Chemistry 3A – Final Exam

Student Name: Pete's Key SID: ______________

Points Breakdown

Question 1
Page 2 : 18 pts
Page 3 : 14 pts
Page 4 : 9 pts

Question 2
Page 5 : 20 pts
Page 6 : 16 pts

Question 3
Page 7 : 20 pts
Page 8 : 20 pts
Page 9 : 20 pts
Page 10 : 20 pts

Question 4
Page 11 : 9 pts
Page 12 : 13 pts

Question 5
Page 13 : 9 pts
Page 14 : 14 pts
Page 15 : 14 pts
Page 16 : 6 pts
Page 17 : 18 pts

Notice: There are 240 possible points. You can earn over 100% on this exam.

Remember: Three member ring electrophiles react differently under acidic (onium) or basic conditions. $K_{eq} = 10^{(\text{pKa conj acid} - \text{pKa acid})}$.

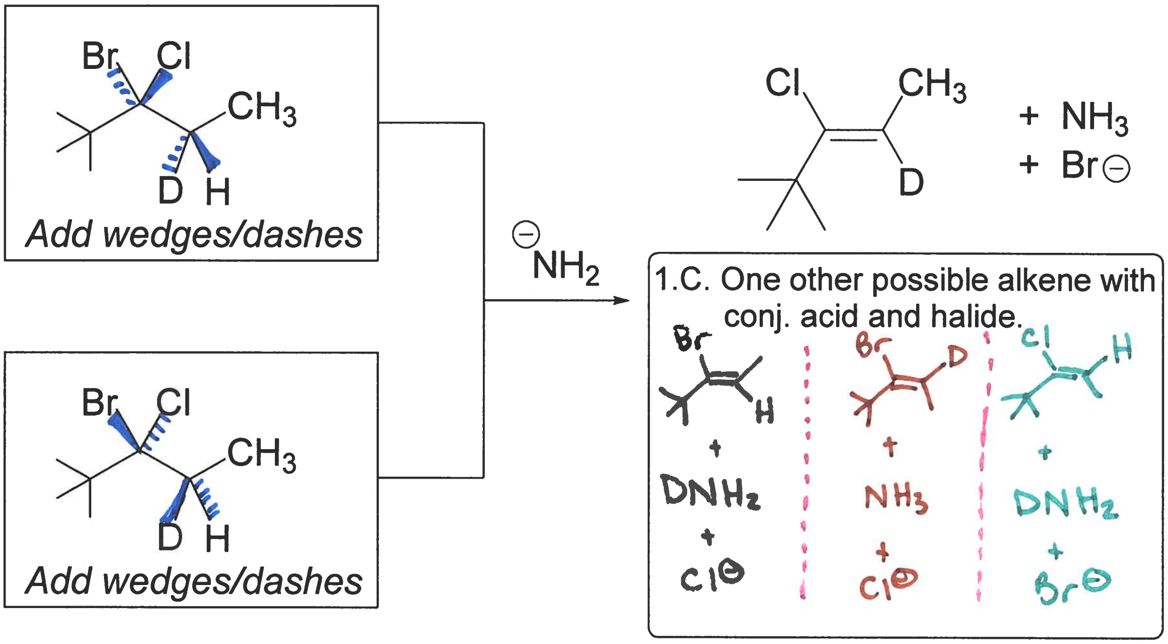
You're going to nail this! ~Pete

This is a capybara. They are friends with all of the animals.

Given: It is possible to generate an alkyne via two consecutive E2 rxns.

Goal: Analyze how these different eliminations take place, and determine possible side products.

1.A. There are two possible stereoisomers that lead to the product shown. Add wedges and dashes to the halogens, hydrogen, and deuterium for each possibility. (6 pts)



1.B. How are the two starting materials related to each other? (2 pts)

The starting materials in 1.A. are
● enantiomers
○ diastereomers
○ constitutional isomers

1.C. What is **ONE** other possible alkene product that would form under the reaction conditions shown in 1.A.? Show the product in the box above, along with the conjugate acid and halide leaving group. (6 pts)

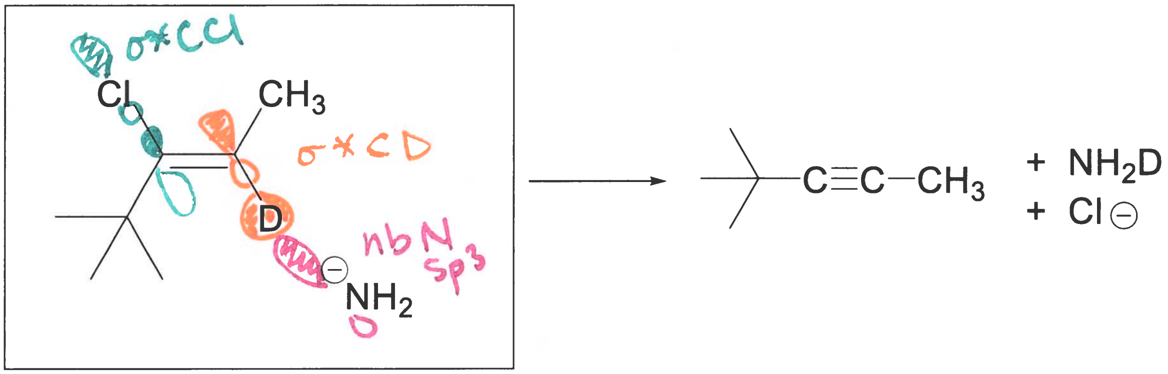
1.D. If the reaction in 1.A. were run with LDA instead of $^{\ominus}NH_2$, would you observe any difference in product distribution? Explain your answer. (4 pts)

Using LDA would give ● similar ○ different product distributions to $^{\ominus}NH_2$ because:

there is only one set of β hydrogens.

