

Name: Answer Key

**CHEM 633: Advance Organic Chemistry**  
**Midterm 1**

Please answer the following questions clearly and concisely.

You may write your answers in the space provided and/or on additional pages.

Please write your initials on each page you wish to turn in.

There are 10 total pages to this exam. Please be sure your copy has 10 pages before you begin.

Molecular models are allowed.

Calculators are unnecessary and prohibited.

Problem	Points
1	____/10
2	____/10
3	____/10
4	____/10
5	____/10
6	____/10
7	____/10
8	____/10
9	____/10
10	____/10
<b>TOTAL</b>	____/100



1. (10 points) Please draw the specified orbital for the following molecules (Think FMO).

a. LUMO of C=CC=O



(2 points each)

b. HOMO of CN(C)C



c. LUMO of allyl cation



d. HOMO of 1,3-butadiene

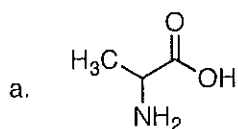


e. HOMO of ethylene

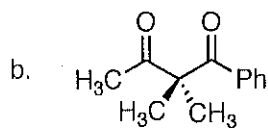


2. (10 points) Please label the following molecules as chiral or achiral. No explanation is necessary.

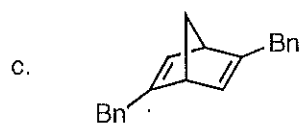
(2 points each)



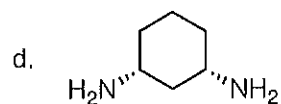
Chiral



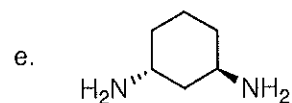
Achiral



Chiral



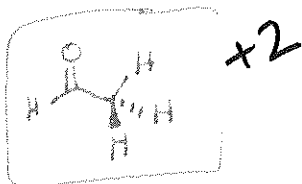
Achiral



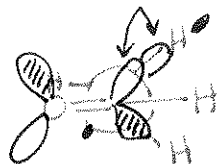
Chiral

3. (10 points) For each of the following molecules, stereoelectronic, rather than steric factors, dictate the geometry of the structure. Draw the most stable conformation and clearly label the dominant stereoelectronic interactions that either stabilize the preferred conformation or destabilize the higher energy conformation.

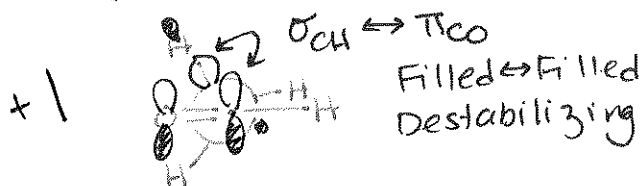
a.



$\sigma_{CH} \leftrightarrow \pi_{CO}^* \rightarrow$  Stabilizing

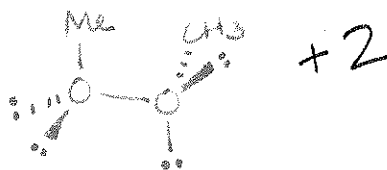
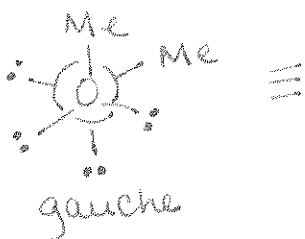
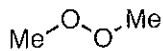


Higher energy conformation

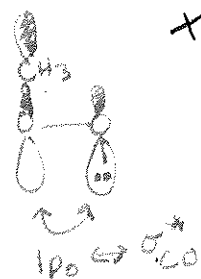


Filled  $\leftrightarrow$  Filled  
Destabilizing

b.



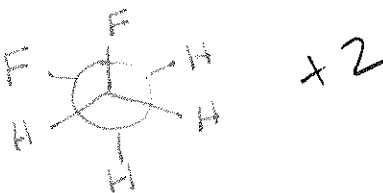
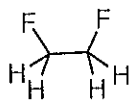
Stabilizing Interaction:



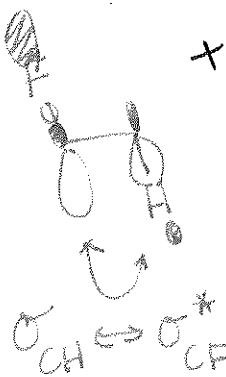
+1

$\times 2!$

c.



