The π bond of an alkene is sufficiently weak to undergo reaction with:

- Hydrogen (H₂)
- Halogen (F₂, Cl₂, Br₂)
- Hydrogen halide (HCl, HBr, HI)
- Water

Each of the above reagents undergoes an addition reaction with an alkene:

Reactions

- Alkenes are similar in structure and do similar reactions.
  - All contain a double bond
  - All contain the same functional group
- Reactions are categorized through different types of mechanisms.
Reactions

Typical for unsaturated systems is the *addition reaction*: $A + B \rightarrow C$

![Addition reaction diagram](image)

Reactions

A LOOK AT THE REACTANTS
Reactions

WHAT IS THE NATURE OF THIS REAGENT?

Reactions

Hydrogen bromide is a strong acid and forms hydronium ions, $\text{H}_3\text{O}^+$, and bromide, $\text{Br}^-$, when dissolved in water.

$\text{H}_3\text{O}^+$ is positively charged, thus it is **electron deficient**

it is **electrophilic** “electron loving”
Reactions

In the presence of an electron-rich species the hydronium ion reacts:

\[
\begin{align*}
\text{H}_3\text{C} &- \text{H}_2\text{C} - \text{C} &= \text{CH}_2 + \text{H}_3\text{C} - \text{C} &= \text{CH}_2 + \text{H}_2\text{O}^+ \\
\text{H}_3\text{C} & & \text{H}_3\text{C} & & \\
\end{align*}
\]

A new positively charged species is formed.

Reactions

The newly formed species, a carbocation, is again electron deficient, thus it is **electrophilic**.

\[
\begin{align*}
\text{H}_2\text{C} &- \text{C} = \text{CH}_2 - \text{CH}_3 \\
\text{H}_3\text{C} & & \text{H} & & \text{CH}_3 \\
\end{align*}
\]
Reactions

One species present that is rich in electrons is $\text{Br}^-$. Since $\text{Br}^-$ bears a negative charge it seeks for neutralization.

It is **nucleophilic** (nuclei are positively charged).

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Reactions

The two species, electrophile and nucleophile, combine and form a new compound.
Reactions

- Electrophiles:
  molecules that contain atoms with empty orbitals, which can accommodate electrons. Typically, these are positively charged.

- Examples:
  \[ \text{BF}_3 \]

Reactions

- Nucleophiles:
  molecules that contain atoms with lone pairs, which can donate electrons. Often these are negatively charged. Almost all the time they contain elements from groups 5–7 of the periodic table, since those have lone pairs.

- Examples:
  \[ \text{H}_2\text{O}, \text{Cl}^-, \text{CH}_3\text{NH}_2 \]
Reactions

**Nucleophiles:**
Organic molecules with double bonds (alkenes, alkynes) are also nucleophilic.

**Examples:**

![Molecular structures](image)

Mechanism

Summarizing our reaction, we realize it is a 2-step mechanism:

1. **STEP 1**
   
   $\text{HBr} + \text{H}_2\text{O} \rightleftharpoons \text{HBr}^\Theta + \text{H}_3\text{O}^\oplus$

2. **STEP 2**
   
   $\text{H}_3\text{C}^-\text{C}^-\text{CH}_2^-\text{CH}_3^+ + \text{Br}^\Theta \rightleftharpoons \text{H}_2\text{C}^-\text{CH}_2^-\text{CH}_3^+ + \text{H}_3\text{C}^\Theta$
Mechanism

Step 1 reaches a carbocation “intermediate.” One new bond is formed.

**Intermediates are species with a very short lifetime. However, their stability (energy) often determines the outcome of a reaction.**

Step 2 completes the reaction by forming a second bond. Again, it is the interplay between positively charged (electrophilic) and negatively charged (nucleophilic) species.
The chemical species that exists at the transition state, with old bonds in the process of breaking and new bonds in the process of forming:
Reactions

Overall reaction coordinate

\[
\begin{align*}
\text{Free energy} & \\
\text{Progress of the reaction} & \\
\end{align*}
\]

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