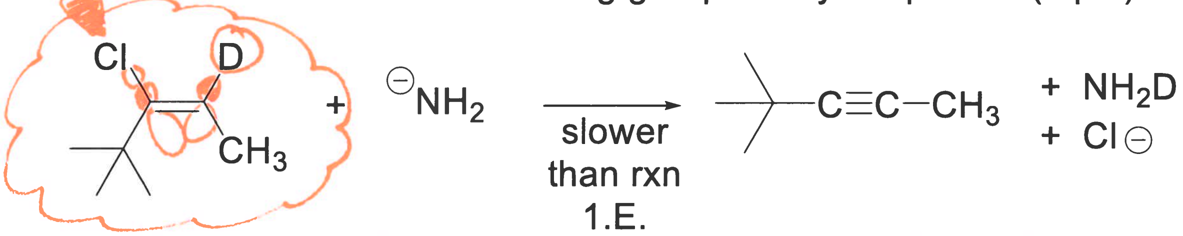
15 words or fewer

1.E. Draw in the molecular orbitals that must overlap for a successful E2 elimination reaction. Also, LABEL those orbitals. (6 pts)



add orbital drawings and labels

1.F. The other alkene isomer can also undergo this elimination yielding an alkyne product. Explain why the rate is so much slower when the beta deuterium and leaving group are syn coplanar. (4 pts)



Slower due to poor orbital overlap.

15 words or fewer

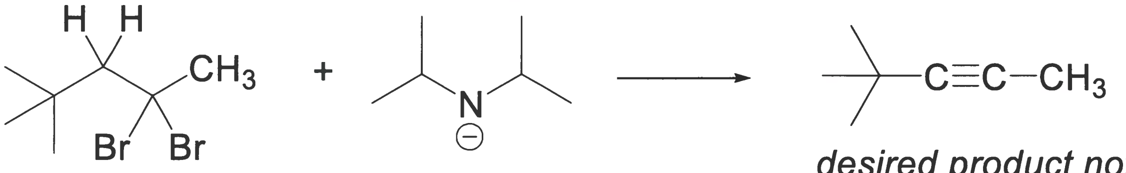
1.G. Why can an alkene undergo E2 elimination with a syn coplanar relationship between the beta deuterium/hydrogen and the leaving group but an alkane cannot? (4 pts)

Alkene is locked in reactive conformation while alkanes will rotate out of eclipsed conformation.

15 words or fewer

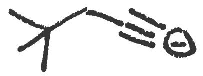
1.H. The reaction below did not yield the desired alkyne product. (9 pts)

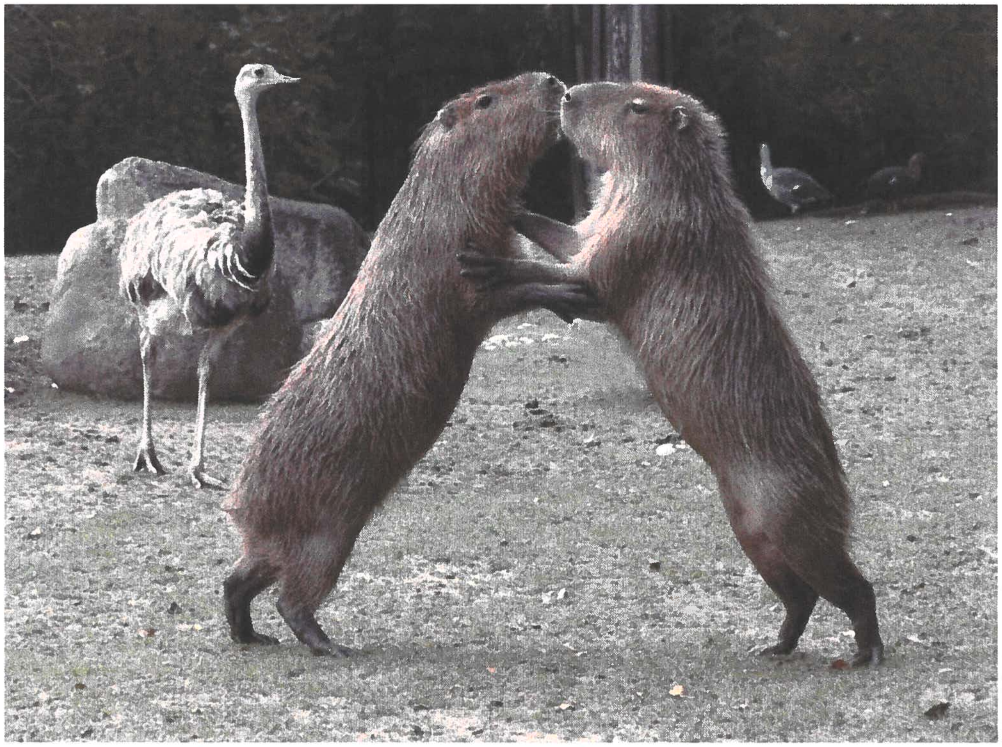
- i) Describe the problem specifically.
- ii) Show the actual product formed.
- iii) Suggest a change to yield the desired product without changing the starting organic compound.



excess

desired product not observed

i) Problem(s):	ii) Actual Product:	iii) Proposed Change(s):
Big base goes for less hindered Hs of the CH_3 group.	 or 	$\boxed{H_2N^{\ominus}}$ instead of LDA to get more substituted alkyne.



