**CHAPTER 1-3 QUIZ**

1. Consider $CHCCH_2COOH$.

(6) a. Draw the Kekulé (line-bond) structure. Show all lone pair electrons.

(2) b. Determine the hybridization of each C and O atom and indicate this in your structure.

(2) c. Determine the bond angles in the molecule (H-C-H angles not needed) and draw in your structure.

(2) d. Number of σ Bonds = _____ Number of π Bonds = _____

(2) e. Draw dipole moment symbols on individual bond(s) in your structure in a. above.

(2) f. Is the **molecule** polar? Yes or No. (Circle one.)

(2) g. Which of the above bonds is the shortest?

2. Consider the sulfate anion, $SO_4^{2-}$

(4) a. Draw a Kekulé (line-bond) structure of the sulfite anion. Show all lone pair electrons and write
the formal charge next to each atom in the ion.

(3) b. On the structure you drew in 2.a. above, use curved arrows to show the movement of electrons and generate **one** resonance form of your original structure, showing all lone pair electrons.

3. Draw the four isomers for the formula $C_4H_9Br$ (4 pts)

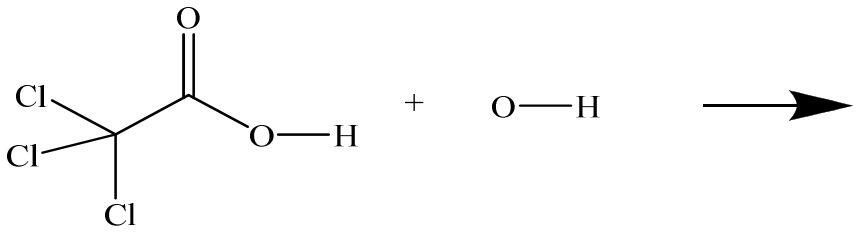
4. Consider the reaction of trichloroacetic acid ($pK_a$ 0.6) plus hydroxide ion ($pK_a$ of the conjugate acid of hydroxide ion = 15.74) in aqueous solution. Complete the equation below by:

(4) a. drawing the structure(s) of the products;

(4) b. adding lone pairs and charges to reactants and products as appropriate;

(4) c. label the acid and base reactants and their corresponding conjugate acid and conjugate base;

(4) d. show the movement of electrons curved arrows to depict how the reaction occurs.




(4) e. Does the equilibrium position favor reactants or products? Briefly explain.

5. (6 pts) Check all that apply for the following molecules:

| | Bronsted-Lowry Acid | Bronsted-Lowry Base | Lewis Acid | Lewis Base |
|---|---|---|---|---|
| $H_2O$ | | | | |
| $MnCl_2$ | | | | |
| $H_2CO_3$ | | | | |

6. Consider the following compounds. Then, answer the questions below:

$CH_3CH_2CH_3$ $H_3CCH_2CHO$ $CH_3CH_2CH_2OH$

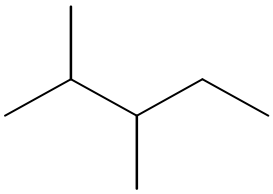
I II III

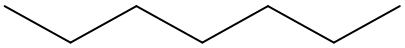
a. (4 pts) Rank them in terms of predictive boiling points from highest BP (1) to lowest BP (3).

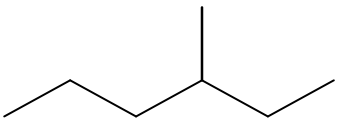
b. (4 pts) Explain the intermolecular forces that would predominate for II in liquid form.

7. (6 pts) Predict the relative boiling points for the following molecules. Rank them in terms of predictive

boiling points from highest BP (1) to lowest BP (3).



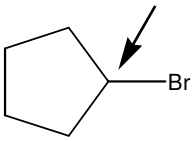


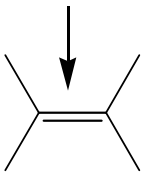


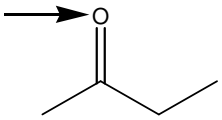
_____ _____ _____

8. (6 pts) Indicate whether the site indicated by the arrow is electrophilic or nucleophilic. Briefly explain

your choice in each case.





**CHAPTE R 4 QUIZ**

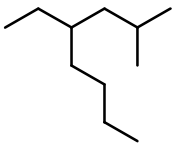


**Table 4.3 Summary: Torsional and Steric Strain Energies in Acyclic Alkanes**

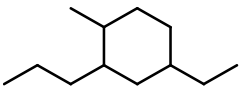
| Type of interaction | Energy increase kJ/mol | kcal/mol |
|---|---|---|
| H,H eclipsing | 4.0 | 1.0 |
| H,$CH_3$ eclipsing | 6.0 | 1.4 |
| $CH_3$,$CH_3$ eclipsing | 11 | 2.6 |
| gauche $CH_3$ groups | 3.8 | 0.9 |

1. Write the names of the following compounds.

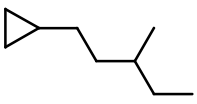
(3) a.



(3) b.



(3) c.



2. Draw the **skeletal** structure of the following compounds.

(2) a. 1,3-diethyl-2-isopropylcyclopentane (2) b. *trans*-1-ethyl-3-methylcyclobutane

3. Consider molecules with the formula $C_4H_{10}$.

(4) a. Draw the **skeletal** structure of 2 constitutional isomers of $C_4H_{10}$.

(2) b. On your structures in 3a. above, label one **1°** carbon and one **2°** carbon.

4. Consider *cis*-1,4-dimethylcyclohexane.

(5) a. Draw and label a chair conformation of the molecule. Number the carbons in the ring consistent with its name.

(5) b. Draw and label the chair conformation **after ring flip** of the structure you drew in 4a. above. Number the carbons in the ring consistent with your numbering in 4a.

(4) c. Briefly discuss which structure, 4a. or 4b., is most stable.

5. Consider 2-methylbutane, with carbons 2 and 3 labeled as shown below.


(5) a. Sight along the C2-C3 bond and draw the Newman projection for the most stable conformation.

