

Organic Chemistry
Notes Part 16

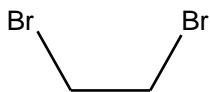
Alkyne alkylation (8th edition, Chapter 9.6, 9th edition, same)

(Problem 9.6) Which of the alkynes of molecular formula C_5H_8 can be prepared in good yield by alkylation or dialkylation of acetylene? Explain why the preparation of the other C_5H_8 isomers would not be practical.

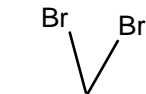
Alkyne synthesis by TWO E_2 eliminations (8th edition, Chapter 9.7, 9th edition, same)

Alkyl dihalides can exist in many different possibilities. Two of these possibilities will lead to an alkyne upon elimination and they are _____ and _____.

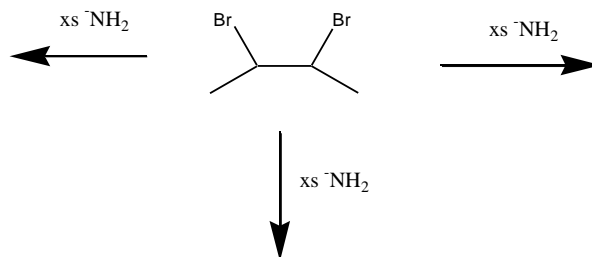
_____ is defined by Carey as “describing two atoms or groups attached to adjacent atoms.” An example is shown below for a _____ dihalide which is defined by Carey as “a compound containing two halogens on adjacent carbons”.



_____ is defined by Carey as “a dihalide of the form R_2CX_2 , in which the two halogen substituents are located on the same carbon.” An example is shown below.



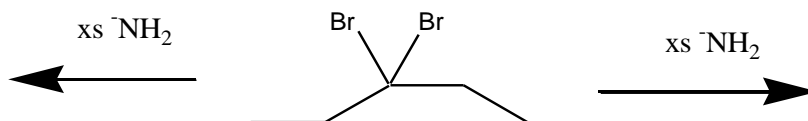
Treatment of the _____ dihalide with TWO equivalents of a strong base leads to three possible products which are an _____, an _____ and a _____. The strong base always used in this class is sodium amide ($^+Na^-NH_2$). Draw the three possible products below.



ORG-

Of the three possible products, we are always going to assume we want to make the _____. Will we make the other two products? _____. The diene is usually stable while the allene is usually not very stable.

Treatment of the geminal dihalide can form two of the three products above when it is treated with two equivalents of sodium amide. Draw the products of the following reaction.

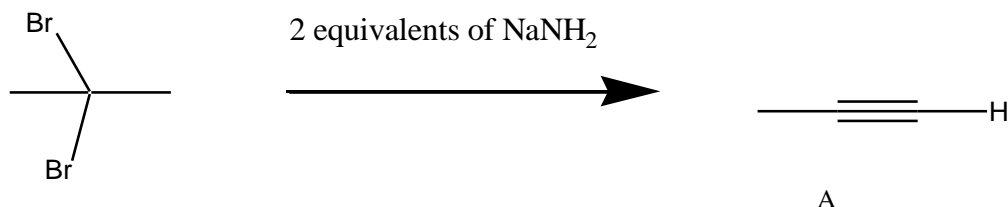


We will again always assume we are going to make the _____.

Some elimination reactions require 3 equivalents of sodium amide to form the alkyne while other elimination reactions require only 2 equivalents of sodium amide to form the alkyne. WHY? The reason is whether the product is an _____ alkyne or a _____ alkyne.

ORG-

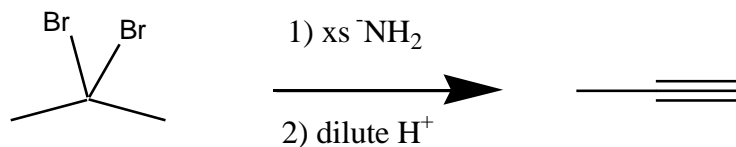
_____ alkyne requires three moles or equivalents of sodium amide due to an acid/base reaction with the proton of the alkyne. If only two equivalents of base are added, the yield of the alkyne will be greatly reduced. Given below is the reaction of a geminal dihalide with two equivalents of base to form the alkyne A.