Stabilizing Interaction:

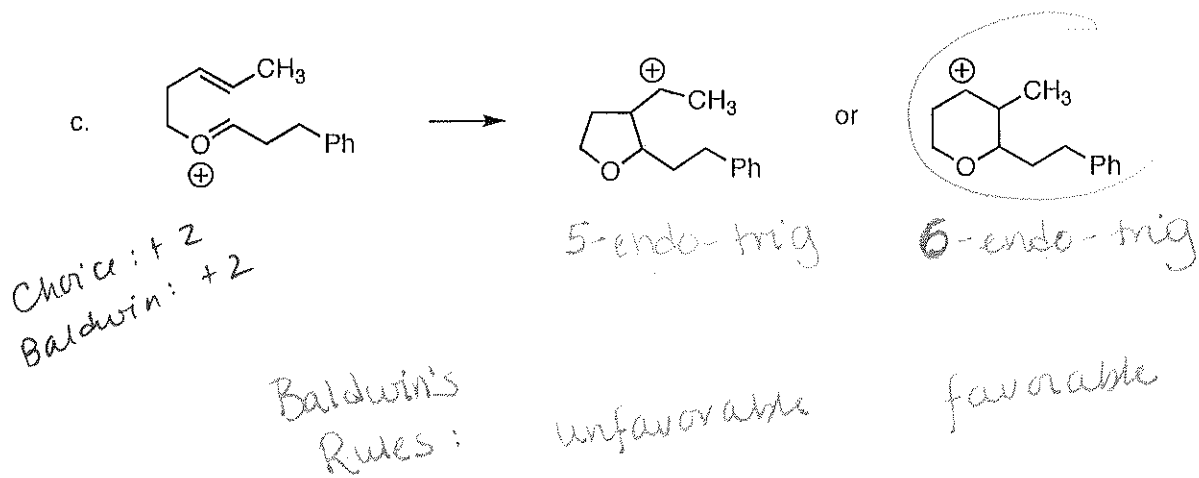
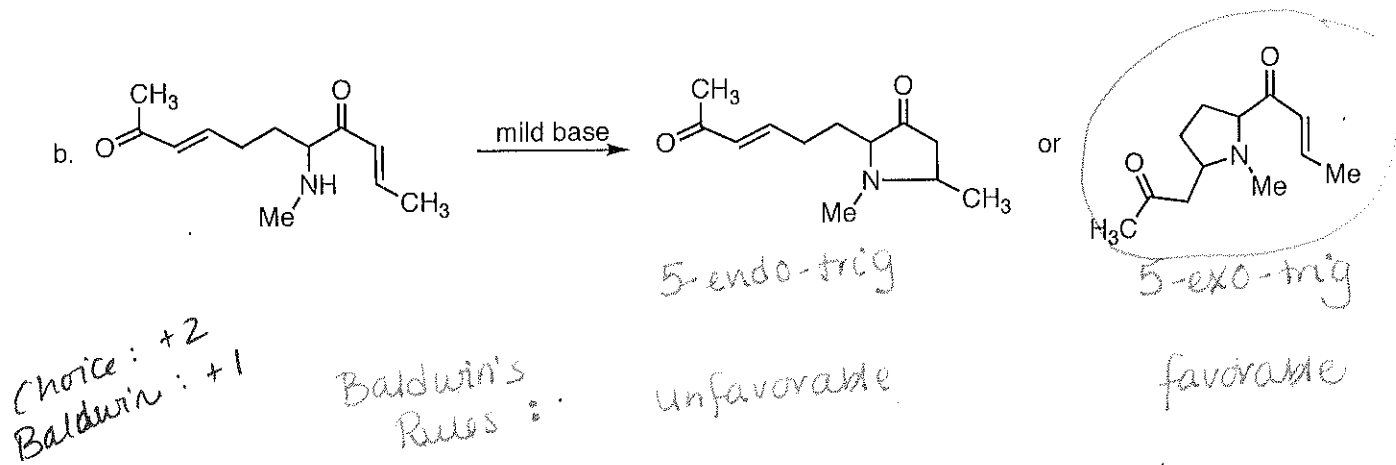
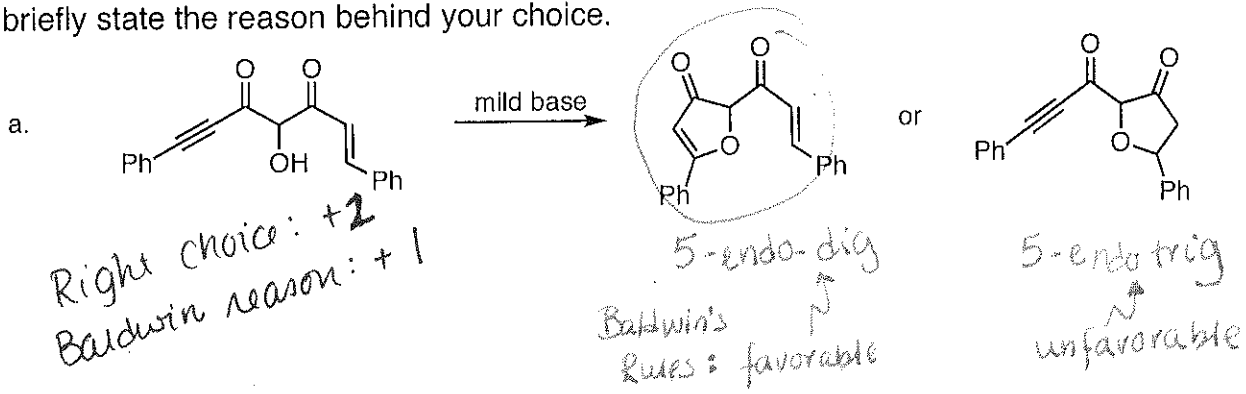


