

Initials: \_\_\_\_\_

1

Name: \_\_\_\_\_

**Chem 633: Advanced Organic Chemistry 2016 ... Final Exam**

This exam is ***closed note, closed book***.

Please answer the following questions *clearly and concisely*. In general, use pictures and less than 10 words in your answers.

Write your answers in the space provided.

Write your initials on each page you want graded.

There are 16 total pages to this exam. The last 2 pages were intentionally left blank and may be used for scratch paper. Please be sure your copy has 16 pages before you begin.

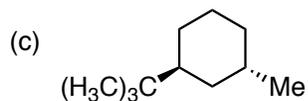
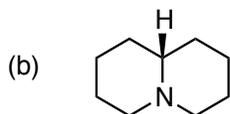
Molecular models are allowed.

Calculators are unnecessary and prohibited.

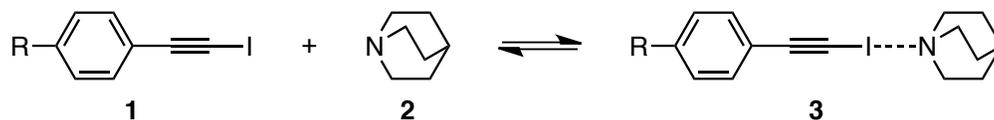
<b>Problem</b>	<b>Points</b>
1	_____/15
2	_____/15
3	_____/4
4	_____/10
5	_____/36
6	_____/20
<b>TOTAL</b>	_____/100

1. (15 points) Please clearly draw the lowest energy conformation of the following molecules.

(a)  $\text{H}_3\text{CCH}_2\text{CH}_2\text{CH}_3$



2. (15 points) Diederich's group studied the following equilibrium reaction (*Org. Lett.* **2014**, 4722).



(a) For substrate **1** where  $\text{R} = \text{Me}$ , the equilibrium constant ( $K_{\text{eq}}$ ) was determined to be  $11 \text{ M}^{-1}$ . Please give the equation that would allow you to convert this  $K_{\text{eq}}$  to  $\Delta\text{G}$ . Also, please approximate  $\Delta\text{G}$  for this  $K_{\text{eq}} = 11 \text{ M}^{-1}$ .

Equation:

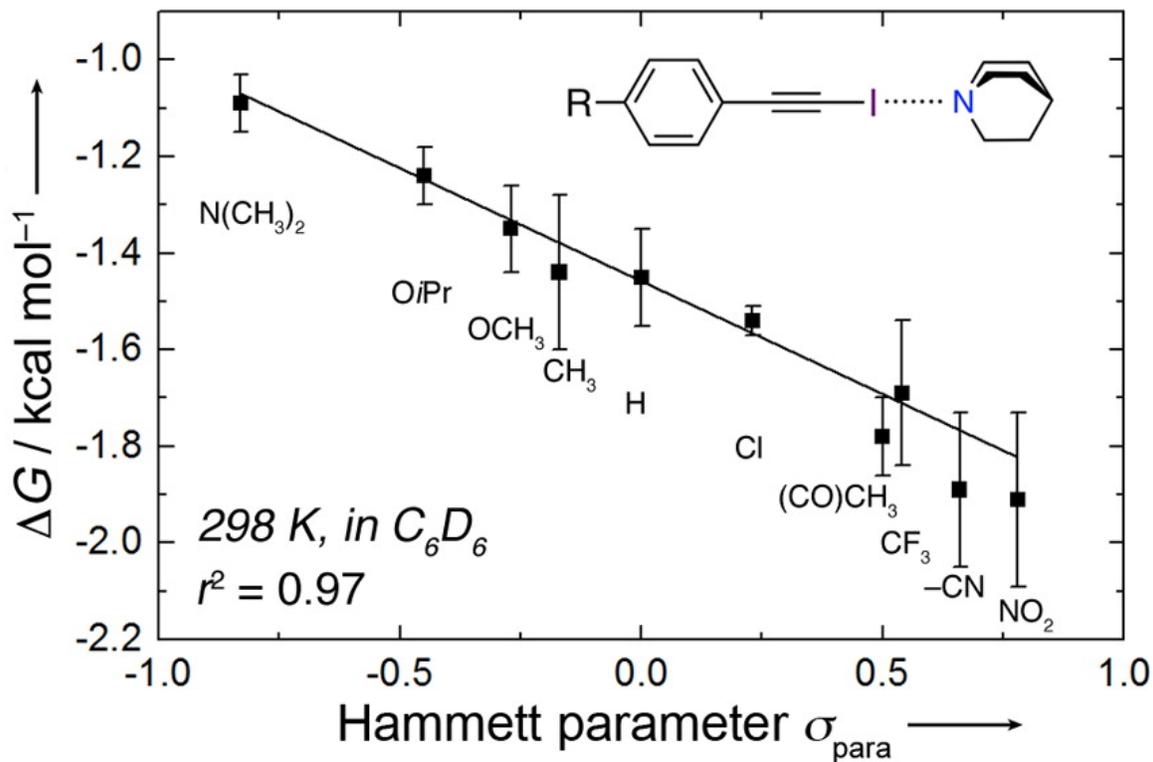
$$\Delta\text{G} \approx \text{_____}$$

Initials: \_\_\_\_\_

3

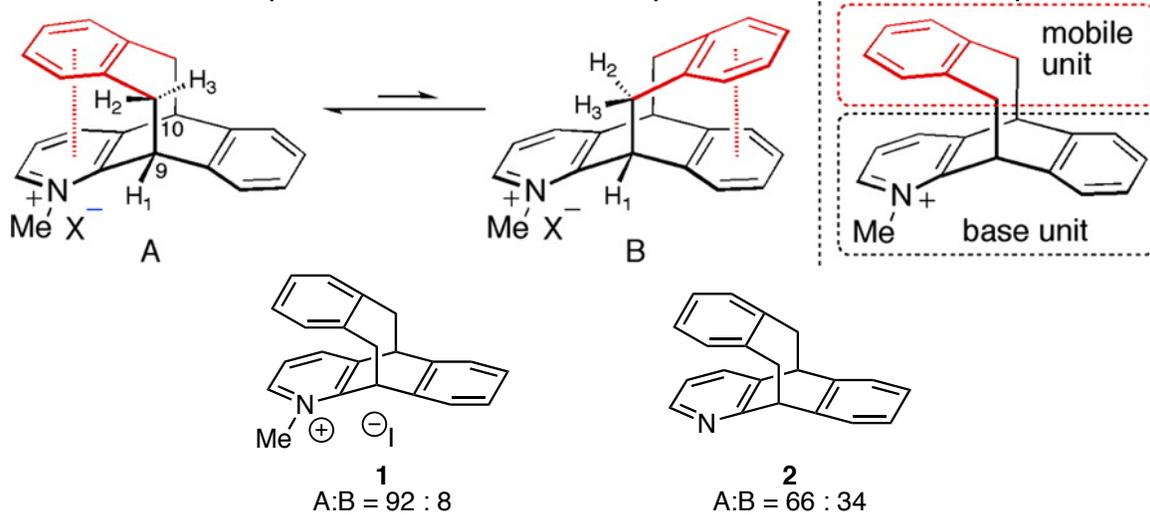
(2 – continued)

(b) What does the following graph tell you?

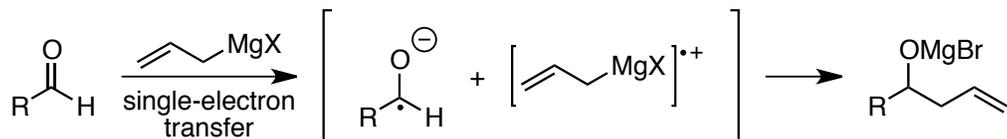
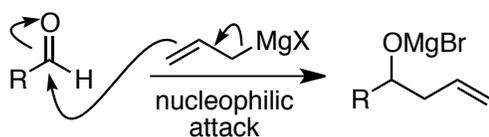


(c) Based on your answer to part (b), please name and draw the major molecular orbital interaction responsible for the formation of complex **3**.

