Chapter 16

Aldehydes and Ketones

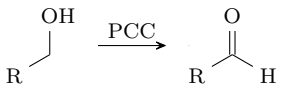
16.1 Electron Pushing

3/28:

- Levin and Weixin[1] are teaching.
- Problem sets are based on lecture content.
- Levin took the class just 13 years ago.
- We're gonna learn a lot about carbonyls this quarter.
- Unit 1: Additions to carbonyls.
- Defines carbonyls, ketones, aldehydes, and formaldehyde.
  - Formaldehyde is the most electrophilic carbonyl compound due to electronics and sterics: Carbons are both electron-donating and bulky.
  - Note that sterics are the primary factor.
- Carbonyls are electrophilic at the carbon (Levin draws the resonance structure).
- Reviews curved arrow formalism.
  - You should be able to write a full English sentence to describe each arrow.
    - In the formaldehyde resonance structure, for example, we can write, "The C=O π bond breaks and the electrons become a lone pair on the oxygen."
    - As another example, consider Et_3N attacking acetic acid, leaving behind the acetate ion. In this case, we can write the two sentences, "The nitrogen lone pair makes a new bond to the hydrogen" and "The O–H bond breaks and the electrons become a lone pair on oxygen."
  - You can draw arrows from negative charges; this notation is assumed to imply there's a lone pair on the negatively charged atom that actually does the attacking.
- Ways to make carbonyls.
  1. Oxidation of alcohols.
  2. Friedel-Crafts acylation.
  3. Ozonolysis.
  4. Diol cleavage.
  5. Alkyne hydration.
  6. Alkyne hydroboration.

[1] WAY-shin

- Oxidation of alcohols.
- General form.



- Mechanism.

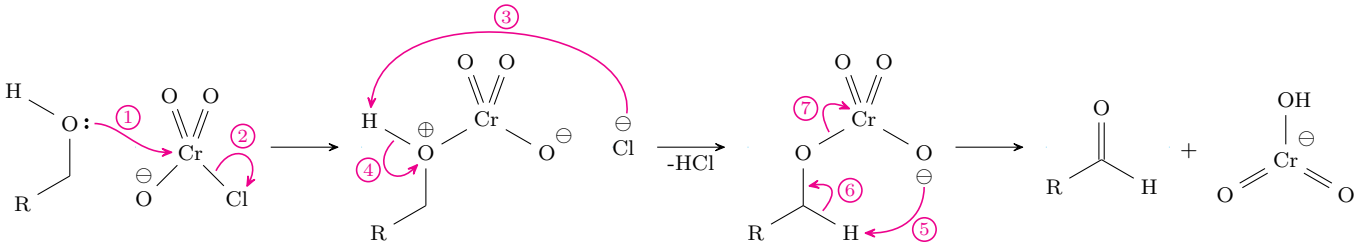
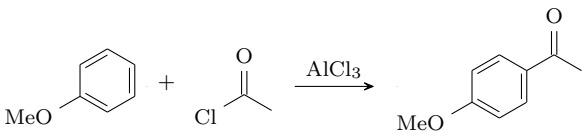


Figure 16.1: Oxidation of alcohols mechanism.

  - We could also draw a resonance structure of the CrO_2OH product that puts the negative charge on one of the previously double-bonded oxygens.
  - The mechanism of this reaction is hotly debated, and the above is only the most likely case.
    - One contested point of this mechanism is what the role of pyridinium is. Some mechanisms show it doing the third-step deprotonation, for example.
  - Note that the numbering of the curved arrows identifies them with the following sentences.
    1. Oxygen lone pair makes Cr–O bond.
    2. Cr–Cl bond breaks; becomes Cl l.p.
    3. Cl l.p. makes H–Cl bond.
    4. O–H bond breaks; becomes O l.p.
    5. O l.p. makes new OH bond.
    6. CH bond breaks and electrons make a new C=O π bond.
    7. O–Cr bond breaks; becomes a Cr l.p.

- Friedel-Crafts acylation.
- General form.



- Mechanism.

