

## Review Guide #6

Lectures: 2/28/05 – 3/4/05 Chapters 18 and 19

Chapter 18: The Chemistry of Aryl Halides, Vinylic Halides and Phenols: Transition Metal Catalysis (cont)

### I. Organometallic Catalysis

Transition metal catalysts are used to bring about reactions that would not otherwise occur. Some important reactions follow. (Please see Review Guide #5 for more information.)

You should know the mechanisms for these reactions.

- A. The Heck reaction: The halogen in aryl halides can be substituted by alkenes and nucleophilic groups using Pd(0) catalysts.
- B. Alkene Polymerization: Titanium and aluminum complexes are used with alkenes to make long polymer chains.
- Hydroformylation: A carbonyl can be added to an alkene using a cobalt catalyst.

### II. Phenols

#### A. Resonance Effects on Acidity

1. The enhanced acidity of phenol is due to resonance stabilization (delocalization of charge) of its conjugate base anion.
2. The polar effect of the benzene ring also stabilizes the negative charge of the phenolate anion.
3. Deactivating groups (ie. nitro group) affect acidity by both resonance and polar effects.  
eg. *m*-Nitrophenol is more acid than phenol because the nitro group is very electronegative, so the polar effect is observed. *p*-Nitrophenol is even more acidic because the nitro group stabilizes the conjugate base anion by resonance.

#### B. Phenol reactions

1. Williamson ether synthesis: When sodium hydroxide solution is added to a phenol, a phenoxide anion that is soluble in the aqueous solution is formed. Aryl ethers can be prepared by the reaction of the phenoxide anion and an alkyl halide.
2. Reactivity of the Aryl-O-bonds
  - a. As aryl halides, phenols do not react under conditions used for S<sub>N</sub>1 (E1) or S<sub>N</sub>2 (E2) reactions. Aryl ethers will cleave only at the alkyl-oxygen bond.
  - b. Stille reaction: Pd catalysts can be used to catalyze substitution at the aryl-oxygen bond. Phenol is treated with triflic anhydride to convert it to a triflate having a good leaving group -OTf. Aryl triflates react readily with organotin derivatives (X-SnMe<sub>3</sub>) in the presence of LiCl and Pd catalyst to give coupling products. The familiar reactions of transition metal complexes – oxidative addition, substitution and reductive elimination – are used in this process that makes new carbon-carbon bonds. (You do not have to know this mechanism.)

## Chapter 19: Chemistry of Aldehydes and Ketones: Carbonyl-Addition Reactions

**I. Chemistry of Aldehydes and Ketones**

Aldehydes and ketones are polar molecules due to their carbonyl group (C=O). The carbonyl carbon is  $sp^2$  hybridized and the carbon-oxygen double bond consists of a sigma and a pi bond.

**A. Spectroscopy of Aldehydes and Ketones**

1. Infrared spectroscopy - The C=O stretching absorption (around  $1710 - 1715 \text{ cm}^{-1}$ ) is the principal absorption. Ketones typically have lower absorptions than aldehydes. As the ring size of ketones decreases, absorption frequency increases. Conjugated double bonds absorb at lower frequencies. Another characteristic absorption is the carbonyl-hydrogen bond of aldehydes around  $2710 \text{ cm}^{-1}$ .
2. Proton NMR spectroscopy - Aldehydes have distinctive low-field absorptions at  $\delta$  9-11, and  $\alpha$  protons of both aldehydes and ketones absorb near  $\delta$  2.5 - downfield from allylic protons.
3. UV spectroscopy - Unconjugated aldehydes and ketones often have weak UV absorptions in the 200 nm range. Conjugated ketones ( $\alpha - \beta$  unsaturated ketones) have strong absorptions at slightly higher wavelengths (232 nm).
4. Mass Spectrometry -  $\alpha$ -Cleavage, inductive cleavage and the McLafferty rearrangement produce important fragments that are observed in mass spectra of aldehydes and ketones. The McLafferty rearrangement and subsequent  $\alpha$ -cleavage produces odd-electron fragment ions with even molecular mass. You should know this mechanism.

**B. Synthesis of Aldehydes and Ketones**

1. Oxidation of Alcohols - Primary alcohols can be oxidized by "Collin's reagent" ( $\text{CrO}_3$  and pyridine) to aldehydes, or with sodium dichromate producing carboxylic acids. Secondary alcohols can be oxidized by sodium dichromate or Collin's reagent to ketones.
2. Friedl-Crafts acylation provides a way to synthesize aryl ketones forming a carbon-carbon bond between the aryl ring and the carbonyl group.
3. Hydration of alkynes with  $\text{Hg}^{2+}$  and acid (water) is a useful way to produce ketones.
4. Hydroboration - oxidation and hydration of alkynes (with  $\text{Hg}^{2+}$  and acid) produce enols which are rapidly converted into the corresponding aldehydes or ketones.
5. Ozonolysis of alkenes with ozone followed by dimethyl sulfate, breaks the carbon-carbon double bond and produces aldehydes or ketones.
6. Periodate cleavage of glycols (1,2 diols) produces aldehydes or ketones.

**C. Aldehyde and Ketone reactions**

1. Reactions with acids - Aldehydes and ketones are weak bases, and are protonated on their carbonyl oxygens to give hydroxy carbocations. Protonation of the carbonyl group activates it for addition reactions.
2. Addition reactions - The most important carbonyl reaction is addition to the C=O double bond. Aldehydes are generally more reactive than ketones in nucleophilic addition reactions for both steric and electronic reasons.
3. Oxidation of aldehydes - Aldehydes can be oxidized to carboxylic acid

**Supplemental Problems**

Some suggested problems are: 19.15, 19.16, 19.18, 19.19, 19.21, 19.23, 19.24, 19.31, 19.34, 19.43, 19.44.