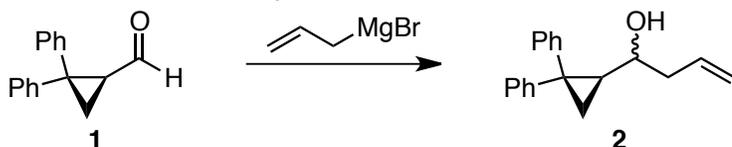
3. (4 points) Yamada et al studied the equilibrium of the following “molecular seesaw balance” (*Org. Lett.* **2015**, 4862). They found that conformation **A** is more strongly favored for pyridinium **1** than for neutral pyridine **2**. Please explain what interaction is responsible for this shift in equilibrium.



4. (10 points) The addition of allyl Grignard reagents to aldehydes has been proposed to occur either via Pathway A or B.

**Pathway A****Pathway B**

(a) Woerpel et al performed the allylation of aldehyde **1** and observed **2** as the only product. What does this result tell you about the mechanism?



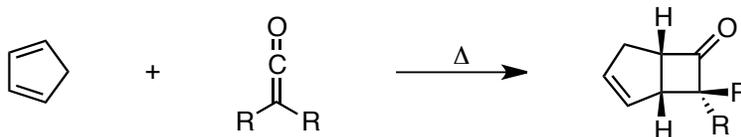
(b) Can you rule out Pathway A or B based on this data? If yes, which Pathway is ruled out?

Initials: \_\_\_\_\_

6

5. (36 points) (Parts of this problem are from Grossman, Chapter 4.)

(a) A [2+2] cycloaddition is the generally accepted mechanism for the following reaction. Please draw the arrows for this arrow-pushing mechanism.



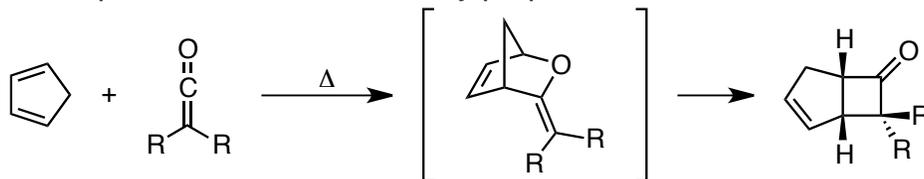
(b) Using any of the three theories discussed in class, please explain the stereochemical requirements of the [2+2] mechanism for the reaction in part (a). Be sure to include a clearly drawn picture in your answer.

Initials: \_\_\_\_\_

7

(5 – continued)

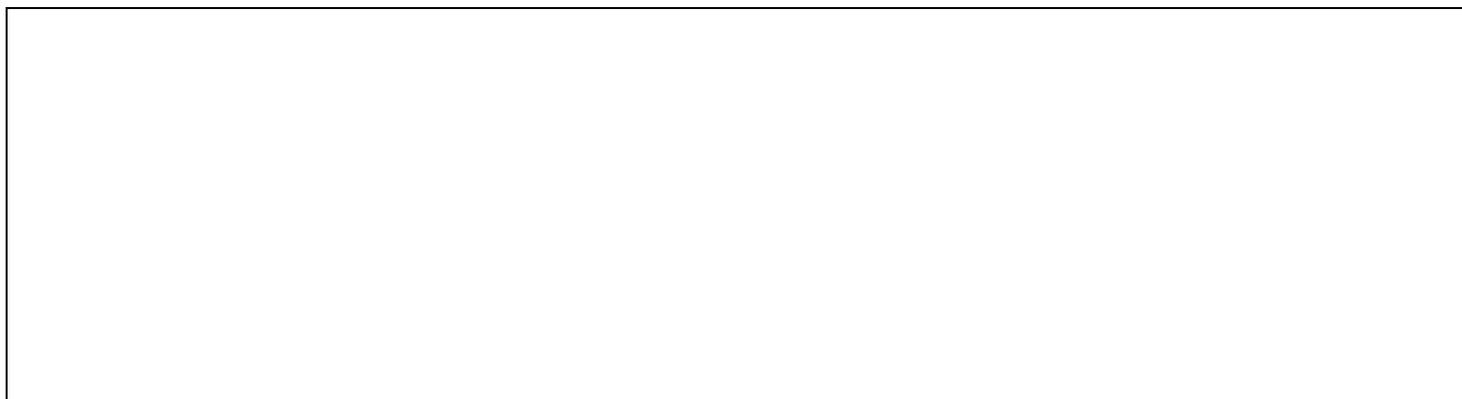
(c) The following two-step mechanism was recently proposed as an alternative mechanism.