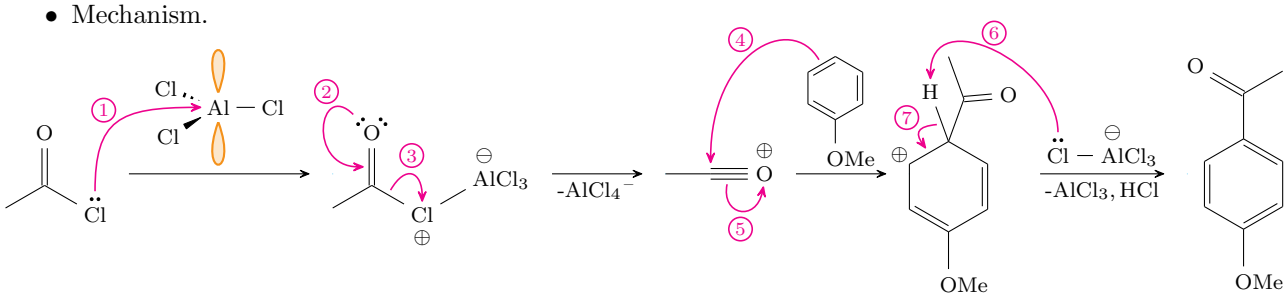
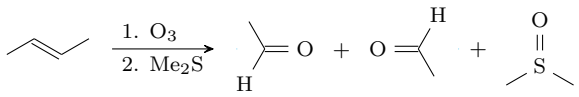


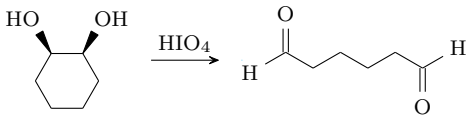
Figure 16.2: Friedel-Crafts acylation mechanism.

  - Note that the charge on aluminum in $AlCl_4^-$ is a *formal* charge; it is not indicative of the presence of a lone pair.
  - Remember that we form the ortho/para product because those dearomatized intermediates benefit more greatly from resonance stabilization.
  - Sentences.
    1. Cl l.p. makes a bond to aluminum.
    2. O l.p. makes C=O π bond.
    3. C–Cl bond breaks; becomes Cl l.p.
    4. C–C π bond breaks, and makes a new C–C bond.
    5. C≡O π bond breaks; makes O l.p.
    6. Cl l.p. makes a bond to H.
    7. C–H bond breaks; becomes a C=C π bond.

- We will not show any sentences hereafter, but it's a good idea to write them if you're still unclear on what the arrows are doing.
- Ozonolysis.
- General form.



- Mechanism.
  - Nearly identical to Dong's first quarter (Figure 7.3 of Labalme (2021)), but a few steps are combined and a few others are separated.
  - If you don't add Me_2S, you can isolate the ozonide intermediate. Use caution, however, as ozonides are explosive.
- Diol cleavage.
- General form.



  - Cis-diols react faster, but aren't necessarily required.
- Mechanism.

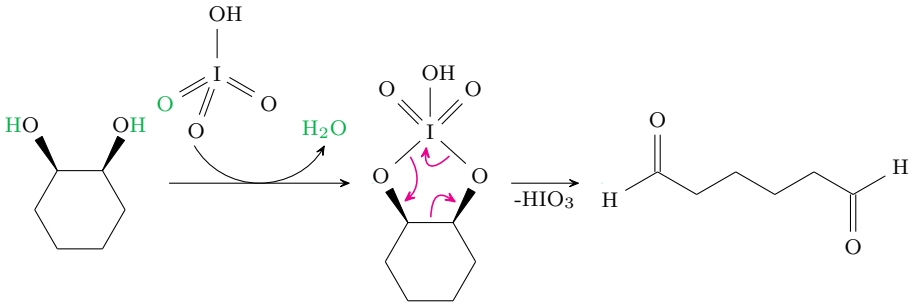
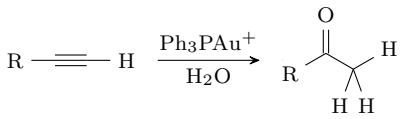


Figure 16.3: Diol cleavage mechanism.

- Alkyne hydration.
- General form.



  - Every place gold is we can use mercury instead, but since gold is less toxic and more active, we prefer to use it (even though it's more expensive). Any of the soft Lewis acid transition metals in the bottom-right corner island will work, though.

- Mechanism.