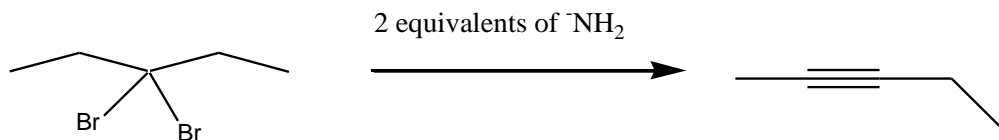
Given below is the acid/base reaction of the alkyne A with sodium amide. Does the equilibrium lie towards the reactants or the products?



An acid is added after the third reaction to form the product. The acid/base step above cannot be stopped and will be carried out even if you only have two equivalents of base. The complete reaction is shown below for conversion of either a geminal or vicinal dihalide to a terminal alkyne.



Only two equivalents are needed when forming an internal alkyne since the acid/base reaction shown above is not a problem.



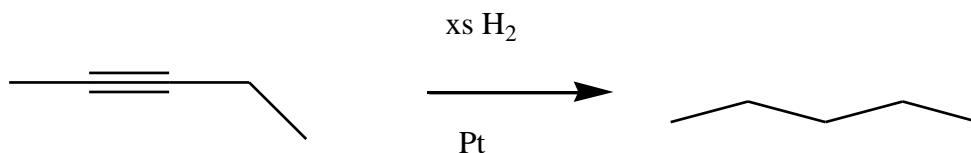
ORG-

Addition reactions of alkynes (8th edition, Chapter 9.8, 9th edition, same)

HELPFUL HINT: Most of the reactions that were studied for addition to alkenes are also seen for addition to alkynes. All of the stereochemical consequences of addition to alkenes are also seen for alkynes. For example, bromine adds _____ to alkynes. Hydrogenation with hydrogen adds _____ to alkynes.

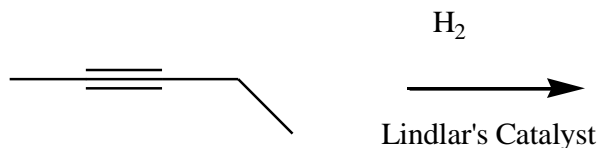
Hydrogenation of alkynes (8th edition, Chapter 9.9, 9th edition, same)

Hydrogenation of alkynes is very dependent on the type of _____ used in the hydrogenation. There are two main types of catalysts for hydrogenation of alkynes. A single _____ catalyst, like Pd, Pt, Ni, or Rh, will convert the alkyne to the alkene with syn addition. However, the alkene is more reactive towards these catalysts and will continue to reduce to the alkane. There is no way to stop the hydrogenation at the alkene step with a single _____ catalyst.



(Problem 9.9) Write a series of equations showing how you could prepare octane from acetylene and any necessary organic and inorganic reagents.

Addition of lead acetate and quinoline to the platinum catalyst on calcium carbonate forms _____ catalyst. This catalyst is deactivated so that it cannot reduce the alkene. Hydrogenation with _____ catalyst will allow formation of the cis-alkene. An example is shown below.



ORG-

Dissolving metal reduction of an alkyne (8th edition, Chapter 9.10, 9th edition, same)

A dissolving metal reduction will add hydrogens to the alkyne in an _____ fashion. Some metals dissolve in ammonia, NH₃, and an example is sodium. Sodium provides the electrons needed for the reduction while ammonia furnishes the protons. The trans products are believed to be formed due to the different stabilities of the radical intermediates formed by addition of a proton to the radical anion. The mechanism is shown below.

