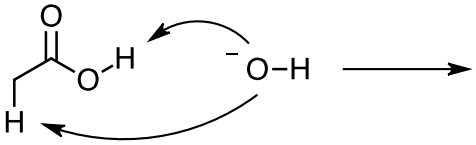
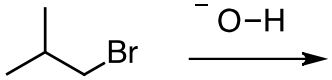
Objective 1: review CHM 12A sub/elim/addition/acid-base reactions.
Quiz Practice problems
Key ideas:
Most organic reactions are polar reactions. A polar reaction involves a nucleophile reacting with an electrophile.
We looked at acid-base, nucleophilic substitution, elimination, and electrophilic addtion reactions in Chem 12A.

Skills:
Given a compound, identify structure features, e.g., alpha carbon, H on beta carbon, leaving group, pi bond.
Given a compound, identify nucleophilic atom or electrophilic atom or both.
Give reactants and reaction conditions, use curved arrows to show how reactants react to form products for acid-base, nucleophilic substitution, elimination, and electrophilic addtion reactions.
Identify major product. Give reasons.

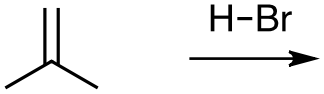
1. a. Two possible acid-base reactions are shown.



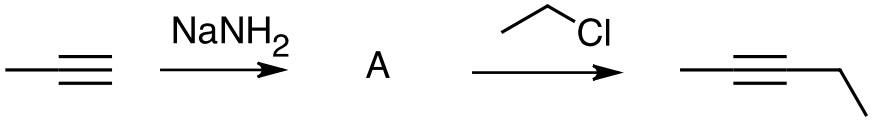
(i) For each acid-base reaction, draw in the missing curved arrow and draw the structures of the products.
(ii) Which acid-base reaction is more likely to occur? Give reasons based on pK_a and stability of the conjugate base.
b. A strong acid, which easily donates its proton, has a weak conjugate base. Does a weak base easily accept a proton? Give reasons.
c. (i) For the alkyl bromide shown below, circle the alpha carbon and box the leaving group. State the number of H's bonded to beta carbons. Identify the nucleophiles and electrophiles in this reaction.



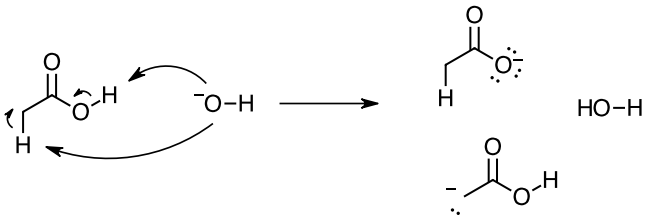
(ii) Use curved arrows to show how OH^- reacts with the alkyl bromide to form a substitution product and elimination product.
d. Substitution reactions are used to convert one _____ into another. What structural features are needed in a substitution reaction?
e. Elimination reactions are used to make a _____ bond. What structural features are needed in a elimination reaction?
f. (i) In the reaction below, identify the nucleophile and electrophile.



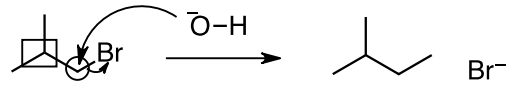
(ii) Use curved arrows to show how the nucleophile reacts with the electrophile. Draw the products of this reaction.
g. (i) Addition reactions are used to ____ ____ atoms or groups to a _____ bond.
(ii) Addition reactions are used to convert an _____ to another _____.
h. The carbons in a C=C bond are called ___ carbons.
i. Making C-C bonds is important in synthesis. What reaction type is the first step? Use curved arrows to show how Compound A forms. Then, use curved arrows to show how A reacts with C_2H_5Cl to form the product.

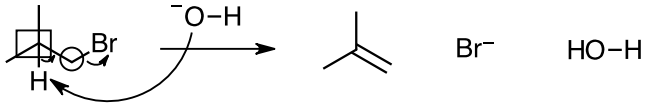


Answers:
a(i).

