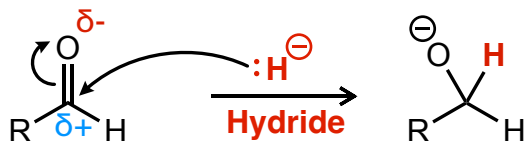
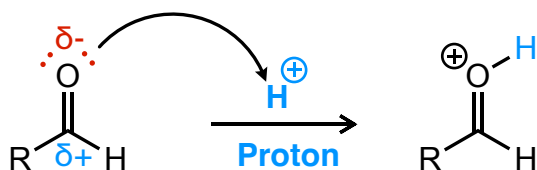


Carbonyl Additions - Aldehydes and Ketones Worksheet Key

1. Considering that the carbonyl group (C=O) can react with nucleophiles or electrophiles, **draw two example mechanisms**, one showing **how hydride interacts with an aldehyde** and one showing how a **proton interacts with an aldehyde**.



nucleophiles are attracted to the $\delta+$ (carbon) end of the C=O bond



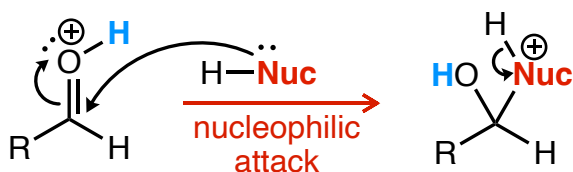
electrophiles are attracted to the $\delta-$ (oxygen) end of the C=O bond

2. In acid catalyzed carbonyl additions, like acetal reactions, the first mechanistic step results in the formation of the species shown below (for an aldehyde).

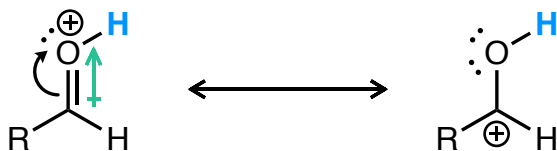
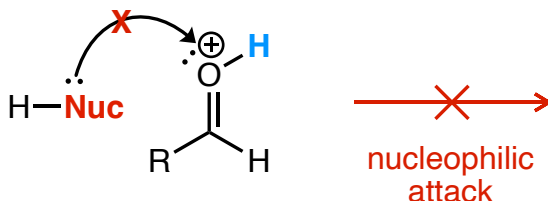
Given this Lewis structure, **why does nucleophilic attack occur at the carbonyl carbon as opposed to the oxygen with the formal positive charge?**

Hint: think about resonance and dipoles.

Reactivity observed:

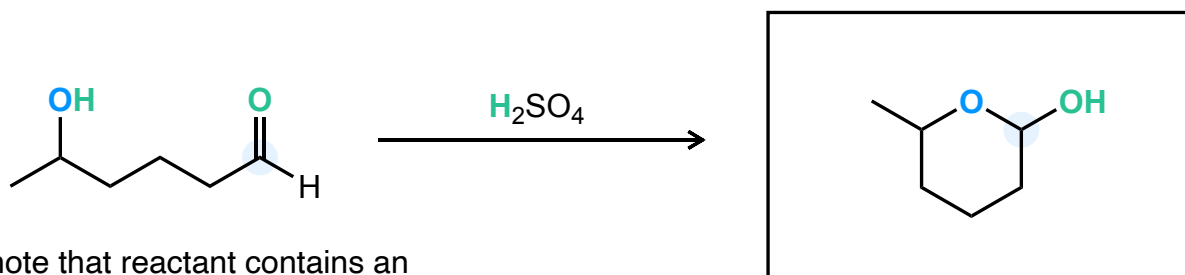
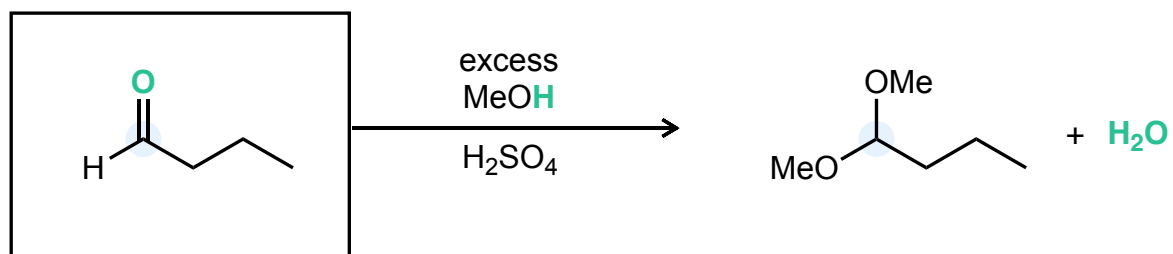
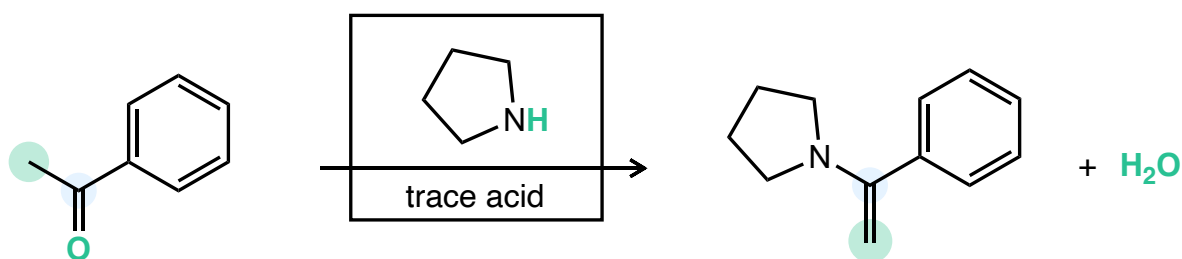
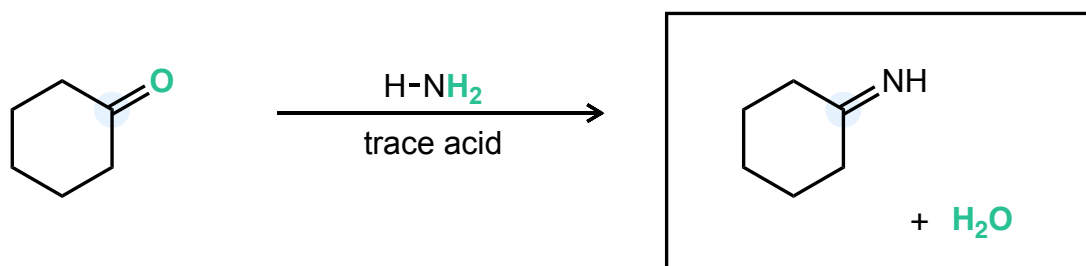
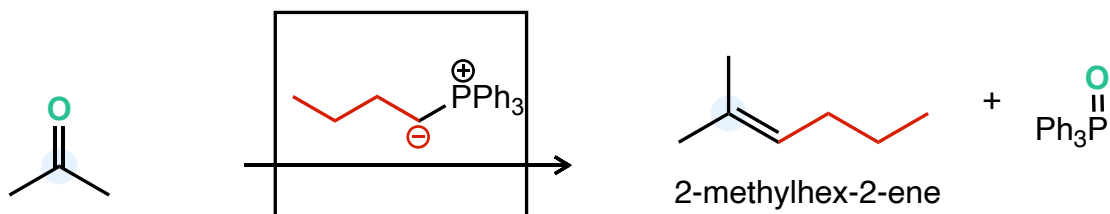


NOT observed:



The C=O bond dipole suggests that the Lewis structure shown above is an illustration of a resonance stabilized carbocation, hence the carbon maintains positive charge in either Lewis structure.

3. Provide the missing **starting material**, **reagent(s)**, or **major product** in each reaction below.

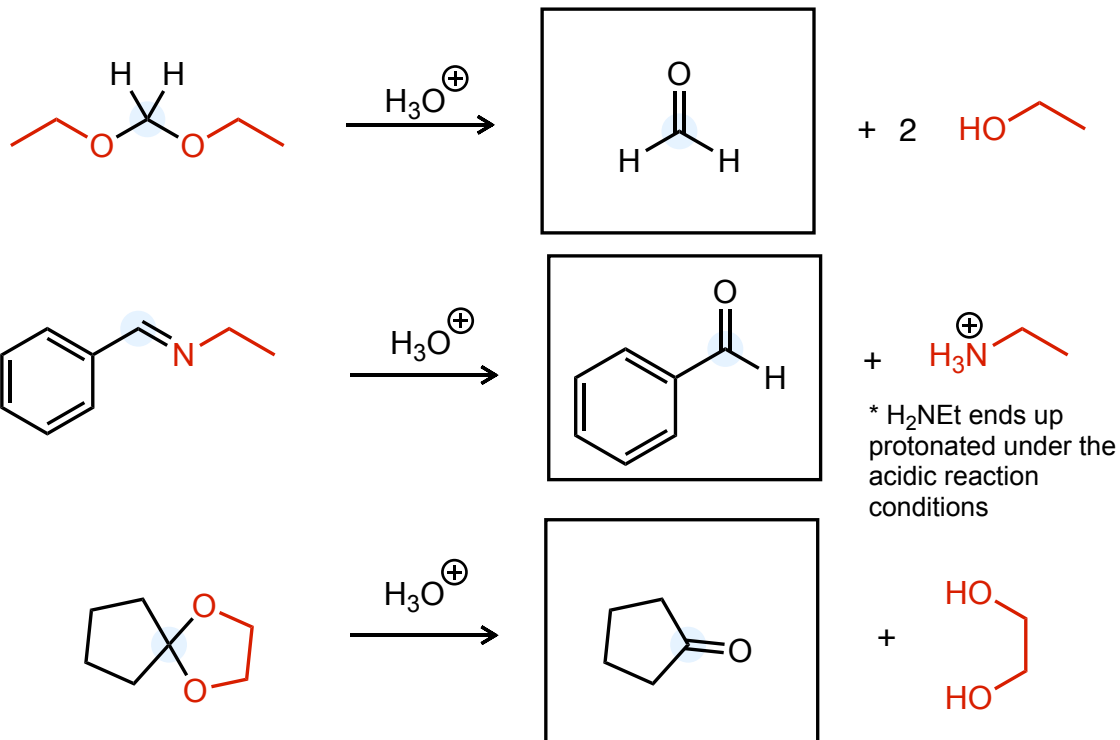


* note that reactant contains an alcohol and an aldehyde in the presence of a strong acid