+1

$\times 2$

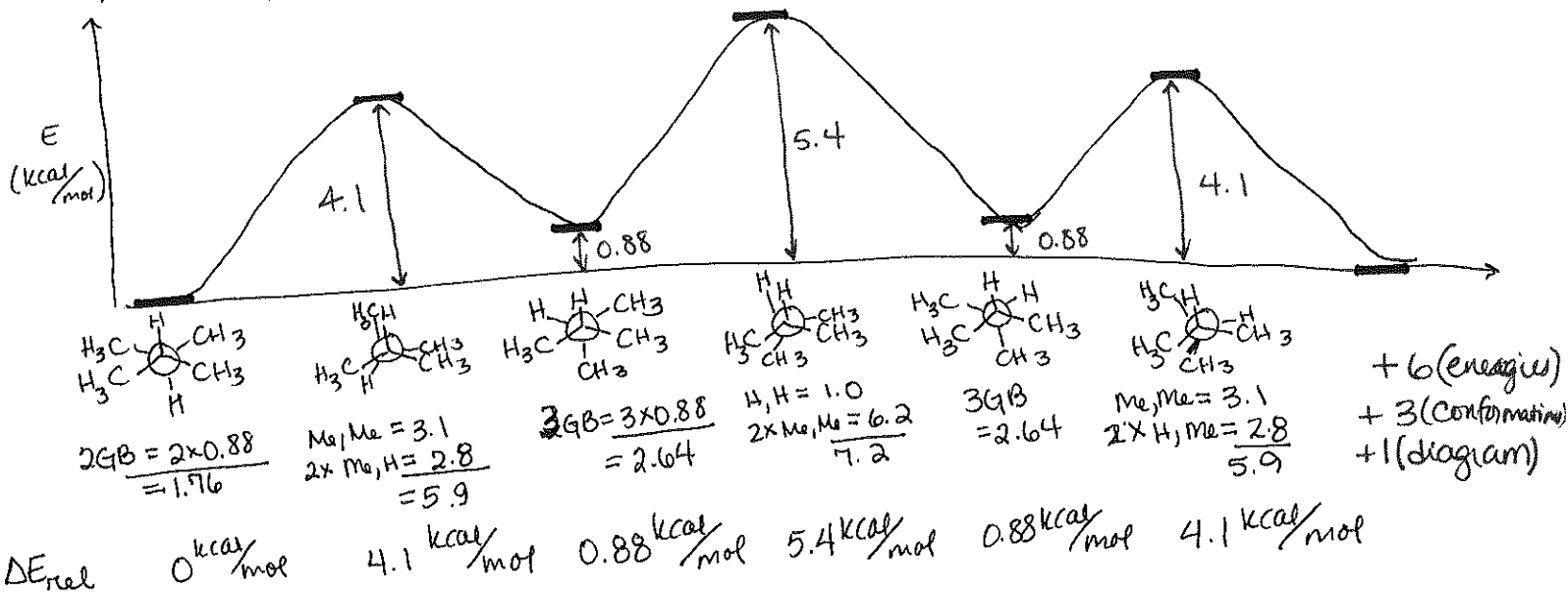
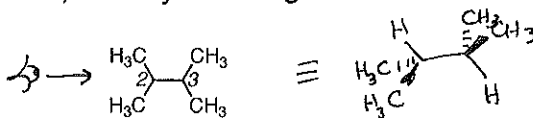
$\sigma_{CF}^*$  is better acceptor.  
 $\sigma_{CH}$  is better donor.