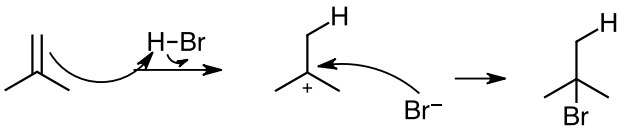


(ii). OH- reacts with H bonded to O. This H is more acidic (pK_a =5, conjugate base is stable with resonance structures) compared to H bonded to C (pKa = 24, conjugate base is less stable).
b. A weak base does NOT easily accept a proton.
E.g., HA <==> $H^+ + A^-$.
If HA is a strong acid, it easily donates its proton to form its conjugate base, A^-. A^- does not react with H^+ to reform the acid, HA. This makes the conjugate base, A^-, weak. This reaction favors the products.
If HA is a weak acid, it does not easily donates its proton to form its conjugate base, A^-. A^- does react with H^+ to reform the acid, HA. This makes the conjugate base, A^-, strong. This reaction favors the reactants.
c. (i) 1 H bonded to beta C.
Nucleophile = OH-.
Electrophile = alpha C in substitution reaction, H on beta C in elimination reaction.

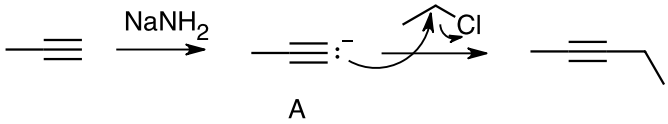




(ii) Substitution reaction: OH^- nucleophile reacts at alpha carbon to form C-O bond and Br leaving group leaves.
Elimination reaction: OH^- nucleophile reacts at H bonded to beta carbon to form H-O bond, C-H bond breaks and forms C=C pi bond, and Br leaving group leaves.
d. Substitution reactions are used to convert one functional group into another. Structural features needed in a substitution reaction are alpha carbon, leaving group, and nucleophile.
e. Elimination reactions are used to make a pi bond. Structural features needed in an elimination reaction are H bonded to beta carbon, leaving group, and nucleophile.
f. (i) C=C pi bond is nucleophile. Acidic H in HBr is electrophile.
(ii)



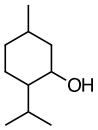
g. (i) Addition reactions are used to add two atoms or groups to a pi bond.
(ii) Addition reactions are used to convert an alkene to another functional group.
h. The carbons in a C=C bond are called vinylic carbons.
i. First step is an acid-base reaction. 2nd step is a substitution reaction.



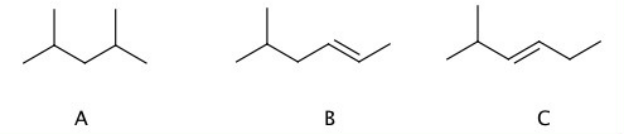
2. Nucleophiles and electrophiles
a. Are anions more likely to be nucleophiles or electrophiles? Are cations more likely to be nucleophiles or electrophiles?
b. Which is the reactive part of $NaOCH_3$? Is this part of $NaOCH_3$ a nucleophile or electrophile?
c. See a pK_a table.
(i) Which substances are good leaving groups?
(ii) Is SO_4^{2-} a good LG?
(iii) Is HPO_4^{2-} a good LG?
(iv) Is the alcohol group a good LG? If not, how can you make this group a better LG?
(v) Is the ether group a good LG? If not, how can you make this group a better LG?
d. Is an alpha carbon a nucleophile or electrophile? What property supports your answer?
e. Is a H bonded to a beta carbon a nucleophile or electrophile? Give reasons.
f. A pi bond is a nucleophile. Why does a pi bond react with HCl but not CH_3COOH?
g. Acetylene reacts with a strong base to form the acetylide ion, $HCC:^-$. Will an electrophile react with the pi bond or the lone pair? Give reasons.
Answers:
a. Anions are more likely to be nucleophiles. Cations are more likely to be electrophiles.

