6.19 Epoxidation of Alkenes

Epoxides are examples of heterocyclic compounds with three-membered rings that contain oxygen. Examples include ethylene oxide and propylene oxide:

\[
\text{H}_2\text{C} = \text{CH}_2 \quad \text{H}_2\text{C} = \text{CHCH}_3
\]

Epoxide Nomenclature

Substitutive nomenclature: named as epoxy-substituted alkanes.

- "epoxy" precedes name of alkane
- 1,2-epoxypropane
- 2-methyl-2,3-epoxybutane

Example structures:

\[
\text{cis-2-Methyl-7,8-epoxyoctadecane}
\]

Problem 6.21: Give the IUPAC name, including stereochemistry, for disparity.

\[
\text{EtOH} \quad + \text{RCOOH} \quad \rightarrow \quad \text{EtO} \quad + \text{RCOOEt}
\]

Example

\[
\text{(52%)}
\]

Epoxidation of Alkenes
Problem 6.22  Give the structure of the alkene, including stereochemistry, that you would choose as the starting material in a preparation of synthetic disparlure. Is disparlure chiral?

Disparlure is chiral.

Epoxidation of cis-2-Butene

The epoxidation of trans-2-butene produces:
A) A single enantiomer
B) A product with one asymmetric carbon atom
C) An optically inactive meso product
D) A racemic mixture
E) 4 different stereoisomers each with 2 chiral carbon atoms

Relative Rates of Epoxidation

<table>
<thead>
<tr>
<th>Alkene</th>
<th>Relative Rate</th>
<th>Relative Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>ethylene</td>
<td>H₂C=CH₂</td>
<td>1</td>
</tr>
<tr>
<td>propene</td>
<td>CH₃CH=CH₂</td>
<td>22</td>
</tr>
<tr>
<td>2-methylpropene</td>
<td>(CH₃)₂C=CH₂</td>
<td>484</td>
</tr>
<tr>
<td>2-methyl-2-butene</td>
<td>(CH₃)₂C=CHCH₃</td>
<td>6528</td>
</tr>
</tbody>
</table>

More highly substituted double bonds react faster. Alkyl groups on the double bond make it more "electron rich."

Question

Which reagent reacts with an alkene to produce an epoxide?
A) CH₃COH
B) CH₃COOH
C) CH₃COOH
D) CH₃OCH

Ozonolysis has both synthetic and analytical applications.

### Synthetic Applications
- **Synthesis of Aldehydes and Ketones**
- **Identification of Substituents on the Double Bond of an Alkene**

### Analytical Applications
- **Identification of Substituents on the Double Bond of an Alkene**

#### 6.20 Ozonolysis of Alkenes

**First Step:**

The reaction of the alkene with ozone produces an ozonide.

\[
\text{C} = \text{C} + O_3 \rightarrow \text{C} = \text{C}^\text{O} \text{O} \text{O}
\]

**Second Step:**

Hydrolysis of the ozonide with water or zinc produces aldehydes or ketones.

\[
\text{C} = \text{C}^\text{O} + \text{H}_2\text{O, Zn} \rightarrow \text{C} = \text{C}^\text{O} \text{C}
\]

As an alternative to hydrolysis, the ozonide can be treated with dimethyl sulfide.

\[
\text{C} = \text{C}^\text{O} + \text{O} \rightarrow \text{C} = \text{C}^\text{O} \text{C}
\]

#### Example

The ozonolysis of a specific alkene yields the following products:

1. **1. O_3**
2. **2. H_2O, Zn**

**Products:**
- \(\text{CH}_3\text{C} = \text{C}\text{CH}_3\) (38%)
- \(\text{CH}_3\text{C} = \text{O}\text{CH}_3\text{CH}_3\) (57%)

As an alternative,

1. **1. O_3**
2. **2. (CH_3)_2S**

**Products:**
- \(\text{CH}_3\text{C} = \text{C}\text{CH}_3\)
The ozonolysis of 2,4-dimethyl-2-pentene will produce:

A) \[
\begin{array}{c}
\text{O} \\
\end{array}
\]
B) \[
\begin{array}{c}
\text{O} + \text{CH}_2=\text{CH}_2 \\
\end{array}
\]
C) \[
\begin{array}{c}
\text{O} + \text{CH}_3\text{CH}=	ext{CH}_2 \\
\end{array}
\]
D) \[
\begin{array}{c}
\text{CH}_3\text{CH}=	ext{CH}_2 \\
\end{array}
\]

6.21
Introduction to Organic
Chemical Synthesis

Retrosynthesis

Prepare cyclohexane from cyclohexanol

```
Br
\text{OH} \rightarrow \text{OCH}_3
```

device a synthetic plan
reason backward from the target molecule
always use reactions that you are sure will work

Prepare cyclohexane from cyclohexanol

```
\text{H}_2 \text{Pt} \rightarrow \text{H}_2 \text{Pt}
```

The only reaction covered so far for preparing alkanes is catalytic hydrogenation of alkenes.
This leads to a new question. "Starting with anything, how can I prepare cyclohexene in a single step by a reaction I am sure will work?"

