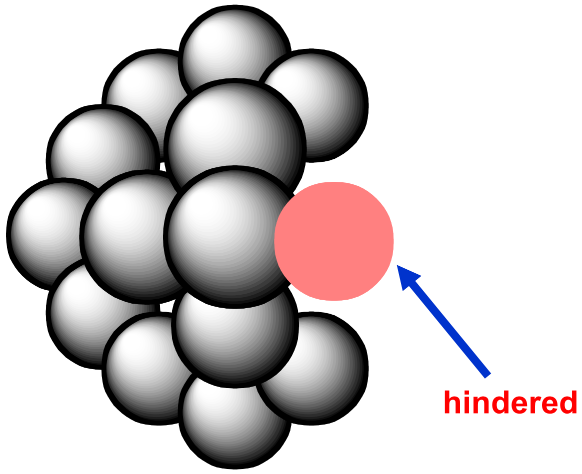
Nucleophiles

$(CH_3)_3CO:^-$ strong base but poor nucleophile





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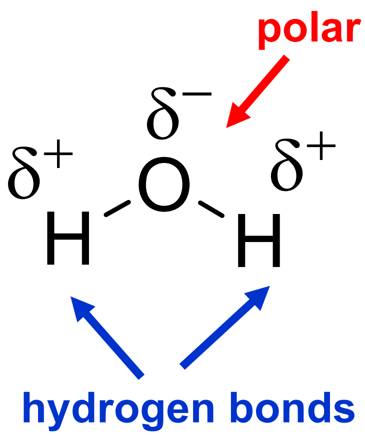
Effect of Solvent on S_N Reactions

The biological medium for chemical reactions is generally H_2O.

H_2O is a *polar* solvent. Also, able to form H-bonds.



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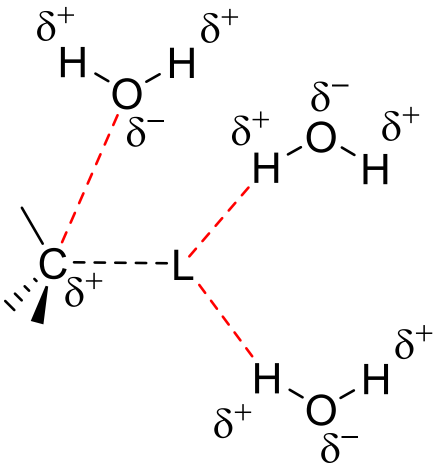
Effect of Solvent on S_N Reactions

S_N1: fastest in polar solvents, particularly those which H-bond.



First transition state stabilized by:

- polar effect at C
- H-bonding to L

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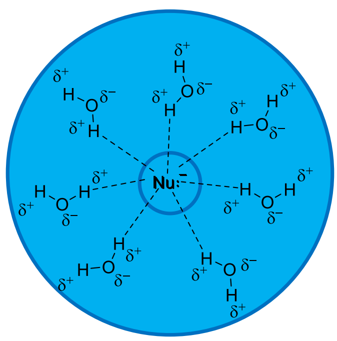
Effect of Solvent on S_N Reactions

S_N2: Solvent can influence Nu:⁻ through H-bonding



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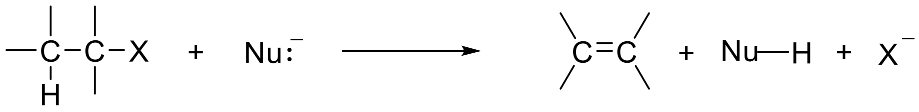
Elimination Reactions (27.6)



- Common mechanisms, E1 and E2.
- Parallel those for S_N1 and S_N2.
- Elimination mechanism determined by base strength:

  - strong base - E2;

  - weak base - E1.

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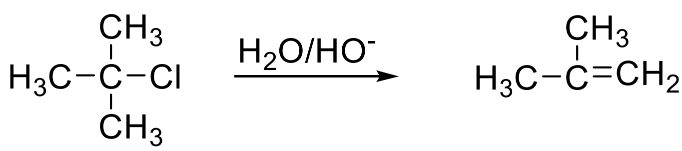
E1 Mechanism



Experiments show: rate = k [C-Cl]

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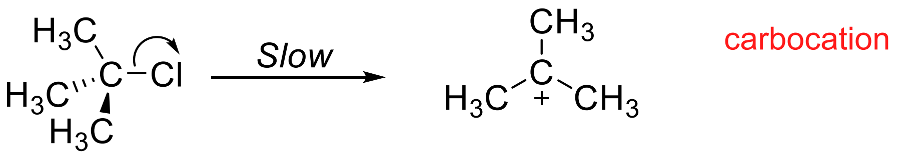
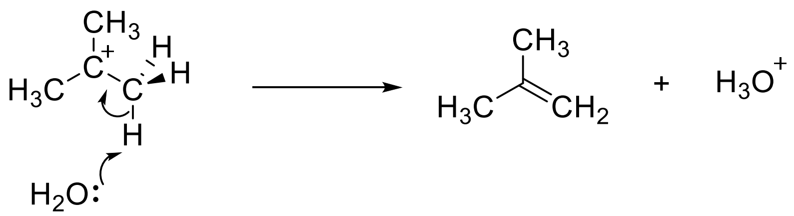
E1 Mechanism