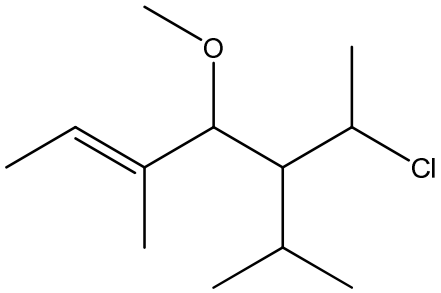
(2) b. Calculate the steric strain energy in kJ/mol for your Newman projection in 5b. above. Show your work.

(5) c. Sight along the C2-C3 bond and draw the Newman projection for the least stable conformation.

(2) d. Calculate the steric strain energy in kJ/mol for your Newman projection in 5d. above. Show your work.

**CHAPTER 5 QUIZ**

1. Consider the molecule shown below.




a. (8 pts) Indicate each of the chiral centers with an asterisk (*).

b. (2 pts) How many possible stereoisomers exist for this molecule?

2. a. (12 pts) Draw (*2R, 4R)* 2,4-dibromopentane ($CH_3CH(Br)CH_2CH(Br)CH_3$) indicating appropriate stereochemistry.

b. (2 pts) Identify the chiral centers with an asterisk.

3. a. (8 pts) Draw a **diastereomer** of (*2R, 4R)* 2,4-dibromopentane.

b. (2 pts) Give the stereochemical designation at each chiral center.

4. a. (8 pts) Draw the **enantiomer** of (*2R, 4R)* 2,4-dibromopentane.

b. (2 pts) Give the stereochemical designation at each chiral center.

5. (6 pts) Circle the structure from one of the compounds in this quiz which is a **meso** compound and briefly explain why you chose the circled structure.

Extra Credit (6 pts)

a. Can a mixture of **diastereomers** be separated by a physical technique such as distillation? Why or why not?

b. What is the enantiomeric excess (*ee*) of a mixture containing 90% of enantiomer A and 10% of
enantiomer B?

**CHAPTER 6 QUIZ**

(9) 1. Complete the following table by indicating whether products OR reactants are favored in a reaction.

| | Favors Products | Favors Reactants | Favors Neither Products or Reactants |
|---|---|---|---|
| ΔH = 40 kJ/mol | | | |
| ΔS = 40 J/K*mol | | | |
| ΔG = 40 kJ/mol | | | |
| $K_{eq}$ = 1 | | | |
| Endothermic reaction | | | |
| Exothermic reactions | | | |

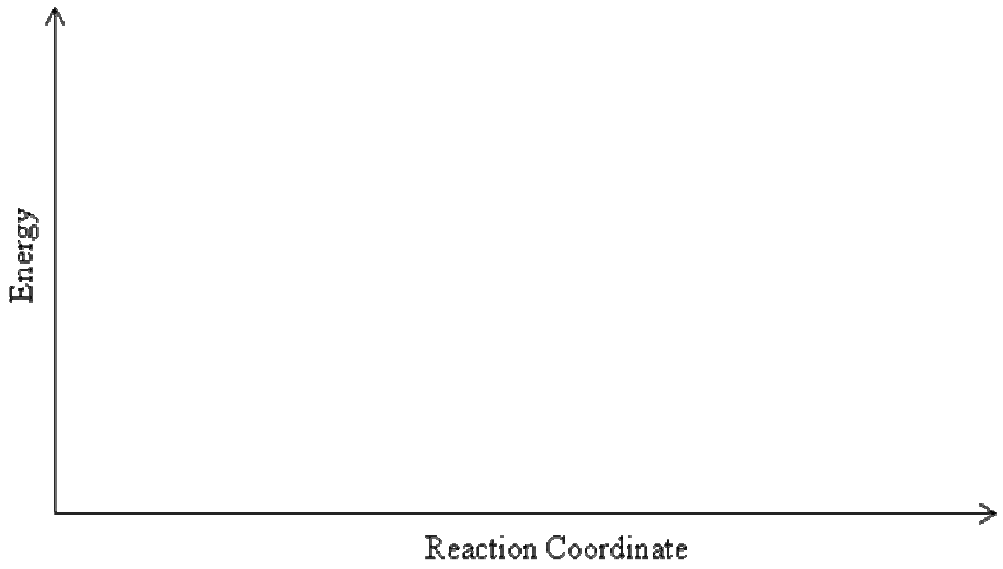
2. (COG 2) Use curved (electron pushing) arrows to cleave the A—B molecule. Write the products after the arrow.

(3) a. **Homolytic** Bond Cleavage: **A : B →**

(3) b. **Heterolytic** Bond Cleavage: **A : B →**

(11) 3. Draw and completely **label** the energy diagram (and clearly indicating ΔH and $E_a$) for the fast, exothermic one-step reaction of :

**$CH_3I + Cl^-$ to produce $CH_3Cl + I^-$**




4. (COG 4) Like other compounds, organic molecules undergo acid-base and oxidation-reduction reactions. Organic molecules also undergo substitution, elimination, and addition reactions.

a. Write a representative reaction in the space below to illustrate substitution, elimination, and addition. Use the appropriate **schematic molecules, parts of molecules, and atoms from the table below**.

b. Provide an example reaction (**real** molecules, parts of molecules, and atoms) for each schematic.

| **Representative Molecules, Parts of Molecules, and Atoms** | | | | | |
|---|---|---|---|---|---|
| —C(X)–C(Y)— | C=C | —C(Z)– | X–Y | Y | X |

(5) **Representative (use Table) Substitution Reaction:**

(3) **Example (real) Substitution Reaction:**

(5) **Representative (use Table) Elimination Reaction:**

(3) **Example (real) Elimination Reaction:**

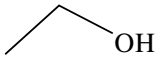
(5) **Representative (use Table) Addition Reaction:**

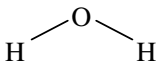
(3) **Example (real) Addition Reaction:**

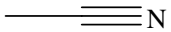
**CHAPTER 7 QUIZ**

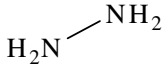
(12) 1. Circle your response for each of the following.

a. Which is the ***best*** solvent for an $S_N2$ reaction:



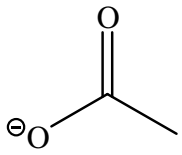




b. The ***best*** leaving group in an $S_N1$ reaction:

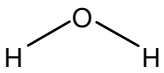




c. The ***worst*** nucleophile in a substitution reaction at a primary carbon:







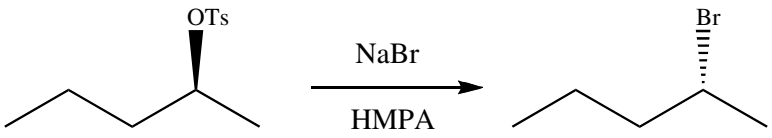


d. For rates of $S_N1$ reactions, which of the following is true with respect to the solvent:

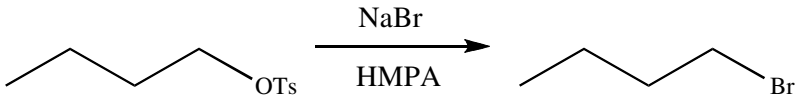
1) The best solvents lower the $\Delta G^{\ddagger}$ by stabilizing the transition state and intermediate.
2) The best solvents raise the $\Delta G^{\ddagger}$ by solvating the substrate.
3) The best solvents lower the $\Delta G^{\ddagger}$ by lowering the free energy of the nucleophile.
4) The best solvents raise the $\Delta G^{\ddagger}$ by lowering the free energy of the nucleophile.

(18) 2. Consider the pair of reactions below to answer the following questions.

(A)




(B)




a. The solvent in these reactions is:

(1) nonpolar aprotic

(2) polar protic
(3) polar aprotic
(4) nonpolar protic

b. The nucleophile in these reactions is:

(1) $Na^+$

(2) alkyl group

(3) $Br^-$

(4) $TsO^-$

c. Which reaction is faster? Explain your answer.

d. Halving the concentration of sodium bromide and keeping the alkyl tosylate concentration the same in these reactions:

(1) quadruples the rate of reaction

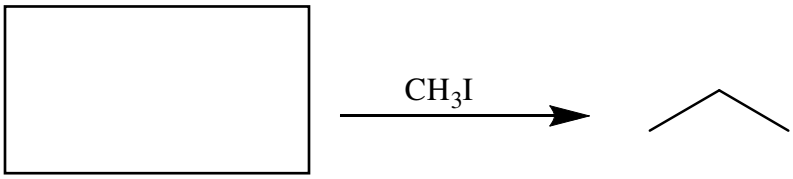
(2) halves the rate of the reaction

(3) has no effect on the rate of reaction

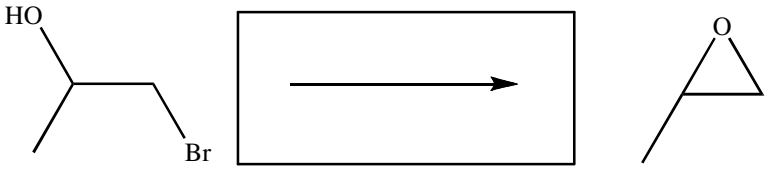
(4) doubles the rate of reaction

(8) 3. Provide the reagents and/or appropriate solvents required for the following transformations.

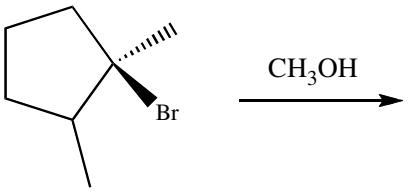
a.




b.



(14) 4. (COG # 6) For the following equation:

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(2 products)

a. Complete the above substitution reaction and draw the reaction mechanism for one of your products below including all lone pair electrons, electron pushing arrows and intermediates.

b. Name the alkyl halide reactant.

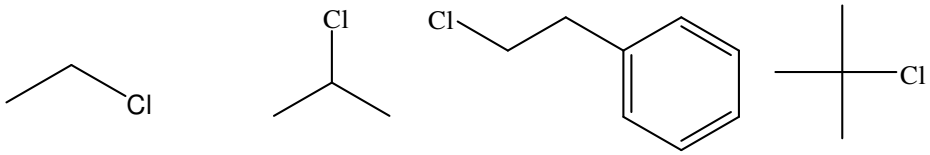
**CHAPTER 8 QUIZ**

(12) 1. Circle your response for each of the following.

b. Which is the ***best*** solvent for an E2 reaction:


e. The ***best*** leaving group in an E1 reaction:


f. The ***best*** substrate in an E2 reaction:

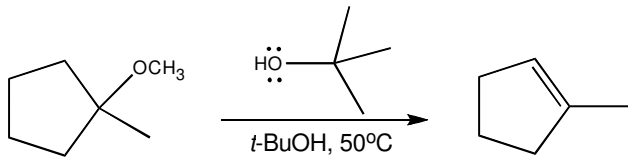



g. For rates of E1 reactions, which of the following is true with respect to the solvent:

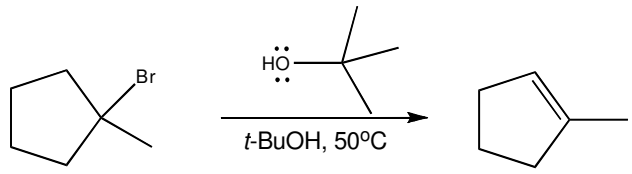
5) The best solvents raise the $\Delta G^{\ddagger}$ by solvating the substrate.
6) The best solvents raise the $\Delta G^{\ddagger}$ by lowering the free energy of the base.
7) The best solvents lower the $\Delta G^{\ddagger}$ by lowering the free energy of the base.
8) The best solvents lower the $\Delta G^{\ddagger}$ by stabilizing the transition state and intermediate.

(16) 2. Consider the pair of reactions below to answer the following questions.

A




B




a. Which reaction is faster? Write “A” or “B” below.

b. Explain your answer to the previous question.

c. Doubling the concentration of the substrate AND *t*-butanol (*t*-BuOH) in these reactions:

(1) causes the reaction mechanism to change

(2) reduces the rate of the reaction twofold

(3) has no effect on the rate of reaction

(4) doubles the rate of reaction

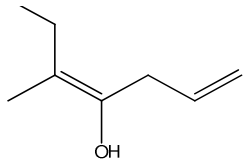
d. The mechanism for these reactions is:

(1) $S_N2$
(2) Electrophilic alkene addition
(3) E2
(4) E1

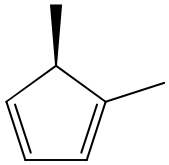
**CHAPTER 10 QUIZ**

1. (5 points) Provide a name for one (1) of the molecules shown below. Remember to include appropriate stereochemistry.

a.