ORG-

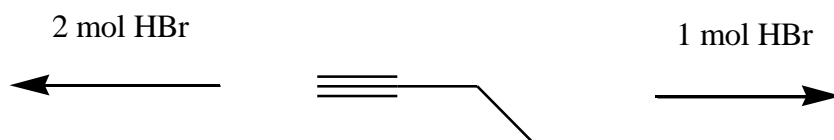
Addition of hydrogen halides to alkynes (8th edition, Chapter 9.11, th edition, same)

Hydrogen halides (HBr, HCl, HF) add to alkynes in Markovnikov fashion.

Hydrogen halides add to *alkenes* in Markovnikov fashion because they form the most stable carbocation.

Addition of a proton to an alkyne forms a vinyl cation which is not stable. The kinetics of the addition of hydrogen halides is given by the rate equation below.

Third order kinetics means that _____ moles of the hydrogen halide are involved and that an unstable vinyl cation is not formed. The mechanism is called Ad_e3 for addition-elimination-termolecular. If one mole of hydrogen halide is added, the haloalkene is formed. If two moles of hydrogen halide is added, the geminal dihalide is formed. Some examples are shown below.



(Problem 9.12) Write a series of equations showing how to prepare 1,1-dichloroethane from ethene.

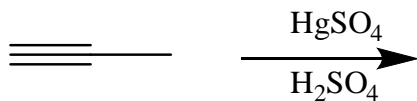
ORG-

Addition of water to alkynes (8th edition, Chapter 9.12, 9th edition, same)

We saw that the addition of water to an alkene can take place in Markovnikov addition with rearrangement fashion, in Markovnikov addition without rearrangement fashion, or in anti-Markovnikov addition fashion. We do not have to worry about the Markovnikov fashion with rearrangement since a stable carbocation does not form upon addition of water to an alkyne.

Markovnikov addition of water to form a ketone

When we added water to an alkene, it took two steps. The first was oxymercuration with Hg(OAc)₂ and H₂O. We then followed that with sodium borohydride to remove the mercury in the demercuration step. For alkynes, we can accomplish both steps with a mixture of reagents. For alkynes, instead of Hg(OAc)₂, we use HgSO₄ and Sulfuric acid. Sulfuric acid will remove the mercury and form the _____. An example is given below



FLASHBACK: [The reaction of mercury with an alkene forms an alcohol with the OH on an sp^3 -hybridized carbon.]

Reaction of mercury with an alkyne forms an alcohol with the OH on an sp^2 -hybridized carbon. This is a big difference and will lead to different products. The _____ is a constitutional isomer of a ketone or aldehyde. They are sometimes called _____ with _____ being the interconversion between the two constitutional isomers. Ketones are energetically favored over enols in most cases and are the final product of Markovnikov addition of water to an alkyne. The mechanism for conversion of the enol form to the keto form is shown below.

Enol conversion mechanism (8th edition, Mechanism 9.2, 9th edition, same)

(Problem 9.14) Show by a series of equations how you could prepare 2-octanone from acetylene and any necessary organic or inorganic reagents. How could you prepare 4-octanone?

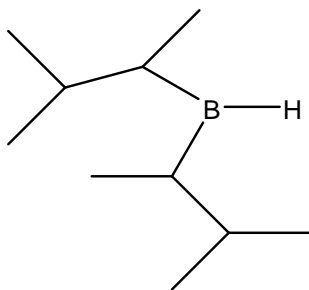
ORG-

Anti-Markovnikov addition of water to form aldehydes (Not covered in your book.)

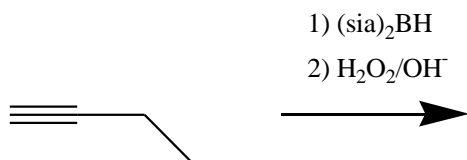
FLASHBACK: [Anti-Markovnikov addition of water to alkenes can be accomplished by adding two reagents. The first reagent is $\text{BH}_3 \cdot \text{THF}$ which forms an organoborane. The second reagent replaces the boron with an OH group.]