Please draw the arrows for this mechanism.

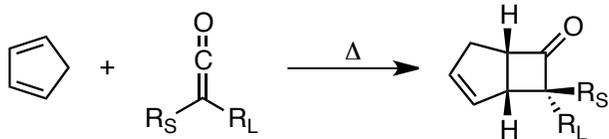


(d) Explain why the C=O and not the C=C bond of the ketene reacts with the 1,3-diene in the first step of the mechanism proposed in part (c).



(5 – continued again)

(e) When an unsymmetrically substituted ketene **2** is used in this reaction, the larger group ( $R_L$ ) is found in the more sterically hindered endo position in the ultimate product (“chemical masochism”), as shown below. Use the mechanism from part (c) to explain (in words and pictures) this phenomenon. You will need to look at the stereochemical result of both steps of the mechanism.



(f) Based on the information in part (e), which step of the mechanism in part (c) is likely the rate-determining step?

(g) Please draw a reaction coordinate diagram for the two-step mechanism (from part (c)) that is consistent with your answer in part (f).

Initials: \_\_\_\_\_

(5 – continued yet again)

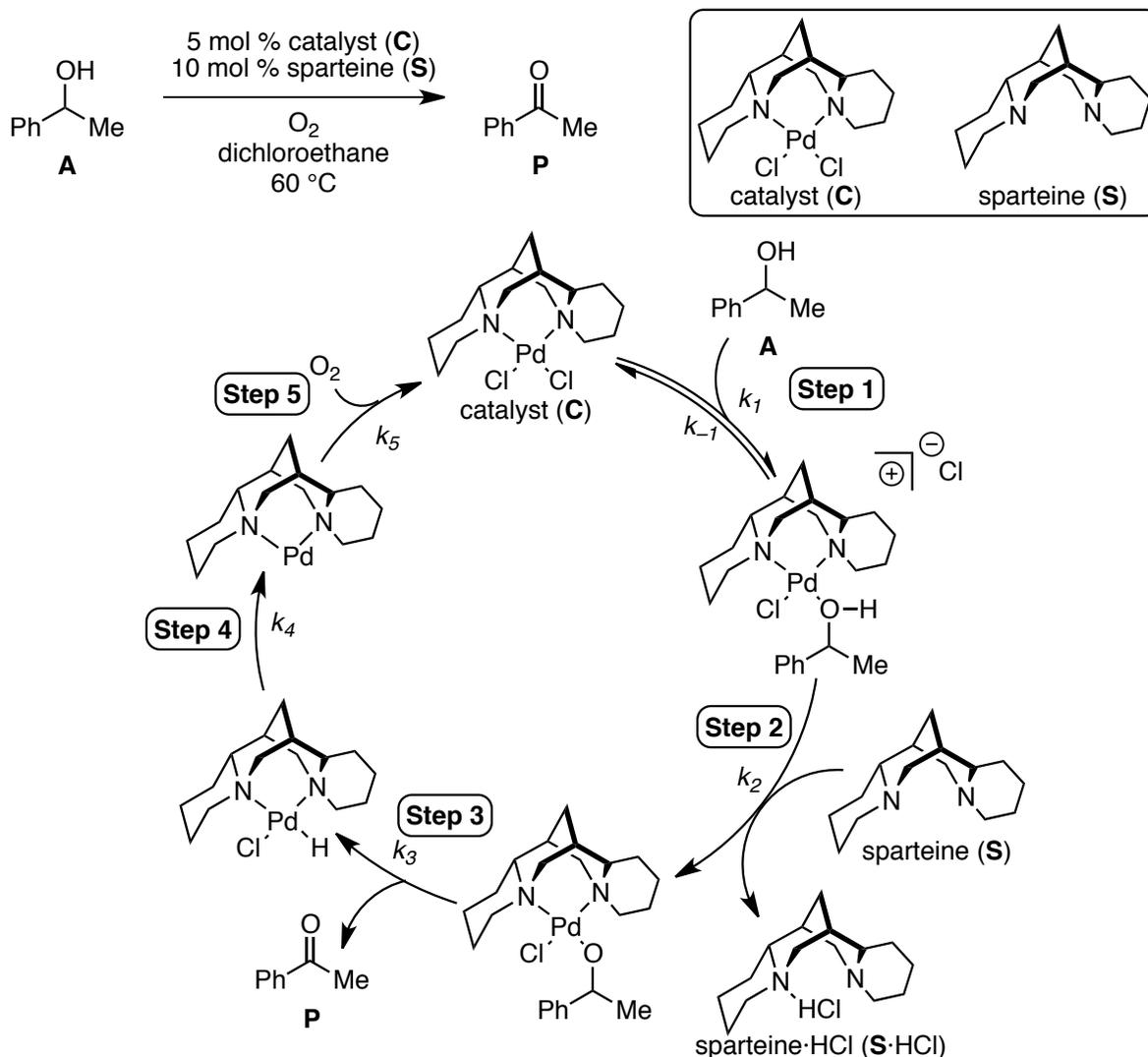
(h) Given all the information above, are the two mechanisms kinetically distinguishable? Please provide rate laws for both mechanisms to explain your answer.