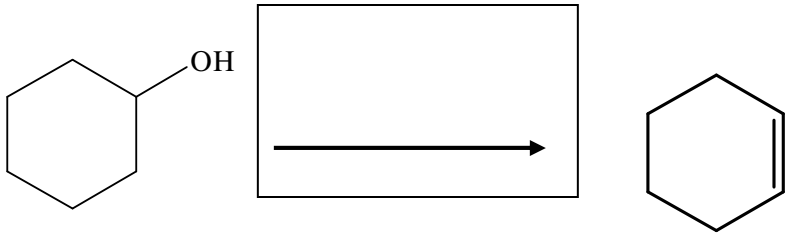

b.



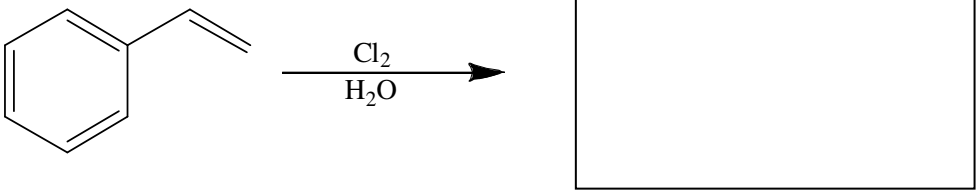
2. (5 points) Draw a structure for *R*-3-isopropyl-2-methylcyclohexene.

3. (20 points) Complete four (4) of the following reactions by drawing and/or writing the reactant, reagents, and/or products as appropriate. **Indicate regiochemistry and stereochemistry with solid-dash-wedge format as appropriate.** You may complete the remaining reaction for five points of extra credit. Circle your problem to be graded as extra credit.

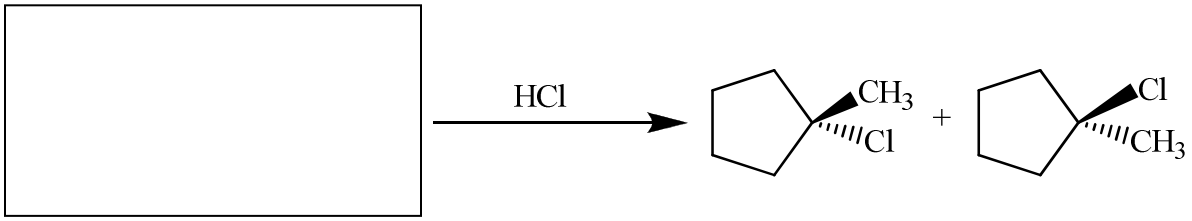
a.



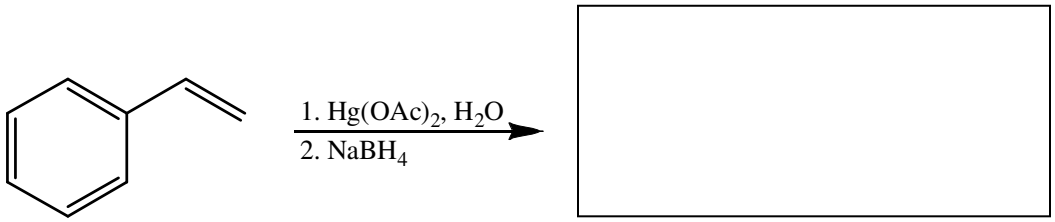
b.



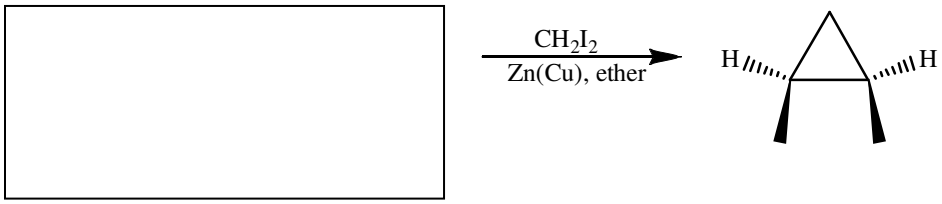

d.




d.




f.

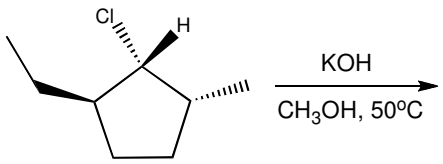



4. a. (18 points) (COG # 6) Use electron pushing arrows to draw the mechanism of the acid catalyzed electrophilic addition of water to 2-methylbutene. Include reactants, products, reagents and any intermediates.

b. (2 points) (COG # 6) Circle the carbocation intermediate.

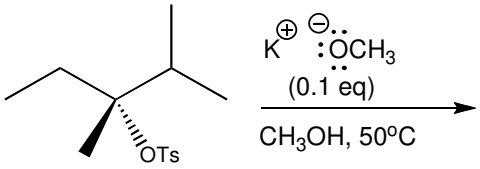
(8) 3. Draw the structure of the major organic product for the following reaction. Indicate the product stereochemistry as appropriate.

a.




b. For your answer in 3a., identify any stereocenter(s) present in the product by an "*" at the appropriate carbon(s). Label the stereocenter(s) as "R" or "S".

(14) 4. (COG # 6) For the following equation:

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_____ _____

minor product major product

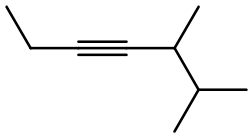
a. Complete the above elimination reaction and draw the reaction mechanism for one of your products below including all lone pair electrons, electron pushing arrows and intermediates.

b. Circle the Zaitsev product.

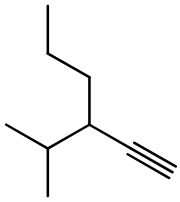
**CHAPTER 11 QUIZ**

(9) 1. Write the name of the structure or draw the structure of the given name.

a.



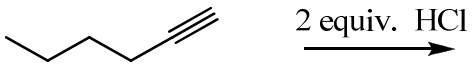
b.