$\text{BH}_3 \cdot \text{THF}$ will reduce three moles of the alkene but can not be used with alkynes because BH_3 might reduce the alkyne all the way down to the alkane. Replacement of two of the hydrogens on BH_3 is needed so that reduction is carried out to the alkene and stops. The reagent used for alkynes is $(\text{sia})_2\text{BH}$. Sia stands for secondary isoamyl. Amyl is an old name for five carbons and isoamyl's

IUPAC name is 2-methylbutane. 2-methylbutane has _____ sets of primary carbons, _____ tertiary carbon and _____ secondary carbon. Bonding at the secondary carbon is present in $(\text{sia})_2\text{BH}$ which is shown below.



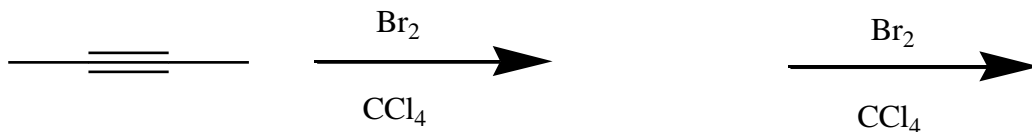
A reaction is shown below which converts an alkyne to an organoborane followed by replacement of the boron with hydroxyl. As seen above for Markovnikov addition of water to an alkyne, an enol is generated. The enol rearranges to the _____ which is also called the _____ form.



ORG-

Addition of Br_2 to an alkyne (8th edition, Chapter 9.13, 9th edition, same)

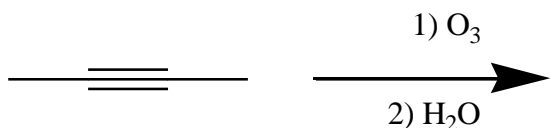
Halides will add to alkynes to form dihaloalkenes or tetrahaloalkanes. Addition of one mole of halide will form the dihaloalkene. Addition of two moles of halide will form the tetrahaloalkanes. An example is shown below.

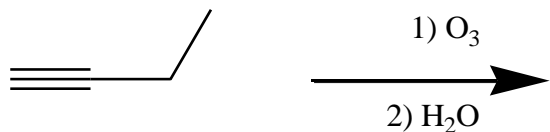


ORG-

Ozonolysis of alkynes (8th edition, Chapter 9.14, 9th edition, same)

Ozonolysis of alkynes produces carboxylic acids. Different products are produced depending on whether the alkyne was terminal or internal. Two examples are shown below.

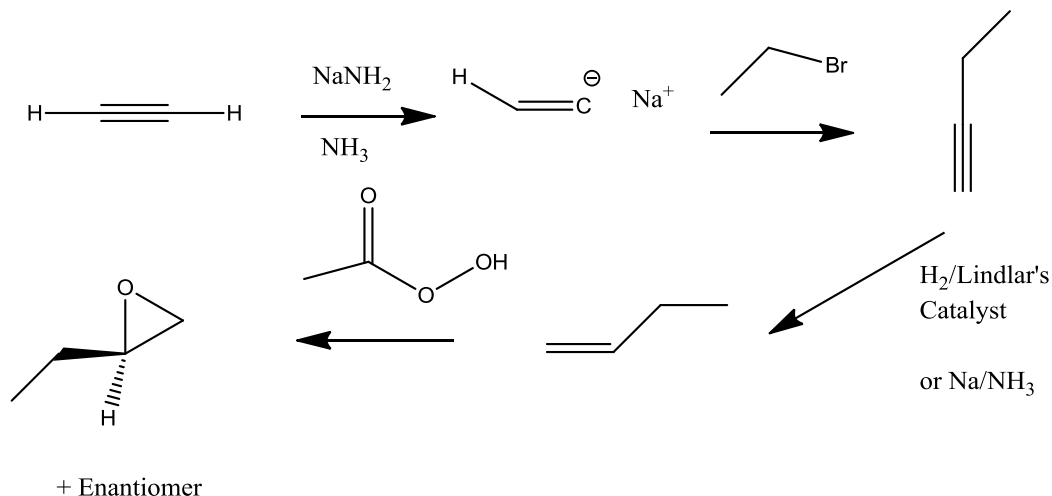




ORG-

Alkynes in synthesis and retrosynthesis (8th edition, not covered, 9th edition, 9.15)

