Learning Guide for Chapter 10 - Alkenes I

I. Introduction to alkenes - p 1
   bond structure, classifying alkenes, reactivity, physical properties, occurrences and uses, spectroscopy, stability
II. Unsaturation number - p 6
III. Nomenclature of alkenes - p 7
IV. Intro to C=C reactions - p 11
V. Addition of HX to alkenes - p 11
VI. Acid-catalyzed hydration of alkenes - p 14

I. Introduction to alkenes

Bond structure
What is the hybridization, geometry, and molecular orbitals of an alkene?

hybridization:
geometry:
molecular orbitals:

What is wrong with the following line structures?

Which is higher in energy, the sigma or the pi bond? Why?

Classifying compounds with C=C's
What is the difference between alkenes, aromatic compounds, and unsaturated compounds?

alkene:

aromatic compound:

unsaturated compound:
Label each of the following.

![Chemical structures](image)

Compounds with more than one C=\text{C} are classified by how far apart they are. Which of the following structures is isolated, conjugated, and cumulated?

![Chemical structures](image)

**Physical properties**

How do the physical properties of alkenes compare to those of alkanes?

- polarity:
- water solubility:
- density:
- flammability:

What can you conclude from the following boiling points?

- bp = 0°C
- bp = -6°C
- bp = 30°C
- bp = 25°C
Reactivity

How does the reactivity of alkenes compare to alkanes?

Which of the following would you predict that an alkene could react as? Why?

- nucleophile
- electrophile
- acid
- base
- radical attackee

How strong of a reagent is an alkene? Why?

Predict the three types of mechanistic steps that an alkene can undergo.

\[
\begin{align*}
\text{alkene} & \quad \text{step} \\
\text{alkene} & \quad \text{step} \\
\text{alkene} & \quad \text{step}
\end{align*}
\]

Occurrence and uses of alkenes

Are alkenes common in nature?

Where are the following two compounds found?

\[
\text{compounds}
\]

Where do alkenes come from?

What is the most abundantly used organic compound, and what can you make with it?

\[
\text{compound}
\]
Spectroscopy

IR: What bands does an alkene have that an alkane does not?

NMR: What chemical shift do H's on C=C's have?

What happens to the splitting in an alkene?
Stability of alkenes

Put the following alkenes in order from most to least stable.

Now consider the alkenes below. Which is the most and least stable?

Which of these two rules takes precedence?

Why are small cyclic alkenes less stable?

normal angle:

What stereochemistry do most alkenes have? cis (or Z)

How big does a ring have to be before it is stable with a trans C=C?
II. Unsaturation Number

In chapter 2 we discussed molecular formulas for alkanes, cycloalkanes, and unsaturated hydrocarbons. What was the formula for a straight chain or branched alkane?

What happens when a pi bond or ring is present?

rings:  

pi bonds:  

both:  

If you have a formula, how can you figure out how many pi bonds or rings are present?

Now let's see what happens when we add other elements to the compounds.

Oxygen:  

Halogens:  

Nitrogen:
Generate a formula for figuring out how many H's a saturated compound would need if you have the number of C's, O's, X's, and N's:

Generate a formula for figuring out how many double bonds or rings you have:

Practice - calculate the unsaturation number for each molecular formula. Then draw a possible structure.

\[
\begin{align*}
C_6H_8 & \quad C_6H_{12}Cl_2 \\
C_6H_{12}O & \quad C_6H_{10}O \\
C_6H_{10}NBr & \quad C_6H_{13}N
\end{align*}
\]

III. Nomenclature of Alkenes

What are the priorities in choosing the principle chain for an alkane?

With alkenes, there is an addition, higher priority.
What are the priorities for numbering an alkane?

With alkenes, the C=C takes priority. The numbers must go across the C=C, and the number of the first carbon is the number of the alkene.

What about cyclic alkenes?

What if there are two or more C=C?

If alkanes end in "ane," what do you think alkenes end in?

How would you specify the location of the C=C?

How will the name change where there is more than one C=C?
If the C=C cannot be included in the principle chain, it must be named as a substituent. What are the two smallest ones called?

For all other substituents, the name comes from the alkyl name. How is it numbered?

**Stereochemistry in nomenclature**

When is it necessary to specify the stereochemistry of an alkene?

When may *cis* and *trans* be used?

When are *E* and *Z* appropriate?

What are the priorities for *E* and *Z*?
When is a number needed in the name with the E or Z?

Practice:
IV. Introduction to C=C reactions

The following are three basic types of reactions - substitution, elimination, and addition.

Addition reactions of C=C are NOT effective on benzene rings. These pi bonds are spread across the whole ring, and therefore don't behave the same as isolated C=C.

V. Addition of HX to alkenes

Alkyl halides can be formed by the reaction of alkenes with hydrogen halide acids like HI, HBr, and HCl. How could this happen?

Which side will the halogen end up on, and why?

What if two carbocations of equal energy could be formed?
What will happen if the carbocation can rearrange?

Show the carbocation(s) and product(s) of the following reactions.

Which of these alkyl halides could be synthesized using this reaction?
When chemists were first investigating this reaction, they noticed that once in a while with HBr, the products were opposite of what they expected. The halogen was on the spot where the less stable C+ would have been. Therefore, a C+ must not be involved in the reaction.

Eventually they discovered that this only occurred when trace amounts of organic peroxides were present. These caused a radical reaction to occur instead.

Why is only a small amount of peroxides necessary to change the products?

Will rearranged products form?

Predict the products of the following reactions.
VI. Acid-catalyzed hydration of alkenes

If sulfuric acid is used instead of HBr or HCl, a different product is formed.

\[ \text{H}_2\text{SO}_4 \]

Why is this reaction different from the reaction with HX?

If H$_2$SO$_4$ in water solution is used, what is the acid that actually reacts with the alkene?

How much acid is needed to make the reaction work?

Why do you think this reaction is called "hydration of an alkene"?

Would phosphoric acid (H$_3$PO$_4$) work?

If one side of the C= C is more substituted than the other, which side gets the OH? Why?

If both sides are equally substituted, what will happen?

Will rearrangements occur?
Predict the products of the following reactions:

\[
\begin{align*}
\text{benzene} & \xrightarrow{\text{H}_3\text{O}^+} \text{product} \\
\text{benzene} & \xrightarrow{\text{H}_2\text{SO}_4} \text{product} \\
\text{benzene} & \xrightarrow{\text{H}_3\text{PO}_4} \text{product} \\
\text{benzene} & \xrightarrow{\text{H}_2\text{SO}_4} \text{product}
\end{align*}
\]

Which of the following alcohols could be formed as the only products of a hydration reaction?

- no - both sides
- plus rearrangements

In the next chapter, we will consider several more addition reactions of alkenes.