Kinetically distinguishable (circle one): YES or NO	
Rate law for 1-step mechanism in part (a):  Rate =	Rate law for 1-step mechanism in part (c):  Rate =

(i) Please propose one additional experiment that will allow you to distinguish between the two mechanisms.

--

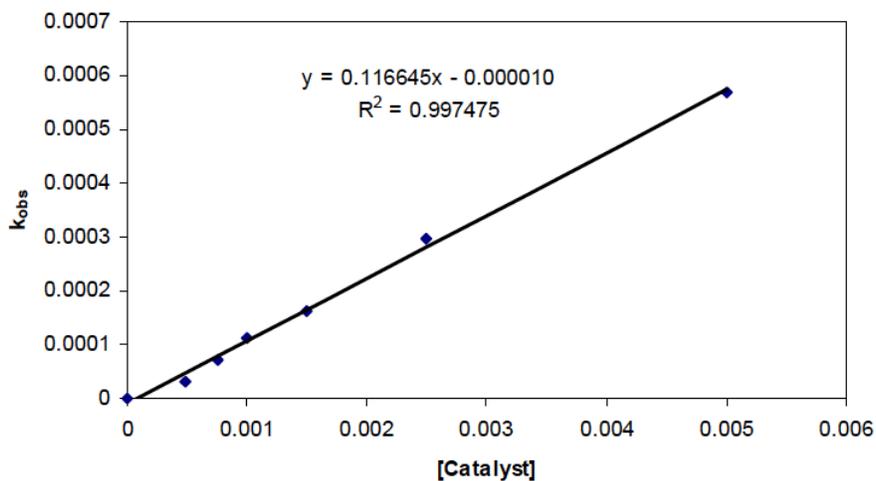
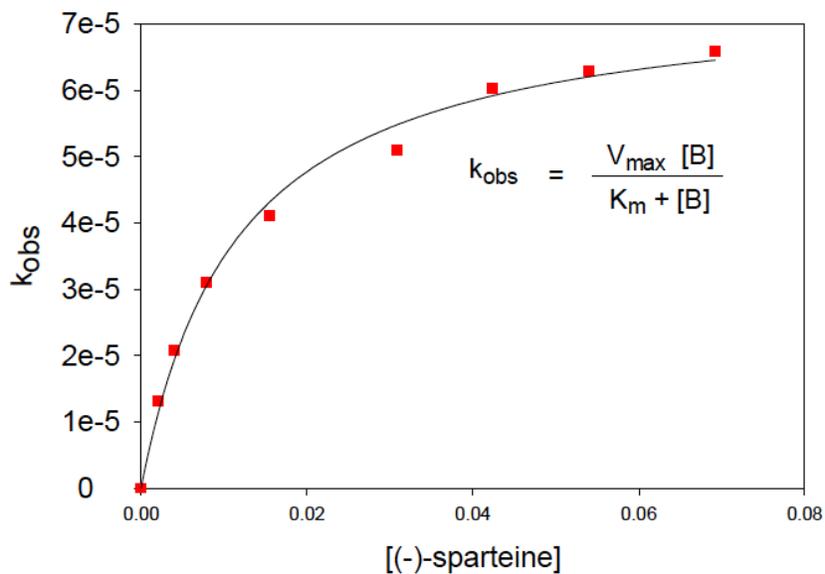
6. (20 points) The Sigman group developed and studied the mechanism of the palladium-catalyzed oxidation of benzylic alcohols, such as **A** (*JACS* **2002**, 8202). The proposed mechanism is shown below.