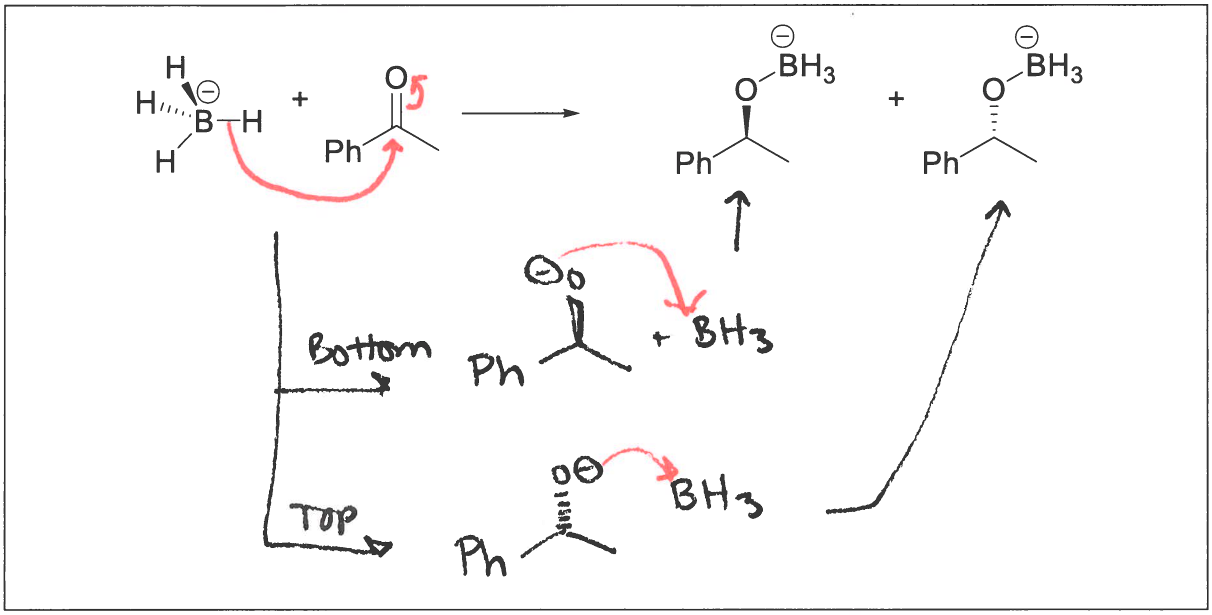
2. As promised, I will teach you about sodium borohydride ($NaBH_4$).

Given: $NaBH_4$ provides nucleophilic hydride similar to $LiAlH_4$.

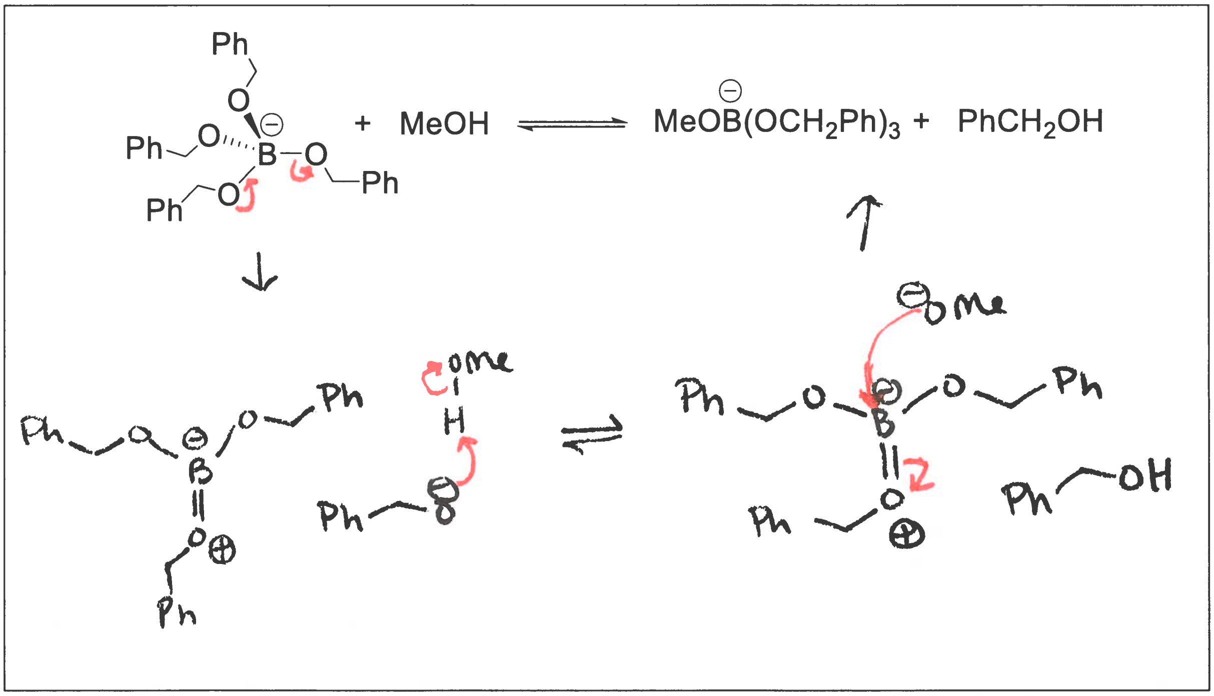
Given: $NaBH_4$ is not a strong enough base to deprotonate alcohols (ROH).

