1 Nomenclature

Notation: Recall the following notation (primary, secondary etc.)

- IUPAC naming priority, **alcohol** > alkene ~ alkyne > halide (more oxidized functional groups have higher priority)
- suffix: -ol
- MULTIPLE FUNCTIONAL GROUPS: highest priority functional group suffix (e.g. -ol for alcohol) at the end
- number to give the -OH the lowest number, and if this is the same numbering from both "ends", THEN (and only then), number to give the first alkene the lowest number
- number to give the first substituent the lowest number ONLY IF ALL ELSE IS EQUAL
- with ONE -OH group (monoalcohol) names as alkanOL (e.g. 1-penatol)
- HOWEVER, with TWO -OH groups (diol) named as alkanEdiol (e.g. 1,3-pentanEdiol)
- note the use of number directly before the functional group in the examples above, used when we have multiple functional groups
- WHEN WE HAVE MULTIPLE FUNCTIONAL GROUPS, they are included in the name in the order: first -ene (if there is one), then -yne (if there is one) followed by -ol.

In addition to IUPAC names, many organic structures have "common" names, that are often historical, but are still widely used, more than the IUPAC names. Some Common Alcohols with Common Names:

- **methanol** *CH₃OH**
- **ethanol** *CH₃OH**
- **iso-propanol** *OH**
- **ethylene glycol** H₂O₂OH
- **glycerol** HO₂O₂OH
- **phenol** *C₆H₄OH

* Those with the * symbol you NEED TO KNOW!
2 Alcohol Acidity, Return to Substituent Effects

- Alcohols are weak acids, the -OH bonds are similar to those in water

**Example:** Simplest alcohol methanol

\[ \text{pKa} \approx 15.5 \]  
\[ \begin{array}{c}
\text{H}_2\text{O} \\
\text{H}_2\text{O}
\end{array} \xrightleftharpoons{} \begin{array}{c}
\text{HO}^{\ominus} \\
\text{H}_3\text{O}^{+}
\end{array} \]

\[ \begin{array}{c}
\text{CH}_3\text{OH} \\
\text{H}_2\text{O}
\end{array} \xrightleftharpoons{} \begin{array}{c}
\text{CH}_3\text{O}^{\ominus} \\
\text{H}_3\text{O}^{+}
\end{array} \]

- The conjugate base anion of water is the hydroxide anion
- The conjugate base anion of an alcohol is generically an alkoxide anion, i.e. the conjugate base anion of methanol is the methoxide anion, the conjugate base of ethanol is the ethoxide anion etc.
- In general we will find that the acidity of alcohols is determined by the energy of the electrons in the conjugate base anion, the lower the electron energy in the base, the weaker the base, the stronger acid is the alcohol
- For Example: Simple Resonance effects significantly influence alcohol Bronsted acidity

\[ \text{pKa} \approx 19.0 \]  
\[ \begin{array}{c}
\text{cyclohexanol} \\
\text{H}_2\text{O}
\end{array} \]

\[ \begin{array}{c}
\text{phenol} \\
\text{H}_2\text{O}
\end{array} \]

\[ \begin{array}{c}
\text{H}_3\text{O}^{+} \\
\text{H}_3\text{O}^{+}
\end{array} \]

- The energy of the non-bonding electrons in the conjugate base anion of phenol are lower compared to cyclohexanol due to resonance delocalization/stabilization, phenol is the stronger acid, has the smaller pKa

2.1 Substituent Effects: Important General Concept

- There are THREE main kinds of substituent effects, INDUCTIVE effect substituents, ALKYL substituent effects and RESONANCE effect substituents
- Substituent effects primarily influence the ENERGIES of the ELECTRONS that are involved in Bronsted acidity, and therefore influence this simple chemical reaction in ways that we are already familiar with
- A complicating factor in Bronsted acidity is that because liberation of a proton generates ions (the proton and the conjugate base anion), we will also sometimes need to take into account ionic solvation effects

1) Recall the Inductive Substituent Effect:

- **Inductive Effect:** This is the polarization of electrons in sigma-Bonds due to electronegative elements
- We previously saw this effect as being responsible for generating BOND DIPOLE MOMENTS

\[ \delta^- \]

- The polarization of electrons occurs because the electrons are STABILIZED by proximity to electronegative elements
- Electronegative elements are electronegative because they have more concentrated positive charges on the nucleus that are not highly shielded by electrons, which lowers the energy (increases the stability) of electrons not only on the electronegative atom but also on adjacent atoms that are connected via sigma-bonds.
The inductive effect normally stabilizes the conjugate base alkoxide anion. The inductive effect decreases rapidly with increasing distance between the electronegative element and the electrons of the base anion, here is an example from earlier in the course:

2) Alkyl groups as substituents:
- Alkyl groups stabilize cations by HYPERCONJUGATION, and destabilized anions due to electron repulsion.
- Alkyl groups stabilize carbocations by hyperconjugation, a form of resonance, hyperconjugation delocalizes electrons and charge, lowers the total energy of the electrons in the cation.

Extra methyl groups weakly destabilize the non-bonding electrons in alcohol conjugate base anions:

- The electron donation effect is actually pretty weak in this case, AND, probably more important is that the extra methyl groups also decrease solvation of the conjugate base anions, lowering the propensity of the alcohols to ionize in water, decreasing their acidity.
3) Alkyl (electron donating) substituents (on a pi-system):

- Simple Alkyl substituents weakly DONATE electron density into the ring as a result of HYPERCONJUGATION.
- The conjugate base anion is thus weakly destabilized by the methyl group. Alkyl groups are WEAKLY donating, because hyperconjugation is a much less effective form of electron donation compared to conventional resonance (below), because the donated electrons are already in a strong sigma bond.

2.2 Substituent Effects on Pi-Systems: Resonance and Inductive Effects (Resonance wins!)

- There are THREE main kinds of substituent effects, INDUCTIVE effect substituents, ALKYL substituent effects and RESONANCE effect substituents.

1) Resonance Donation into pi-Systems:
- Other substituents can stabilize positive charges and destabilize negative charges on pi-systems such as benzene rings via the inductive AND resonance electron donation and electron repulsion effects.
- Such effects are often larger than alkyl group substituent effects.
- Substituents can be classed as ELECTRON DONATING or ELECTRON WITHDRAWING when attached to pi-systems, depending upon whether they have inductive or resonance effects.
- The resonance in a substituent usually wins over the inductive effect when both are in effect.

2) Stronger Electron Donating substituents on a pi-system:
- Minor resonance contributors show how substituents DONATE electrons into a pi-system, e.g. benzene ring:

- The -NMe₂ substituents withdraws electron density via the inductive effect, BUT, the inductive effect is overwhelmed by the resonance donating effect, -NMe₂ is overall ELECTRON DONATING.
- Electron donating substituents DECREASE the Bronsted acidity of phenols.

3) Electron Withdrawing substituents on a pi-system:
- Minor resonance contributors show how substituents WITHDRAW electrons from a pi-system, e.g. benzene ring:

- The conjugate base pi-anion is resonance DESTABILIZED by the electron DONATING -NMe₂ group. The resonance donating effect is stronger than any inductive stabilization by the electronegative nitrogen.
• The -CHO substituent withdraws electron density via the inductive effect, AND via the resonance effect illustrated by the minor resonance contributors, -CHO is overall ELECTRON WITHDRAWING
• Electron withdrawing substituents INCREASE the Bronsted acidity of phenols

4) Position of Substituents on a pi-system:
• The pKa of unsubstituted phenol is ca. 9.0
• Consider 4-nitrophenol:

• The conjugate base pi-anion is resonance STABILIZED by the electron WITHDRAWING -CHO group
• The -CHO group is electron withdrawing on a pi-system, electron withdrawal occurs by both resonance and inductive effects

• The conjugate base pi-anion of 4-nitrophenol is directly stabilized by the inductive AND resonance effect of the nitro (-NO2) substituent, the formal negative charge is delocalized onto the carbon that the -nitro group is attached, the negative charge is further resonance stabilized by the nitro group, the base anion is stabilized and the acid is thus stronger.