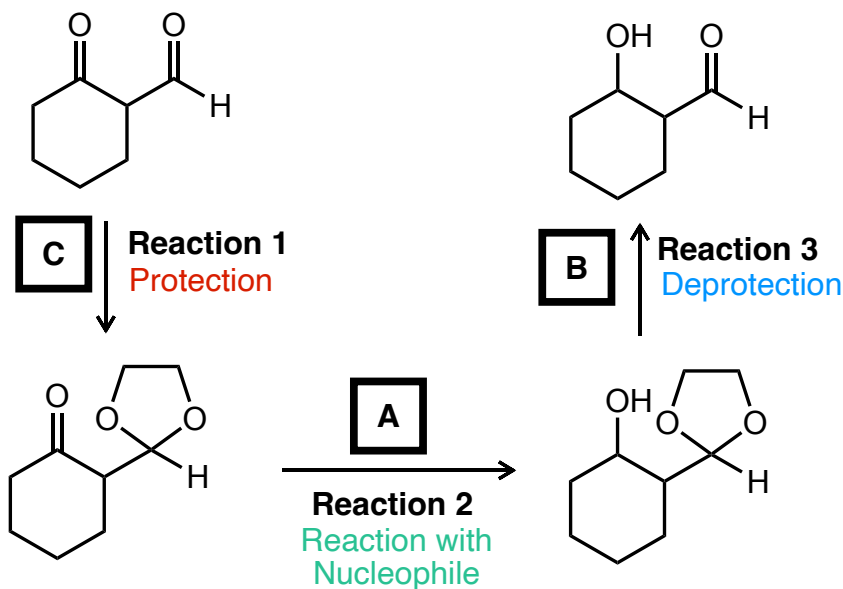
product is a cyclic hemiacetal

4. Many carbonyl addition reactions are reversible. Considering this, identify the carbonyl compound formed from the following reactions.

Note: It may be helpful to identify the reactant functional group and think about what carbonyl would have generated it.



5. Often times, acetal (or ketal) reactions are referred to as protection reactions because they protect the C=O bond from nucleophiles. The process shown below is an example of this. For each reaction, select the appropriate reaction description and the reagents needed for the transformation.



Reaction descriptions:

- X. Protection
- Y. Deprotection
- Z. Reaction with Nucleophile

Reagents

- A. 1. $NaBH_4$
2. H_3O^+

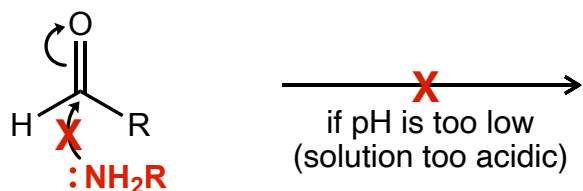
B. H_3O^+

- C. 1 equiv. OCCO
 H_3O^+

In this example, an important question to ask is why is the aldehyde protected and not the ketone? Keep in mind that aldehydes are more reactive than ketones.

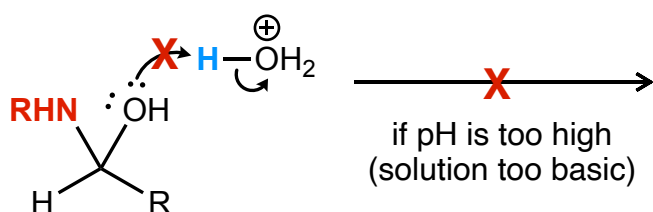
6. Although the formation of an imine, **requires** acidic conditions (pH range of 4-5), **the mechanism assumes nucleophilic attack of H_2NR first**, rather than protonation of the carbonyl oxygen. **So why is the pH range of 4-5 so important?**

A. Explain why an even lower pH would slow down (or stop!) the first step of this mechanism (check your class notes or the book for the mechanism). The mechanism for the nucleophilic attack is shown below.



The most basic reactant in this reaction is the amine (NH_2R). If the solution becomes too acidic, too much of the amine becomes **protonated**, at which point the conjugate acid ammonium species is no longer a nucleophile, and can no longer attack the $\text{C}=\text{O}$ bond.

B. Additionally, **why does a higher pH slow down the elimination of the carbonyl oxygen?** The mechanism for the desired elimination of the carbonyl oxygen is shown.



If the solution becomes too basic, the alcohol in the intermediate carbinolamine cannot become **protonated** to form water, which acts as a leaving group upon formation of the $\text{C}=\text{N}$ bond of the product imine (shown below).