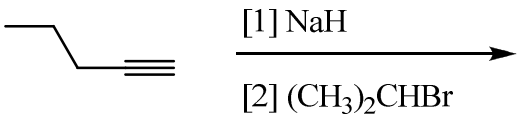
c. 4,6,6-trichloro-3-heptyne

(16) 2. (COG 6c.) Complete **4** of the following **5** reactions by writing/drawing the reactant(s), reagent(s), or product(s) as appropriate. **Show stereo and regio chemistry as appropriate.** Some reactions may require multiple steps. You may complete a 5th reaction for 4 points of **extra credit**.

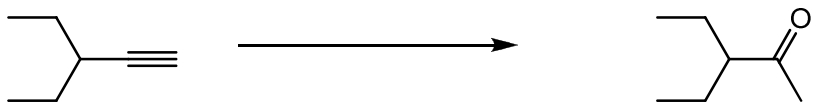
a.



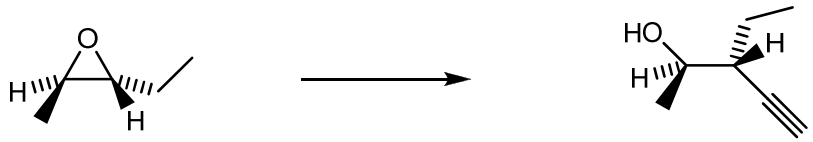

b.



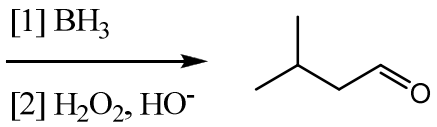
c.



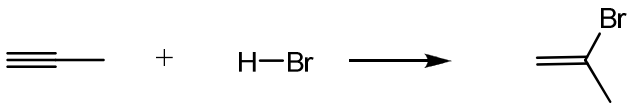

d.



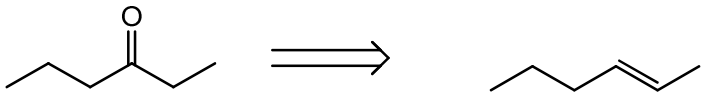

e.




(15) 3. Write the mechanism of the following reaction. Include the structures of reactant(s), intermediate(s) and product(s). Use curved arrows to show the movement of electrons. Show all lone pairs and formal charges.



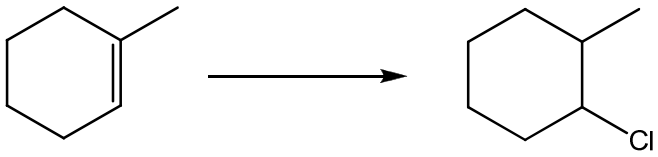

(10) 4. (COG 5) Use the retro-synthesis technique and write the stepwise reactions to make the target product molecule from any combination of the given starting material(s).



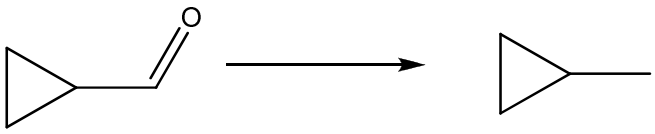
**CHAPTER 12 QUIZ**

1. (12 points) Classify the following reactions as reduction, oxidation or neither.

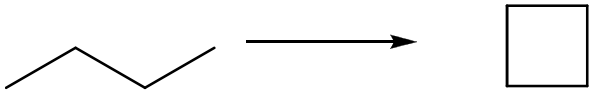
a.



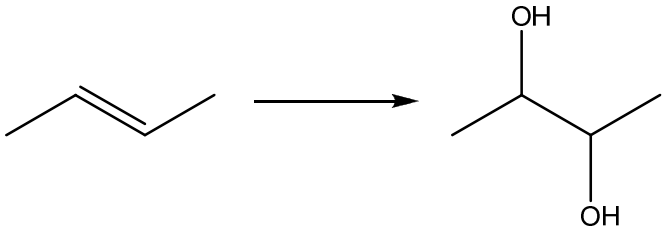

b.




c.

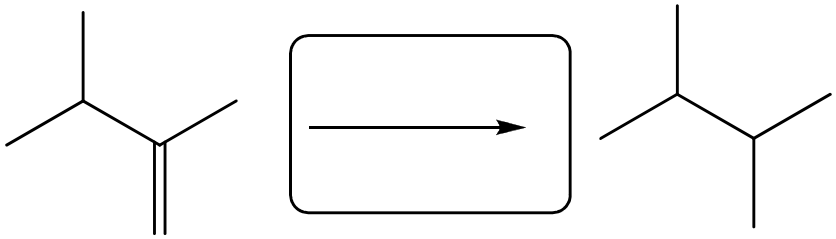


d.

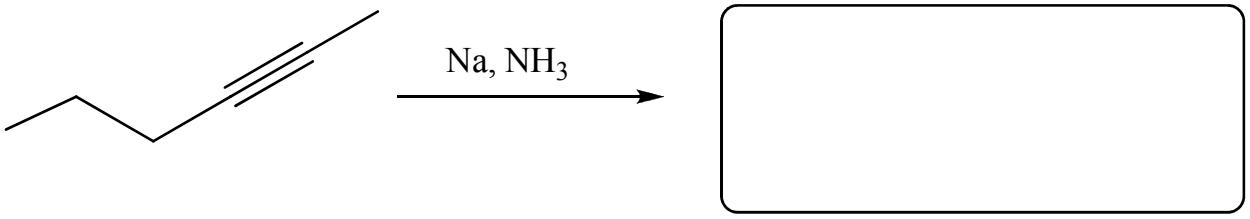



2. (20 points) Complete each of the following reactions by drawing and/or writing the reactant, reagents, and/or products as appropriate in the boxed area. Indicate regiochemistry and stereochemistry with solid-dash-wedge format as appropriate.