Alkynes are used in many synthesis reactions. The example on page 360 and below is incorrect. What is incorrect about the synthesis? Correct it.



(Problem 9.16) Outline a synthesis of E- $\text{CH}_2=\text{CHCH}_2\text{CH}_2\text{CH}=\text{CHCH}_3$ from propyne, organic compounds with four carbons or fewer, and any necessary reagents.

Polymers that conduct electricity (Not covered in your book. Nobel Prize, 2000)

Acetylene can be polymerized to form two different forms of polymers. The two types are all-cis-polyacetylene (copper colored) and all-trans-polyacetylene (silver colored). It was found that the all-cis conducted electricity much better than the all-trans. An example of the two different forms is given below. Ref: http://nobelprize.org/nobel_prizes/chemistry/laureates/2000/chemadv.pdf

Spectroscopy and Spectrometry (8th edition, Chapter 13, 9th edition, same)

Spectroscopy is the interaction of organic matter with electromagnetic radiation. Spectrometry is the interaction of organic matter with highly charged species. There are three different types of spectroscopy that will be discussed in this class. There is one type of spectrometry discussed in this class.

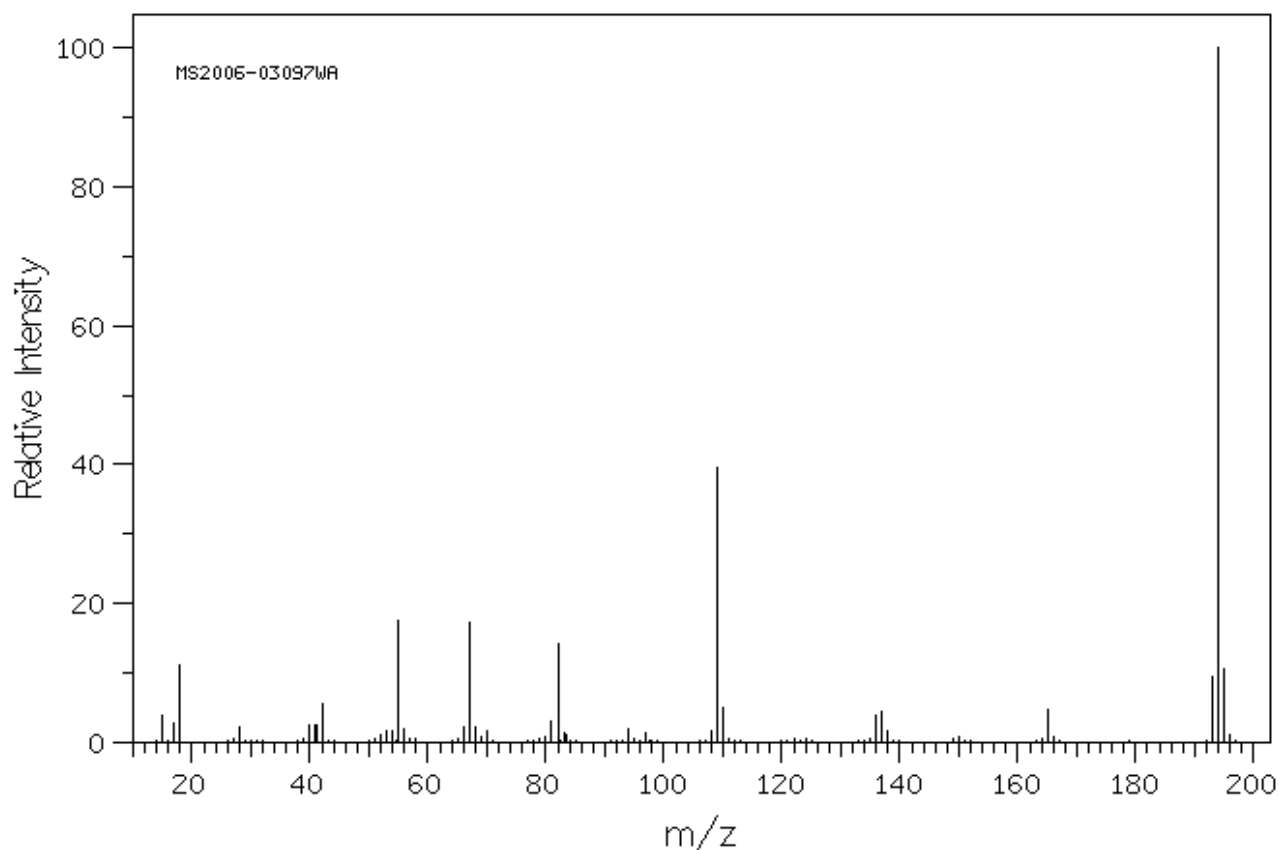
<u>Spectroscopy</u>	<u>Electromagnetic radiation</u>	<u>Uses</u>
Infrared (IR)	Infrared	Functional groups
Nuclear Magnetic Resonance	Radio waves	Connectivity of atoms
UV-Vis	Ultra-violet and visible	Conjugation
Spectrometry		

