



Iverson CH320N



**Organic Chemistry is the study of carbon-containing molecules. This class has two points.**

*The first point of the class is to understand the organic chemistry of living systems. We will teach you how to think about and understand the most amazing molecules on the planet!!*

You will learn how MRI scans work.

You will learn the basic principles of pharmaceutical science and how many drugs work.

You will learn about the special bond that holds carbohydrates such as glucose in six-membered rings, connects carbohydrate monomers together to make complex carbohydrate structures and is critical to DNA and RNA structure.

You will learn how soap is made from animal fat and how it works to keep us clean.

You will learn the important structural reason proteins, the most important molecular machines in our bodies, can support the chemistry of life.

You will learn how important antibiotics like penicillins work, including ones that make stable covalent bonds as part of their mode of action.

You will learn why carrots are orange and tomatoes are red.

You will learn the very cool reason that the DNA and RNA bases are entirely flat so they can stack in the double helix structure.

You will learn even more about why fentanyl is such a devastating part of the opioid problem and how Naloxone is an antidote for a fentanyl overdose.

You will learn even more details about why Magic Johnson is still alive, decades after contracting HIV, and how the same strategy is being used to fight COVID.

You will learn about the surprising chemical reason the Pfizer and Moderna mRNA vaccines elicit strong immune responses.

*The second point of organic chemistry is the synthesis of complex molecules from simpler ones by making and breaking specific bonds, especially carbon-carbon bonds.*

You will learn how carbon-metal bonds lead to new carbon-carbon bonds.

You will learn how most reactions of carbonyl compounds involve only the four common mechanistic elements operating in only a few common patterns.

You will learn how, by simply adding a catalytic amount of base like  $\text{HO}^-$  to aldehydes or ketones, you can make new carbon-carbon bonds, giving complicated and useful products.

You will learn a reaction that can convert vinegar and vodka into a common solvent.

You will learn why molecules with six-membered rings and alternating double bonds are stable.

You will learn a reaction that can turn model airplane glue into a powerful explosive.

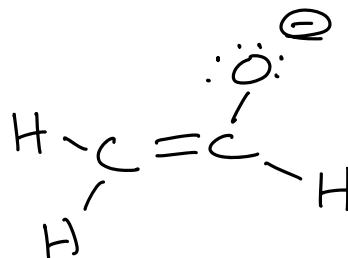
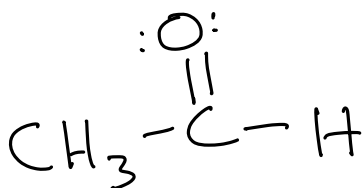
Most important, you will develop powerful critical thinking skills:

1. You will learn how to look at a molecule and accurately predict which atoms will react to make new bonds, and which bonds will break during reactions.
2. You will learn how to analyze a complex molecule's structure so that you can predict ways to make it via multiple reactions starting with less complex starting molecules.

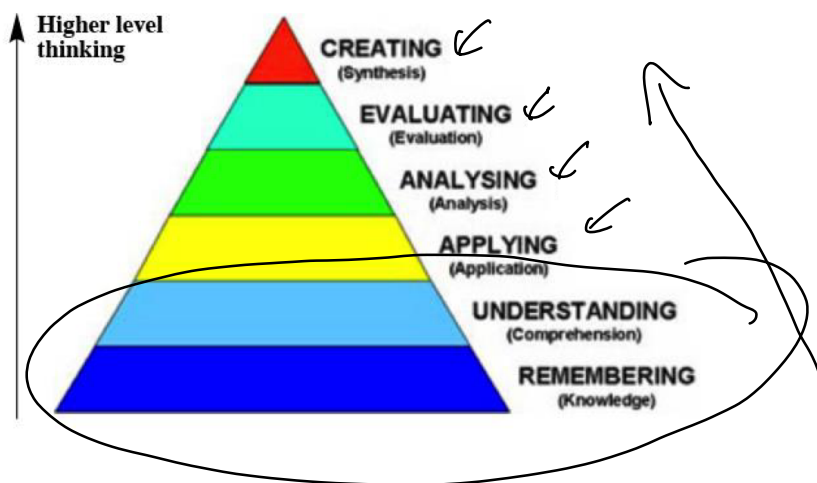
The ability to rationally synthesize new molecules changed human destiny and drives the economies of the world by enabling:

1. The synthesis of new drugs to cure disease, dramatically increase human life span and improve everyone's quality of life.
2. The development of lubricants and components for virtually all machines.
3. The creation of new methods for integrated circuit production enabling faster computation.
4. The creation of new materials for millions of uses including 3d printing and biodegradable plastics.
5. The synthesis of new pigments for dyes, paints and cosmetics.
6. The synthesis of all synthetic clothing fibers.
7. The production of highly refined and cleaner burning fuels.
8. The creation of batteries to store energy, the most important element of the renewable energy solution.
9. ...to name just a FEW applications.

*In other words, essentially everything that makes modern life so incredible!*

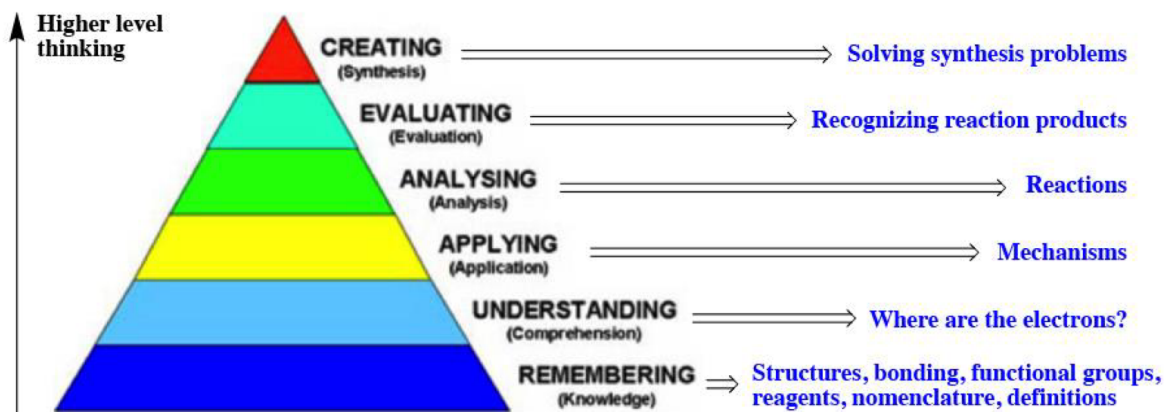


## Bloom's Taxonomy of Learning



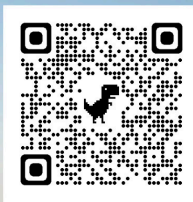
## Bloom's Taxonomy of Learning

## Organic Chemistry Analog



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## Useful Definitions:

**Mechanism** – A scheme that illustrates all reaction intermediates, as well as the flow of electrons and movement of atoms during bond breaking and bond making processes. Remember that arrows are used only to indicate the movement of electrons. Movement of atoms is assumed, but not explicitly indicated, by the arrows.

**Nucleophile** – A molecule that contains an atom with a lone pair AND a full or partial negative charge.

**Electrophile** – A molecule that contains an atom with a full or partial positive charge AND can be attacked by a nucleophile without creating a non-viable species such as a pentavalent (five bonds) carbon.

**Brønsted-Lowry Base** – A molecule containing at least one atom with a lone pair that will accommodate binding to a proton during a proton transfer reaction.