1st Step (same as for S_N1) (rate determining step)



2nd Step A base (H_2O, most abundant) removes H^+ to form C=C:



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E1 Mechanism

Same rate determining step as S_N1, thus same controlling factors:

- Strong base not required
- H-bonding solvents promote reaction
- E1 most common when leaving group is on 3° carbon
- E1 and S_N1 often co-occur.

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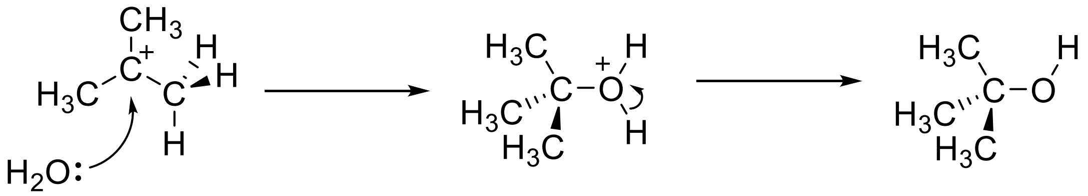
for previous example:



- Ratio of E1 : S_N1 controlled by relative rates of the 2 alternative fast steps.
- If leaving group is changed, overall rate changes but E1 : S_N1 ratio unchanged.

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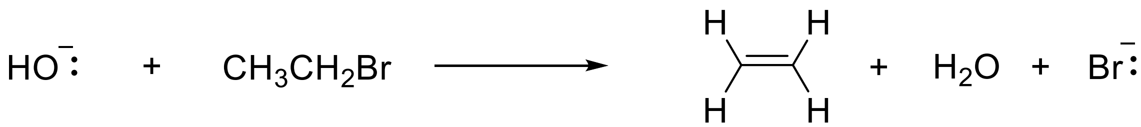
E2 Mechanism



Experiments show:

rate = k [CH_3CH_2Br] [HO^-]

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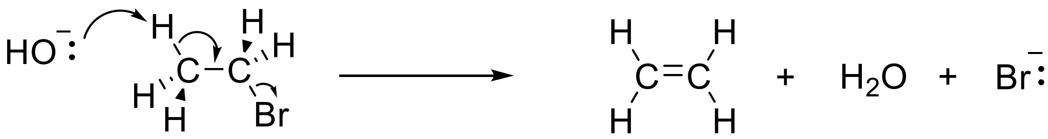
E2 Mechanism



Concerted bond breaking and bond formation

- Halide **and** base involved in single, rate determining step
- Like S_N2 Must have strong base - *e.g.* HO:$^{-}$
- Possible for 1°, 2° and 3° compounds.

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E2 Mechanism

S_N2:

- Requires backside attack;
-
- Difficult if reaction centre crowded;

- Rate order is 1° > 2° > 3°.

E2:

- Easily accessible H^+ is removed

- Little difference in ease of H^+ removal for 1°, 2° and 3°

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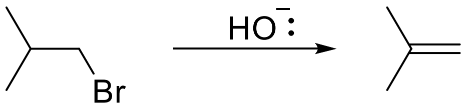
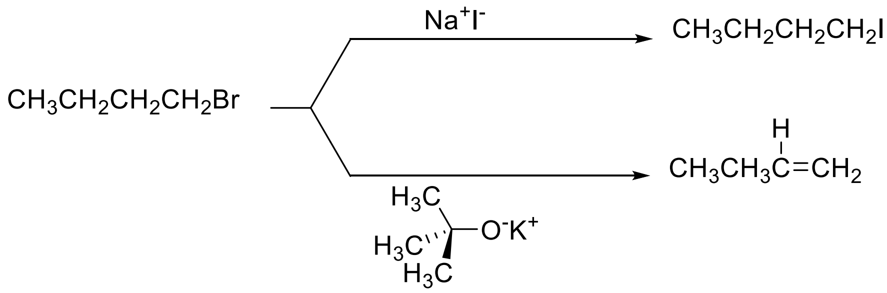
Questions

1. The rate of the following reaction is dependent on [alkyl bromide] and [OH^-]. Draw an energy profile of the reaction and the transition state structure(s).



2. Account for the following reactions:



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✱ Homework ✱

Chemistry – the central science 3rd Ed

Brown et al.

Problems 27.40, 27.77

Answers on Blackboard

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