example: $NaBH_4 + MeOH \longrightarrow$ no reaction

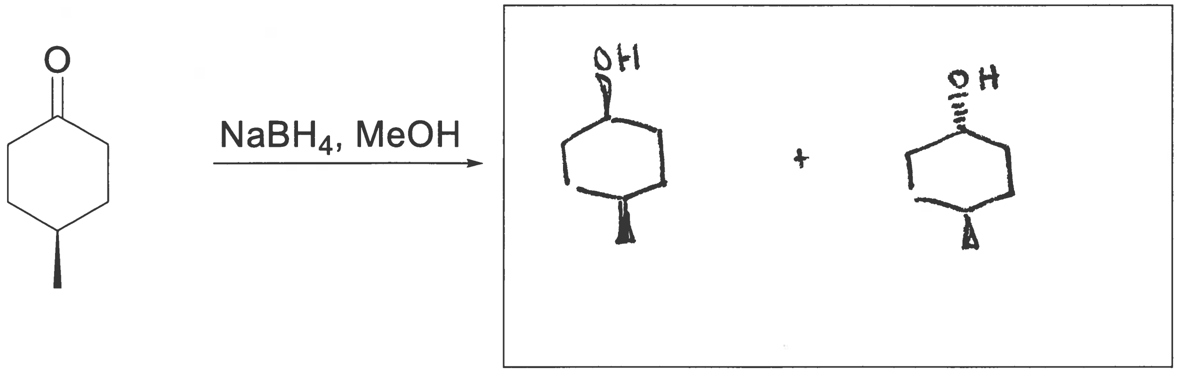
2.A. Provide a mechanism for the reaction below. Label stereodetermining steps as top or bottom. (10 pts)

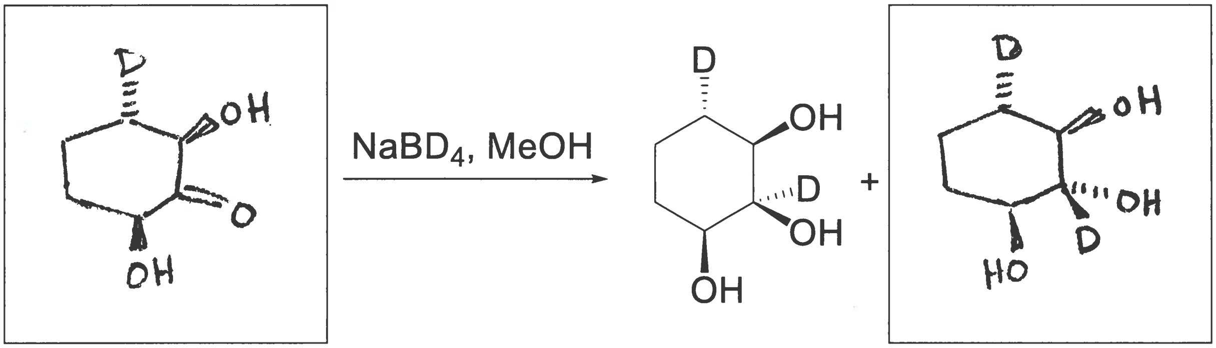


2.B. Add arrows to the mechanism below. Make sure that the K_{eq} of any Bronsted acid/base steps is close to 1. All intermediates must have **filled octets.** (10 pts)



2.C. Unlike $LiAlH_4$, $NaBH_4$ can react in the presence of an alcohol solvent. Predict the products or reagents of the reactions below. (12 pts)



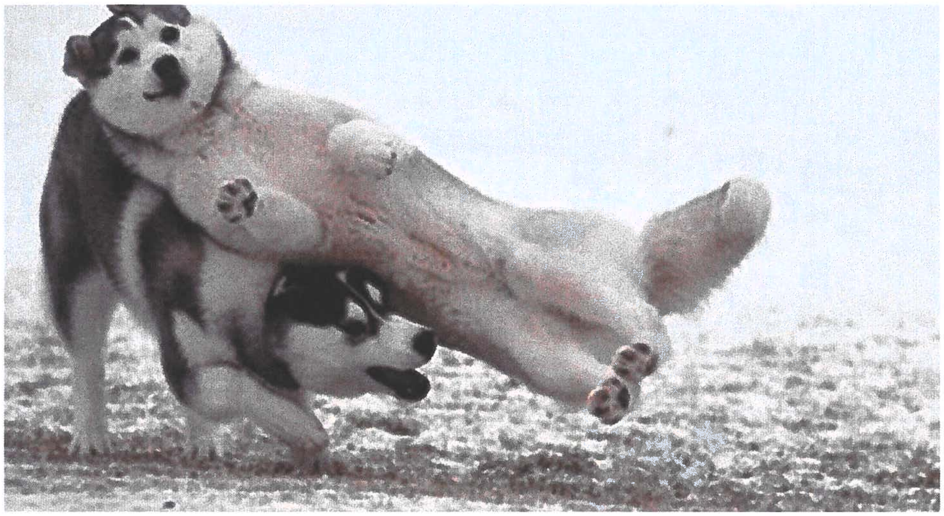


2.D. Why is the LAH hydride more basic than the $NaBH_4$ hydride? (4 pts)
Hint: think of periodic trends

$LiAlH_4$ is more basic than $NaBH_4$ because: the Al-H has a larger dipole than B-H

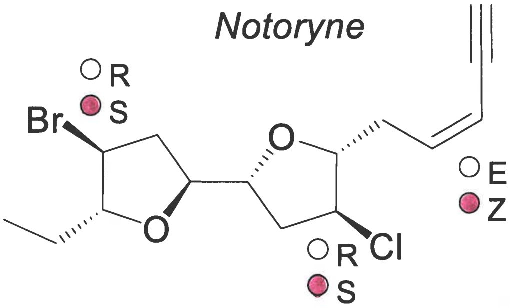
EN (Al) < EN(B)