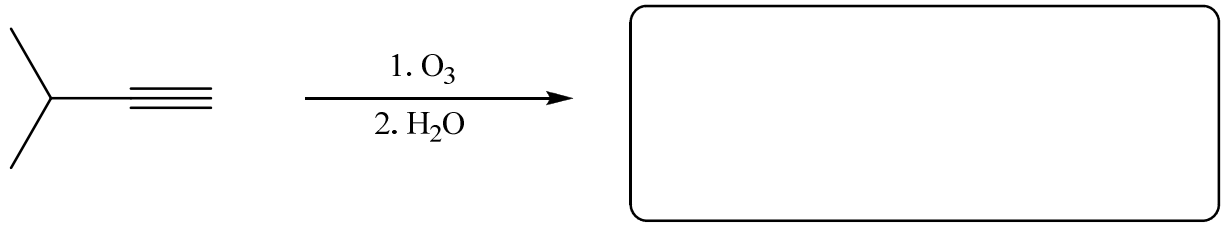
a.



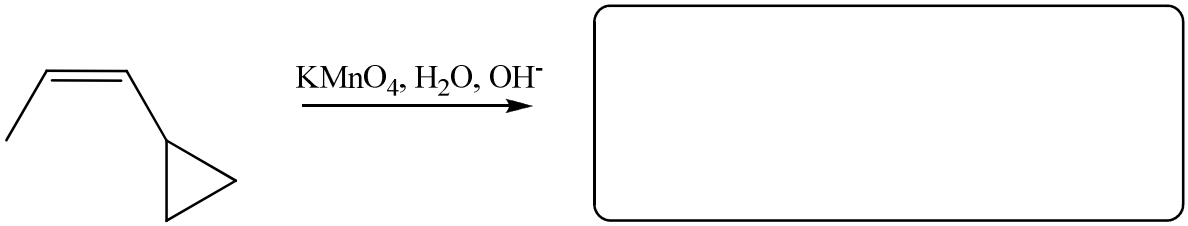
b.




c.

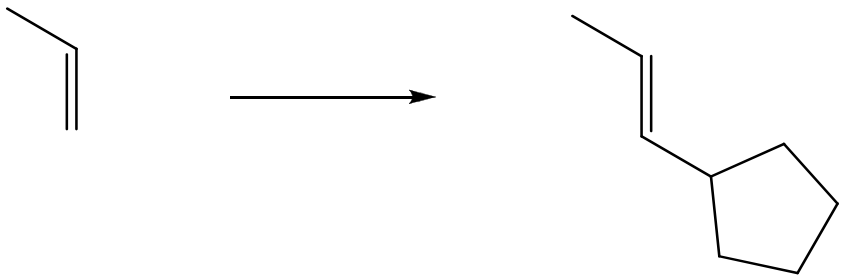



d.

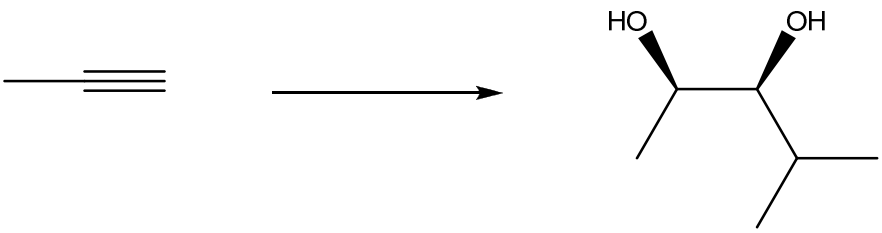



3. (18 points) (COG # 5) Starting with the given compounds on the left, synthesize the following molecules using any reagents necessary. Multiple steps are required.

a.



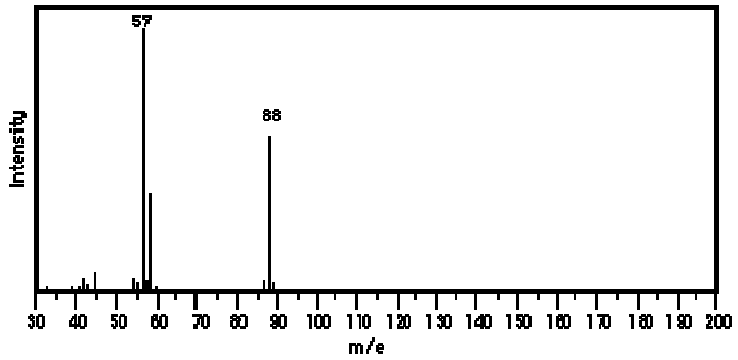
b.



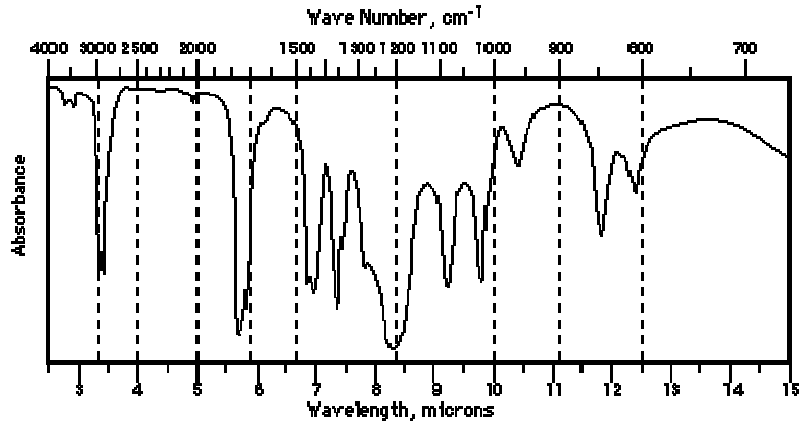
**CHAPTER 13-14 QUIZ**

Use Mass; Infrared; $^{1}H$ and $^{13}C$ NMR spectra to solve the structure with empirical formula of $C_4H_8O$. ***Show all work*** in the space below to ***justify*** the structure you draw.