**Lewis Base** – A molecule that can donate a lone pair in a bond-forming process.

**Brønsted-Lowry Acid** – A molecule that can donate a proton during a proton transfer reaction.

**Lewis Acid** – A molecule that can accept a lone pair in a bond-forming process.

**Leaving group** – A group that will be relatively stable when it departs, such as a small neutral species like H<sub>2</sub>O or N<sub>2</sub>, or a group such as a halide atom that departs as a relatively stable ion.

**Stereochemistry** – Refers to which of the possible stereoisomers predominate in a reaction. The details of the mechanism dictate whether a reaction will involve certain features such as *syn* addition, *anti* addition, require an antiperiplanar transition state geometry, involve stereochemical InVERSiON, etc.

**Regiochemistry** – Refers to which of the possible product constitutional isomers predominate in a reaction. The details of the mechanism dictate whether a reaction will predominately give products that are consistent with Markovnikov's rule, are exactly inconsistent with Markovnikov's rule (anti-Markovnikov), are consistent with Zaitsev's rule, give most reaction at the more substituted carbon, etc.

**Key Recognition Element (KRE)** – Characteristic functional groups in relation to a new carbon-carbon bond seen with many of the reactions encountered in second semester Organic Chemistry. Being able to identify the KRE's in product molecules for *each* reaction learned will greatly simplify the process of deciding which reactions to use in complex synthesis problems.

**Intermediate** – A species produced during a reaction mechanism that is less stable than the starting materials or products. It exists for a short time and knowing a key intermediate's structure can help predict stereochemistry and regiochemistry of a reaction (for example a carbocation intermediate or radical intermediate that predicts predominant products seen in many first semester reactions).

**Transition State** – A theoretical structure that represents the highest energy species encountered in moving between starting materials, intermediates or products during a reaction mechanism. Predicting the properties of a presumed transition state can sometime predict reaction stereochemistry or regiochemistry (for example an anti-periplanar transition state geometry required for an E2 reaction).

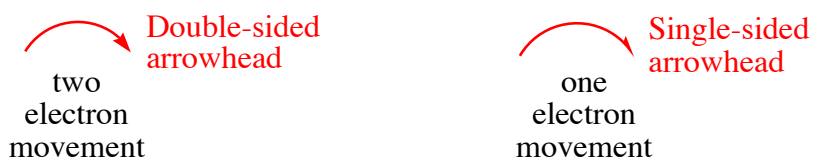
# Mechanisms: The Basics

## A) The Correct Use of Arrows to Indicate Electron Movement

The ability to write an organic reaction mechanism properly is key to success in organic chemistry classes. Organic chemists use a technique called **arrow pushing** to depict the flow or movement of electrons during chemical reactions. Arrow pushing helps chemists keep track of the way in which electrons and their associated atoms redistribute as bonds are made and broken. The first essential rule to keep in mind is the following:

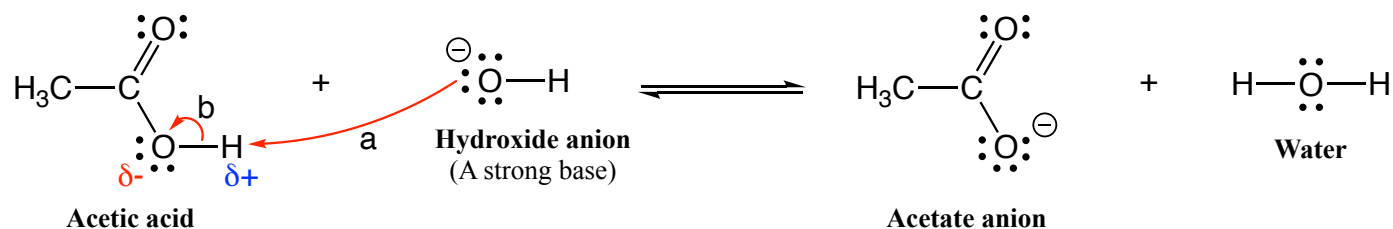
### First rule: Arrows are used to indicate movement of *electrons*

A regular arrow (double-sided arrowhead) is used to indicate the movement of two electrons, while a line with a single-sided arrowhead (sometimes called a “fish hook arrow”) is used for single electron movement involved with radical reactions.



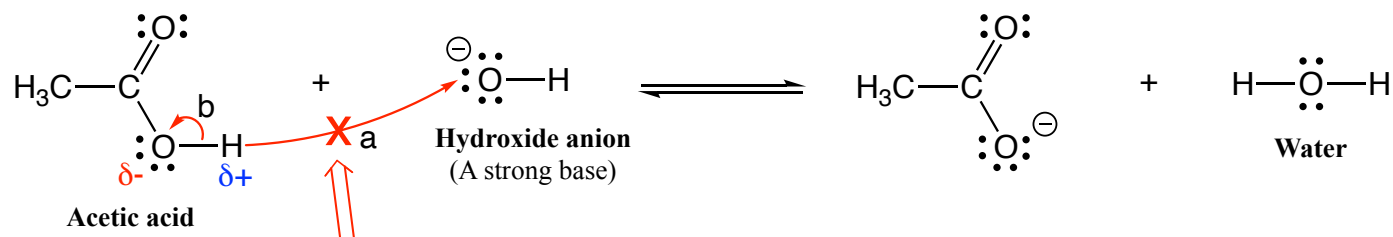
The great majority of reactions that will be discussed in this class involve movement of pairs of electrons, so they are represented by double-sided arrowheads.

### Second Rule: Arrows are never used to indicate the movement of atoms directly. The arrows only show atom movement indirectly as a consequence of electron movement when covalent bonds are made and broken.



Correct use of arrows to indicate electron movement during reaction

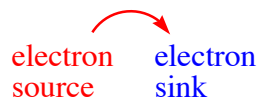
A common mistake students can make is that they will erroneously write an arrow pointing *from* the H of the acetic acid *to* the O atom of the hydroxide anion (arrow a below). This is wrong, because such an arrow would be indicating the H *atom* movement directly, not *electron* movement!



Incorrect arrow because it is pointing in the wrong direction! Never use arrows to indicate atom movement directly



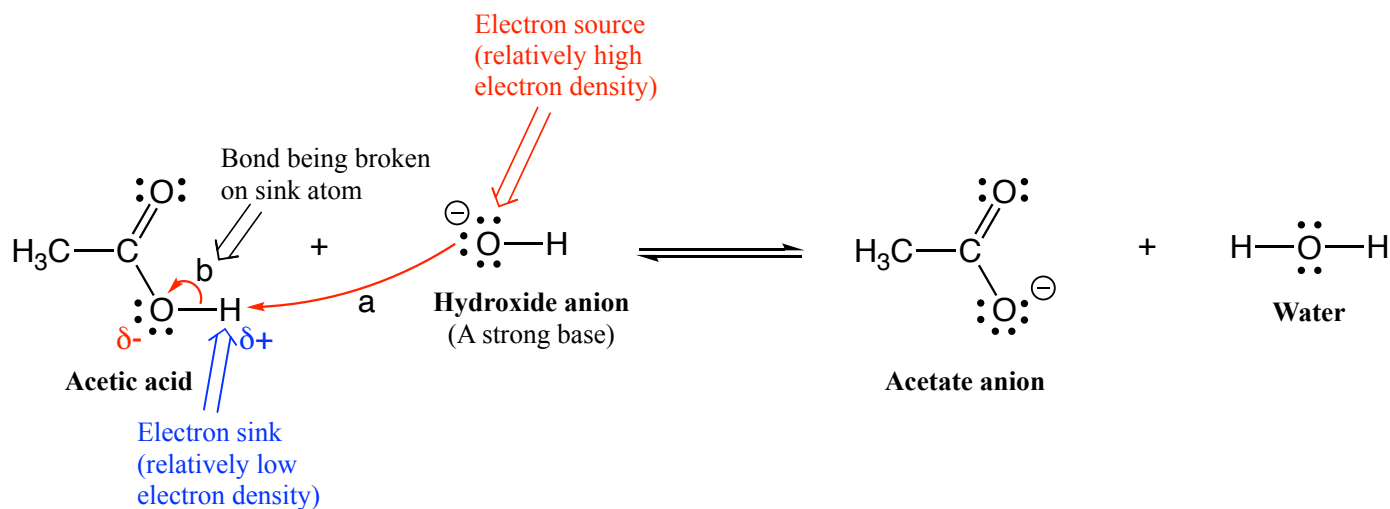
**Third Rule: Arrows always start at an electron source and end at an electron sink.**



An **electron source** is a bond or a lone pair of electrons. It is either a  $\pi$  bond or a lone pair on an atom of relatively high electron density in a molecule or ion, or a bond that must break during a reaction. An **electron sink** is an atom on a molecule or ion that can accept a new bond or lone pair of electrons.

