The double bond of an **alkene** consists of a sigma ($\sigma$) bond and a pi ($\pi$) bond. Because the carbon-carbon $\pi$ bond is relatively weak, it is quite reactive and can be easily broken and reagents can be added to carbon. Reagents are added through the formation of single bonds to carbon in an addition reaction.

**Introduction**

An example of an alkene addition reaction is a process called hydrogenation. In a hydrogenation reaction, two hydrogen atoms are added across the double bond of an alkene, resulting in a saturated **alkane**. Hydrogenation of a double bond is a thermodynamically favorable reaction because it forms a more stable (lower energy) product. In other words, the energy of the product is lower than the energy of the reactant; thus it is exothermic (heat is released). The heat released is called the heat of hydrogenation, which is an indicator of a molecule’s stability.

Although the hydrogenation of an alkene is a thermodynamically favorable reaction, it will not proceed without the addition of a **catalyst**.
Common catalysts used are insoluble metals such as palladium in the form Pd-C, platinum in the form PtO2, and nickel in the form Ra-Ni. With the presence of a metal catalyst, the H-H bond in H2 cleaves, and each hydrogen attaches to the metal catalyst surface, forming metal-hydrogen bonds. The metal catalyst also absorbs the alkene onto its surface. A hydrogen atom is then transferred to the alkene, forming a new C-H bond. A second hydrogen atom is transferred forming another C-H bond. At this point, two hydrogens have added to the carbons across the double bond. Because of the physical arrangement of the alkene and the hydrogens on a flat metal catalyst surface, the two hydrogens must add to the same face of the double bond, displaying syn addition.

Common Applications

Hydrogenation reactions are extensively used to create commercial goods. Hydrogenation is used in the food industry to make a large variety of manufactured goods, like spreads and shortenings, from liquid oils. This process also increases the chemical stability of products and yields semi-solid products like margarine. Hydrogenation is also used in coal processing. Solid coal is converted to a liquid through the addition of hydrogen. Liquefying coal makes it available to be used as fuel.

References


Problems

Complete the following reactions. Provide stereochemistry if necessary.

1. \[
\begin{align*}
\text{H} & \quad \text{H} \\
\text{C} & \quad \text{C} \\
\text{H} & \quad \text{C} \\
\text{H} & \quad \text{H}
\end{align*}
\]
\( + \quad \text{H}_2 \quad \text{Pd/C} \quad ?

2. \[
\begin{align*}
\text{C}_6\text{H}_5 & \quad \text{Br} \\
\text{C}_6\text{H}_5 & \quad \text{C}_6\text{H}_5 \\
\text{C}_6\text{H}_5 & \quad \text{C}_6\text{H}_5
\end{align*}
\]
\( + \quad \text{H}_2 \quad \text{Pd/C} \quad ?

3. \[
\begin{align*}
\text{C}_6\text{H}_{10} & \quad \text{C}_6\text{H}_{10} \\
\text{C}_6\text{H}_{10} & \quad \text{C}_6\text{H}_{10} \\
\text{C}_6\text{H}_{10} & \quad \text{C}_6\text{H}_{10}
\end{align*}
\]
\( + \quad \text{H}_2 \quad \text{Pd/C} \quad ?

4. \[
\begin{align*}
\text{CH}_3 & \quad \text{CH}_3 \\
\text{C}_6\text{H}_{10} & \quad \text{C}_6\text{H}_{10} \\
\text{C}_6\text{H}_{10} & \quad \text{C}_6\text{H}_{10}
\end{align*}
\]
\( + \quad \text{H}_2 \quad \text{Pd/C} \quad ?

5. \[
\begin{align*}
\text{C}_6\text{H}_{10} & \quad \text{Br} \\
\text{C}_6\text{H}_{10} & \quad \text{C}_6\text{H}_{10} \\
\text{C}_6\text{H}_{10} & \quad \text{C}_6\text{H}_{10}
\end{align*}
\]
\( + \quad \text{H}_2 \quad \text{Pd/C} \quad ?

6. \[
\begin{align*}
\text{CH}_3 & \quad \text{CH}_3 \\
\text{C}_6\text{H}_{10} & \quad \text{C}_6\text{H}_{10} \\
\text{C}_6\text{H}_{10} & \quad \text{C}_6\text{H}_{10}
\end{align*}
\]
\( + \quad \text{H}_2 \quad \text{Pd/C} \quad ?

7. \[
\begin{align*}
\text{CH}_3 & \quad \text{CH}_3 \\
\text{C}_6\text{H}_{10} & \quad \text{C}_6\text{H}_{10} \\
\text{C}_6\text{H}_{10} & \quad \text{C}_6\text{H}_{10}
\end{align*}
\]
\( + \quad \text{H}_2 \quad \text{Pd/C} \quad ?

Answers

1. 

2. 

3. 

4. 

5. 

6. 

Hydrogens add (syn addition) to the side opposite the bulky (CH$_3$)$_2$CH group due to steric hindrance.

7. 

Hydrogens add (syn addition) to the side opposite the CH$_3$ group, as this side is less hindered.

Contributors

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