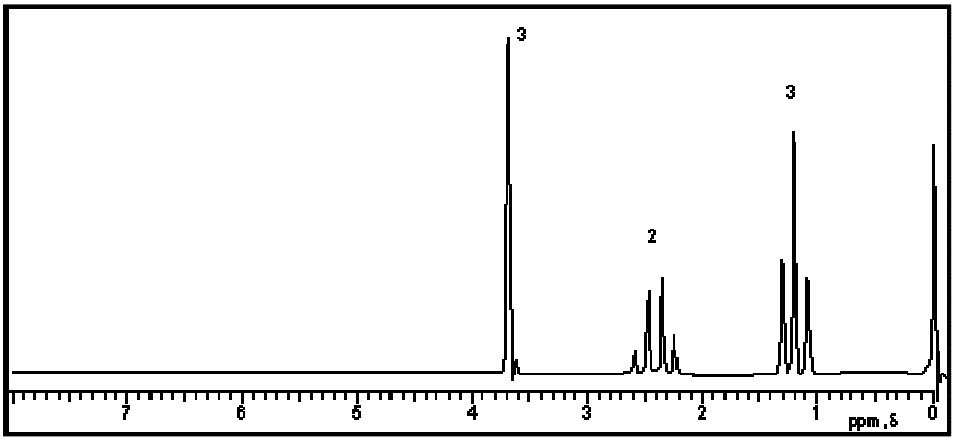
Mass Spec:




IR




H NMR:



**$^{13}$C Spectral Data:**

| | |
|---|---|
| Singlet, 172ppm | Triplet, 26.1ppm |
| Quadruplet, 50.4ppm | Quadruplet, 9.1ppm |

**MIDTERM EXAM**

**Problem I, Fundamentals (56 points)**

(12) 1. Briefly define three of the following four terms. You may use an example in your definition. There is no extra credit or substitution credit for the fourth term, so clearly indicate which definitions you wish to have graded.

a. resonance

b. Brønsted-Lowry base

c. conformational isomers

d. $sp^3$ hybridization

(4) 2. Fill in the blank with the best answer. Acetic Acid, $CH_3COOH$, is a _____.

a. Lewis acid b. Lewis base

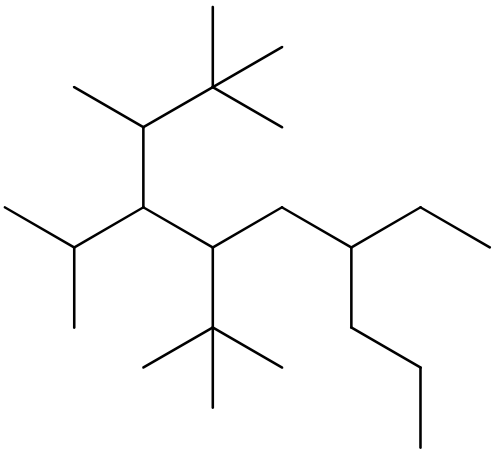
c. Brønsted-Lowry acid d. Brønsted-Lowry base

e. Both a and c

(6) 3. Draw the structure of (3R, 6*S*)-6-isobutyl-2-methyl-3-ethylheptane

Problem I continued

(10) 4. Consider the molecule shown below.



a. Write the name for the structure.

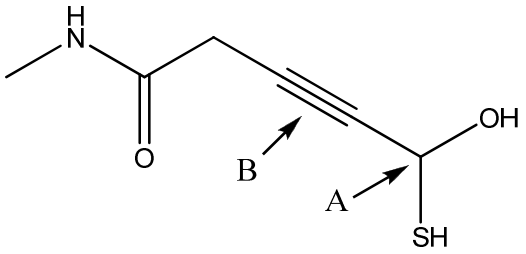
b. Identify each chiral center on the molecule above with an asterisk.

(8) 5. Draw a valid Kekulé structure for $H_2CON$, showing all nonbonding electrons and formal charges.

(6) 6. Draw two constitutional isomers with the molecular formula $C_3H_6$. Identify the functional group(s) present in the two molecules you have drawn.

Problem I continued

(12) 7. Consider the following compound.




a. Circle and name four functional groups in the compound.

b. What is the hybridization of the nitrogen atom?

c. What are the bond angles around the atom marked **A**?

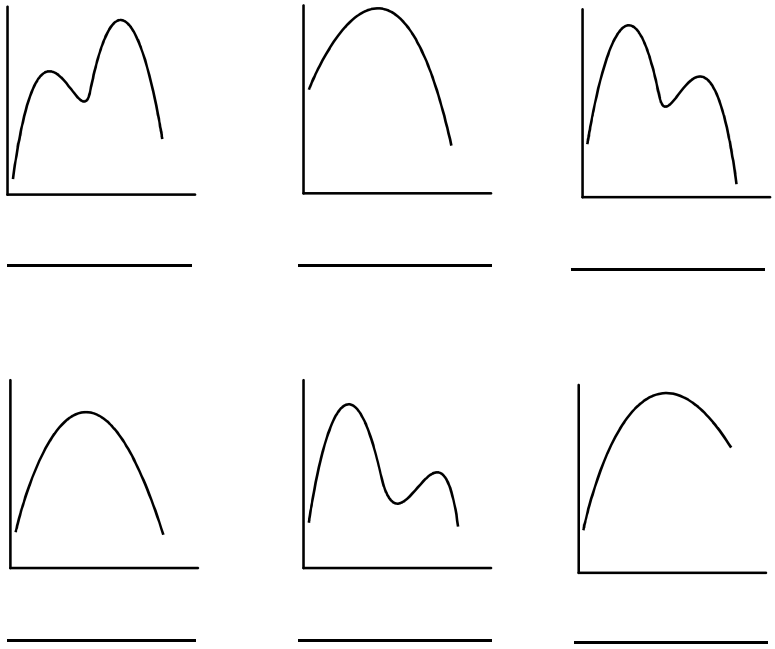
d. Describe the geometry about the nitrogen atom.

e. The triple bond marked **B** is made up of _____ $\sigma$ and _____ $\pi$ bond(s).

**Problem II, Understanding Organic Reactions (44 points)**

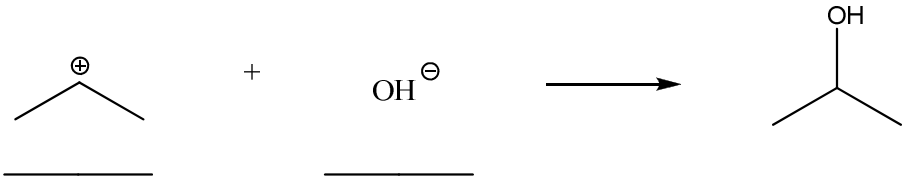
(20) 1. Consider the six energy diagrams (energy on the y-axis and reaction progress on the x-axis) and statements a-j. Place the statement letter on the line below each diagram for which it applies. Each diagram may have multiple letters; use all letters; letters may be used more than once.