b. The reactive part of $NaOCH_3$ is OCH_3^-. OCH_3^- is a nucleophile.
c. (i) Good leaving groups are weak bases.
(ii) SO_4^{2-} is a good LG.
(iii) HPO_4^{2-} is a good LG?
(iv) The alcohol group a not a good LG. Make this group a better LG by protonating the O.
(v) The ether group a not a good LG? Make this group a better LG by protonating the O.
d. An alpha carbon is an electrophile. The alpha carbon is less electronegative than a leaving group and has a partial positive charge.
e. A H bonded to a beta carbon is an electrophile? This H is slightly less electronegative than C. This H reacts with a Nu:- in an elimination reaction.
f. A a pi bond reacts with HCl but not CH_3COOH because a pi bond is a weak nucleophile and reacts with a strong electrophile. HCl is a strong acid; CH_3COOH is a weak acid and is not a strong enough electrophile to react with a pi bond.
g. Acetylene reacts with a strong base to form the acetylide ion, HCC:$^-$. An electrophile reacts with the lone pair rather than the pi bond because the lone pair is a stronger nucleophile than the pi bond.

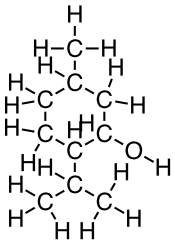
3. Menthol is a compound that gives a cool sensation.



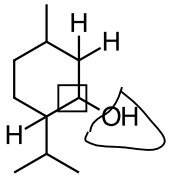
a. What is the chemical formula of menthol? Draw the Lewis structure of menthol to support your answer.
b. Circle the most acidic proton. What is the approximate pK_a?
c. Box the alpha carbon(s). Draw in the H's bonded to the beta carbon(s). Triangle the leaving group(s).
d. Which skeletal structure matches $(CH_3)_2CHCH_2CHCHCH_3$?



Answers:
a. $C_{10}H_{20}O$



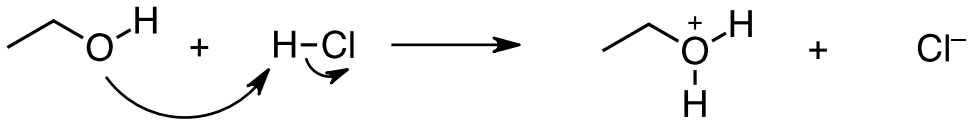
b. See pK_a table. The most acidic H is the H bonded to the O with a pKa of approximately 17.
c. The alpha carbon is the C bonded to the O.
The beta carbons are the carbons bonded to the alpha carbon.
The leaving group is OH.



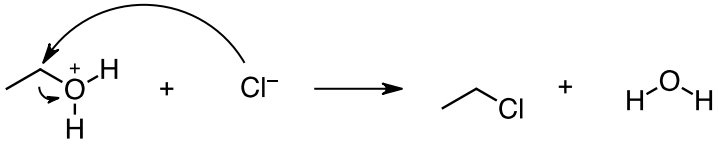
d. $CH_3)_2CHCH_2CHCHCH_3$ = B
Draw in the H's to confirm your answer.

4. Ethanol (C_2H_5OH) is the alcohol that we humans can drink in small quantities without getting too sick. It is also organic solvent and is produced by fermentation of sugar.
a. HCl reacts with ethanol to produce $C_2H_5OH_2^+$ and Cl^-. Use curved arrows to show how reactants produce products. What is the reaction type?