10 words or fewer



3. Notoryne was isolated from the red algae *Laurencia nipponica* in 1991 and was recently synthesized. (*J. Org. Chem.*, **2018**, *83*, p. 12863)

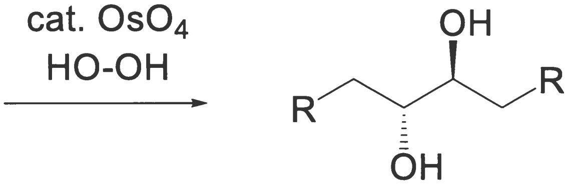
3.A. How many stereocenters are in Notoryne? (2 pts) 6



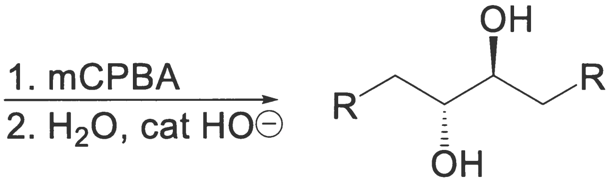
3.B. Label the stereocenters with halogens attached as R or S and the alkene as E or Z. (6 pts)

3.C. The research group tried many different approaches to achieve the desired stereochemical outcomes seen in Notoryne. Which alkene starting materials were used to give the diols below? (8 pts)

i)



ii)

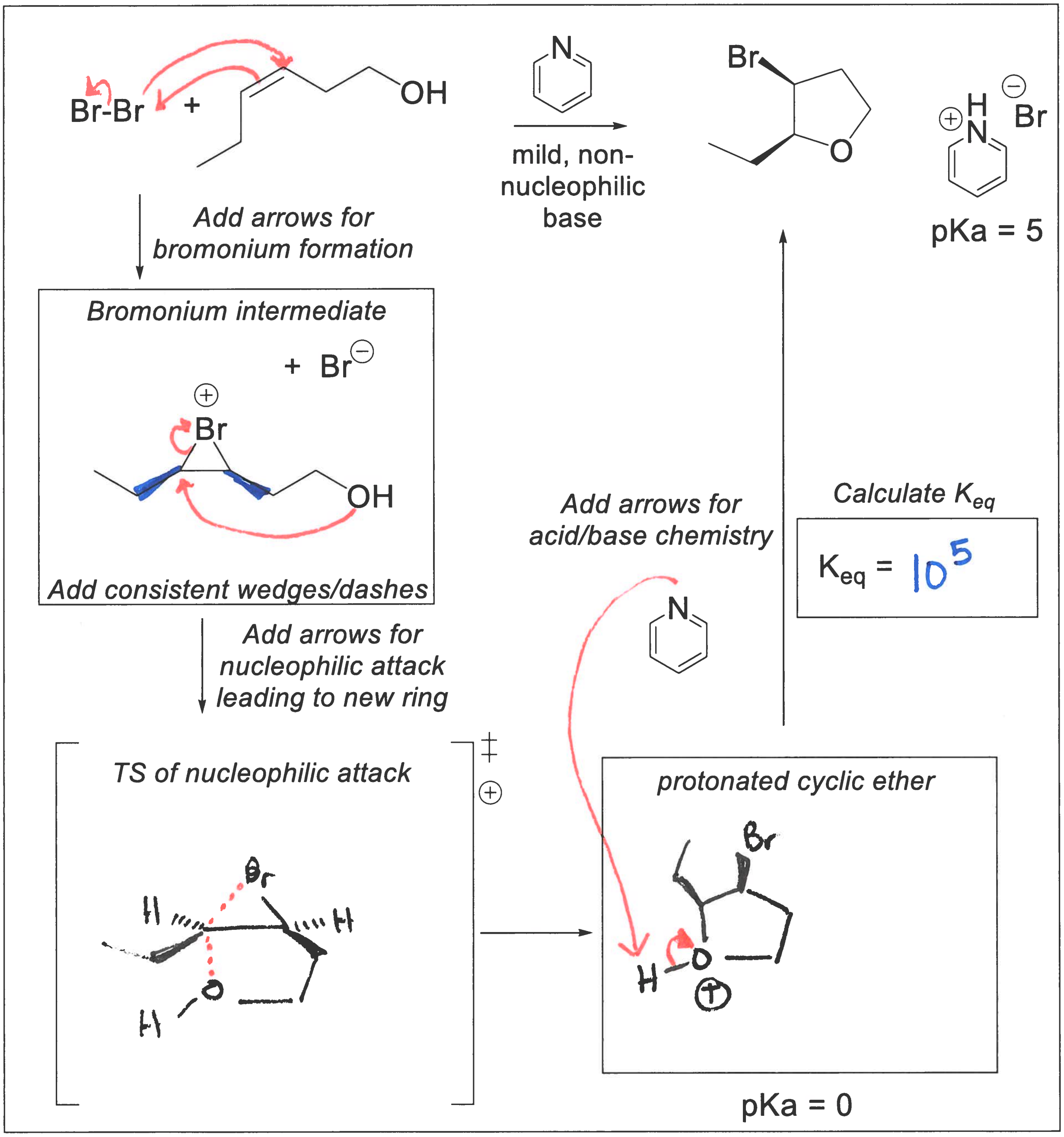


3.D. Would you expect a different stereochemical outcome of the second reaction if it were run with catalytic acid instead? Explain. (4 pts)

Reaction 3.C.ii. would have ● the same ○ a different stereochemical outcome if run with catalytic acid because: there is still inversion of stereochemistry.

15 words or fewer

3.E. Draw a reasonable curved arrow mechanism, paying close attention to the flow provided. (16 pts)



3.F. Explain the fact that oxygen attacks to only give the shown product and not another regioisomer despite both carbons of the bromonium having similar substitution in ten words or fewer. (4 pts)

We only see the given nucleophilic attack because:

4-membered ring has more ring strain.