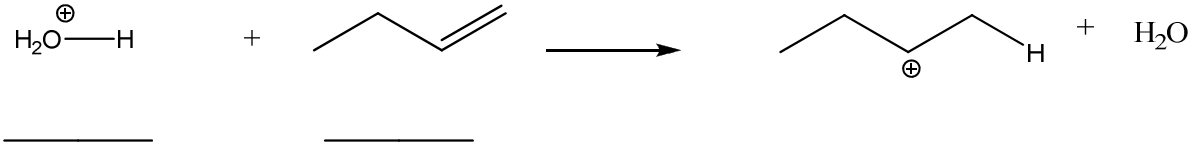
a. Two-step reaction for which $K_{eq}$ is < 1.
b. One-step reaction.
c. Exothermic reaction.
d. Endothermic reaction.
e. Reaction with one transition state.
f. Reaction in which one intermediate is formed.
g. Reaction for which $K_{eq}$ is > 1.
h. Reaction for which $\Delta G°$ is zero.

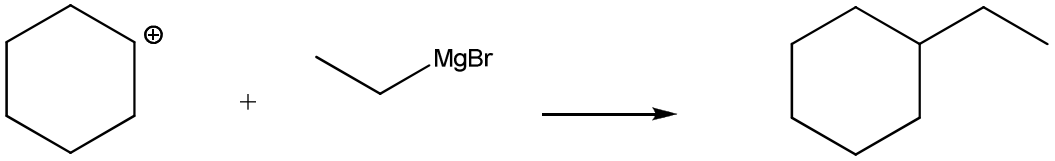


Problem II continued

(12) 2. In the blanks beneath the reactants, identify the nucleophile and electrophile in the following reactions:

a. 


b. 


c. 


(12) 3. For the reactions above, supply electron pushing arrows and any missing non-bonding electron pairs to indicate how the nucleophile and electrophile react to form the product.

**Problem III, Acids and Bases (44 points)**

Consider the reaction of acetic acid, $CH_3CO_2H$ ($pK_a$ = 4.80) plus hydroxide ion ($pK_a$ of the conjugate acid = 15.74) in aqueous solution.

(6) 1. Write the balanced chemical equation showing reactants and products.

(12) 2. Re-write the reaction from 1 above, showing Kekulé structures for all reactants and products.

(6) 3. On the structures you drew in 2 above, show the movement of electrons using electron-pushing arrows to depict how the reaction occurs.

(6) 4. On the structures you drew in 2 above, identify both conjugate acid-base pairs.

(4) 5. On the structures you drew in 2 above, write the $pK_a$'s of the acids in the reaction.

(8) 6. As written in 2 above, is the reaction product- or reactant-favored? <u>Briefly</u> explain.

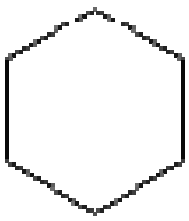
**Problem IV, Stereochemistry (54 points)**

(18) 1. Consider *trans*-1-ethyl-2-methylcyclohexane.

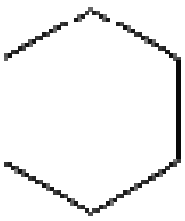
(6) a. Draw the **most stable** chair conformation.

(4) b. Draw the conformation after the structure you drew in 1.a. above undergoes ring flip.

(4) c. Complete the structures of *trans*-1-ethyl-2-methylcyclohexane and a diastereomer provided below, using dashes and wedges as appropriate.



*trans*-1-ethyl-2-methylcyclohexane

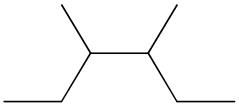


**Diastereomer** of

*trans*-1-ethyl-2-methylcyclohexane

(4) d. On the diagram of the **diastereomer**, assign and label R and S designations to the chiral centers.

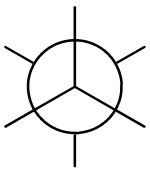
Problem IV continued



(36) 2. Consider the following molecule:

(4) a. Write the name of the given molecule.

(10) b. Sight along the C3-C4 bond and complete the Newman projection below for the **most stable** conformation.



(Circle One)

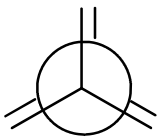
Eclipsed

Staggered

(6) c. Using the table below, calculate the steric strain for the Newman projection you drew in 2b. above. Show your work in the area to the right of the Newman projection.

| Interaction | Cause | Energy cost (kJ/mol) | Energy cost (kcal/mol) |
|---|---|---|---|
| H ↔ H eclipsed | Torsional strain | 4.0 | 1.0 |
| H ↔ $CH_3$ eclipsed | Mostly torsional strain | 6.0 | 1.4 |
| $CH_3$ ↔ $CH_3$ eclipsed | Torsional plus steric strain | 11 | 2.6 |
| $CH_3$ ↔ $CH_3$ gauche | Steric strain | 3.8 | 0.9 |

(10) d. Sight along the C3-C4 bond and complete the Newman projection below for the **least stable** conformation.



(Circle One)

Eclipsed

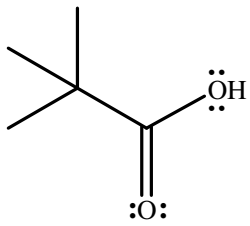
Staggered

Problem IV continued

(6) e. Using the table in IV. 2. c., calculate the steric strain energy for the Newman projection in 2d. above. Show your work in the area to the right of the Newman projection.

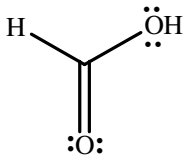
**Extra Credit**

(20 points) The series of carboxylic acids shown below have $pK_a$ values that differ by more than 2 orders of magnitude. Using your knowledge of inductive effects and resonance as appropriate, briefly explain this trend. (Hint: consider how these factors influence the stability of the conjugate bases of these acids.)

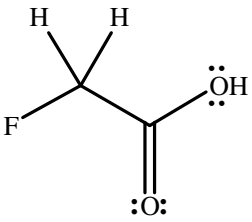



$pK_a$

5.0




3.7




2.7