Answer Key

1. Classify the alkenes below as one of the following: *monosubstituted, disubstituted, trisubstituted, or tetrasubstituted.* (15 points)

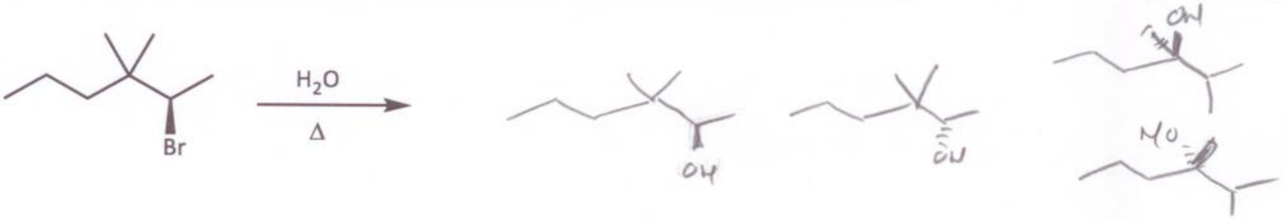
   a. 2-methyl-1-pentene disubstituted

   b. 2-methyl-2-pentene trisubstituted

   c. 4-methyl-1-pentene monosubstituted

2. For the following substitution reactions show the product (or products). Indicate whether the reaction proceeds by the S_N1 or S_N2 mechanism. (Be very clear about any stereochemistry outcomes) (10 points)

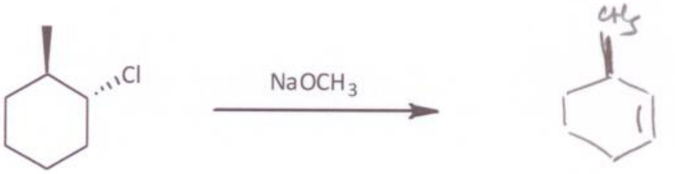
a.



b.

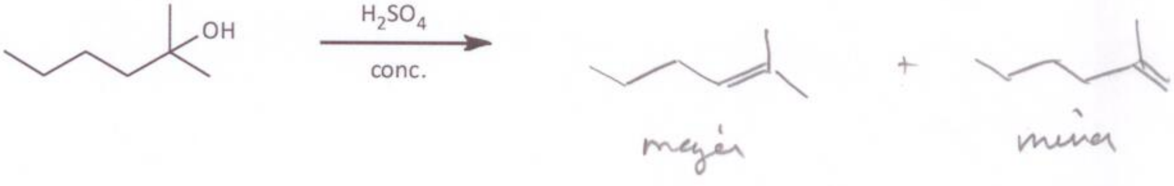
3. For the following elimination reactions show the product (or products). (Be very clear about any stereochemistry outcomes). (10 points)

a.

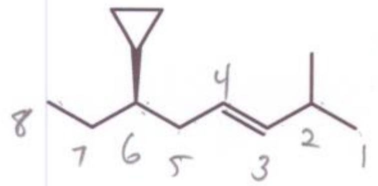


only

b.



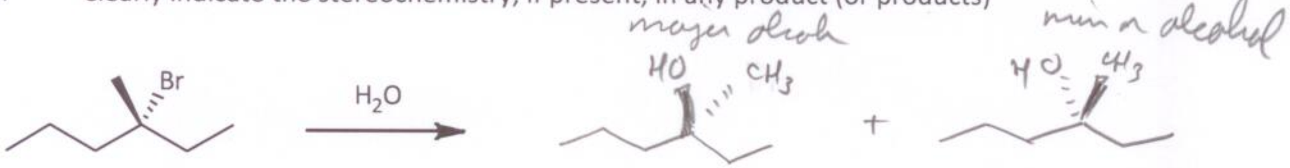
4. Name the following compound. Assign stereochemistry where necessary using the appropriate notation. (10 points)