Prepare cyclohexane from cyclohexanol

```
\text{H}_2 \text{Pt} \rightarrow \text{H}_2 \text{Pt}
```

ask yourself the key question
"Starting with anything, how can I make cyclohexane in a single step by a reaction I am sure will work?"
Prepare cyclohexane from cyclohexanol

\[
\text{OH} \underset{\text{H}_2\text{SO}_4, \text{heat}}{\xrightarrow{\text{H}_2\text{SO}_4}} \text{H}_2 \underset{\text{Pt}}{\xrightarrow{\text{Pt}}} \text{OH}
\]

Akenes can be prepared by dehydration of alcohols.
The synthesis is complete.

**Question**

Which one of the following outlines the best synthesis of trans-2-chlorocyclohexanol?
A) Heat a mixture of cyclohexanol and Cl₂ to 400°C.
B) 1. Treat cyclohexene with HCl; 2. Treat product of reaction 1 with peroxyacetic acid.
C) 1. Hydrogenation of cyclohexene in the presence of Pt; 2. Treat product of reaction 1 with Cl₂ in H₂O.
D) 1. Treat bromocyclohexane with KOC(CH₃)₂ in DMSO; 2. Treat product of reaction 1 with Cl₂ in water.

**Question**

Which one of the following is not stereospecific?
A) reaction of cis-2-butene with peroxyacetic acid
B) hydroboration-oxidation of 1-methylcyclopentene
C) addition of Br₂ to trans-2-pentene
D) addition of HBr to cis-2-butene in the presence of peroxides

**Question**

Which combination of reagents is the best choice for carrying out the conversion shown?
A) 50% water - 50% sulfuric acid
B) 1. H₂SO₄
2. H₂O, heat
C) 1. O₂
2. H₂O, Zn
D) 1. BH₃·THF
2. H₂O, NaOH

**Chirality (continued)**

Di-substituted cyclopentanes and cyclohexanes

A plane of symmetry bisects a molecule into two mirror image halves. Chlorodifluoromethane has a plane of symmetry.
A plane of symmetry bisects a molecule into two mirror image halves.

1-Bromo-1-chloro-2-fluoroethene has a plane of symmetry.

A point in the center of the molecule is a center of symmetry if a line drawn from it to some element, when extended an equal distance in the opposite direction, encounters an identical element.

1,2-Disubstituted Cyclopentanes

<table>
<thead>
<tr>
<th>CH₃</th>
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</tr>
</thead>
<tbody>
<tr>
<td>R-</td>
<td>CH₃</td>
</tr>
</tbody>
</table>

meso

No plane of symmetry

1,3-Disubstituted Cyclopentanes

<table>
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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>R-</td>
<td>CH₃</td>
</tr>
</tbody>
</table>

meso

No plane of symmetry
As long as any one conformer of a compound has a plane of symmetry, the compound will be achiral.
How many stereoisomers?

**Maximum number of stereoisomers** = \(2^n\)

where \(n\) = number of structural units capable of stereochemical variation

structural units include chiral carbons and cis and/or trans double bonds

number is reduced to less than \(2^n\) if meso forms are possible

Hexalose sugar

- 4 chiral carbons
- 16 possible stereoisomers (no meso forms)

Cholic acid

- 11 chiral carbons
- \(2^{11} = 2048\) stereoisomers
- a second is the enantiomer of natural cholic acid
- 2046 are diastereomers of cholic acid

How many stereoisomers?

maximum number of stereoisomers = \(2^n\)

where \(n\) = number of structural units capable of stereochemical variation

structural units include chiral carbons and cis and/or trans double bonds

number is reduced to less than \(2^n\) if meso forms are possible

How many stereoisomers?

3-Penten-2-ol

6.22
Reactions of Alkenes with Alkenes:
Polymerization / Stereochemistry
A polymer is a large molecule composed of many smaller repeating units.

First synthetic polymers:
- Polyvinyl chloride (PVC) in 1838
- Polystyrene in 1839

Now, 250 billion pounds produced annually, worldwide.

Introduction

Classes of Polymers

Addition, or chain-growth, polymers

Addition Polymers

Three kinds of processes (intermediates):
- Free radicals
- Carbocations
- Carbanions

Examples of addition polymers:
- polypropylene: plastics
- polystyrene: foam insulation
- poly(acrylonitrile): Orlon® fiber
- poly(methyl α-methacrylate): Plexiglas®
Likewise...

H₂C=CHCl → polyvinyl chloride
H₂C=CHC₂H₅ → polystyrene
F₂C=CH₂ → Teflon

Likewise...

Low-density polyethylene:
- soft and flimsy
- highly branched, amorphous structure
Cationic Polymerization

Alkene is treated with an acid. Intermediate must be a stable carbocation.

Anionic Polymerization

Alkene must have an electron-withdrawing group like C=O, C≡N, or NO₂. Initiator: Grignard or organolithium reagent.

Stereochemistry

Isotactic and syndiotactic polymers are stronger and stiffer due to their regular packing arrangement. Anionic intermediate usually gives isotactic or syndiotactic polymers. Free radical polymerization is nearly random, giving branched atactic polymers.

Ziegler-Natta Catalyst

Polymerization is completely stereospecific. Either isotactic or syndiotactic, depending on catalyst. Polymer is linear, not branched. Example of catalyst: solution of TiCl₄ mixed with solution of (CH₂CH₃)₃Al and heated for an hour.