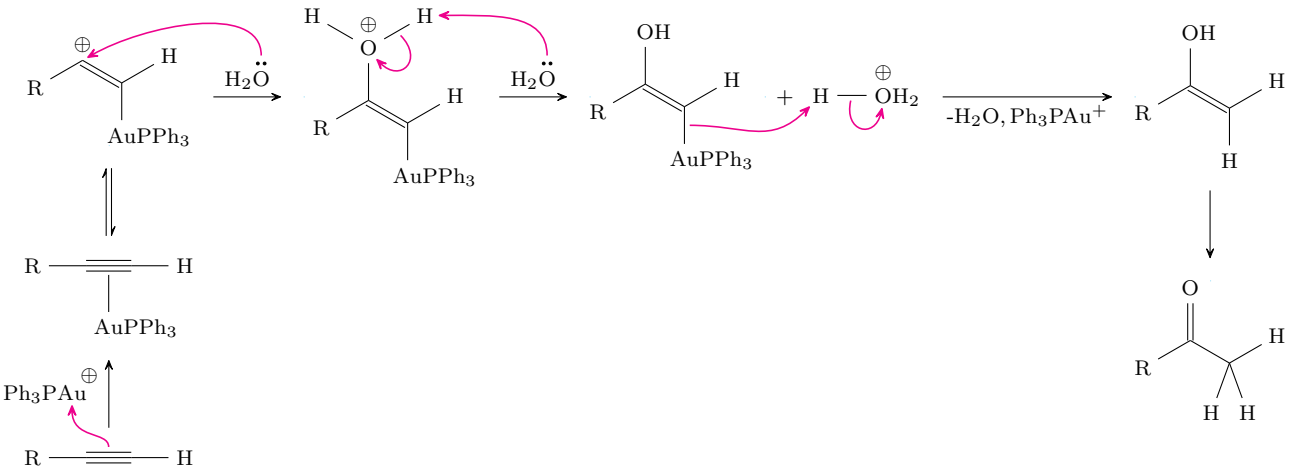
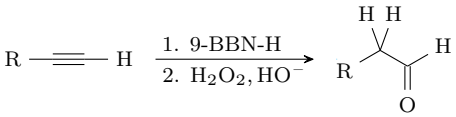


Figure 16.4: Alkyne hydrogenation mechanism.

  - We won't need to know the arrow-pushing mechanism for the tautomerization until Unit 3.

- Alkyne hydroboration.
- General form.



- **9-BBN-H**: 9-Borabicyclo[3.3.1]nonane, a source of R_2B-H with really big R groups, just like $(sia)_2BH$.
  Structure

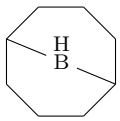


Figure 16.5: 9-Borabicyclo[3.3.1]nonane (9-BBN-H).

- Mechanism.
  - The **enol boronate** undergoes another kind of tautomerization (which, again, we'll see in Unit 3) to yield the final product.