• The pKa of unsubstituted phenol is ca. 9.0
• Consider 3-nitrophenol:

• The conjugate base anion is NOT DIRECTLY stabilized by the nitro (-NO2) substituent because the formal negative change is not delocalized onto the carbon that the substituent is attached to, there is no resonance stabilization although there is still some inductive stabilization of the conjugate base anion, 3-nitrophenol is more acidic than phenol but less acidic than 4-nitrophenol.
Summary of Electron Withdrawing/Donating Substituents WHEN ATTACHED TO PI-BONDING SYSTEMS

- \(\text{donating and withdrawing ability when bonded to a pi-system measured relative to hydrogen}\)

- \(\text{distinguishing the D- and W- groups is easier than it looks (no memorization!!)}\)

\(\text{the donating groups have non-bonding electrons or electrons in pi-bonds that can be used to DONATE to the attached pi-system}\)

\(\text{just about every other substituent is withdrawing due to the presence of electronegative elements, W- groups do NOT have non-bonding electrons on the atoms that is connected to the pi-system}\)

3 Oxidation/Reduction: Definition

- \(\text{the General Chemistry Definition of oxidation and reduction is the addition and subtraction of electrons}\)

- \(\text{Counting electrons in ORGANIC structures is difficult because the electrons are mainly shared in covalent bonds}\)

- \(\text{There are formal ways of counting electrons in bonds that require learning rules, so we will skip this}\)

- \(\text{There is also a slightly less formal way that we WILL use, that focuses attention on the ATOMS that are involved in the bonds that are made and are broken for the organic structure in question}\)

- \(\text{When a new bond is made (for example) from a carbon atom to a MORE ELECTRONEGATIVE atom (usually oxygen), that is OXIDATION (the more electronegative element "takes" an electron from the carbon)}\)

- \(\text{When a new bond is made (for example) from carbon atom to a LESS ELECTRONEGATIVE atom (usually hydrogen), that is REDUCTION (the more electronegative element "gives" an electron to the carbon)}\)

**Oxidation:** Making NEW BONDS to more electronegative elements, usually oxygen

**Reduction:** Breaking OLD BONDS to (removing or replacing) less electronegative elements, usually hydrogen

Attention is focused on the atoms that are involved in the BONDS THAT ARE MADE and BROKEN, other atoms are not important

**Examples**

- For the starting organic structure, the new bonds are to both to the less electronegative hydrogen (2 x H added), thus, overall REDUCTION of the organic structure

- For the starting organic structure, the new bonds are to both to the more electronegative bromine (2 x Br added), thus, overall OXIDATION of the organic structure

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• for the starting organic structure, bonds are broken to less electronegative H atoms (2 x H are removed), thus, overall OXIDATION of the organic structure

• for the starting organic structure, the new bonds are to the more electronegative bromine AND to the less electronegative H (1 x Br and 1 x H added), thus, overall NEITHER oxidation or reduction of the organic structure

• for the starting organic structure, the new bonds are to the more electronegative oxygen AND to the less electronegative H (1 x O and 1 x H added), thus, overall NEITHER oxidation or reduction of the organic structure:

NOTE the fact that a H atom is also added to the structure via the -OH group is irrelevant, it is only the atoms that are involved in forming bonds to the organic structure that are important.

4 Preparation of Alcohols

4.1 Review of Reactions We Have Already Seen

Recall:

1. Hg(OAc)$_2$ / $\text{H}_2\text{O}$
2. $\text{NaBH}_4$

1. $\text{BH}_3$ · THF
2. $\text{OH}/\text{H}_2\text{O}_2$

$\text{H}_2$ $\text{Pd}/\text{C}$

• There are conditions where catalytic hydrogenation (reduction) of C=C bonds can be performed without reducing a C=O bond (see the last example above), but this is a bit specialized for this course

4.2 Hydride Reduction of the Carbonyl Group

Catalytic hydrogenation can actually get quite subtle, with different catalysts, one functional group can be reduced in the presence of another, e.g.:

$\text{H}_2$ $\text{Raney Nickel}$

adds 2 H to BOTH C=C and C=O bonds
To prepare an alcohol, however, we need to do **selective reduction** of ONLY the C=O bond, HOW?