(a) Assuming Step 2 is rate-limiting and all subsequent steps to regenerate **C** are rapid and irreversible, please write a “one plus” catalytic rate expression for this catalytic cycle. Use the rate constants depicted in the catalytic cycle above, and apply the steady-state approximation to the concentration of any relevant intermediates. Express your rate law in terms of **A**, **S**, and  $[\text{catalyst}]_{\text{total}}$ .

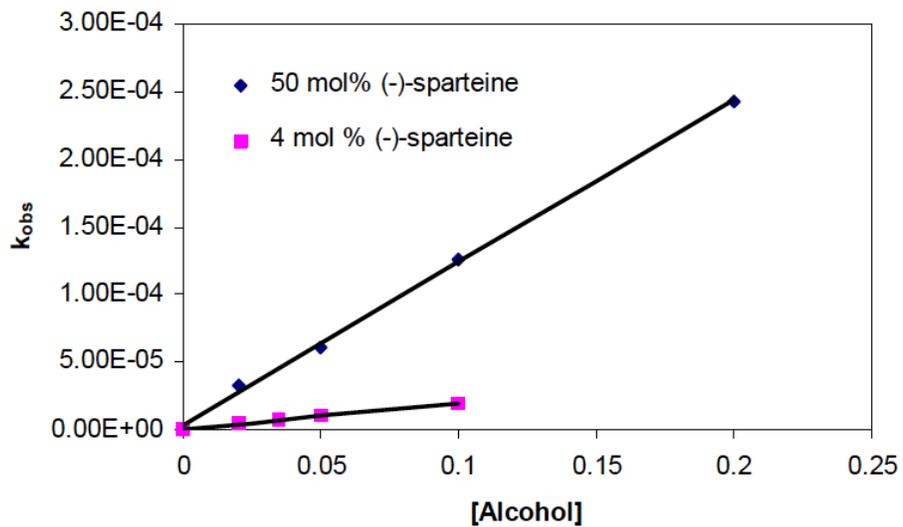
(6 – continued)

(b) What do the following graphs tell you?



Initials: \_\_\_\_\_

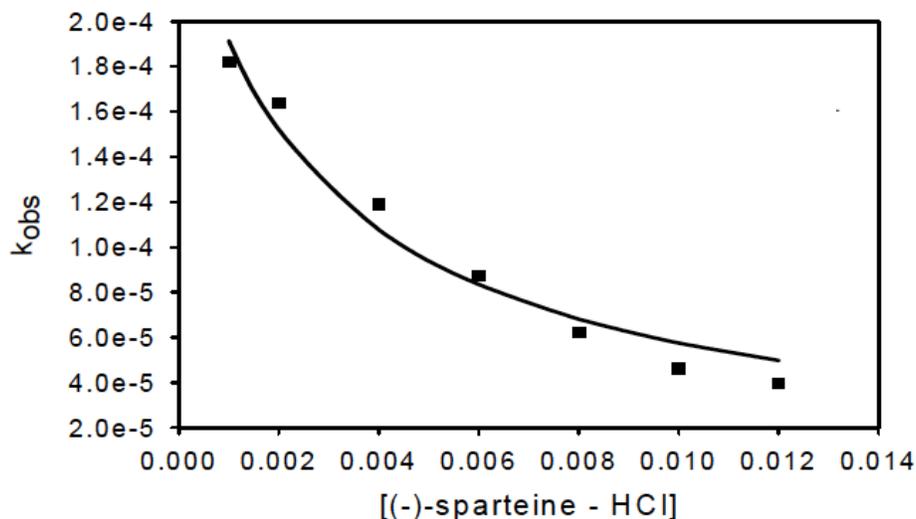
(6 – continued)