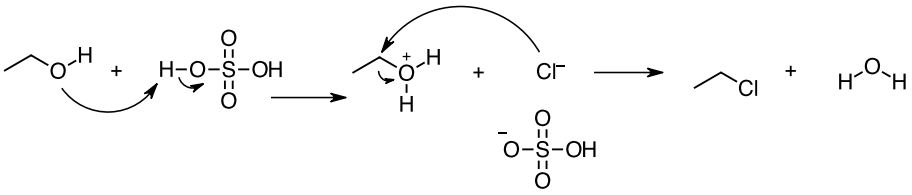
b. $C_2H_5OH_2^+$ reacts with Cl^- to form ethyl chloride. Use curved arrows to show how reactants produce products. What is the reaction type?
c. Cl^- will not react with ethanol to produce ethyl chloride. Explain why.
d. Another way to convert ethanol to ethyl chloride is to use H_2SO_4 and NaCl. Use curved arrows to show how this reaction occurs.
e. Ethyl chloride spray is used as a topical anesthetic (it freezes and numbs the skin.) Ethyl chloride reacts with a base to form ethylene (which is used to make polyethylene plastic). What base could you use? Use curved arrows to show how this base reacts with ethyl chloride to produce ethylene. What is the reaction type?
f. Ethylene reacts with HCl to form ____. Fill in the blank. Use curved arrows to show how reactants produce products. What is the reaction type?
Answers:
a. acid-base reaction



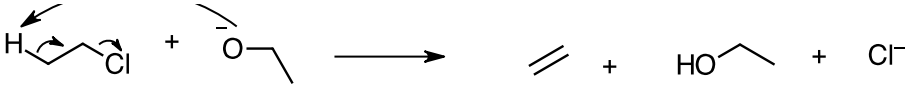
b. substitution reaction



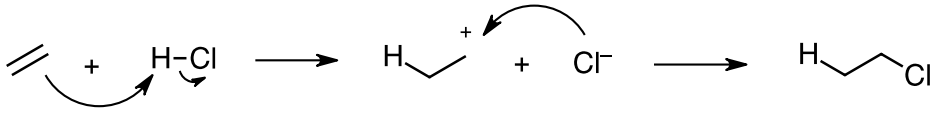
c. Reaction will not occur because –OH is a poor leaving group.
d.



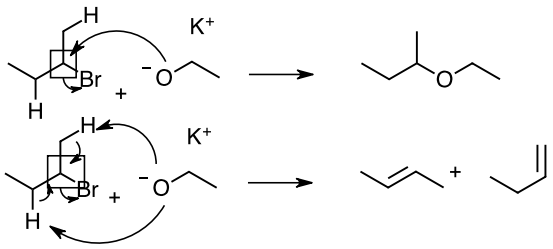
e. elimination reaction



f. Ethylene reacts with HCl to form ethyl chloride. addition reaction

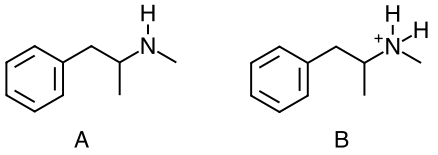


5. 2-bromobutane is a colorless liquid with a pleasant odor but is toxic and flammable.
a. 2-bromobutane reacts with KOC_2H_5.
(i) Circle the nucleophilic atoms in 2-bromobutane. Box the electrophilic atoms in 2-bromobutane.
(ii) Which is the reactive part of KOC_2H_5? Is this part of KOC_2H_5 a nucleophile or electrophile? Is it strong or weak? Big or small?
(iii) Draw the structure of the substitution and two elimination products. Use curved arrows to show how each product is formed.
(iv) Which product is the major product? Give reasons.
b. You want to synthesize 2-chloroobutane from 2-bromobutane. Would you use HCl or Cl^-? Explain why one works and the other does not.
c. Does HCCH react with 2-bromobutane? If so, draw the structure of the product.
d. Does $HCC:^-$ react with 2-bromobutane? If so, draw the structure of the product.
Answers:
(i) No nucleophilic atoms in 2-bromobutane. The electrophilic atom is the alpha carbon.
(ii) The reactive part of KOC_2H_5 is the O with (-) charge. This part of KOC_2H_5 is a small, strong nucleophile.
(iii)



(iv) The major product is 2-butene. 2° R-Br and strong nucleophile favors elimination. 2-butene is a disubstituted alkene and is more stable than monosubstituted 1-butene.

