Synthesis of Ketones and Aldehydes

1. Ph\(-\text{OH}\) → Ph\(-\text{CHO}\)  
   \(\text{PCC}\)

2. Ph\(-\text{OH}\) → Ph\(-\text{CO}\)  
   \(\text{H}_2\text{CrO}_4\)

3. Ph\(-\text{C\(\equiv\)H}\)  
   1. BH\(_3\)·THF  
   2. NaOH, H\(_2\)O\(_2\)  
   Ph\(-\text{OH}\) → Ph\(-\text{CHO}\)  
   \(\text{PCC}\)

4. Ph\(-\text{C\(\equiv\)H}\) → Ph\(-\text{OH}\) → Ph\(-\text{CO}\)  
   \(\text{H}_2\text{O}, \text{H}^+\), \(\text{H}_2\text{CrO}_4\)

5. Ph\(-\text{C\(\equiv\)H}\)  
   1. O\(_3\)  
   2. Me\(_2\)S  

6. Ph\(-\text{C\(\equiv\)H}\)  
   Aldehyde  
   1. RMgBr  
   2. H\(^+\)  
   Ph\(-\text{OH}\) → Ph\(-\text{C\(\equiv\)H}\)  
   \(\text{H}_2\text{CrO}_4\)  
   Ketone

7. Ph\(-\text{C\(\equiv\)H}\)  
   acid or ester  
   1. LiAlH\(_4\)  
   2. H\(^+\)  
   Ph\(-\text{OH}\) → Ph\(-\text{C\(\equiv\)H}\)  
   \(\text{PCC}\)  
   aldehyde

8. R\(-\text{Br}\) → R\(-\text{OH}\) → R\(-\text{CHO}\)  
   \(\text{NaOH}\), \(\text{PCC}\)

9. Br → R\(-\text{OH}\) → R\(-\text{CO}\)  
   \(\text{NaOH}\), \(\text{H}_2\text{CrO}_4\)

10. Ph\(-\text{C\(\equiv\)H}\)  
    Markovnikov Addition  
    \(\text{Hg}^{2+}, \text{H}_2\text{O}\), \(\text{H}_2\text{SO}_4\)  
    \(\text{PCC}\)  
    Ketone

11. Ph\(-\text{C\(\equiv\)H}\)  
    Anti-Markovnikov Addition  
    1. (Sia)\(_2\)BH  
    2. NaOH, H\(_2\)O\(_2\)  
    Ph\(-\text{C\(\equiv\)H}\) \(\text{MECH}\)  
    Aldehyde
Reactions of Ketones and Aldehydes

19

\[
\begin{align*}
\text{aldehyde or ketone} & \quad \text{1. RMgBr} \quad \left[\begin{array}{c} R' R \\ \text{anion intermediate} \end{array}\right] \quad \text{Protonate} \quad \text{OH} \\
& \quad \text{2. H}^+ \\
\end{align*}
\]

**Anionic**

18.12, 10.9

20

\[
\begin{align*}
\text{aldehyde or ketone} & \quad \text{NaBH}_4 \quad \text{or LiAlH}_4 \\
& \quad \left[\begin{array}{c} R' R \\ \text{anion intermediate} \end{array}\right] \quad \text{Protonate} \quad \text{OH} \\
\end{align*}
\]

**Anionic**

18.12, 10.11

21

\[
\begin{align*}
\text{aldehyde or ketone} & \quad \text{KCN, HCN} \\
& \quad \left[\begin{array}{c} R' R \\ \text{anion intermediate} \end{array}\right] \quad \text{Protonate} \quad \text{OH} \\
\end{align*}
\]

**Anionic**

18.15

22

\[
\begin{align*}
\text{aldehyde or ketone} & \quad \text{H}_2\text{O}, \text{OH}^- \\
& \quad \left[\begin{array}{c} \text{OH} \\ \text{tetrahedral "hydrate"} \end{array}\right] \quad \text{"Hydrates" are present only as transient equilibrium species. They never form to 100% and are never isolable. Always in equilibrium their aldehyde or ketone.} \\
\end{align*}
\]

**Anionic**

18.14

23

\[
\begin{align*}
\text{aldehyde or ketone} & \quad \text{H}_2\text{O}, \text{H}^+ \\
& \quad \left[\begin{array}{c} \text{OH} \\ \text{tetrahedral "hydrate"} \end{array}\right] \quad \text{"Hydrates" are present only as transient equilibrium species. They never form to 100% and are never isolable. Always in equilibrium with their aldehyde or ketone.} \\
\end{align*}
\]

**Cationic**

18.14
Cationic


Notes:
- Reactions are reversible
- The “hemiacetal” is an intermediate, and can never be isolated
- The acetal can be isolated.
- Equilibrium considerations (LeChatelier’s principle) apply. When water is plentiful, things go to the left. When water is scarce or removed, and alcohol is abundant, things drive to the right.
- Use $\text{H}_2\text{O}/\text{H}^+$ to hydrolyze an acetal back to an aldehyde or ketone
- Use $\text{MeOH}/\text{H}^+$ to convert an aldehyde to an acetal
- Use $\text{HOCH}_2\text{CH}_2\text{OH}/\text{H}^+$ to convert a ketone to an acetal
- Aldehydes or ketones can be temporarily “protected” as their acetals, then later “deprotected” by hydrolysis

Cationic


Notes:
- “Z” can be a carbon, nitrogen, oxygen, or hydrogen atom/group.
- The “aminol” can’t be isolated, it’s only present at equilibrium.
- Equilibrium factors apply. Water drives to the carbonyl side; removal of water drives to the imine side.
“Tollens test” is a common chemical test for aldehydes. Ag$^+$ undergoes redox reaction with aldehydes to produce shiny Ag metal, or a “silver mirror”.

Notes:
- Acidic conditions. Doesn’t work well for molecules with acid-sensitive functionality.
- Works best for aromatic carbonyls. Saturated carbonyls are slower and less efficient.
- Acidic nature is complementary to the basic analog below.

No Mech Responsibility

Basic conditions. Doesn’t work well for molecules with base-sensitive functionality.

Basic nature is complementary to the acidic analog above.

No Mech Responsibility

Notes:
- Unique access to 2-hydroxyacids.

Used in combination with reaction 21, the formation of the hydroxy-nitrile.