(c) Please show that your catalytic rate expression from (a) is consistent with this data.

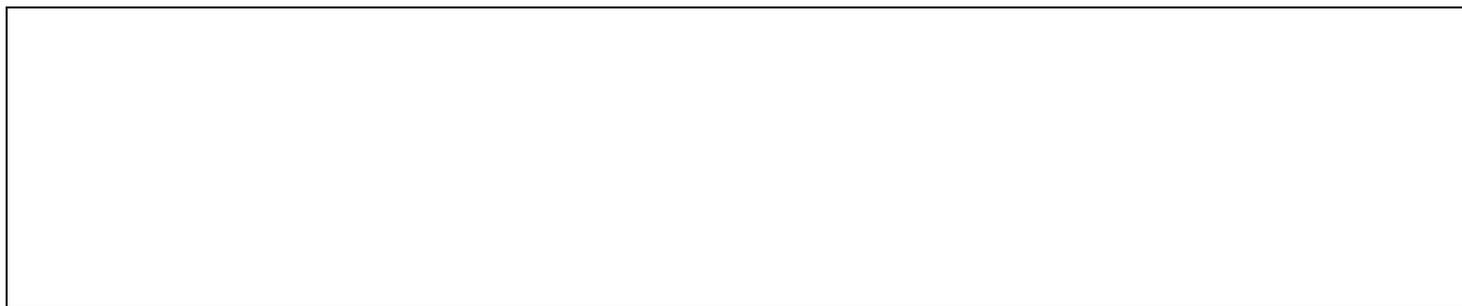
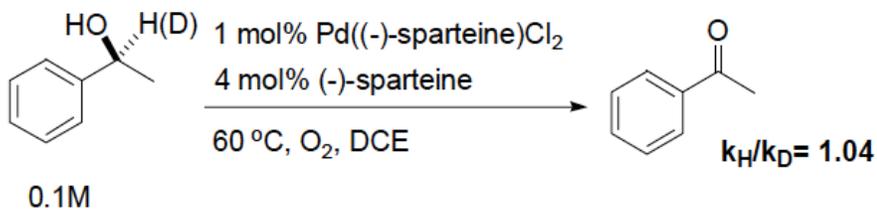
(6 – continued)

(d) The researchers then ran an additional experiment, using 50 mol % **S** (high **[S]**). What does the following graph tell you? Is this data consistent with step 2 being the rate-determining step?



(e) They also performed two kinetic isotope effect experiments, at different concentrations of sparteine. Given this data, and all data above, what is the rate-determining step under each of these conditions (low and high **[S]**)?

**Low [S]:**

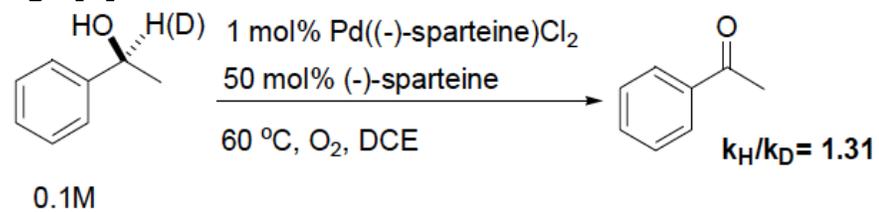


Initials: \_\_\_\_\_

14

(6 – continued)

**High [S]:**



**Initials:** \_\_\_\_\_

*This page has intentionally been left blank, so that you may use it for scratch paper.*

**Initials:** \_\_\_\_\_

*This page has intentionally been left blank, so that you may use it for scratch paper.*