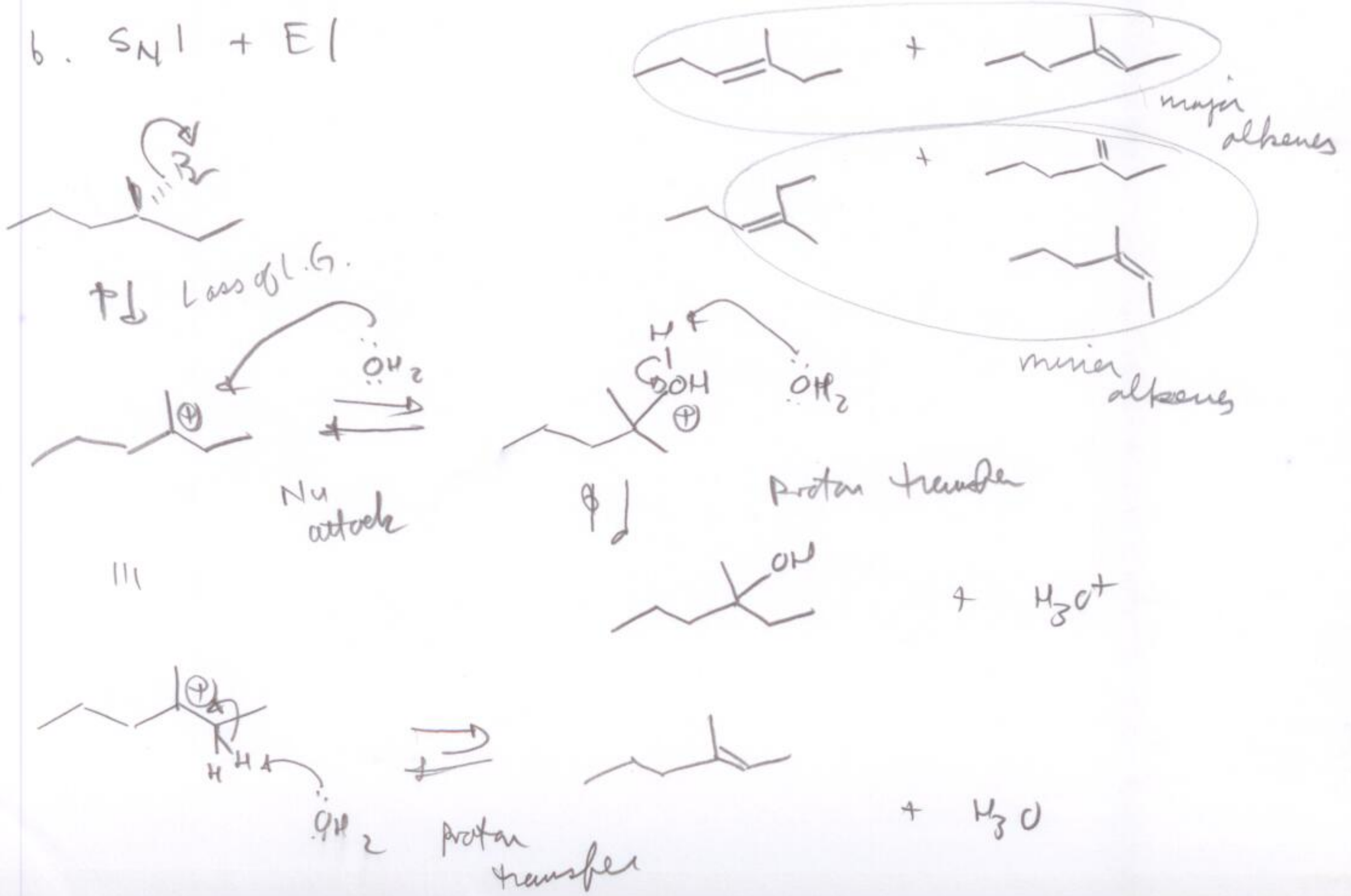
(3E, 6R) –
6 – cyclopropyl – 2 – methyloct – 3 – ene

5. Consider the following reaction: (25 points)

a. Draw all of the products for this reaction.
b. What type of mechanism(s) does this reaction proceed under (S_N2, S_N1, E2, or E1 – or some mix)
c. Show the complete mechanism for the reaction, including all steps.
d. Label each step of the reaction with one of the following: *nucleophilic attack, loss of a leaving group, proton transfer, or carbocation rearrangement.*
e. Clearly indicate the stereochemistry, if present, in any product (or products)

