1. Suggest a plausible arrow-pushing mechanism for the following reactions.

a. \[
\text{cat. HCl} \quad \begin{array}{c}
\text{CH}_3\text{OH} \\
65 \degree \text{C}, 21 \text{ h}
\end{array}
\]

\[
\begin{array}{c}
\text{O} \\
\text{OCH}_3
\end{array}
\rightarrow
\begin{array}{c}
\text{HO-} \\
\text{CH}_3
\end{array}
\rightarrow
\begin{array}{c}
\text{O} \\
\text{OCH}_3
\end{array}
\]

b. \[
\text{10 mol \% Et}_3\text{N} \quad \begin{array}{c}
\text{CH}_3\text{OH} \\
20 \degree \text{C}, 1 \text{ h}
\end{array}
\]

\[
\begin{array}{c}
\text{O} \\
\text{OCH}_3
\end{array}
\rightarrow
\begin{array}{c}
\text{HO-} \\
\text{CH}_3
\end{array}
\rightarrow
\begin{array}{c}
\text{O} \\
\text{OCH}_3
\end{array}
\]

Answer:

\[
\begin{array}{c}
\text{O} \\
\text{H-A}
\end{array}
\rightarrow
\begin{array}{c}
\text{+OH} \\
\text{A-}
\end{array}
\rightarrow
\begin{array}{c}
\text{-OH} \\
\text{A:}
\end{array}
\rightarrow
\begin{array}{c}
\text{H} \\
\text{A-}
\end{array}
\rightarrow
\begin{array}{c}
\text{O} \\
\text{HOMe}
\end{array}
\rightarrow
\begin{array}{c}
\text{O} \\
\text{H-B:}
\end{array}
\rightarrow
\begin{array}{c}
\text{O} \\
\text{OCH}_3
\end{array}
\rightarrow
\begin{array}{c}
\text{O} \\
\text{OCH}_3
\end{array}
\rightarrow
\begin{array}{c}
\text{O} \\
\text{H}
\end{array}
\]

b. Using the pK\(_a\)s below, estimate the relative ratios of HCl/protonated lactone/protonated methanol at the beginning of the reaction.
Since MeOH is the solvent and present at around 20 moles/L, it will have about 20 times more of the protons than we estimate here.

The important point is that most of the protons reside on MeOH$_2^+$, not HCl. However, since HCl is 10$^5$ more acidic, you can't predict which species is acting as the acid catalyst. Use H-A to symbolize the acid catalyst in your arrow-pushing mechanism.

2. Suggest a plausible arrow-pushing mechanism for the following reaction.$^2$

Answer:

3. Suggest a plausible arrow-pushing mechanism for the following reaction.$^3$

Answer:

4. Suggest a plausible arrow-pushing mechanism for the following transformation.$^4$
5. Suggest a plausible arrow-pushing mechanism for the following transformation.

Answer:

6. Suggest a plausible arrow-pushing mechanism for the following transformation.

Answer:

This is called the benzilic rearrangement.
7. Suggest a plausible arrow-pushing mechanism for the following transformation.\(^8\)

![Chemical structure and reaction mechanism]

\[
\begin{align*}
\text{O}_2\text{N} & \quad \text{O}_2\text{N} \\
\text{Ar} & \quad \text{Ar}
\end{align*}
\]

Answer:

![Mechanism diagram]

Additional Problems

8. Suggest a plausible arrow-pushing mechanism for the following transformation.\(^9\)

![Chemical structure and reaction mechanism]

Answer:
9. Suggest a plausible arrow pushing mechanism for the following reaction.\(^\text{10}\)

\[
\begin{align*}
\text{Thiophene} & \xrightarrow{\text{BrCN, } \text{K}_2\text{CO}_3} \text{Thiophenol} \\
\text{Ph} & \text{OH} \quad \text{Ph} & \text{OH} \\
\end{align*}
\]

62 °C, 24 h

Answer:

\[
\begin{align*}
\text{Thiophene} & \xrightarrow{\text{BrCN, } \text{K}_2\text{CO}_3} \text{Thiophenol} \\
\text{Ph} & \text{OH} \quad \text{Ph} & \text{OH} \\
\end{align*}
\]

\[
\begin{align*}
\text{Thiophene} & \xrightarrow{\text{BrCN, } \text{K}_2\text{CO}_3} \text{Thiophenol} \\
\text{Ph} & \text{OH} \quad \text{Ph} & \text{OH} \\
\end{align*}
\]

10. Suggest a plausible arrow-pushing mechanism for the following transformation.\(^\text{11}\)

\[
\begin{align*}
\text{Br} & \xrightarrow{\text{CH}_3\text{CO}_3\text{H, } \text{BF}_3\cdot\text{OEt}_2} \text{Br} \\
\text{Cl}_3\text{CCH}_3 & \text{50 °C, 10 d} \\
\end{align*}
\]

70% 

Answer:

\[
\begin{align*}
\text{Br} & \xrightarrow{\text{CH}_3\text{CO}_3\text{H, } \text{BF}_3\cdot\text{OEt}_2} \text{Br} \\
\text{Cl}_3\text{CCH}_3 & \text{50 °C, 10 d} \\
\end{align*}
\]

\[
\begin{align*}
\text{Br} & \xrightarrow{\text{CH}_3\text{CO}_3\text{H, } \text{BF}_3\cdot\text{OEt}_2} \text{Br} \\
\text{Cl}_3\text{CCH}_3 & \text{50 °C, 10 d} \\
\end{align*}
\]

I recommend that you also work these additional problems in Carey and Sundberg, 5th Ed.

Chapter 4 (Substitution) 4.2, 4.3, 4.13, 4.17

References

1 Cook, Cyril; Liron, Frederic; Guinchard, Xavier; Roulland, Emmanuel J. Org. Chem. 2012, 77, 6728 - 6742
11 Charles Fehr “A Novel Three-Carbon Ring Expansion Sequence Synthesis of Exaltone® and (±)-Muscone” Helvetica Chimica Acta 1983, 66, 2512–2518,