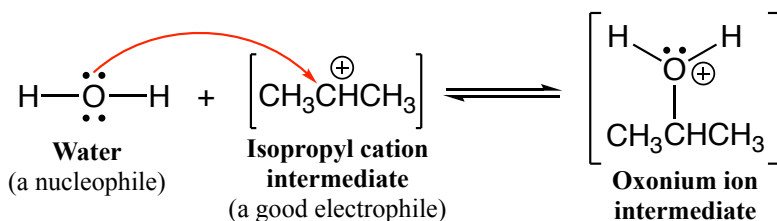
**Fourth rule: Breaking a bond will occur to avoid overfilling valence (hypervalence) on an atom serving as an electron sink.**

In these cases, the electron source for the arrow is the bond being broken, and the sink is an atom able to accommodate the electrons as a lone pair, generally an electronegative atom such as an O atom or a halogen. If an ion is created, that ion is often stabilized by resonance delocalization or other stabilizing interactions.

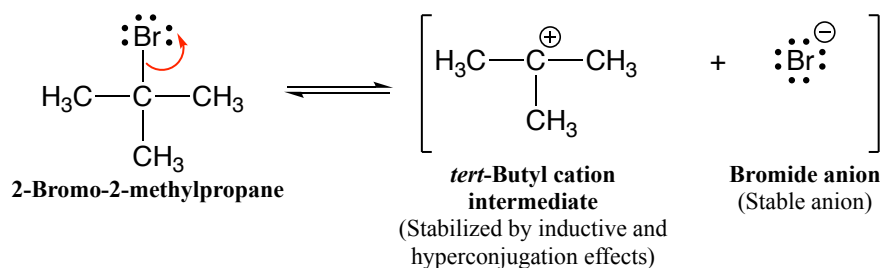


**Polar Reaction Mechanisms:** Polar reactions are most of what you will see in organic chemistry. There are only four different mechanistic elements that combine to make up the different steps of almost all the mechanisms you saw in CH320M/CH328M. Better yet, in CH320N the following four mechanistic elements are pretty much all you need to think about until we get to electrophilic aromatic substitution.

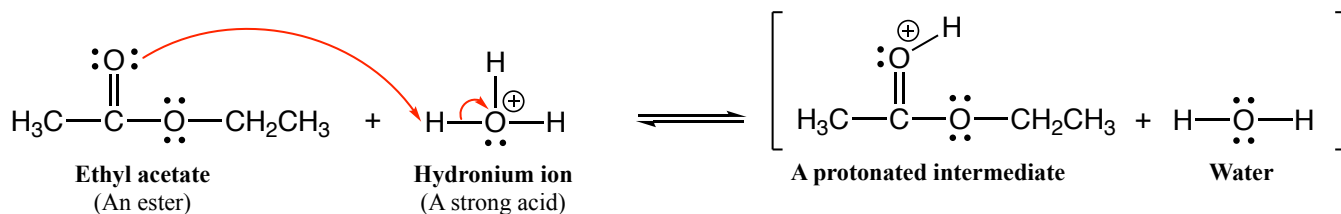
- 1. Make a new bond between a nucleophile (source for an arrow) and an electrophile (sink for an arrow).** Use this element when there is a nucleophile present in the solution as well as an electrophile suitable for reaction to occur.



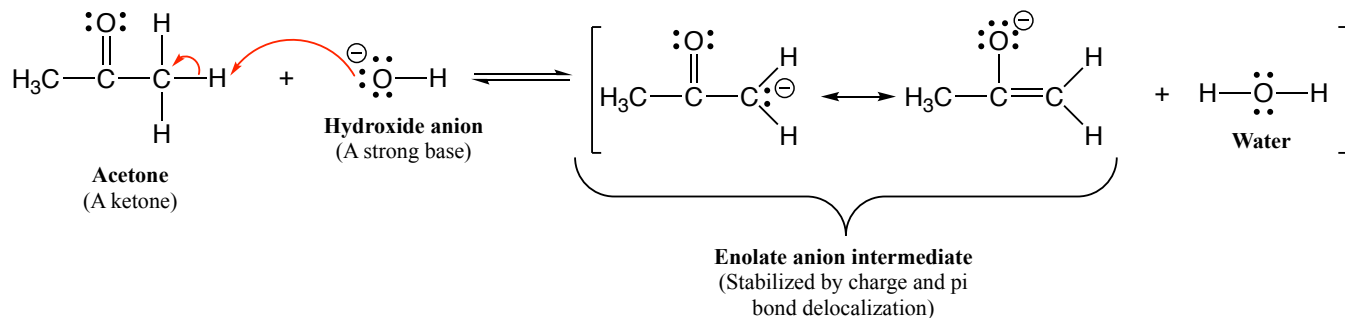
- 2. Break a bond so that relatively stable molecules or ions are created** Use this element when there is no suitable nucleophile-electrophile or proton transfer reaction, but breaking a bond can create neutral molecules or relatively stable ions, or both.



- 3. Add a proton** Use this element when there is no suitable nucleophile-electrophile reaction, but the molecule has a strongly basic functional group or there is a strong acid present.



- 4. Take a proton away** Use this element when there is no suitable nucleophile-electrophile reaction, but the molecule has a strongly acidic proton or there is a strong base present.



The situation is even simpler than you might expect because 1 and 2 are the functional reverse of each other, as are 3 and 4.

# Mechanism Summary

The following questions and mechanistic elements are described from the point of view of the carbon-containing reagent, written in the form of a flowchart.

Is there a strong acid present or is the carbon-containing reagent a strong base?

**YES**  
⇒

**Add a proton**

⇓  
**NO**

Is there a strong base present or is the carbon-containing reagent a strong acid?

**YES**  
⇒

**Take a proton away**

⇓  
**NO**

Are there a nucleophile and electrophile present?

**YES**  
⇒

**Make a bond**

⇓  
**NO**

Can a bond be broken to create stable molecules or ions?

**YES**  
⇒

**Break a bond**

⇓  
**NO**

Think about alternative mechanistic elements (radical reaction, S<sub>N</sub>2, E2, etc.)