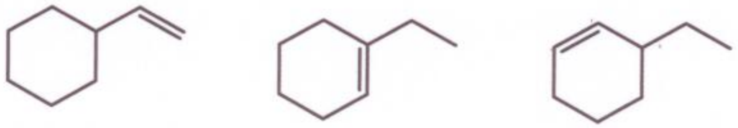


b. S_N1 + E1



6. Consider the following series of alkenes. (15 points)

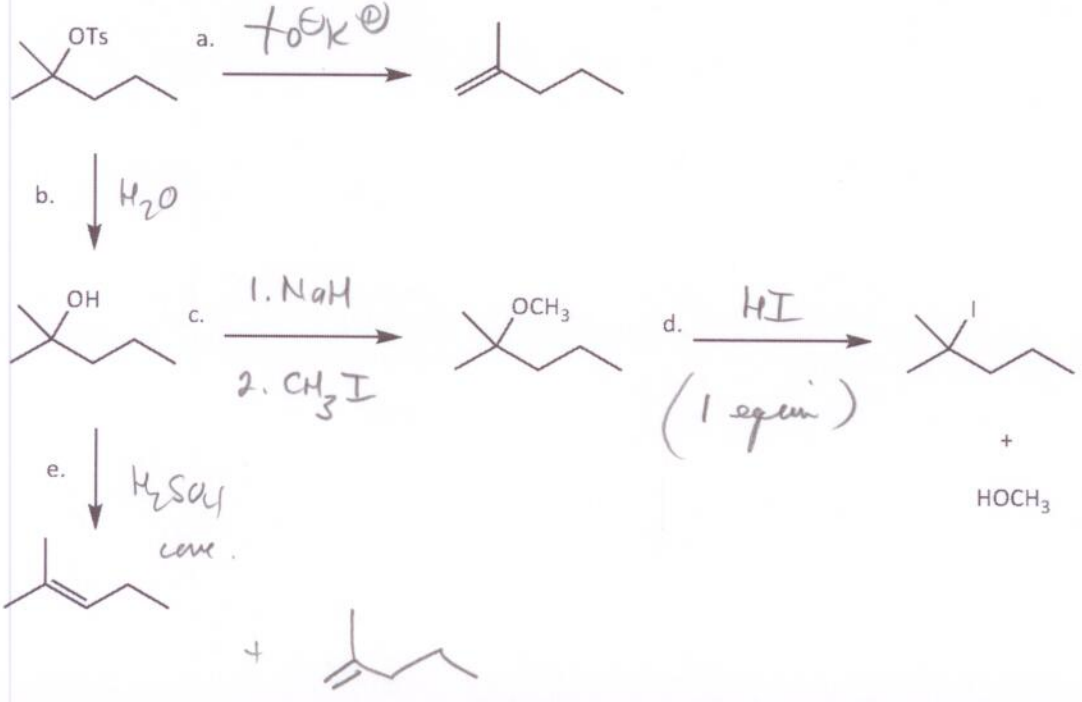
  a. Rank each of them from most stable (1) to least stable (3).
  b. Name each alkene (use E/Z notation *if necessary*)
  c. Predict which alkene will have the most exothermic heat of hydrogenation ($\Delta H_{\text{hydrog.}}$) (hint: remember, hydrogenation is alkene $+H_2 \rightarrow$ alkane)



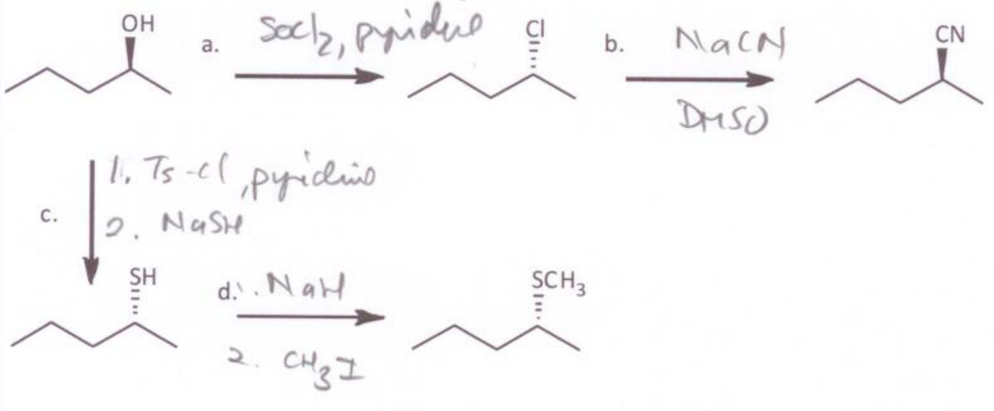
Rank	3	1	2
Name	cyclohexylethene	1-ethyl cyclo-hexane	3-ethyl cyclohexane
ΔH_{hydrog}	✓		