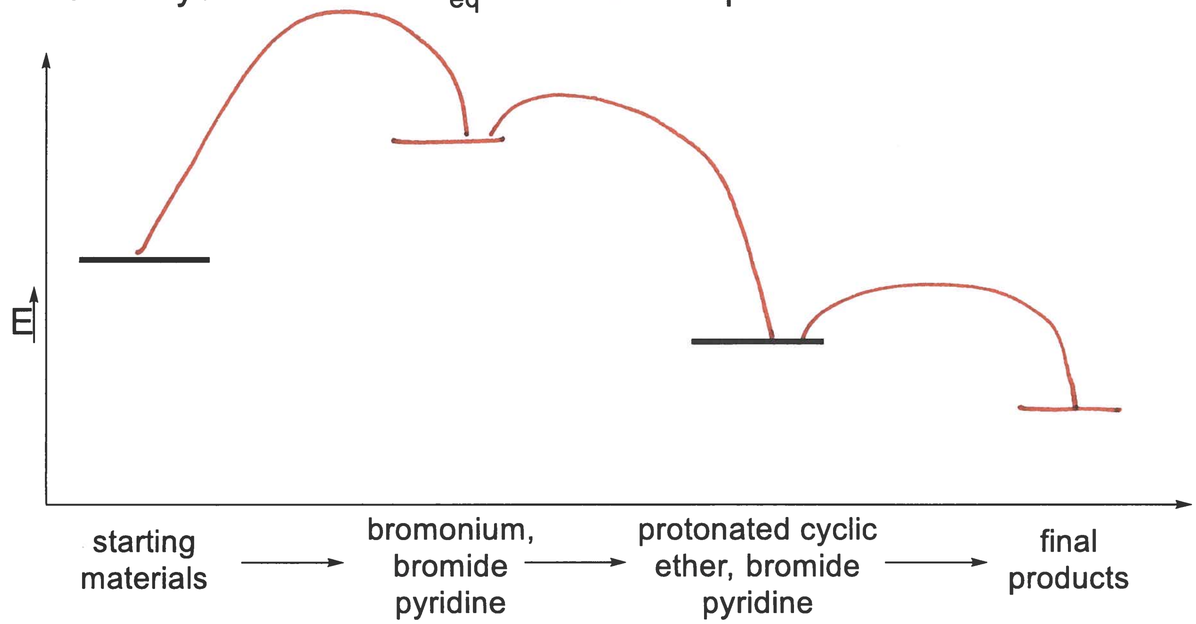
10 words or fewer

3.G. Finish the energy diagram for the mechanism in 3.E. using the given information below. (9 pts)

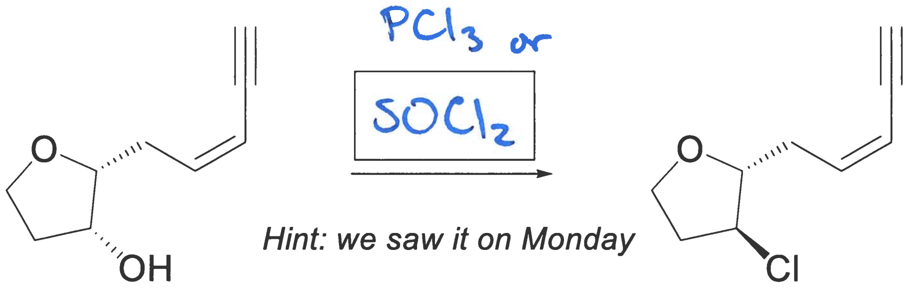
Given: bromonium formation is endothermic and rate determining

Given: the reaction is overall exothermic

Given: you calculated K_{eq} for the last step



3.H. What reagent(s) would you use for the following reaction? (3 pts)



PCl_3 or

$\boxed{SOCl_2}$

Hint: we saw it on Monday

3.I. Why is HCl not a reasonable answer to question 3.H.? Specifically, describe **TWO** possible reactions that would compete with the desired reaction. There may be more than two. (8 pts)

One possible side reaction if you use HCl in question 3.H. is

protonate ring oxygen instead.

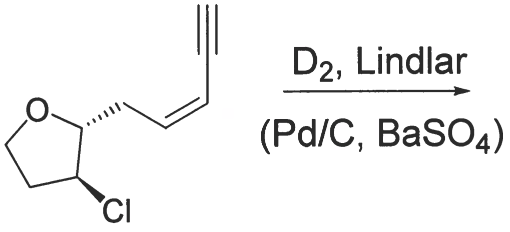
10 words or fewer

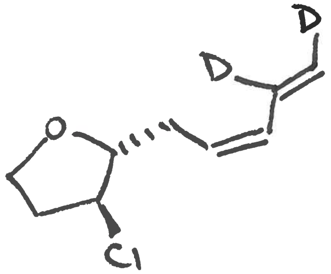
Another side reaction if you use HCl in question 3.H. is

protonate a π bond instead.