6. Methamphetamine is a stimulant. Two forms of methamphetamine are shown below.

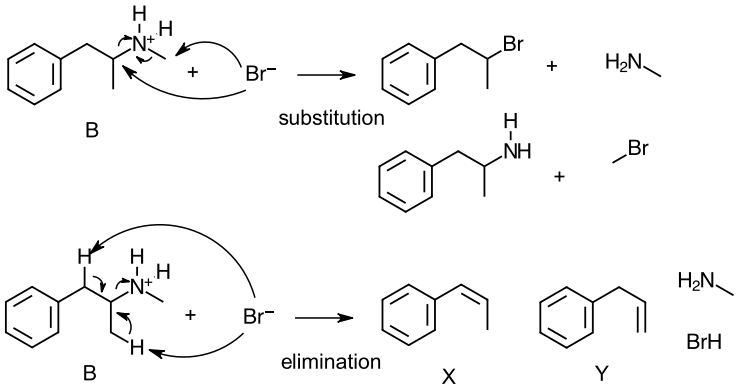


A B

a. How many alpha carbons are in Structure A?
b. Which form of methamphetamine has the better leaving group? Give reasons.
c. Structure A does not react with Br^-. Explain why.
d. Structure B reacts with Br^-. Draw the structure of the all the possible substitution and elimination products.
e. Which product is the major product? Give reasons.

Answers:

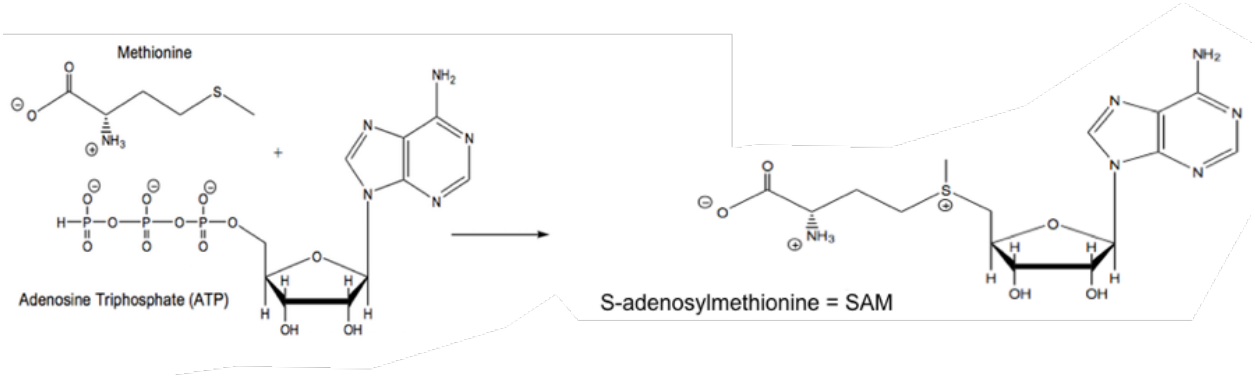
a. Structure A has two alpha carbons. Each C bonded to N is an alpha C.
b. B has the better leaving group. The NRH_2 group is a weaker base than the NHR group. See pK_a table.
c. Structure A does not react with Br^- because NHR is a poor leaving group.
d.



e. Elimination product X (disubstituted alkene) is the major product. Br^- is a small, weak $Nu:^-$. Need a small, strong $Nu:^-$ to react at a 1° alpha C to form the substitution product.

7. S-adenosylmethionine (SAM) is an alkylating agent that is found in biological reactions. The synthesis of SAM is shown below.

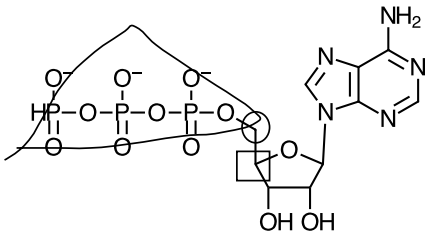
a. Identify the reaction type.
b. Circle the alpha carbon(s) and box the beta carbon(s). Is the alpha carbon a chirality center?
c. Triangle the leaving group.
d. What is the nucleophile?
e. State the reaction mechanism type.



Answers:

a. substitution reaction.

b and c.



The alpha carbon is not a chirality center.

d. $Nu:^-$ = S in methionine

e. S_N2 mechanism