A Lewis base (e.g. hydride anion) tends not to react with another Lewis base, and so does not react with the alkene, but DOES react with the carbonyl (C=O) group, which can act as a Lewis acid

**Some (new) reagents:**

- **Electrons not in bond, very reactive**
  - Al larger, electrons in weaker Al-H bond
  - B smaller, electrons in stronger B-H bond

**Sodium Hydride (NaH)**
- very reactive

**Lithium Aluminum Hydride (LiAlH₄)**
- "masked hydrides"
- less reactive, more useful

**Sodium Borohydride (NaBH₄)**
- least reactive, most selective

**In Principle:**

- Both hydride anion and the alkene are nucleophiles (Lewis bases), thus no reaction there
- A hydride anion (H⁻) and a proton (H⁺) are equivalent to 2 hydrogen atoms (2 H.)

**In Practice:**

- NaH is too reactive and too strong a Bronsted base (less selective). NaH will usually deprotonate an aldehyde/ketone rather than add to the C=O bond, LiAlH₄ or NaBH₄ used instead

- The BH₄⁻ anion is less reactive than H⁻ because the electrons are in a bond, therefore lower in energy
- Overall, BH₄⁻ supplies H⁻, EtOH supplies H⁺. Together H⁻ and H⁺ make H₂.
Example: (stereochemistry ignored)

Why does the NaBH₄ reduce the ketone and not the ester, and the LiAlH₄ reduce both?

- The less reactive NaBH₄ reduces aldehydes and ketones but not esters.
- The more reactive LiAlH₄ also reduces esters (and acids).
- The \((H₃Al-H)⁻\) bond is weaker than the \((H₃B-H)⁻\) bond, and so is more reactive.
- Esters and acids are less reactive than aldehydes and ketones due to better resonance stabilization.

Alternatively:

We can consider that C=O to be a simple \(\pi\)-system (the same way that a benzene ring is a larger \(\pi\)-system), and the ester has a strong donating group attached to the carbon of the C=O, which decreases its reactivity towards a Lewis base/nucleophile, aldehydes/ketones have only weak donating groups attached to the carbon of the C=O group, they are more reactive.

To reduce the less reactive esters, the more reactive LiAlH₄ is required.

More on LiAlH₄:
- The AlH₄⁻ ion will react violently with water and alcohols, so the proton has to be added in a second ACID WORKUP step, hence the notation: 1. LiAlH₄ ... 2. H₃O⁺
- In this second acid workup step, just enough dilute acid is used to "complete" the reaction.
- The protonation is essentially instantaneous, i.e. this is NOT the same as acid catalyzed addition of water to an alkene (for example), which requires higher concentrations of acid, a lot of time and usually some heat.

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this is our first example of an addition/elimination mechanism, we will see this again later.....

• note REMOVAL of the -OR group of the ester in the elimination step
• elimination occurs because the -OR is a reasonable leaving group (but not great!), AND elimination is favored by entropy, AND, occurs because the species that is eliminating already has a negative charge on oxygen
• NOTE that the -OR leaving group will get protonated in the acid step to form usually a simple alcohol (HOR) that is often not included in the products since it is not part of the main organic structure, it is a BY-PRODUCT
• A negatively charged oxygen CAN BE a leaving group, but only if the reaction STARTS with high chemical potential reactants that provide the energy to allow an oxygen anion to leave, for example a strong Lewis base that is an anion, e.g. the aluminum hydride anion (AlH4–)

Examples: (steric chemistry ignored)

NaBH4 reacts ONLY with the aldehyde, the ester is less reactive and the alkene is also a Lewis base
LiAlH4 reacts with the aldehyde AND the carboxylic acid (the acid reaction proceeds via addition/elimination)
The H3O+ in the LiAlH4 reaction does NOT react with the alkene, because in this context, H3O+ means “add just enough dilute aqueous acid to protonate the negatively charge oxygen atoms”. When acid catalyzes water addition to the C=C bond of an alkene the acid concentrations are high, the reaction time is long and the temperature has to be high, the context defines the meaning of H3O+.