4. (10 points) Please predict and circle the major product in each the following reactions and briefly state the reason behind your choice.

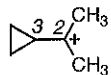


5. (10 points) Please draw a torsional energy diagram illustrating the barrier to rotation around the C2-C3 bond of 2,3-dimethylbutane, clearly labeling the relative energy and geometry of each conformation.

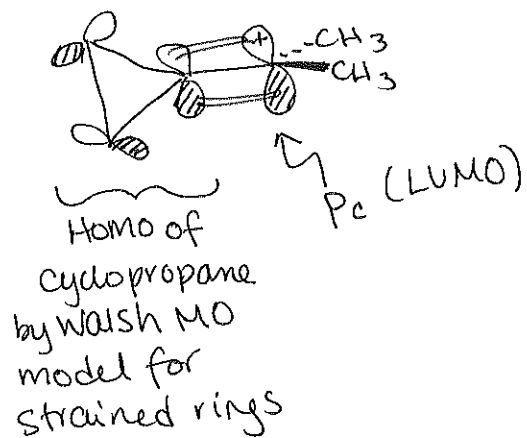
Gauche-butane (GB) = 0.88 kcal/mol  
 H, H eclipsing = 1.0 kcal/mol  
 H, Me eclipsing = 1.4 kcal/mol  
 Me, Me eclipsing = 3.1 kcal/mol



6. (10 points) Please explain the unusually high energy barrier to rotation about the C2-C3 bond of the following cation.

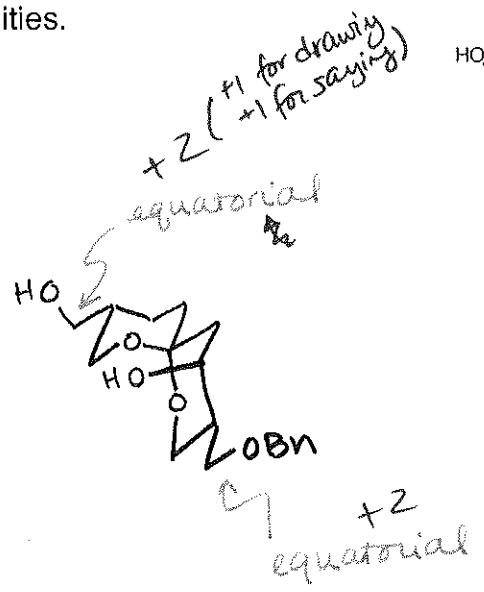
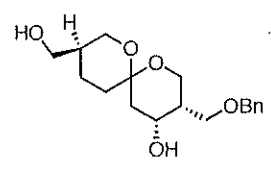


Cyclopropyl groups donate electron density to empty p-orbitals giving some  $\pi$ -bonding character to C2-C3 bond.



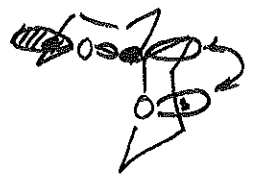
$\pi$ -bonding character / donate e-density / stabilize  $\oplus$  charge / FMO +6

7. (10 points) Please draw the most stable conformation of the following dioxospiran. Please point out the features that make your proposed conformation lower in energy than the other possibilities.



OH is axial, but has lowest A-value of the 3 substituents.  
+2

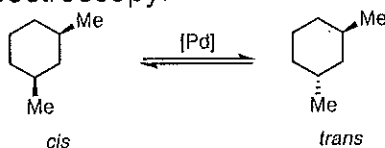
Anomeric effect stabilizes this conformation, too: +4  
(Abbreviated structure shown for clarity.)



2 anomeric stabilizations.

+1 for saying "anomeric effect."

8. (10 points) Consider the *cis-trans* isomerization of 1,3-dimethylcyclohexane, which may be easily isomerized under a variety of conditions using a palladium catalyst. You may assume that both isomers are observable by spectroscopy.



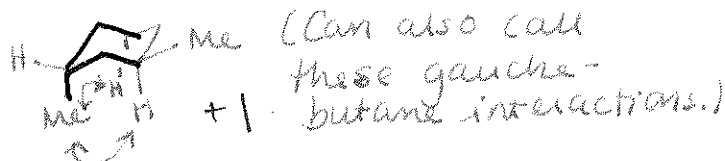
(3 total)

a. Please predict which isomer (*cis* or *trans*) is more stable, and clearly illustrate the rationale behind your prediction.

+2 cis is more stable.  
Both Me's are equatorial.



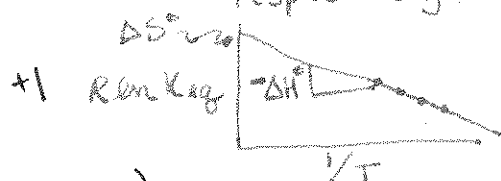
In *trans*, 1,3-diaxial interactions are sterically destabilizing.



(3 total)

b. Explain how one can experimentally determine  $\Delta H^\circ$  and  $\Delta S^\circ$  of this process. Include all equations and graphs that are necessary for analyzing the data.

1. Measure ratio of *cis*:*trans* at multiple temperatures.
2. Determine <sup>+1</sup> equilibrium constant ( $K_{eq} = \frac{[trans]}{[cis]}$ ) at each temperature.
3. Plot  $R \ln K_{eq}$  vs.  $1/T$ . Perform least-squares fit.  
 $\Delta H^\circ$  and  $\Delta S^\circ$  can be extracted from the slope and the y-intercept, respectively.



$$\Delta G^\circ = -RT \ln K_{eq} = \Delta H^\circ - T\Delta S^\circ$$

$$R \ln K_{eq} = -\Delta H^\circ \left(\frac{1}{T}\right) + \Delta S^\circ \quad ] +1$$

(2 total)

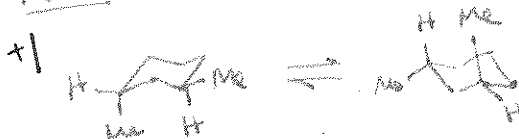
c. The experimentally determined enthalpy and entropy of isomerization are given below. Provide an explanation of the magnitudes and signs of enthalpy and entropy. (+1 if defining  $\Delta H$  &  $\Delta S$  correctly)

$$\Delta H^\circ = 1.97 \text{ kcal/mol}$$

$$\Delta S^\circ = 1.6 \text{ eu}$$

+1  $\Delta H^\circ$  is positive, so equilibrium is enthalpically uphill.  $\Rightarrow$  Correlates w/ increased gauche butane interactions in *trans* (see part a).

$\Delta S^\circ$  is positive  $\Rightarrow$  favored entropically.  
*Cis* can only access di-equatorial conformation.  
*Trans* has 2 conformations (more disordered).



(2 total)

d. Using the experimental data, explain how the equilibrium constant for this reaction varies as a function of temperature.

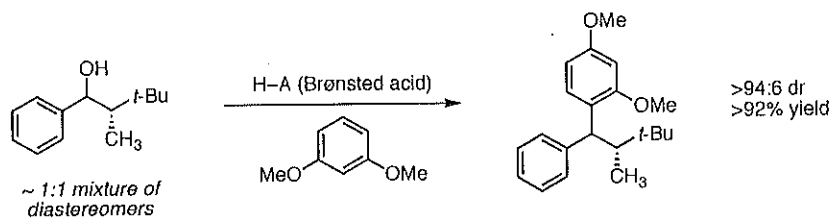
$$\ln K_{eq} \propto -\frac{1}{T}$$

$$+2 \quad K_{eq} \propto T$$

At low temps, *cis* is highly favored.  
At very high temps ( $> 1200 \text{ K}$ ), *trans* is highly favored.

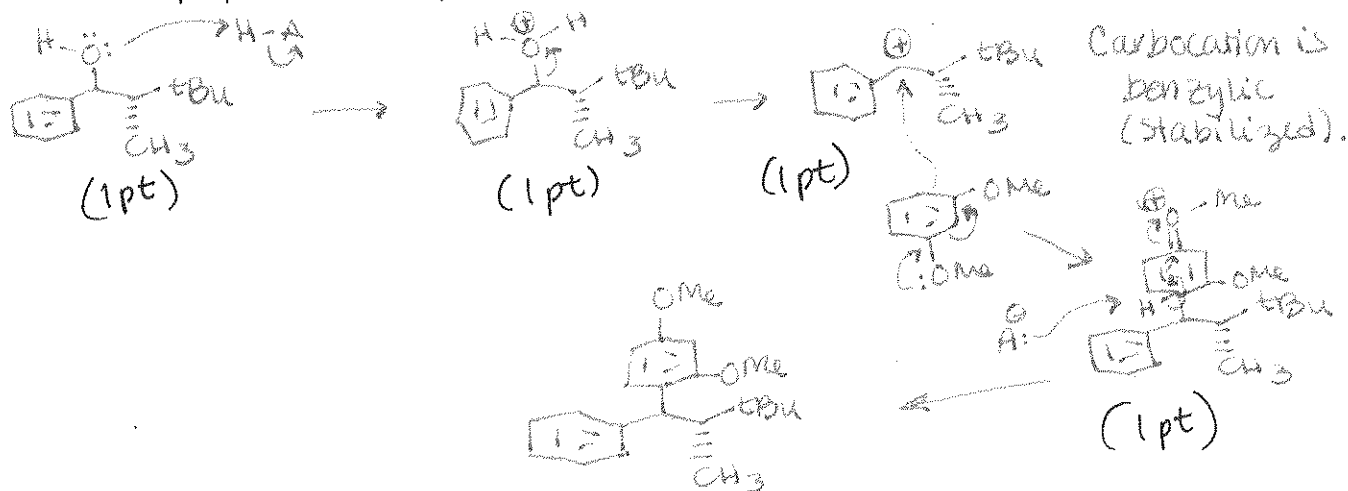
$K_{eq}$  increases w/ temperature.

9. (10 points) Bach showed that stereocenters adjacent to a benzylic hydroxy group can dictate the facial preference for the following acid-promoted Friedel-Crafts reaction (*JACS* 2005, 127, 9348).



4 points

a. Please propose an arrow-pushing mechanism for this transformation.



b. Predict the stereochemistry of the major product. Please rationalize your prediction by clearly illustrating all relevant stereoelectronic and steric interactions. (HINT: The diastereoselectivity of this reaction does NOT depend on the relative stabilities of the diastereomeric products.)

stereochemistry depends on which face of the carbocation is attacked... +1