7. Explain why fluoride (F^-) is a better nucleophile in DMSO than in ethanol. (10 points)

8. Show how to accomplish all of the following transformations, i.e., fill in the reagents over each arrow. (25 points)

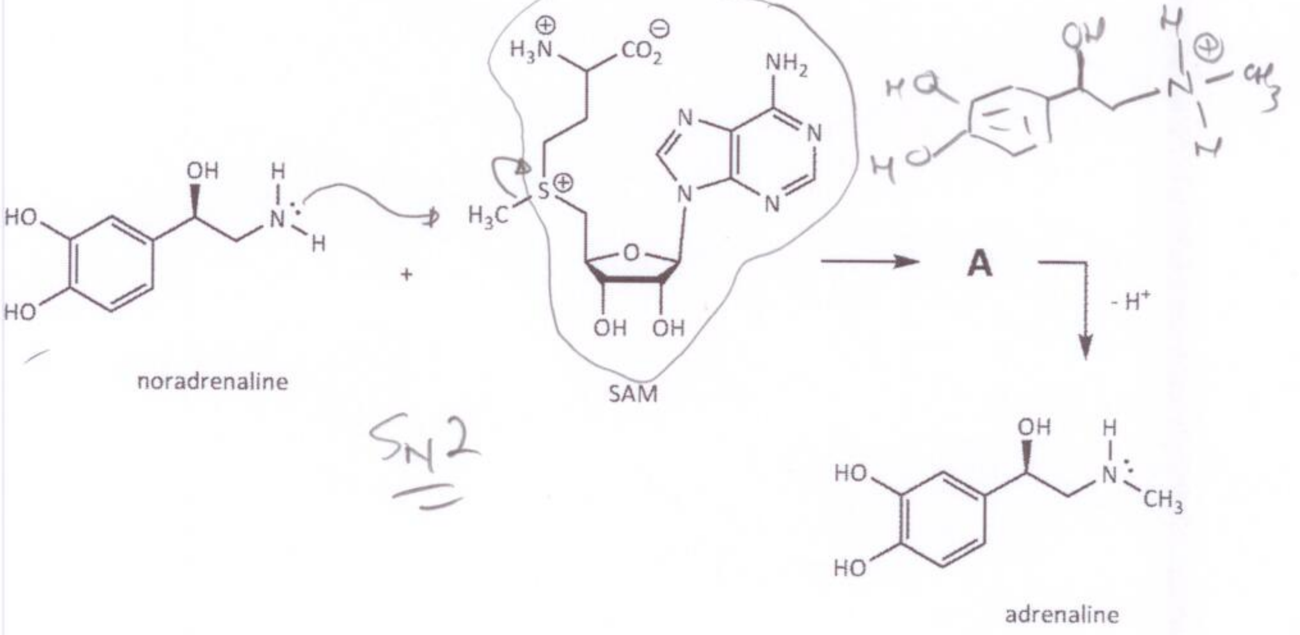


9. Show how to accomplish all of the following transformations, i.e., fill in the reagents over each arrow. Some of the steps might require more than one step (1. 2. , etc.) (20 points)



10. Nature's "methylating" reagent is *S*-adenosylmethinone (SAM) shown below. It is the biochemical reagent responsible for the near instantaneous production of adrenaline from noradrenaline. (20 points)

a. What is the reaction mechanism for this transformation?
b. Circle the leaving group.
c. Show the steps of the mechanism with electron pushing (that leads to intermediate A).
d. What is the likely structure of intermediate **A.**



SN2

TABLE 9.5 Dependence of S_N2 Reaction Rate on the Basicity of Nucleophiles from Different Periods of the Periodic Table in Methanol

$$\text{Nuc:}^- + H_3C{-}I \xrightarrow[25\,^\circ C]{CH_3OH} \text{Nuc}{-}CH_3 + I^-$$

Nucleophile	pK_a of conjugate acid*	k (second-order rate constant, $M^{-1}\,s^{-1}$)	log k
Group 6A Nucleophiles			
PhS^-	6.52	1.1	+0.03
PhO^-	9.95	7.9×10^{-5}	−4.1
Group 7A Nucleophiles			
I^-	−10	3.4×10^{-3}	−2.5
Br^-	−8	8.0×10^{-5}	−4.1
Cl^-	−6	3.0×10^{-6}	−5.5
F^-	3.2	5.0×10^{-8}	−7.3

