Initials: _____

Name: Answer Key

Chem 633: Advanced Organic Chemistry
Midterm 1

Please answer the following questions *clearly and concisely.*

Write your answers in the space provided.

Write your initials on each page you want graded.

There are 8 total pages to this exam. Please be sure your copy has 8 pages before you begin.

Molecular models are allowed.

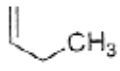
Calculators are unnecessary and prohibited.

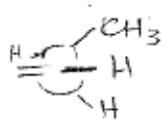
Problem	Points
1	_____/20
2	_____/10
3	_____/15
4	_____/15
5	_____/10
6	_____/20
7	_____/10
TOTAL	_____/100

Initials: _____

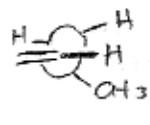
5 pts each. (all or nothing).

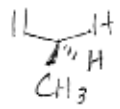
1. (20 points) Please clearly draw the lowest energy conformations of the following molecules. No explanation is necessary.

(a) 

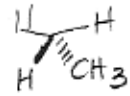


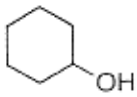
or

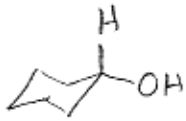


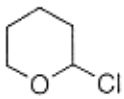


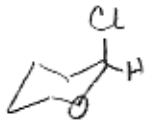
or



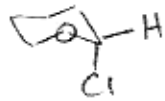
(b) 

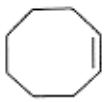


(c) 



or



(d) 

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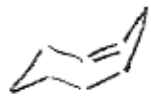
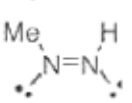
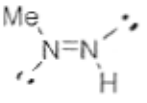


2. (10 points) The N–H stretching frequency of *cis*-methyl diazine is 200 cm^{-1} lower than the trans isomer (Craig, N. C.; Kliewer, M. A.; Shih, N. C. *J. Am. Chem. Soc.* **1979**, *101*, 2480). Please provide an explanation for this result.

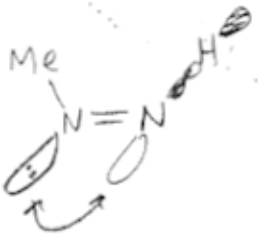


cis
ν(N–H) = 2188 cm^{-1}
weaker N–H bond

vs.



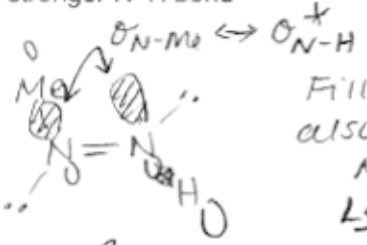
trans
ν(N–H) = 2317 cm^{-1}
stronger N–H bond



$lp_N \leftrightarrow \sigma^*_{NH}$

Filled - unfilled
weakens N–H bond

+5

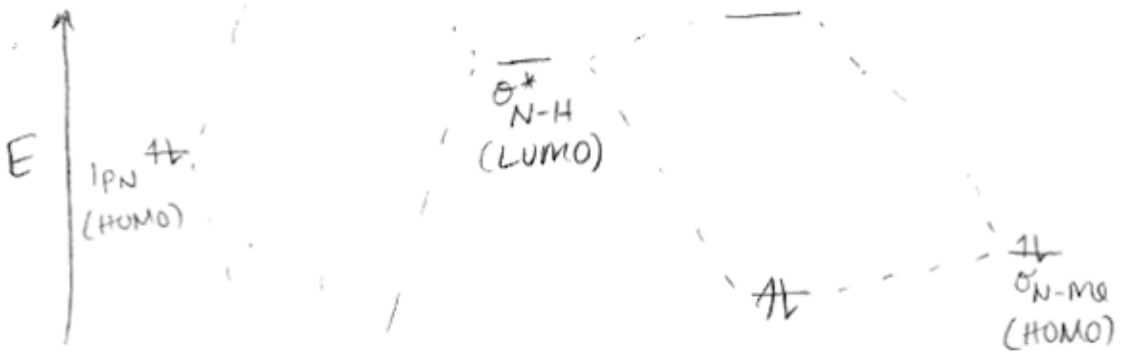


Filled-unfilled also weakens N–H bond, but less so.

+3

(+1 if said $lp_N \not\leftrightarrow \sigma^*_{NH}$)

+1 if noted $\sigma_{NH} \leftrightarrow \sigma^*_{NMe}$ to stabilize N–H.

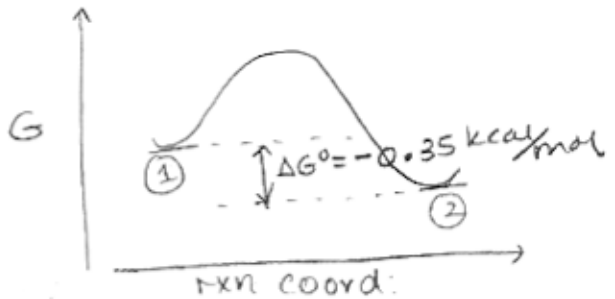


+2 (can also say in words)

More stabilizing ⇒ Stronger interaction / more e⁻ donation from $lp_N \leftrightarrow \sigma^*_{NH}$

3. (15 points) Somewhat surprisingly, one of the *t*-butyl (CMe_3) groups adopts an axial position in the preferred conformation of 1,3,5-tri(*t*-butyl)hexahydro-1,3,5-triazine (Jones, R.; Katrizky, A.; Snarey, M. *J. Chem. Soc. B* **1970**, 135).

(a) Please draw a reaction coordinate diagram for this reaction.

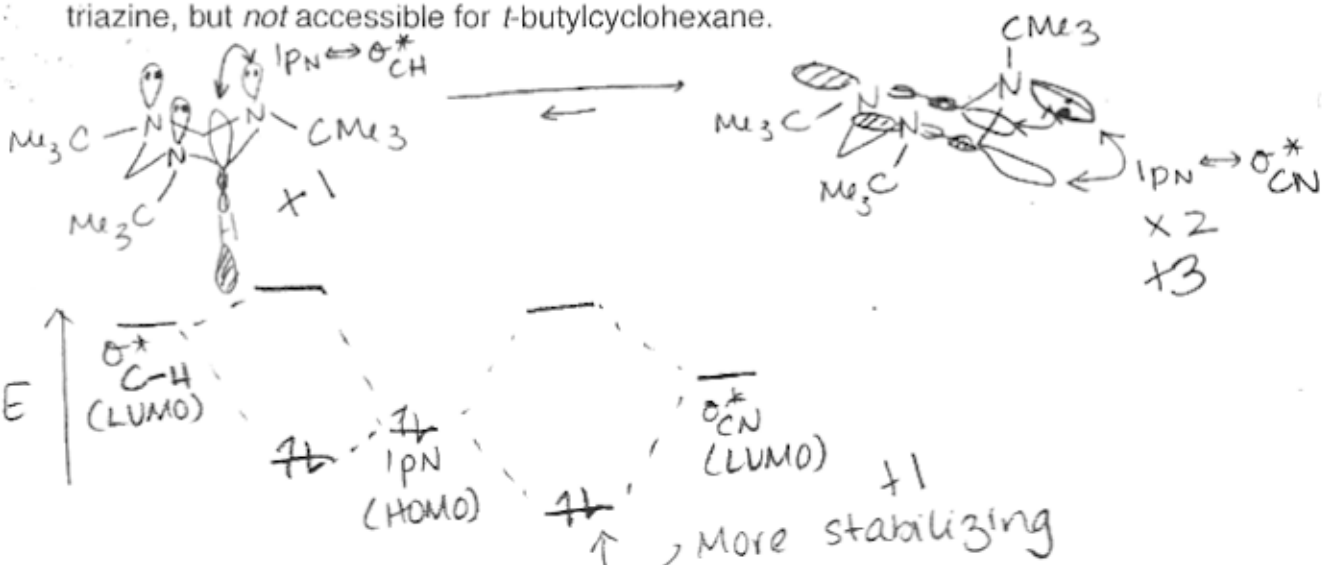


5 points
-1: no y axis or x axis
-1: ΔG° = –0.35 kcal/mol missing

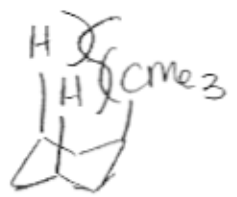
(b) Please rationalize the preference for conformation **2**. In your answer, please address (1) why conformation **2** is more stable than conformation **1** and (2) why the conformation with an axial *t*-butyl group is accessible for hexahydro-1,3,5-triazine, but *not* accessible for *t*-butylcyclohexane.

10 points

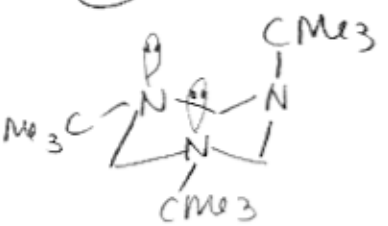
(1)



(2)



vs.



5 points (+3 if no comment on these being absent in (2)).

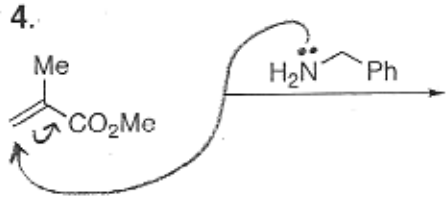
tBu clashes into axial H's. 2 1,3-diaxial interactions.

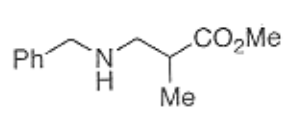
No axial H's on the axial tBu face of the triazine.

(+1 for saying ΔA value is big: gauche-butane)

Initials: _____

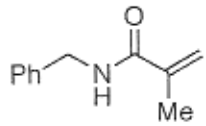
4. (15 points) (a) The reaction of benzylamine and methyl methylacrylate results exclusively in the formation of product **3**. Please explain the selectively for product **3** over **4**.





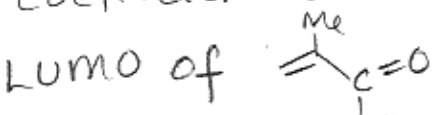
3
100%
1,4-addition

\+

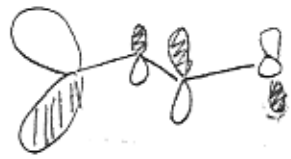


4
0%
1,2-addition

Coefficient-controlled.

LUMO of 

:



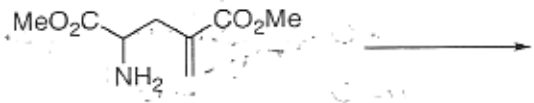
+5

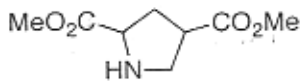
largest coefficient. +2

+1 for H_2NBn = Soft Nuc.

-1 if LUMO is a little wrong (-1/mistake)

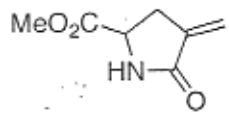
(b) In contrast, product **6** is the exclusive product in the intramolecular addition of an amine to a similar electrophile (Baldwin, J.; Cutting, J.; Dupont, W.; Kruse, L.; Silberman, L.; Thomas, R. *J. Chem. Soc., Chem. Commun.* **1976**, 736). Please explain the selectivity for product **6** over **5**.





5
0%

\+



6
100%

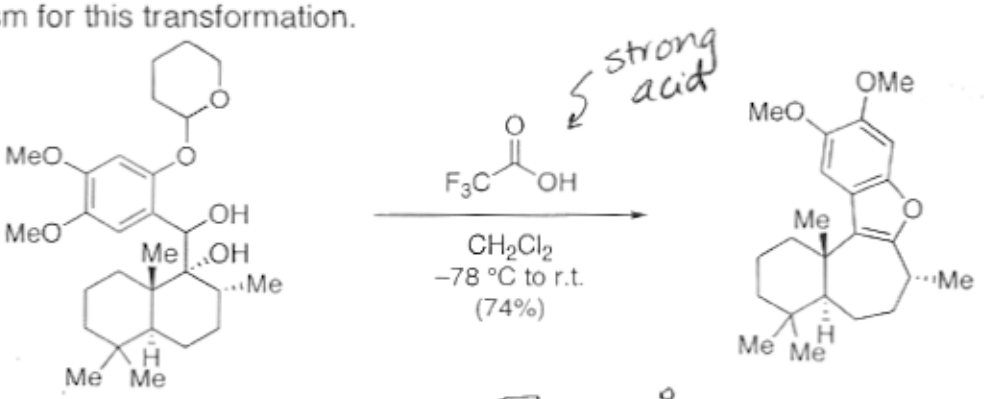
Baldwin's Rules:

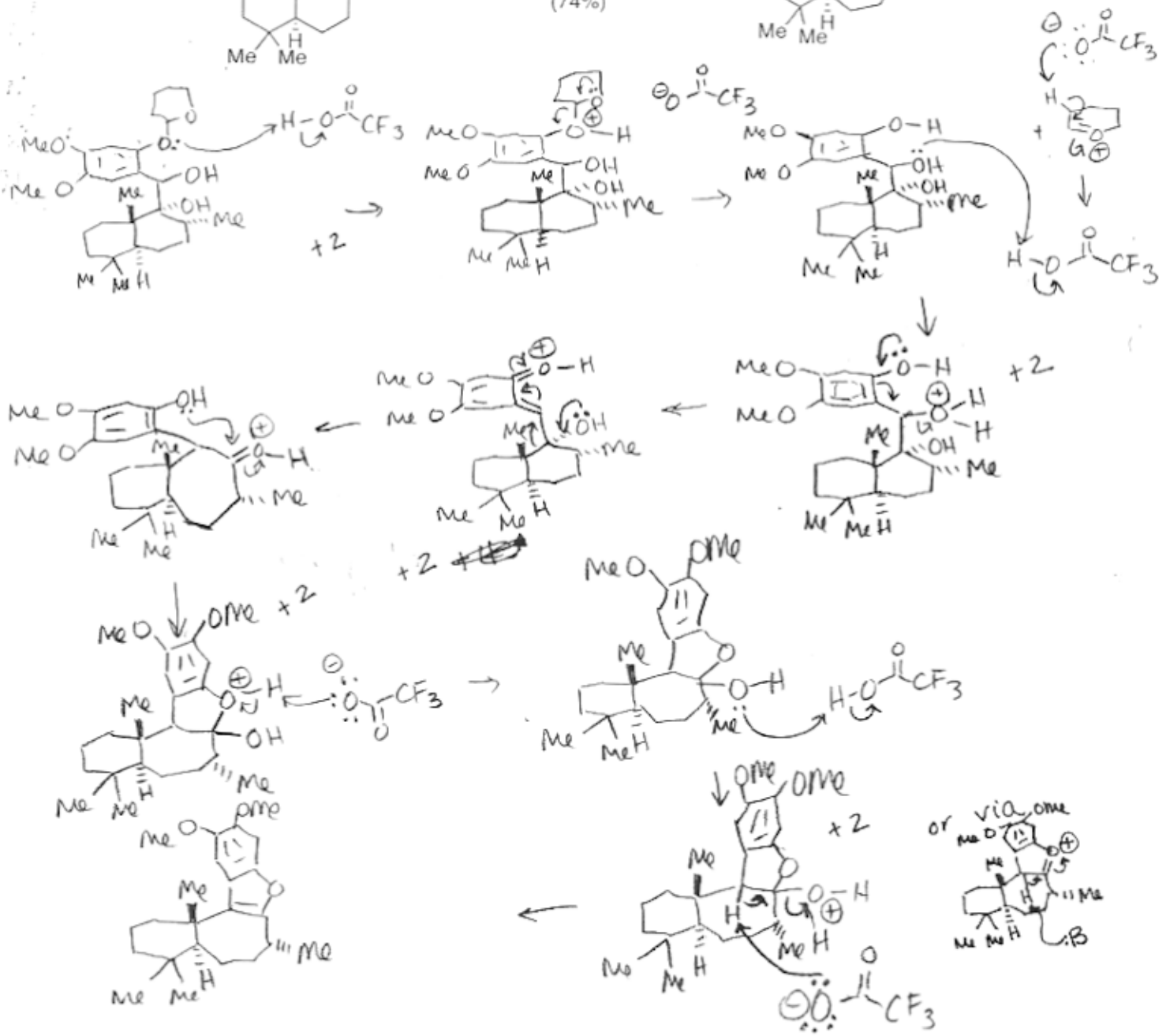
5-endo-trig ×3

↳ Ring is too small for nucleophile to attack at the correct angle. ×2

5-exo-trig ×3

5. (10 points) George and coworkers reported the following acid-catalyzed rearrangement in their recent synthesis of liphagal (George, J. H.; Baldwin, J. E.; Adlington, R. M. *Org. Lett.* **2010**, *12*, 2394). Please propose a reasonable arrow-pushing mechanism for this transformation.





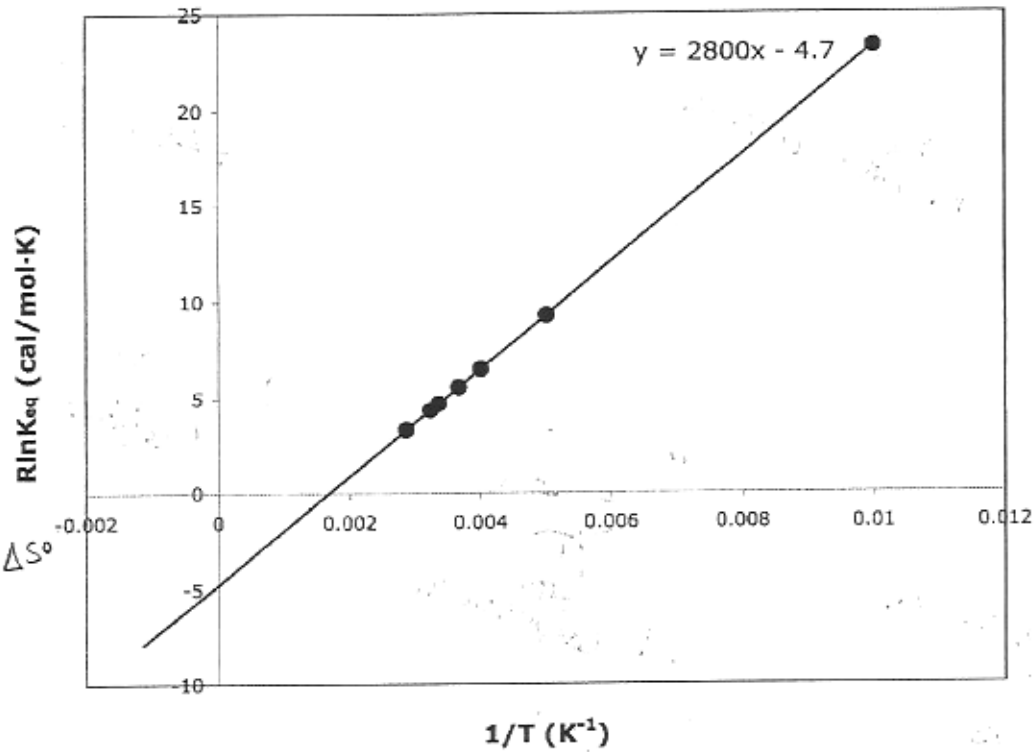
-1 / step if skipped drawing protonation
-1 if removed THP 2nd (dicationic intermediate)

Initials: _____ → units must be given.

5pts each → all or nothing. For (c) & (d), I will take your answers to a-c into account.

6. (20 points) The equilibrium constant (K_{eq}) of the equilibrium between **A** and **B** was measured at various temperatures, giving the plot shown below.

$$A \rightleftharpoons B$$



$R \ln K_{eq} = -\frac{\Delta H^\circ}{T} + \Delta S^\circ$

cal/mol·K

(a) What is ΔH° for this equilibrium?

-2.8 kcal/mol

(b) What is ΔS° for this equilibrium?

-4.7 e.u. (or -4.7 cal/mol·K)

(c) What is ΔG° for this equilibrium? (at 25 °C)

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$$
$$= -2.8 \text{ kcal/mol} - (298 \text{ K})(0.0047 \tfrac{\text{kcal}}{\text{mol·K}})$$
$$= -2.8 \text{ kcal/mol} - (1.4 \text{ kcal/mol})$$
$$\Delta G^\circ = -1.4 \text{ kcal/mol}$$

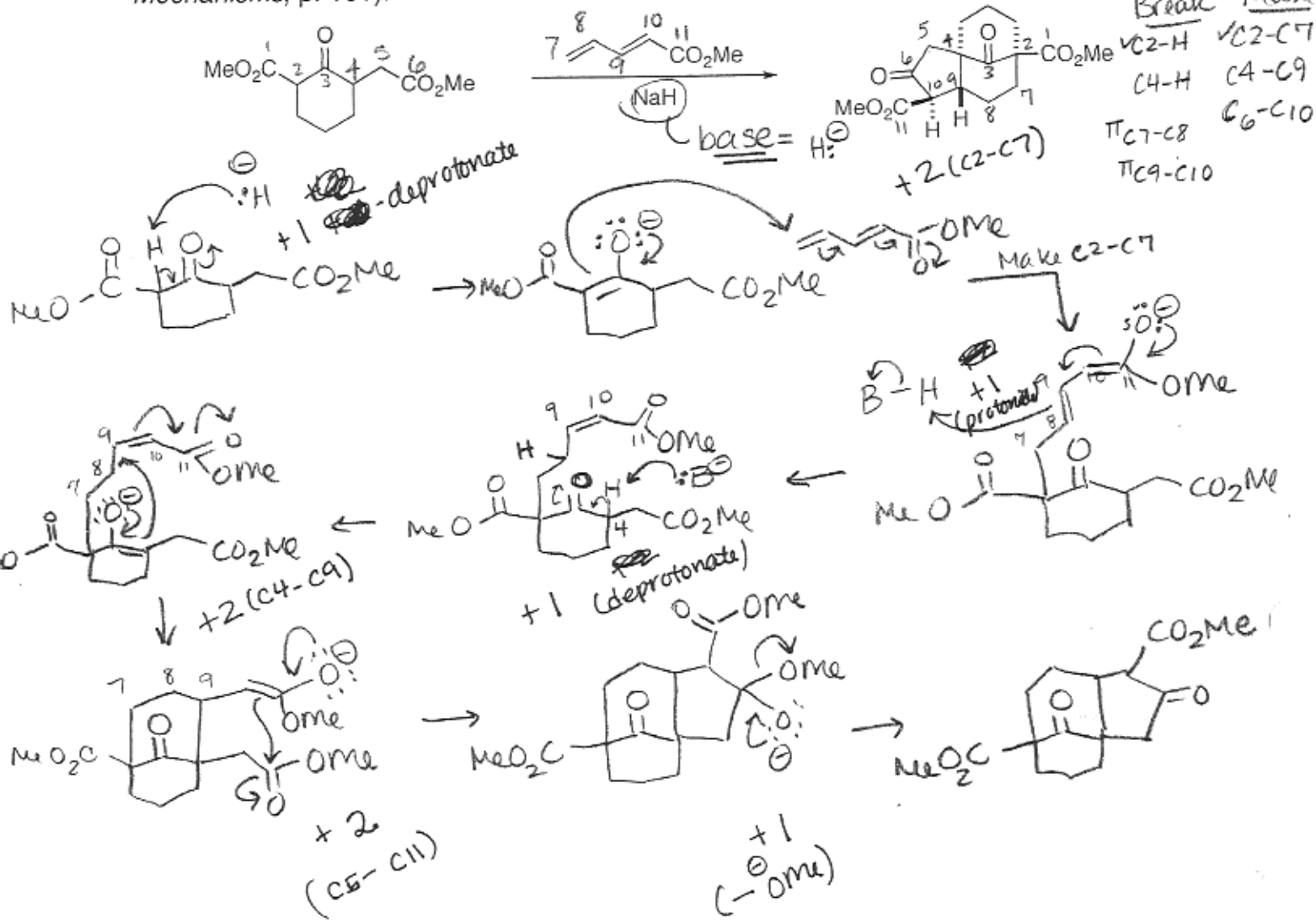
3.5
298
× 0.0047
2086
11920
1.4006

(d) At 25 °C, what is the ratio of **A** : **B**?

A : B = 1 : 10 (favoring B)

Initials: _____

7. (10 points) Please propose a reasonable arrow-pushing mechanism for the following transformation (Grossman, *The Art of Writing Reasonable Organic Reaction Mechanisms*, p. 101).



Students: Grossman, Ch 1-3 were fair game for the exam. Please anticipate that you will see more Grossman problems on future exams.