The spectrometry we will study in this class is _____ spectrometry.

ORG-

Mass Spectrometry (8th edition, Chapter 13.24, 9th edition, same)

Mass spectrometry is used for determining the molecular weight of a compound and possibly identifying components of a compound. Mass spectrums identify a **cation radical** or cation. If the particle of interest is not positively charged, it will not be seen. An example of a mass spectrum is given below. There are a couple of terms that you should with which you should become familiar.



Mass spectrum of caffeine. Courtesy of the Integrated Spectral Data Base System for Organic Compounds by the Japanese National Institute of Advanced Industrial Science and Technology. http://riodb01.ibase.aist.go.jp/sdbs/cgi-bin/cre_index.cgi?lang=eng

Many spectra will be used from this resource.

Terms

M/Z: mass to charge ratio. For our purposes, the charge will be assumed to be one so that the value of m/z corresponds to the mass.

Mass ion peak: M^+ is the molecular ion for the molecule. For caffeine ($C_8H_{10}N_4O_2$), this peak is at 194. For most molecules the M^+ peak is seen on the mass spectrum but it is not seen if formation of a stable cation is possible. (i.e. tertiary alcohols)

$M+1$ peak: This peak is one mass unit greater than the mass ion peak. For caffeine, this peak is seen at 195.

$M+2$ peak: This peak is two mass units greater than the mass ion peak. For caffeine, this peak is seen at 196.

Base peak: This peak is the peak with the relative intensity of 100 %. The base peak is caused by the most stable cation. For caffeine, the base peak is at 194.

Resolution: Resolution is measured from peak heights and spacing. The two resolutions are low resolution and high resolution. Low resolution is to whole numbers (i.e. 44) while high resolution is to more numbers (i.e. 44.04356)

Possible methods to make the cation for MS

EI: Electron ionization with a stream of high energy electrons (70 electron volts). All of the spectra shown in class will be EI.

CI: Chemical Ionization is caused by a carrier gas (usually methane) reacting with electrons to make primary ions (CH_4^+ and CH_3^+). These ions then react with sample. This may be used when the mass ion peak does not show up with EI.

FAB: Fast atom bombardment is accomplished by using Xenon atoms.