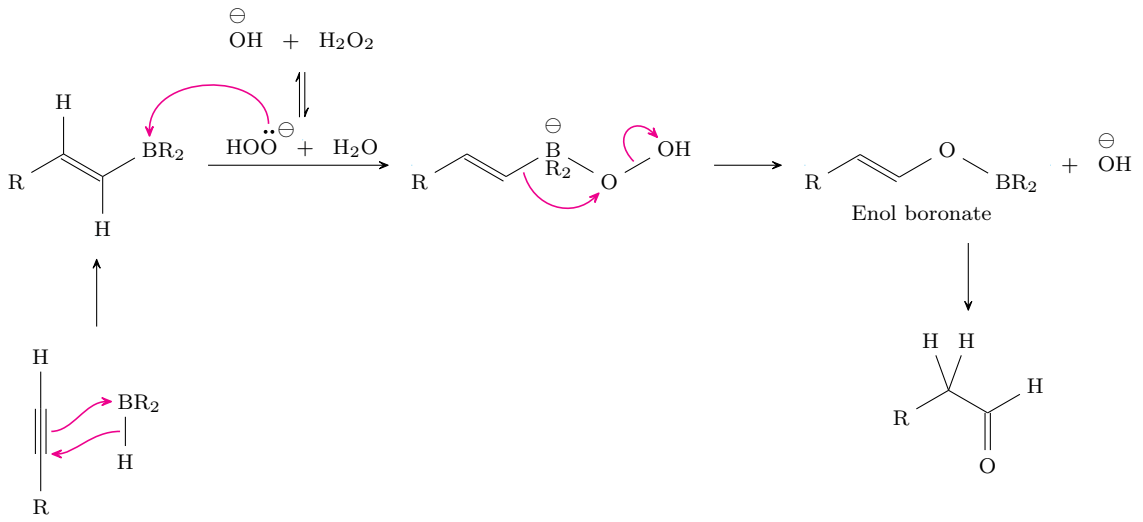


Figure 16.6: Alkyne hydroboration mechanism.

- The two(-ish) most important mechanisms in CHEM 222 are Figure 16.7 promoted either by acid or base.

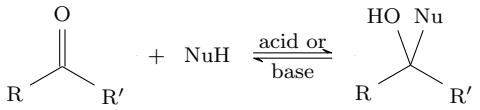
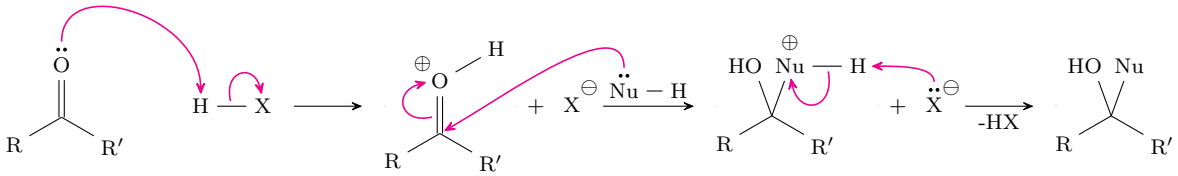
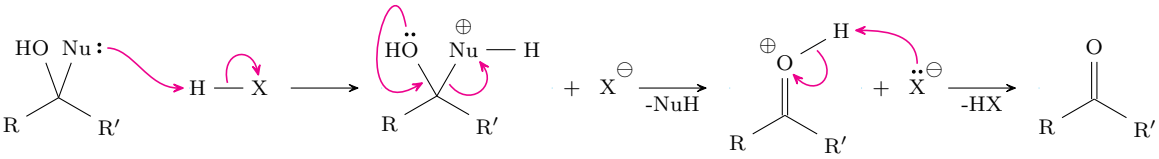


Figure 16.7: The key mechanism in CHEM 22200.

- Acidic mechanism.



(a) Forward direction.



(b) Reverse direction.

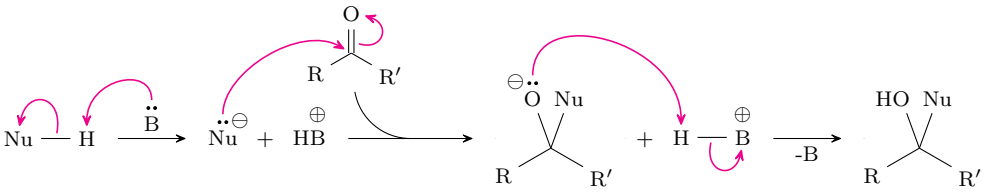
Figure 16.8: Nucleophilic addition/elimination with carbonyls (acid-promoted).

  - The forward and reverse mechanisms are the same.

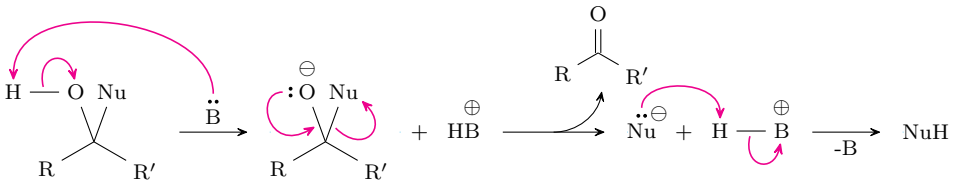
- **Principle of microscopic reversibility**: The lowest energy path in the forward direction must be the lowest energy path in the reverse direction.

- Basic mechanism.

  - B: means base, not boron.



(a) Forward direction.



(b) Reverse direction.

Figure 16.9: Nucleophilic addition/elimination with carbonyls (base-promoted).