5 Reactions of Alcohols

5.1 Oxidation

Here are a couple of oxidation reactions

\[
\begin{align*}
\text{alcohol} & \quad \xrightarrow{\text{NaBH}_4} \quad \text{alcohol} \quad \xrightarrow{\text{LiAlH}_4, \text{H}_3\text{O}^+} \quad \text{aldehyde} \quad \xrightarrow{\text{add 1 oxygen atom}} \quad \text{carboxylic acid}
\end{align*}
\]

• These reactions can be CONTROLLED by appropriate choice of reagent/conditions

New Cr(VI) Reagent #1:

\[
\begin{align*}
\text{Na}_2\text{Cr}_2\text{O}_7 + \text{H}_2\text{SO}_4 & \quad \xrightarrow{\text{H}_2\text{O}} \quad \text{HO-Cr-OH} + \text{Na}^+ -\text{HSO}_4^-
\end{align*}
\]

• the reagent is sodium dichromate and sulfuric acid dissolved in water, this generates chromic acid "in situ"

Example with a SECONDARY Alcohol

• oxidation to form a KETONE

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• mechanisms involving oxidation/reduction of metals do not follow the usual patterns of Lewis acid/base Bronsted acid/base reactions, AND they tend to be specialized and specific, for this reason you do not have to know this mechanism

Example with a PRIMARY Alcohol:
• oxidation to form a carboxylic acid
THE overall process is as follows:

• note that formation of the aldehyde from the alcohol is oxidation (removes 2 H atoms)
• note that formation of the acid from the hydrate is oxidation (removes 2 H atoms)
• note that formation of the hydrate from the aldehyde is NEITHER oxidation or reduction

Details: FIRST, formation of the aldehyde via the same mechanism as above

Details: SECOND, conversion of the aldehyde into the hydrate in the presence of water and an acid catalyst, you DO NEED TO KNOW THIS MECHANISM. Remember, the reaction conditions involve sulfuric acid in water, the next step is simply acid catalyzed addition of water to the aldehyde

Final Detail: THIRD, conversion of the hydrate (a geminal di-alcohol) into a carboxylic acid, via the same mechanism as before, the chromic acid removes 2 hydrogen atoms from the hydrate, which forms the carboxylic acid, the mechanism by which chromic acid does this is the same as formation of the aldehyde from the primary alcohol, you don't need to know this and it is not shown again here
• the hydrate gets oxidized to a carboxylic acid because it is now a (di) alcohol

Example with a TERTIARY Alcohol:

• tertiary alcohols cannot be oxidized, the necessary hydrogen atom is missing

New Cr(VI) Reagent #2:

\[ \text{CrO}_3 + \text{HCl} + \text{CH}_2\text{Cl}_2 \rightarrow \text{Pyridinium chlorochromate (PCC)} \]

• CH2Cl2 is the SOLVENT, therefore there is NO WATER here, so any aldehydes that are formed cannot make a hydrate, so further oxidation to a carboxylic acid will not occur

PCC with a PRIMARY Alcohol:

\[ \text{don't need to know!!!} \]
5.2 Formation of Alkyl Halides

- Consider the following substitution reaction, is it possible?

\[
\text{R} - \text{CH}_2\text{OH} \xrightarrow{\text{LA}} \text{R} - \text{CH}_2\text{X} + \text{OH}^{\ominus}
\]

- It doesn't work! in fact, goes in reverse - "OH will substitute for X" (think standard SN2 reaction)
- "OH is too poor a leaving group, need to make a better leaving group!

Reactions with Haloacids: HCl, HBr, HI, etc.

- Reactions with Haloacids: HCl, HBr, HI, etc.
• this is better, we have seen strategies like this before
• however, SN1 mechanism for 2° and 3° alcohols, thus, still the usual problem with the cation intermediate, elimination, rearrangements etc.
• SN2 mechanism for 1° alcohols, but still, the halide anions are poor nucleophiles, something better is needed
• these reactions are actually usually performed using concentrated HBr, HCl etc., and so the initial protonation is probably via H3O+, but that is not a critical point, in a mechanism you show protonation using either the hydronium ion or the acid

Reaction with PBr₃ (phosphorous tribromide):

• SN2 mechanism works well with both 2° and 1° alcohols due to better leaving group, good reaction
• only problem is 3° halides, which still don’t work well for steric reasons (recall, no SN2 at 3° centers!)

Reaction with SOCl₂ (thionyl chloride):

• here we see an ADDITION/ELIMINATION mechanism, we will see a lot of these later in the semester
• we will see that many reactions that form small stable molecules, such as SO₂, are fast and exothermic
• again, SN2 mechanism works well for 1° and 2° alcohols, avoids cation intermediates, good reaction
• again, only problem is no SN2 in 3° alcohol case

Reaction Summary

<table>
<thead>
<tr>
<th>Preferred Reagents</th>
<th>Chloride</th>
<th>Bromide</th>
</tr>
</thead>
<tbody>
<tr>
<td>1° alcohol</td>
<td>SOCl₂</td>
<td>PBr₃</td>
</tr>
<tr>
<td>2° alcohol</td>
<td>SOCl₂</td>
<td>PBr₃</td>
</tr>
<tr>
<td>3° alcohol</td>
<td>HCl</td>
<td>HBr</td>
</tr>
</tbody>
</table>

5.3 Formation of Tosylate Esters

Why are Tosylates Useful?
• Try this substitution reaction:

• Now try this one:

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this is OK, except that is will rarely be useful because you need to protonate the -OH first, THEN add the nucleophile (which is a Lewis base and often a reasonable Bronsted base) and hope that the nucleophile doesn’t just get protonated, hmmmm, something better is really needed….

• Finally this one:

  - The tosylate anion is highly resonance stabilized, it is low energy non-bonding electrons, which is why it is such a good leaving group

Where do tosylate (esters) come from?

\[
R\text{-OH} + \text{Tosyl chloride} \xrightarrow{\text{pyridine}} R\text{-OTs} \\
\text{alcohol} \quad \text{tosyl chloride} \quad \text{tosylate (ester)}
\]

\[
R\text{-OH} + \text{Tosyl chloride} \xrightarrow{\text{pyridine}} R\text{-OTs} \\
\text{alcohol} \quad \text{tosyl chloride} \quad \text{tosylate (ester)}
\]

• you don’t need to know the mechanism, but you DO need to know that you need pyridine to remove the proton

some clarification on notation and structure…..

\[
\text{"Tosyl" group} = -\text{Ts} \quad \text{\(\text{"Tosylate" group} = \ominus\text{OTs}\) (para-toluenesulfonate)}
\]

Examples: Useful reactions:

weak nucleophile \(\text{Na}^+\text{-}\text{Br}\)

weak nucleophile \(\text{Na}^+\text{-}\text{CN}\)

weak nucleophile \(\text{H}_3\text{CO}\)

weak nucleophile \(\text{H}_3\text{N}\)
5.4 Dehydration (a Review)

Recall:

\[
\begin{align*}
  &\text{H}_3\text{C}-\text{C}-\text{CH}_3 \quad \text{conc. H}_2\text{SO}_4 \quad \text{heat} \\
  &\rightarrow \quad \text{H} = \text{C} = \text{C}-\text{CH}_3 + \text{H}_2\text{O}
\end{align*}
\]

Compare, the Pinacol Rearrangement: (another kind of alcohol dehydration)

\[
\begin{align*}
  &\text{H}_3\text{C}-\text{C}-\text{CH}_3 \quad \text{H}_2\text{SO}_4 \quad \text{H}_2\text{O} \\
  &\rightarrow \quad \text{H}_3\text{C}-\text{C}-\text{CH}_3 + \text{H}_2\text{O}
\end{align*}
\]