ESI: Electrospray ionization concerns using a voltage across a spray coming out of a liquid chromatograph machine. John Fenn won the Nobel price in 2002 for this technique which is used on proteins and peptides.

Soft Laser Desorption: This technique is where a laser is used to form a cation from large molecules. Koichi Tanaka won the Nobel prize in 2002 for this technique and an example of this technique is MALDI. (Matrix Assisted Laser Desorption/Ionization)

Types of MS

MS: The first type is to use just a MS to generate a mass spectrum. This is an older technique and has been overtaken by other methods.

GC/MS: This type stands for gas chromatograph/mass spectroscopy. The GC separates compounds while the MS determines the mass spectrum for each component.

LC/MS: This type stands for liquid chromatography/mass spectroscopy. It is a newer method and uses an HPLC to separate compounds before they are analyzed.

MS/MS: This type stands for having two mass spectral machines in tandem. The first MS separates the molecule into parent ions. The parent ions are then collapsed to form daughter ions in the second machine.

FT-MS: This type stands for Fourier Transform-Ion Cyclotron Resonance Mass Spectrum.

TOF: Time of flight separates the particles.

Quadrupole Mass Filter: This type uses four (hence quadrupole) voltage carrying rods to separate the particles.

How to Read a Mass Spectrum

1) Look to see if the M^+ peak is even or odd. If it is even like in caffeine above (194), the molecule contains an even number of nitrogens (4 being even). If the M^+ peak is odd, the molecule contains an odd number of nitrogens.

ORG-

2) Look at the M+2 peak in comparison to the M+ peak. This will help you identify which elements may be present.

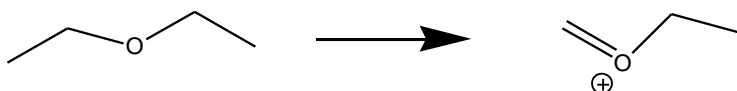
<u>M+ (relative intensity)</u>	<u>M+2 (relative intensity)</u>	<u>Element Present</u>
100	100	Br
100	35	Cl
100	4.4	S

3) Look at the fragmentation patterns. Functional groups fragment in predictable ways. Some examples of functional groups are below.

a) Look for CH₂ next to benzene
m/z 91

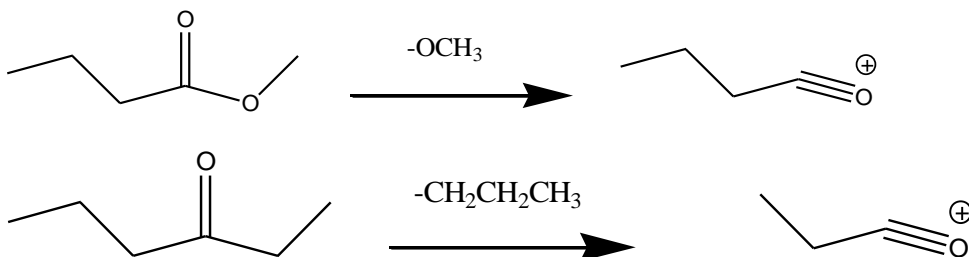
Ethers (8th edition, Chapter 16.18, 9th edition, 16.17)

b) Ethers fragment at the alpha carbon to furnish the stable carbocation. Look for loss of the group attached to the alpha carbon. In the example of diethylether below, -15 or methyl.



Carbonyls (8th edition, Chapter 17.16, 9th edition, 17.15)

c) Carbonyl compounds are carbon double bonded to an oxygen. Loss of one of the side groups forms the very stable acylium ion. Examples below are for an ester and a ketone.



d) Some other fragmentation patterns are rearrangements like a Diels Alder or the McLafferty rearrangement.

Calculations

1) M+1 (Not in your book.)