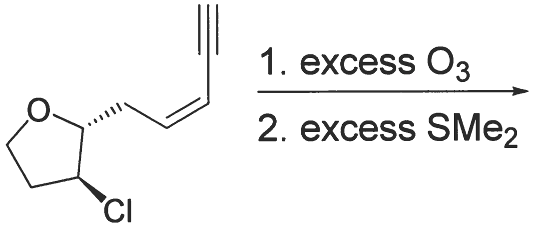
10 words or fewer

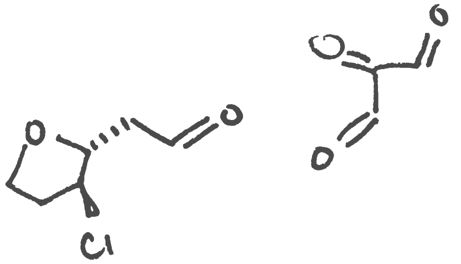
3.J. Predict the product(s) of the reaction below. (4 pts)



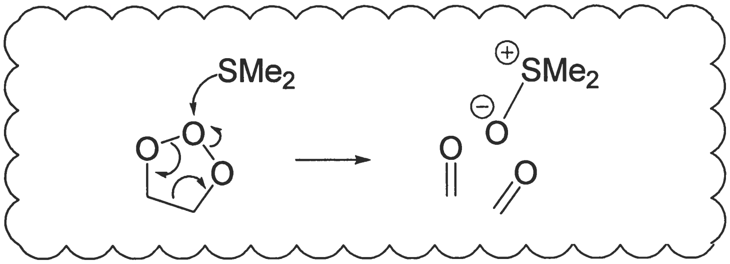


3.K. Alkynes can also react with ozone, following the same overall mechanism as alkenes, but leading to a different outcome. Predict the products of the reaction below. (8 pts)

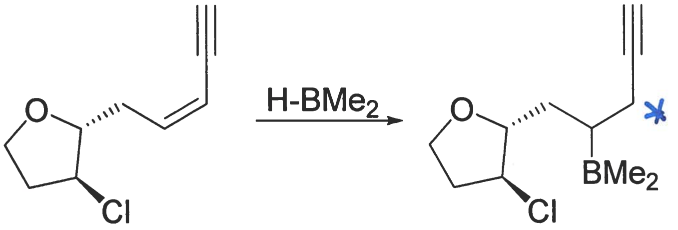


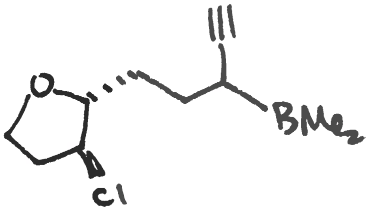


+ 2 DMSO



3.L. Hydroboration of the alkene functional group selectively gives the regioisomer below. Show the other possible regioisomer and explain why it is less likely to be formed without a steric argument. (8 pts)



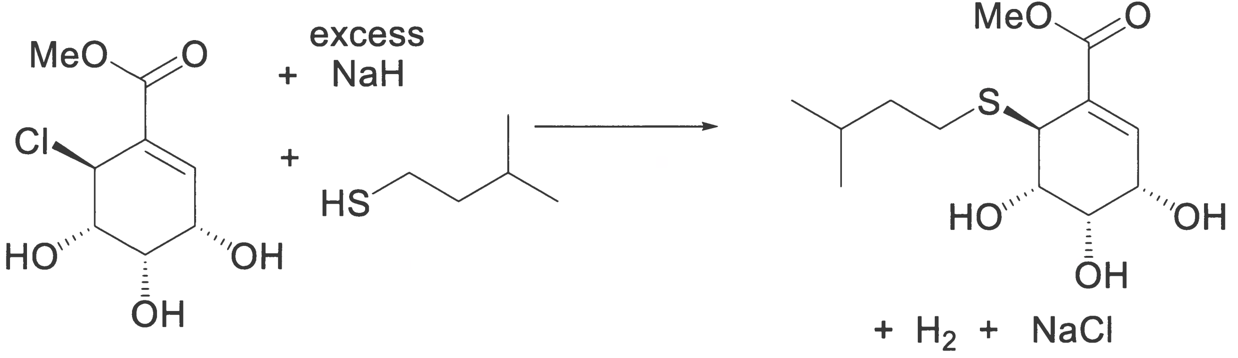


unobserved regioisomer

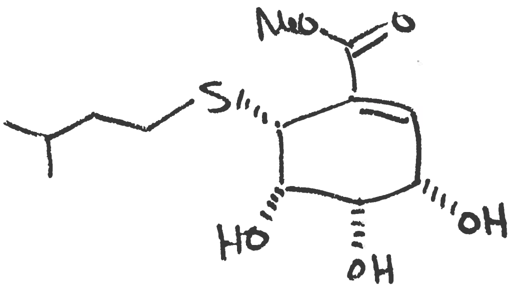
This is the only regioisomer observed because: δ⊕ @ the starred carbon better stabilized by hyperconjugation

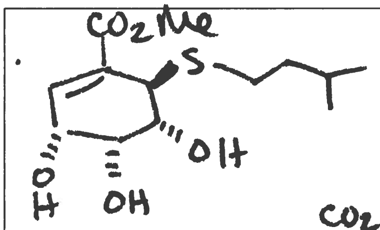
4. In exam 2, we looked at a molecule that helped absorb stinky molecules. Let's investigate some of the other reactivity those researchers looked into.

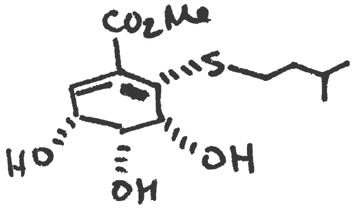
Given: The reaction run under these particular conditions provide only one stereoisomeric product.