Geminal  
Dihaloalkanes

Vicinal  
Tetrahaloalkanes

Alkynes

Aldehydes/Ketones

Vicinal  
Dihaloalkanes

Vicinal  
Diols

Alkenes

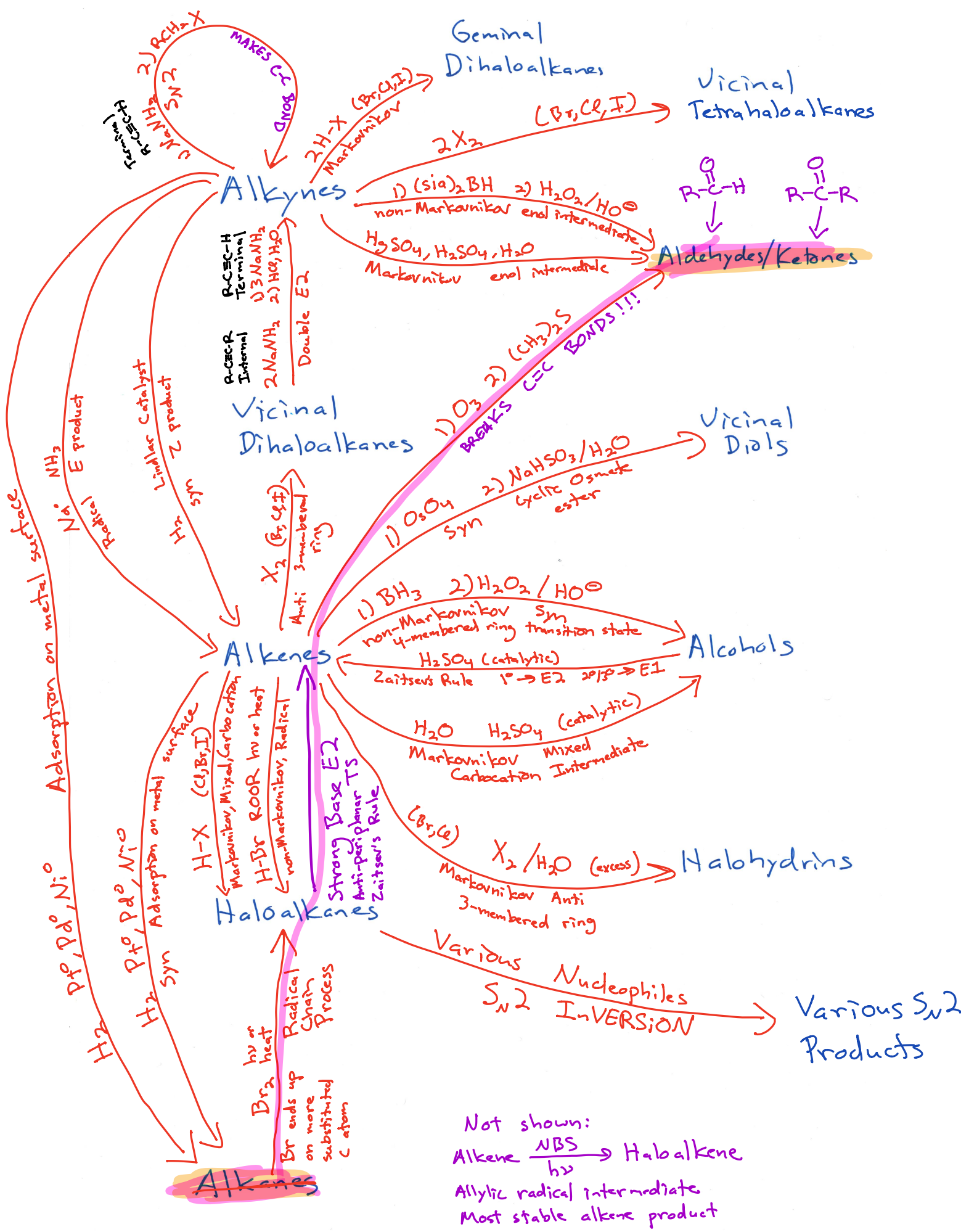
Alcohols

Haloalkanes

Halohydrins

Various  $S_N2$   
Products

Alkanes



Geminal  
Dihaloalkanes

Vicinal  
Tetrahaloalkanes

Alkynes (DFW)

Carboxylic  
Acids



Aldehydes,  
Ketones

Vicinal  
Diols

Vicinal or Geminal  
Dihaloalkanes (Waco)

Epoxides

Alkenes (Austin)

Alcohols

Halohydrins

Allylic  
Halides

Haloalkanes (S.M., N.B.)

Ethers

Thiols

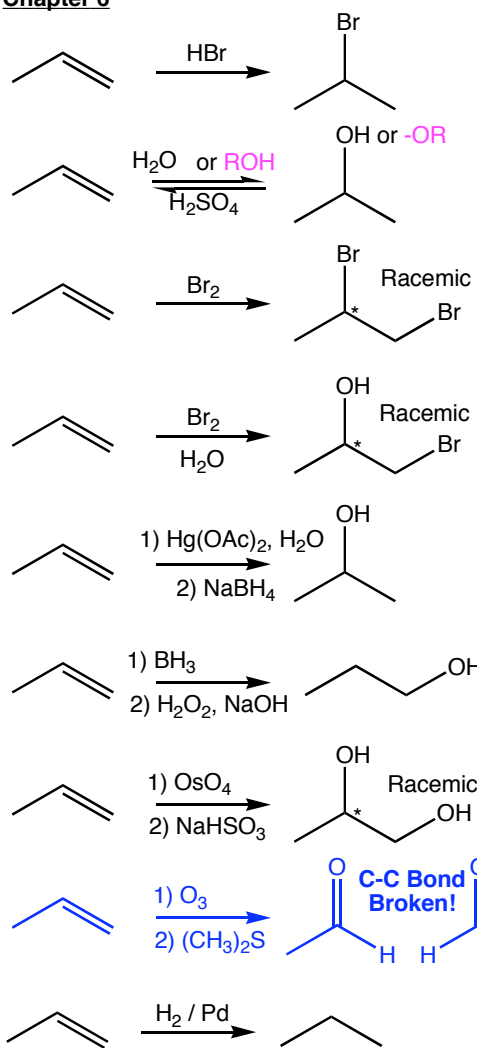


Alkyl  
Sulfonates

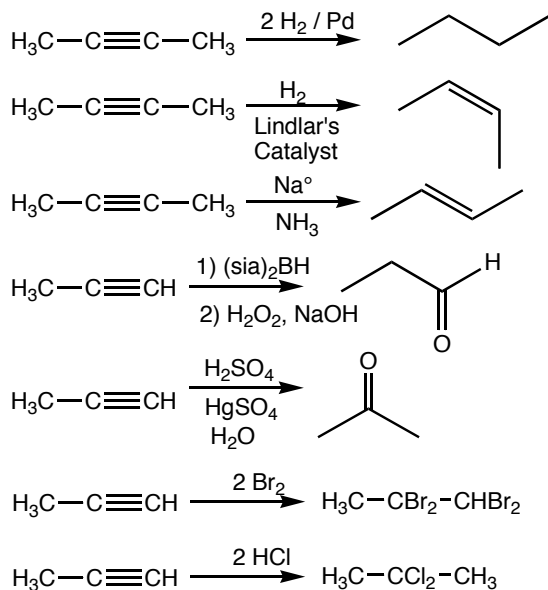
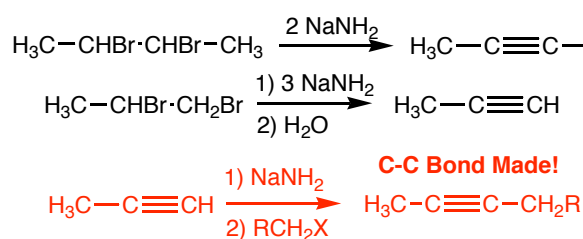
Alkanes (S.A.)



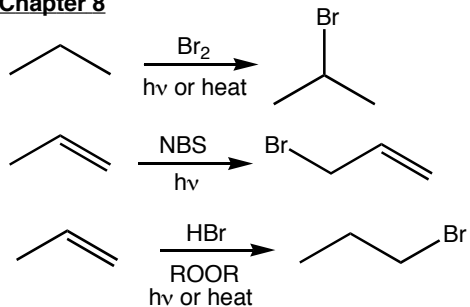
### Chapter 6



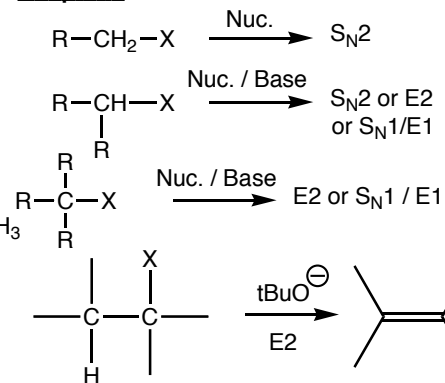
### Chapter 7



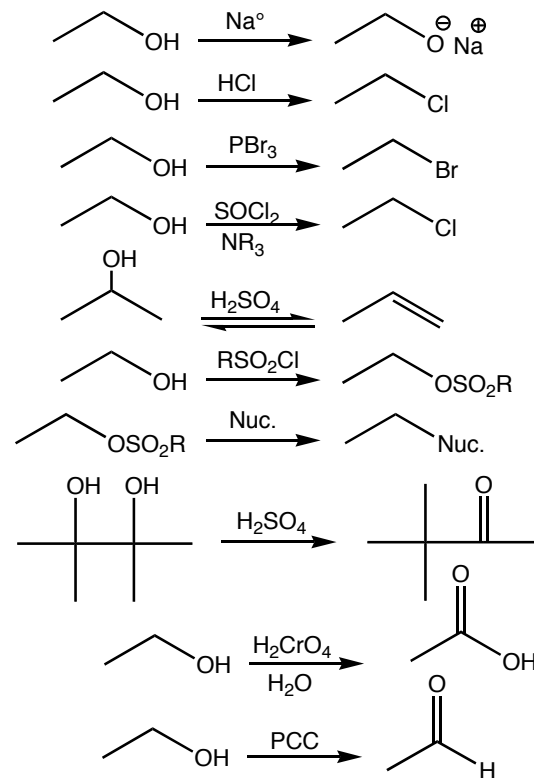
### Chapter 8



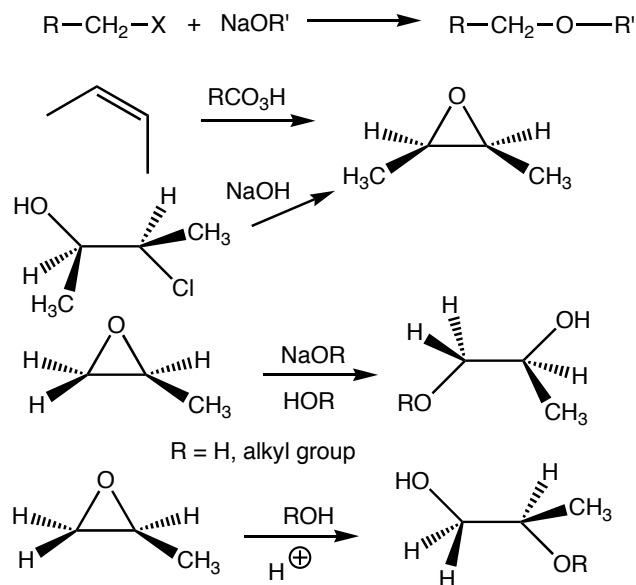
### Chapter 9



### Chapter 10



### Chapter 11



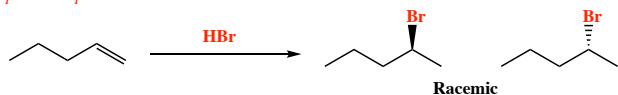


## Chapter 6

### 1) Reaction of Alkenes with HX to Give Haloalkanes

Mechanism Keys: **Carbocation intermediate (rearrangement possible)**, add the proton to make the more stable carbocation **when there is a difference** Regiochemistry: **Markovnikov** Stereochemistry: **Mixed**

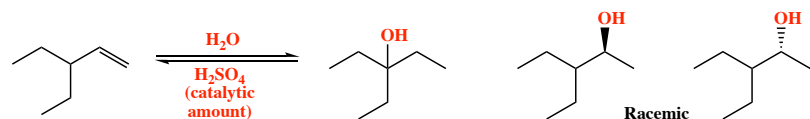
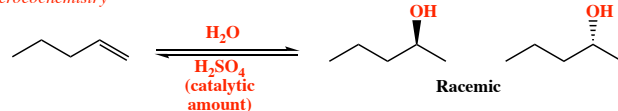
Replace the pi bond with bonds to X on the more substituted carbon and H on the less substituted carbon with mixed stereochemistry



### 2) Acid-Catalyzed Hydration of Alkenes to Give Alcohols

Mechanism Keys: **Carbocation intermediate (rearrangement possible)** add the proton to make the more stable carbocation **when there is a difference** Regiochemistry: **Markovnikov** Stereochemistry: **Mixed**

Replace the pi bond with bonds to OH on the more substituted carbon and H on the less substituted carbon with mixed stereochemistry



Rearrangement possible

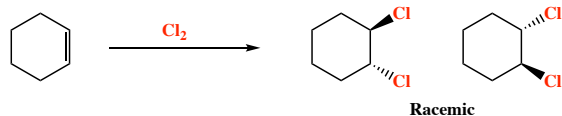
From rearranged carbocation intermediate

Product with no rearrangement

### 3) Halogenation of Alkenes to Give Vicinal Dihalokanes

Mechanism Keys: **Three-membered ring halonium ion intermediate** Regiochemistry: **N/A** Stereochemistry: **Anti**

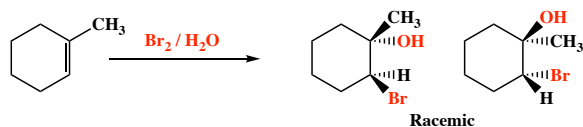
Replace the pi bond with bonds to X with anti stereochemistry only



### 4) Hydrohalogenation of Alkenes to Give Halohydrins

Mechanism Keys: **Three-membered ring halonium ion intermediate**, water will attack the more highly substituted carbon **because that has more positive charge** Regiochemistry: **Markovnikov** Stereochemistry: **Anti**

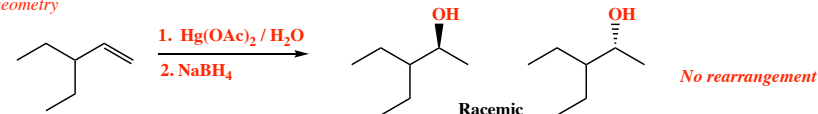
Replace the pi bond with bonds to OH on the more substituted carbon and X on the less substituted carbon with anti stereochemistry only



### 5) Oxymercuration-Reduction of Alkenes to Give Alcohols

Mechanism Keys: **Does not rearrange**, the OH ends up on the more highly substituted carbon Regiochemistry: **Markovnikov** Stereochemistry: **Mixed**

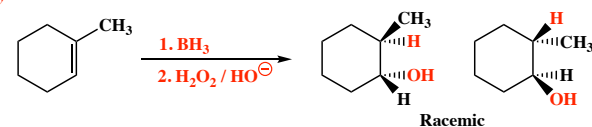
Replace the pi bond with bonds to OH on the more substituted carbon and H on the less substituted carbon with mixed geometry



### 6) Hydroboration-Oxidation of Alkenes to Give Alcohols

Mechanism Keys: **Four-membered ring transition state as H and B atoms add simultaneously to same face of pi bond**, the H atom goes on the more substituted carbon atom Regiochemistry: **non-Markovnikov** Stereochemistry: **Syn**

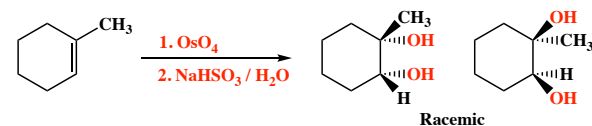
Replace the pi bond with bonds to H on the more substituted carbon and OH on the less substituted carbon with syn geometry only



### 7) Geminal Dihydroxylation of Alkenes to Give Vicinal Diols (the Ozzy Osbourne reaction)

Mechanism Keys: **Cyclic osmate ester intermediate makes it so both OH groups are added to the same face of the double bond** Regiochemistry: **N/A** Stereochemistry: **Syn**

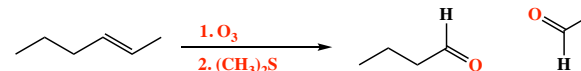
Replace the pi bond with bonds to OH with syn geometry only



### 8) Ozonolysis of Alkenes to Give Aldehydes and Ketones

Mechanism Keys: **Malozonide that then rearranges into an ozonide intermediate**, explaining why the carbon-carbon bond is broken Regiochemistry: **N/A** Stereochemistry: **N/A**

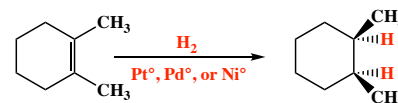
Replace the carbon-carbon double bond with two double bonds to an O atom (C=O) while **BREAKING THE C=C!**



### 9) Hydrogenation of an Alkene to Give Alkanes

Mechanism Keys: **Alkene and H2 adsorb on metal surface**, then new bonds form to both carbon atoms essentially **simultaneously** so the H atoms add to the same face Regiochemistry: **N/A** Stereochemistry: **syn**

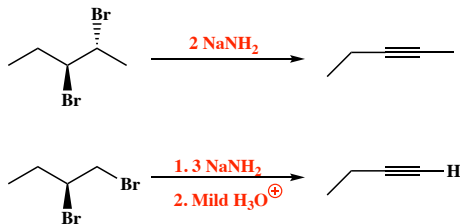
Replace the pi bond with bonds to H with syn geometry only



## Chapter 7

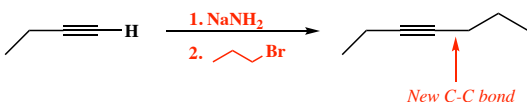
### 10) Reaction of Vicinal Dihalides with Base to Give Alkynes

Mechanism Keys: **Double E2 reaction**. For terminal alkynes, **3 equivalents of base are needed because the terminal H atom is also removed and must be replaced in mild acid** Regiochemistry: N/A Stereochemistry: N/A  
Replace the bonds to X with two pi bonds to give an alkyne



### 11) Reaction of Terminal Alkynes with Base then a Primary Haloalkane to Give an Alkyne with a New C-C Bond

Mechanism Keys: **S<sub>N</sub>2 reaction**. Haloalkane must be primary to avoid E2. Regiochemistry: N/A Stereochemistry: N/A  
Replace the terminal C-H bond with a new C-C bond to the carbon that had the C-X bond.

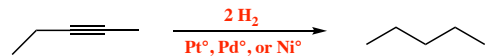


### 12) Hydrogenation of Alkynes to Give Alkanes

Mechanism Keys: Alkyne and H<sub>2</sub> adsorb on metal surface, then new bonds form to both carbon atoms essentially simultaneously. Happens twice and cannot be stopped because alkenes produced as intermediates react faster than alkynes

Regiochemistry: N/A Stereochemistry: N/A

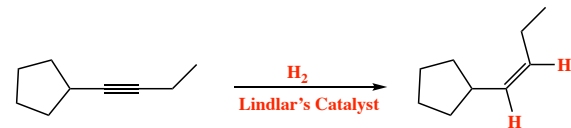
Replace the two pi bonds with four bonds to H atoms



### 13) Reduction of Alkynes with H<sub>2</sub> and Lindlar's Catalyst to Give Z Alkenes

Mechanism Keys: Alkene and H<sub>2</sub> adsorb on metal surface, then new bonds form to both carbon atoms essentially simultaneously. Pb and quinoline poison the catalyst so the reaction stops at a Z alken Regiochemistry: N/A Stereochemistry: Syn

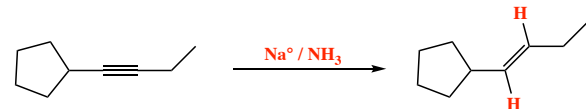
Replace one pi bond of an alkyne with bonds to H atoms to give only a Z product



### 14) Reduction of Alkynes with Na<sup>+</sup> and NH<sub>3</sub> to Give E Alkenes

Mechanism Keys: Radical mechanism, two one-electron transfers from Na<sup>+</sup>, followed by adding two protons from NH<sub>3</sub>, the more stable *trans* alkene (less steric strain) predominates. Regiochemistry: N/A Stereochemistry: Anti

Replace one pi bond of an alkyne with bonds to H atoms to give only an E product

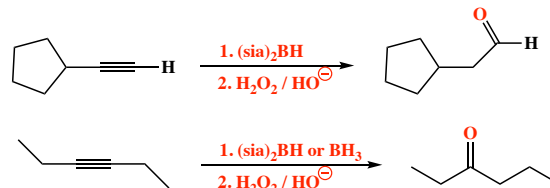


### 15) Hydroboration-Oxidation of Terminal Alkynes to Give Aldehydes (Using the "Antler" Reagent)

Mechanism Keys: Four-membered ring transition state as H and B atoms add to same face of pi bond, enol intermediate followed by enol-keto tautomerization, "antlers" ensure regiochemical control so that H adds to more substituted carbon.

Regiochemistry: non-Markovnikov Stereochemistry: N/A

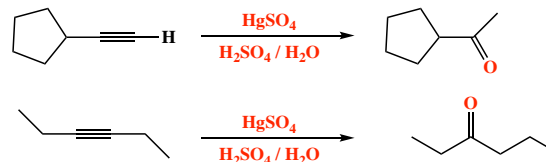
Replace the two pi bonds of a terminal alkyne with double bonds to an O atom to give an aldehyde. When the alkyne is not terminal, a ketone is the product.



### 16) Oxymercuration-Reduction of Alkynes to Ketones

Mechanism Keys: Enol intermediate followed by enol-keto tautomerization. O atom ends up bonded to more substituted carbon Regiochemistry: Markovnikov Stereochemistry: Mixed

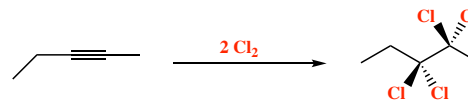
Replace the two pi bonds of an alkyne with double bonds to an O atom to give a ketone. When the alkyne is terminal the internal carbon ends up as the C=O



### 17) Reaction of Alkynes with X<sub>2</sub> to Give Tetrahaloalkanes

Mechanism Keys: X<sub>2</sub> reacts with both pi bonds Regiochemistry: N/A Stereochemistry: N/A

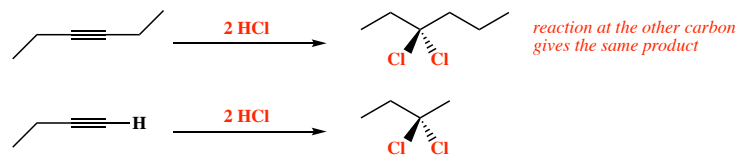
Replace both pi bonds with 2 bonds to X atoms for each carbon atom.



### 18) Reaction of Alkynes with HX to Give Geminal Dihalidealkanes

Mechanism Keys: HX reacts with both pi bonds, and both X atoms always end up on the same carbon atom, which is the internal carbon of terminal alkynes Regiochemistry: Markovnikov Stereochemistry: N/A

Replace both pi bonds on one carbon with 2 bonds to X atoms, and the other carbon with 2 bonds to H. For terminal alkynes, the internal carbon gets the two bonds to X and the terminal carbon gets the two bonds to H

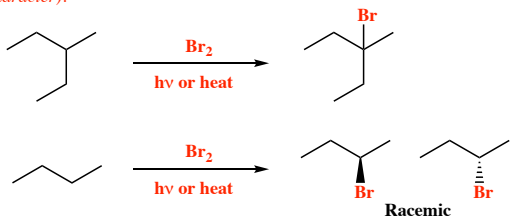


## Chapter 8

### 19) Free Radical Halogenation of Alkanes to Give Haloalkanes

Mechanism Keys: **Free radical chain process, initiation when Br<sub>2</sub> is exposed to light (hv) or heat to give Br radicals that abstracts an H atom on the most substituted carbon during the propagation step** Regiochemistry: **Br ends up on most substituted C atom** Stereochemistry: **N/A**

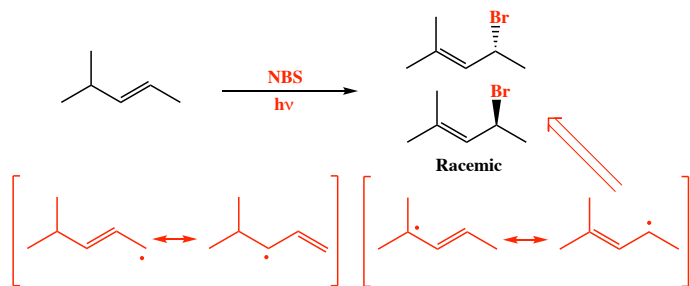
*On the most substituted carbon with an H atom, replace one C-H bond with a C-Br bond. Use Br<sub>2</sub> because it is more selective than Cl<sub>2</sub> (Hammonds postulate: The Br<sub>2</sub> reaction has an endothermic first step so the transition state has more radical character).*



### 20) Allylic Halogenation of Alkenes to Give Haloalkanes

Mechanism Keys: **Free radical chain process, initiation when NBS is exposed to light (hv) to give Br radicals that abstracts an H atom on the carbon adjacent to the C=C to create allylic radical intermediates that add a Br atom to make the most stable product (most highly substituted alkene)** Regiochemistry: **Br ends up on the carbon adjacent to the most stable possible alkene product** Stereochemistry: **N/A**

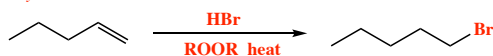
*Analyze both of the contributing structures for both allyl radicals that are possible, consider adding a Br atom to the location of each carbon radical on each contributing structure, analyze each of these possible products and choose the most stable alkene (most substituted alkene) as the predominant product*



### 21) Reaction of Alkenes with HBr in the Presence of H<sub>2</sub>O<sub>2</sub> and Heat to Give Haloalkanes

Mechanism Keys: **Radical mechanism initiated by peroxide and hv or heat, product comes from most stable radical** Regiochemistry: **non-Markovnikov** Stereochemistry: **Mixed**

*Replace the pi bond with bonds to Br on the less substituted carbon and H on the more substituted carbon with mixed geometry*



## Chapter 9

### 22) Substitution vs. Elimination of Haloalkanes to Give Various Substitution Products and Alkenes From Elimination

**S<sub>N</sub>2**: Nucleophile attacks backside of carbon-leaving group bond as the leaving group departs

Regiochemistry: **N/A** Stereochemistry: **InVERSiON**

**E2**: Base removes H atom on carbon adjacent to leaving group as the leaving group departs. The H atom being removed and the leaving group must be in an antiperiplanar geometry for reaction to take place

Regiochemistry: **Zaitsev product (most highly substituted alkene)** Stereochemistry: **determined by antiperiplanar transition state requirement**

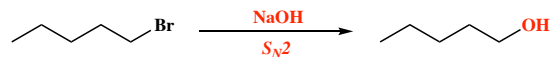
**S<sub>N</sub>1**: Leaving group departs to give carbocation intermediate then nucleophile binds to carbocation

Regiochemistry: **N/A** Stereochemistry: **Scrambled (not quite racemic)**

**E1**: Leaving group departs to give carbocation intermediate that loses a proton on an adjacent carbon to give an alkene

Regiochemistry: **Zaitsev product (most highly substituted alkene)** Stereochemistry: **N/A**

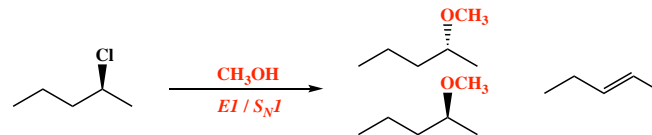
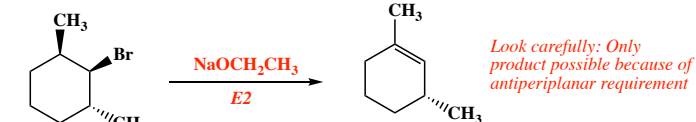
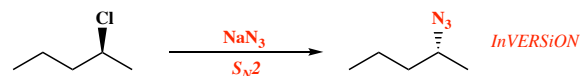
**Primary haloalkane - S<sub>N</sub>2 only (except when KOtBu is the base)**



**Secondary haloalkane - S<sub>N</sub>2 when nucleophile is not strong or very weak base**

**E2 when nucleophile is a strong base**

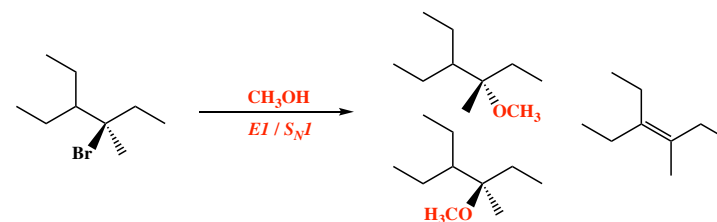
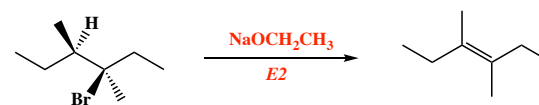
**E1/S<sub>N</sub>1 when nucleophile is a very weak base**



**Tertiary haloalkane - S<sub>N</sub>2 never**

**E2 when nucleophile is anything but a very weak base**

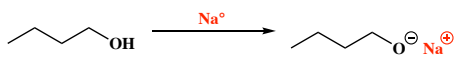
**E1/S<sub>N</sub>1 when nucleophile is a very weak base**



## Chapter 10

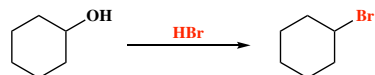
### 23) Reaction of Alcohols with Alkali Metals ( $\text{Na}^\ominus$ , $\text{Li}^\ominus$ ) to Give Alkoxides

Mechanism Keys: **Alkali metals react with alcohols to make alkoxides and  $\text{H}_2$**  Regiochemistry: **N/A** Stereochemistry: **N/A**  
Replace the H atom of an OH group with a negative charge



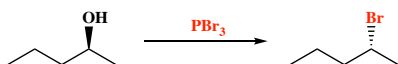
### 24) Reaction of Alcohols with HX to Give Haloalkanes

Mechanism Keys: **Alcohols react with HX by protonating the OH group (thus creating a good leaving group), then the halide anion reacts via an  $\text{S}_{\text{N}}2$  mechanism for primary alcohols and via an  $\text{S}_{\text{N}}1$  mechanism for secondary/tertiary alcohols, to give a haloalkane** Regiochemistry: **N/A** Stereochemistry: **InVERSION for  $\text{S}_{\text{N}}2$  and scrambled for  $\text{S}_{\text{N}}1$**   
Replace the alcohol OH group with X. This reaction must be used with tertiary alcohols as  $\text{PBr}_3$  and  $\text{SOCl}_2$  only work with primary and secondary alcohols.