Divide the M +1 peak by 1.1 to determine the number of carbons present in the molecule. Some examples follow.

i) Assume the M+ peak is 100 % relative intensity and the M +1 peak is at 10 %. Dividing the M + 1 peak by 1.1 tells you that there are 9 carbons in the compound. This method rarely gives you exact whole numbers.

ii) Assume the M + peak is at 40 % relative intensity and the M +1 peak is at 4.8. The M+ must be converted to 100 %. Dividing 100 by 40 gives a factor of 2.5. Multiplying 4.8 by 2.5 gives a value of 12. Dividing 12 by 1.1 gives 10.9 carbons. The M+ peak was NOT 100 so it had to be converted to 100 and multiplying it by 2.5 made it 100. The M +1 peak had to be multiplied also.

ORG-

2) Rule of 13 (Not in your book.)

The rule of 13 will give you a molecular formula for the alkane (C and H) for a corresponding molecular weight. Some examples follow.

a) Assume you have a molecular weight of 400. Divide 400 by 13 which gives you 30.7692. Thirty is the number of carbon atoms. (Multiply the remainder (.7692) times 13 to get 10. Add this number, 10, to the whole number, 30, to get the number of hydrogens, 40.) OR, multiply thirty (number of carbons times twelve) to get the mass of carbon. This would be 360. Subtraction of 360 from 400 will also give you forty hydrogens. So the molecular formula is $C_{30}H_{40}$ which equals 400.

b) Assume you have a compound that you think is caffeine. You do a mass spectrum and it gives you a molecular weight of 194. Dividing 194 by 13 gives you 14.9231. Multiplying 0.9231 by 13 gives you 12. Therefore, the molecular formula of the alkane is $C_{14}H_{26}$. Caffeine has four nitrogen atoms and two oxygen atoms which equals 88. Subtract 6 carbons and 16 hydrogens to get 88. Therefore, the molecular formula for caffeine is $C_8H_{10}N_4O_2$.

ORG-

3) Exact calculation from a high resolution mass spectrum. (Not in your book.)

N_2O and CO_2 both give a low resolution M^+ peak at 44. However, they give different values at high resolution.

$N = 14.00307$

$O = 15.99491$

$C = 12.00000$

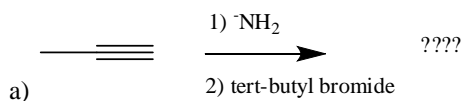
CO_2 is 43.9898 while N_2O is 44.0011. These compounds will show up at those exact numbers at high resolution allowing you to decide the molecular formula.

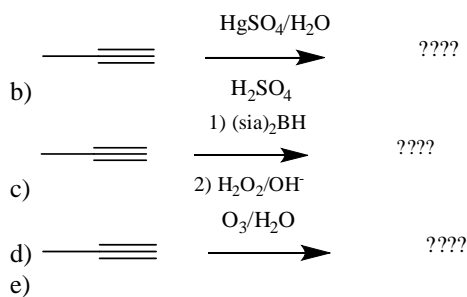
Want more work with MS?

Try <http://svmsl.chem.cmu.edu/vmsl/default.htm> for the virtual mass spectrum lab.

Questions:

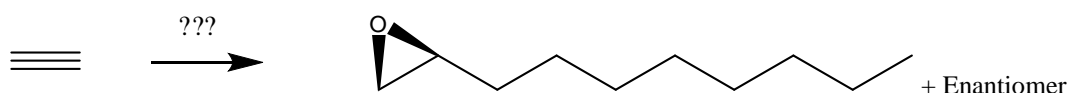
1) Give the product(s) (if any) for the following reactions.





2) Solution A was prepared by dissolving potassium acetate in methanol. Solution B was prepared by adding potassium methoxide to acetic acid. Reaction of methyl iodide either with solution A or with solution B gave the same major product. Why?

3) Work the following synthesis problem indicating the steps necessary for conversion from acetylene to compound A.



4) Give three different ways to make 2-butyne. You must start with three different classes. For example, you can not use a geminal dichloride and then use a geminal dibromide. This would count as one way to make the alkyne.

EXTRA NOTES: