8.11
Substitution and Elimination as Competing Reactions

Alkyl halides can react with Lewis bases by nucleophilic substitution and/or elimination.

\[
\begin{align*}
\text{alkyl halide} + \text{Lewis base} &\rightarrow \text{substitution product} \\
\text{alkyl halide} + \text{alkoxide ion} &\rightarrow \text{elimination product}
\end{align*}
\]

Two Reaction Types

How can we tell which reaction pathway is followed for a particular alkyl halide?

\[
\begin{align*}
\text{β-elimination} &\rightarrow \text{elimination product} \\
\text{nucleophilic substitution} &\rightarrow \text{substitution product}
\end{align*}
\]

Elimination versus Substitution

A systematic approach is to choose as a reference point the reaction followed by a typical alkyl halide (secondary) with a typical Lewis base (an alkoxide ion).

The major reaction of a secondary alkyl halide with an alkoxide ion is elimination by the E2 mechanism.

Example

CH\(_2\)CH(CH\(_3\))\(_2\) + Br\(_2\) → CH\(_3\)CH=CH\(_2\) + CH\(_3\)CH\(_2\)Br

Na\(_2\)O\(_2\)CH\(_2\)\(_2\) ethanol, 55°C

(13%) (87%)

Figure 8.8

E2
Which one of the following alkyl halides would be expected to give the highest ratio of substitution to elimination on treatment with sodium ethoxide in ethanol (50°C)?

**A)** 1-bromopentane

**B)** 2-bromopentane

**C)** 3-bromopentane

**D)** 2-bromo-3-methylbutane

When is Substitution Favored?

Given that the major reaction of a secondary alkyl halide with an alkoxide ion is elimination by the E2 mechanism, we can expect the proportion of substitution to increase with:

1) decreased crowding at the carbon that bears the leaving group

Uncrowded Alkyl Halides

Decreased crowding at carbon that bears the leaving group increases substitution relative to elimination.

**Primary alkyl halide**

\[ \text{CH}_3\text{CH}_2\text{CH}_2\text{Br} \]

**Na\text{CH}_3\text{CH}_3**

**Ethanol, 55°C**

\[ \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3 + \text{CH}_3\text{CH=CH}_2 \]

(91%) (9%)

But a Crowded Alkoxide Base Can Favor Elimination Even with a Primary Alkyl Halide

**Primary alkyl halide + bulky base**

\[ \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br} \]

**K\text{O}[\text{CH}_2\text{CH}_3]**

**Tert-butyl alcohol, 40°C**

\[ \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{O}[\text{CH}_2\text{CH}_3]_3 + \text{CH}_3\text{CH}(\text{CH}_3)_2\text{CH=CH}_2 \]

(13%) (87%)

When is Substitution Favored?

Given that the major reaction of a secondary alkyl halide with an alkoxide ion is elimination by the E2 mechanism, we can expect the proportion of substitution to increase with:

1) decreased crowding at the carbon that bears the leaving group

2) decreased basicity of the nucleophile
**Question**

Which one of the following statements is true?
A) CH₂CH₂S⁻ is both a stronger base and more nucleophilic than CH₃CH₂O⁻
B) CH₂CH₂S⁻ is a stronger base but less nucleophilic than CH₃CH₂O⁻
C) CH₂CH₂S⁻ is a weaker base but is more nucleophilic than CH₃CH₂O⁻
D) CH₂CH₂S⁻ is both a weaker base and less nucleophilic than CH₃CH₂O⁻

**Weakly Basic Nucleophile**

Weakly basic nucleophile increases substitution relative to elimination

**Secondary alkyl halide + weakly basic nucleophile**

- **CH₂CH₂CH₂CH₃**
- **Cl⁻**
- **KCN**
- **DMSO**
- **pKₐ (HCN) = 9.1**
- **CH₂CH₂CH₂CH₃CN**
- **(70%)**

**Question**

Which one of the following compounds gives the highest substitution-to-elimination ratio (most substitution least elimination) on reaction with 2-bromobutane?
A) NaOCH₃
B) NaNH₂
C) NaN₃
D) NaC≡CH

**Tertiary Alkyl Halides**

Tertiary alkyl halides are so sterically hindered that elimination is the major reaction with all anionic nucleophiles. Only in solvolysis reactions does substitution predominate over elimination with tertiary alkyl halides.

**Question**

Which one of the following statements is true concerning substitution and elimination in tert-butyl bromide?
A) the mechanism generally believed to be available to (CH₃)₃Br are S₄N₁ and E₁
B) the mechanism generally believed to be available to (CH₃)₃Br are S₄N₁, S₂, and E₁
C) the mechanism generally believed to be available to (CH₃)₃Br are S₄N₁, S₂, and E₂
D) the mechanism generally believed to be available to (CH₃)₃Br are S₄N₁, E₁ and E₂
Example

\[(\text{CH}_3)_2\text{CCH}_2\text{CH}_3 + \text{CH}_3\text{Br} \rightarrow \text{CH}_3\text{CH}==\text{CHCH}_2\text{CH}_3 + \text{CH}_3\text{C}==\text{CCH}_2\text{CH}_3\]

**Question**

Reactions proceeding through this mechanism give a racemic mixture:
A) \(S_n1\)
B) \(S_n2\)
C) E1
D) E2

**Question 9**

Methyl bromide reacts with sodium ethoxide in ethanol by this mechanism:
A) \(S_n1\)
B) \(S_n2\)
C) E1
D) E2

**Question**

3-bromo-3-methylpentane reacts with sodium ethoxide in ethanol by this mechanism:
A) \(S_n1\)
B) \(S_n2\)
C) E1
D) E2