### 25) Reaction of Alcohols with $\text{PBr}_3$ to Give Bromoalkanes

Mechanism Keys: **Primary and secondary alcohols react with  $\text{PBr}_3$  to give an intermediate with an O-P bond (thus creating a good leaving group), that reacts with bromide anion via an  $\text{S}_{\text{N}}2$  mechanism to give a haloalkane** Regiochemistry: **N/A** Stereochemistry: **InVERSION**  
Replace the alcohol OH group with Br with InVERSION of any stereochemistry at the carbon that was bonded to the OH group of the original alcohol. Primary and secondary alcohols only because tertiary alcohols cannot react via  $\text{S}_{\text{N}}2$ .



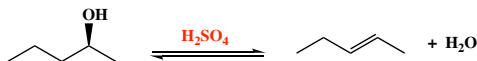
### 26) Reaction of Alcohols with $\text{SOCl}_2$ to Give Chloroalkanes

Mechanism Keys: **Primary and secondary alcohols react with  $\text{SOCl}_2$  to give an intermediate with an O-S bond (thus creating a good leaving group), that reacts with chloride anion via an  $\text{S}_{\text{N}}2$  mechanism to give a haloalkane** Regiochemistry: **N/A** Stereochemistry: **InVERSION**  
Replace the alcohol OH group with Cl with InVERSION of any stereochemistry at the carbon that was bonded to the OH group of the original alcohol. Primary and secondary alcohols only because tertiary alcohols cannot react via  $\text{S}_{\text{N}}2$ .



### 27) Reaction of Alcohols with Sulfuric Acid to Give Alkenes

Mechanism Keys: **Alcohols react with  $\text{H}_2\text{SO}_4$  to give alkenes via a carbocation intermediate, in a mechanism that is the exact reverse of hydration of an alkene, this is a reversible equilibrium process (Le Chatlier)** Regiochemistry: **Zaitsev** Stereochemistry: **N/A**  
Replace the alcohol OH group with a new pi bond chosen to make the Zaitsev product (most substituted alkene)



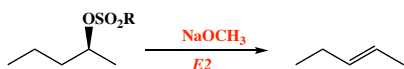
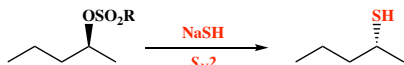
### 28) Reaction of Alcohols with Sulfonyl Chlorides to Give Sulfonyl Esters

Mechanism Keys: **Alcohols react as nucleophiles with sulfonyl chlorides to give sulfonyl esters, a good leaving group** Regiochemistry: **N/A** Stereochemistry: **Retention (not InVERSION)**  
Replace the alcohol OH group with a new sulfonyl ester, without changing the stereochemistry



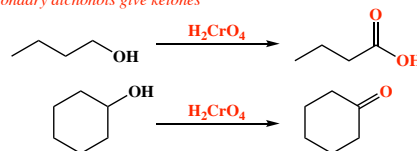
### 29) Reaction of Sulfonyl Esters with Nucleophiles to Give Various Substitution and Elimination Products

Mechanism Keys: **Sulfonyl esters react with nucleophiles and bases analogous to haloalkanes** Regiochemistry: **E2 and E1 give Zaitsev product alkene** Stereochemistry:  **$\text{S}_{\text{N}}2$  gives InVERSION,  $\text{S}_{\text{N}}1$  scrambled, E2 gives product based on antiperiplanar transition state**  
Replace the sulfonyl ester with a nucleophile with InVERSION or carry out an elimination to give the Zaitsev alkene (most substituted) based on the same rules used with haloalkanes



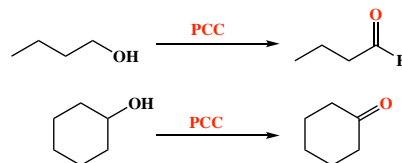
### 30) Reaction of Alcohols with Chromic Acid (Jones Reagent) to Give Carboxylic Acids and Ketones

Mechanism Keys: **The mechanism with primary alcohols involves a chromate ester intermediate then loss of an H atom on the carbon of the original alcohol to give an aldehyde, that adds water then reacts again. Secondary alcohols react once to give a ketone** Regiochemistry: **N/A** Stereochemistry: **N/A**  
Replace every H atom on the carbon attached to the OH group with bonds to O atoms. Primary alcohols give carboxylic acids, secondary alcohols give ketones



### 31) Reaction of Alcohols with PCC (Pyridinium Chlorochromate) to Give Aldehydes and Ketones

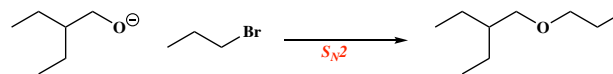
Mechanism Keys: **The mechanism with primary alcohols involves a chromate ester intermediate then loss of an H atom on the carbon of the original alcohol to give an aldehyde, and because there is no water it stops there. Secondary alcohols react once to give a ketone** Regiochemistry: **N/A** Stereochemistry: **N/A**  
Replace an H atom on the carbon attached to the OH group with a pi bond to an O atom. Primary alcohols give aldehydes, secondary alcohols give ketones



## Chapter 10

### 32) Reaction of Alkoxides with Primary Haloalkanes to Give Ethers (Williamson Ether Synthesis)

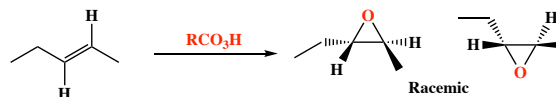
Mechanism Keys: **Alkoxides and primary haloalkanes react via an  $\text{S}_{\text{N}}2$  mechanism. The haloalkane must be primary to avoid E2.** Regiochemistry: **N/A** Stereochemistry: **N/A**  
Choose the alkoxide and haloalkane so the haloalkane is primary



### 32) Reaction of Alkenes with Peroxides to Give Epoxides

Mechanism Keys: **Alkenes react with peroxides in a single concerted step to give the epoxide and a carboxylic acid** Regiochemistry: **N/A** Stereochemistry: **N/A**

Create the epoxide from the alkene, making sure to keep the groups consistent (groups that are cis on the alkene stay cis in the epoxide) and add the O atom to both the top and bottom faces of the alkene



### 33) Reaction of Halohydrins with Base to Give Epoxides

Mechanism Keys: **Halohydrins react with base to deprotonate the OH group and give an alkoxide intermediate, which attacks the backside of the C-X bond in a single step to give the epoxide** Regiochemistry: **N/A** Stereochemistry: **N/A**  
Create the epoxide from the halohydrin by lining up the OH group to be antiperiplanar to the X before making the new bond from O to the carbon of the original C-X bond



### 34) Reaction of Epoxides in Acid or Base to Give Vicinal Diols

Mechanism Keys: **Epoxides react with hydroxide from the backside of the C-O bond via an  $\text{S}_{\text{N}}2$  mechanism at the less-hindered carbon, and in acid epoxides are protonated to give a positively-charged intermediate analogous to the halonium ion intermediate, so water attacks the more substituted carbon** Regiochemistry: **In base, OH adds to less-hindered carbon atom, in acid OH adds to the more substituted carbon atom** Stereochemistry: **Anti (backside attack on epoxide C-O bond)**

Create the vicinal dihalide by adding the OH from the less-hindered side in base and more hindered side in acid, inverting the chiral center at the carbon of the attack and retaining stereochemistry at the carbon that keeps the O atom of the original epoxide, always giving trans product in both cases