• Let's treat this as a mechanism problem, how to solve it and what basic principles can we use to guide us?
• Look carefully at the reagents/conditions (in this case, acid in water)
• Look for differences in start and end structures
• Need to remove \(-\text{H}\) and \(-\text{OH}\) and do an alkyl shift
• Acid catalyzed, therefore protonate first, no anionic intermediates in presence of acid

The Mechanism:

• protonate to make a good leaving group (\(\text{H}_2\text{O}\))
• usual carbocation rearrangement to make a more stable (resonance stabilized) cation intermediate
• Deprotonation at the end regenerates the acid catalyst

Example Mechanism Problem: A "Hidden" Pinacol rearrangement
6 Alcohols: Summary of Reactions

Do NOT start studying by trying to memorize the reactions here!

Work as many problems as you can, with this list of reactions in front of you if necessary, so that you can get through as many problems as you can without getting stuck on eth reagents/conditions, and so that you can learn and practice solving reaction problems. Use this list AFTER you have worked all of the problems, and just before an exam. By then you will have learned a lot of the reagents/conditions just by using them and you will only have to memorize what you haven’t learned yet. Then do the following:

• Cover the entire page of reagents/conditions with a long vertical strip of paper, see if you can write down the reagents/conditions for each reaction, check to see which you get correct, if COMPLETELY correct, circle Y, if incorrect or even slightly incorrect, circle N. In this way you keep track of what you know and what you don’t know.
• Keep coming back to this list and so the same thing only for those reactions you circled N, until all are circled Y.
• Knowing the reagents/conditions on this page is INSUFFICIENT to do well on an exam since you will ALSO need to recognize how to use and solve reaction problems in different contexts, this page ONLY helps you to learn the reagents/conditions that you have not YET learned by working problems.

CH\(_2\)OH

\[ \text{LiAlH}_4 \] \text{EtOH} \quad \text{Y / N}

\[ \text{NaBH}_4 \] \text{EtOH} \quad \text{Y / N}

\[ \text{LiAlH}_4 \text{ also does this reaction} \]

\[ \text{EtOH} \]

\[ \text{H}_2 \] \text{Pd/C} \quad \text{Y / N}

\[ \text{H}_2 \text{O} \]

\[ \text{NaBH}_4 \text{ does NOT do this reaction} \]

\[ \text{NaBH}_4 \]

\[ \text{CH}_2\text{Cl}_2 \text{ solvent is optional} \]

\[ \text{PCC} \]

\[ \text{CH}_2\text{Cl}_2 \text{ solvent is optional} \]

\[ \text{NaBH}_4 \]

\[ \text{EtOH} \]

\[ \text{H}_2 \text{O} \]

\[ \text{PCC} \text{ can also be used to do this reaction} \]

\[ \text{CH}_3(\text{CH}_2)\text{Cl}_2 \]

\[ \text{SOCl}_2 \] \text{Y / N}

\[ \text{SOCl}_2 \text{ does NOT work for 3° alcohols} \]

\[ \text{OH} \]

\[ \text{OH} \]

\[ \text{PBr}_3 \] \text{Y / N}

\[ \text{PBr}_3 \text{ does NOT work for 3° alcohols} \]

\[ \text{OH} \]

\[ \text{HCl} \] \text{Y / N}

\[ \text{SOCl}_2 \text{ does NOT work for 3° alcohols} \]

\[ \text{OH} \]

\[ \text{HBr} \] \text{Y / N}

\[ \text{PBr}_3 \text{ does NOT work for 3° alcohols} \]

\[ \text{OH} \]

\[ \text{Cl-SO}_{\text{3}} - \text{CH}_3 \text{ (TsCl)} \] \text{Y / N}

\[ \text{Cl-SO}_{\text{3}} - \text{CH}_3 \text{ (TsCl)} \]

\[ \text{Na}^+ - \text{CN} \text{ and many other SN2 reactions of tosylates} \] \text{Y / N}

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