* pK_a values in water

(Source: Marc Loudon *Organic Chemistry* 6th edition, Roberts and Co., 2016, p. 399)

12. Using the data in the table below (Table 9.6) clearly explain the following: (15 points)

a. The order of nucleophile strength of the halides in *protic* solvents (CH_3OH).

iodide is the fastest/strongest nucleophile - going toward fluoride the solvent has greater H-bonding so has larger solvent shell, so gets slower

b. The order of nucleophile strength of the halides in *aprotic* solvents (DMF).

aprotic solvent do not stablize the nucleophile so the more concentrated charge and basic halide is the more nucleophilic

c. What is the "strongest" nucleophile in the table using DMF as a solvent.

cyanide

Same answers as practice exam

11. Consider the table (Table 9.5, next page) regarding the S_N2 reaction of select nucleophiles from Group 6A and 7A with methyl iodide (CH_3I). Note that this question requires complete explanations for each part (not just one or two word answers) (50 points)

    a. Which data in the table indicate the trend in nucleophile strength for Group 6A elements – which one is the "stronger" nucleophile? Explain your answer.

    b. For the Group 7A nucleophiles, given the trend in the pK_a of the conjugate acid, is acidity a factor in predicting how strong the nucleophile is? Explain your answer.

    c. What effect would switching the solvent of the reaction to DMSO have on the rate of reaction of the nucleophiles in Group 7A with methyl iodide? Explain your answer.

    d. Where would the nucleophile $PhSe^-$ be placed in the Table? Explain your answer.

    e. For the "nothing" reaction in the table – the reaction of methyl iodide with iodide – how would you measure the rate constant for the reaction if "nothing" seems to happen (note the leaving group in this case). Explain your answer.

Same answers

10. Consider the table (next page) regarding the S_N2 reaction of select nucleophiles from Group 6A and 7A with methyl iodide (CH_3I). Note that this question requires complete explanations for each part (not just one or two word answers) (50 points)

a. Which data in the table indicate the trend in nucleophile strength for Group 6A elements – which one is the "stronger" nucleophile? Explain your answer.

the rate constants tell the "strength" - the larger the value, the faster the reaction - this how a nucleophile is ranked in terms of strength. Therefore $^{\ominus}SPh$ is ~10^4 times stronger (faster) than $^{\ominus}OPh$

b. For the Group 7A nucleophiles, given the trend in the pK_a of the conjugate acid, is acidity a factor in predicting how strong the nucleophile is? Explain your answer.

the acidity trend would suggest that $F^{\ominus}$ should be a stronger nucleophile than $I^{\ominus}$, since $F^{\ominus}$ is by definition a stronger base. So in this series the acidity alone doesn't account for the observed trend.

c. What effect would switching the solvent of the reaction to DMSO have on the rate of reaction of the nucleophiles in Group 7A with methyl iodide? Explain your answer.

changing to an aprotic solvent, the nucleophile receives less stabilization due to lack of H-bonding; the most concentrated charge is $F^{\ominus}$ using DMSO so the trend reverses - $F^{\ominus}$ is strongest, $I^{\ominus}$ is weakest Nu

d. Where would the nucleophile PhSe⁻ be placed in the Table? Explain your answer.

Would be an entry above $PhS^{\ominus}$ in the table and k would be greater than 1.1. Selenium is actually below sulfur in the periodic table, so the trend would be same as observed w/ the 7A element (in CH_3OH solvent)

e. For the "nothing" reaction in the table – the reaction of methyl iodide with iodide – how would you measure the rate constant for the reaction if "nothing" seems to happen (note the leaving group in this case). Explain your answer.

$$\underbrace{CH_3-I + I^{\ominus} \longrightarrow CH_3-I + I^{\ominus}}$$ "a nothing reaction"

as shown, can't tell anything changed, so how to measure rate? Use a radioisotope of iodine (e.g. ^{131}I). Follow the rate to form 50% mixture

$$CH_3-I + {}^{131}I^{\ominus} \underset{K=1}{\rightleftharpoons} CH_3-{}^{131}I + I^{\ominus}$$