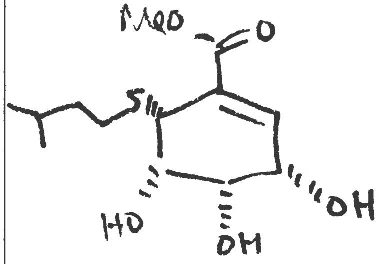
4.A. This reaction **DOES** **NOT** proceed through S_N1 chemistry. Provide two other products you would expect if this were an S_N1 reaction. (6 pts)



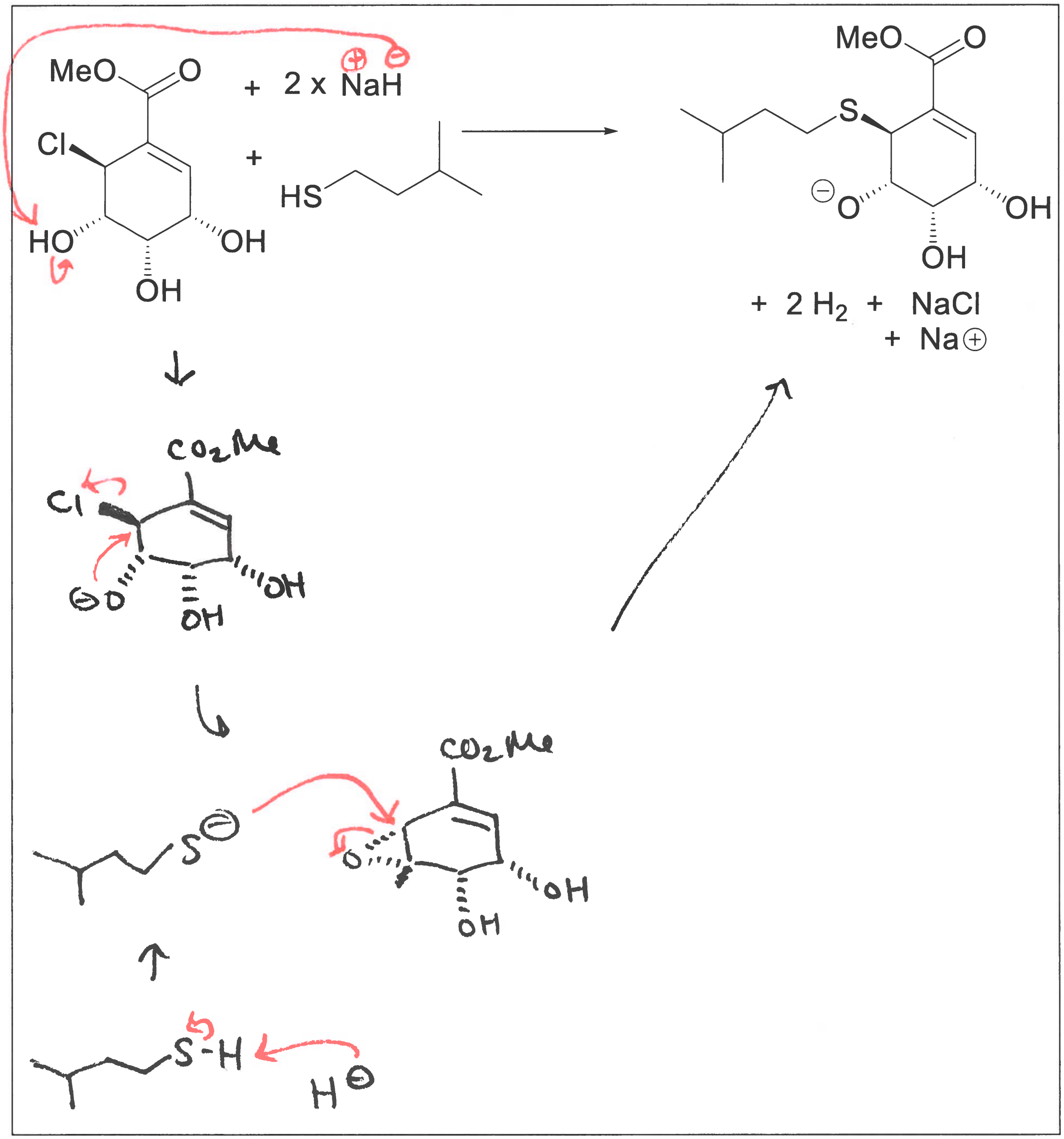




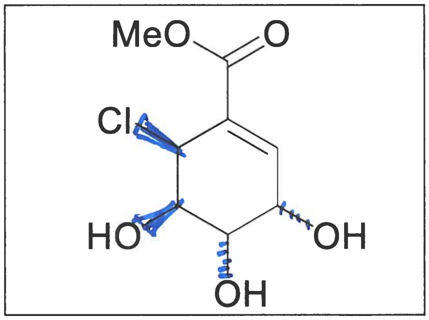
4.B. This reaction **DOES** **NOT** proceed directly through S_N2 of the sulfur nucleophile displacing the chloride leaving group. What would the S_N2 product look like? (3 pts)



4.C. Based on the previous information, provide a reasonable mechanism leading to this product. (10 pts)



4.D. Add wedges and dashes to the structure to the right consistent with a stereoisomer of the starting material that **CANNOT** undergo the mechanism in 4.C. (3 pts)

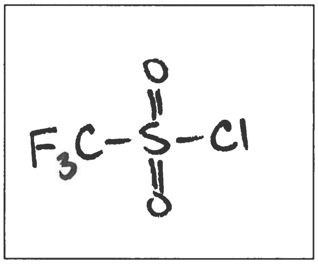


any stereoisomer with Cl and adjacent HO cis.

5. Sulfur is a very versatile atom due to its ability to hold charge. Pingfang Li's group has done some research that we're going to analyze. (*J. Org. Chem.*, **2019**, ASAPs)

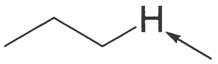
5.A. Dimethylsulfoxide is usually non-nucleophilic. However, in the presence of an incredible electrophile, the oxygen acts as a nucleophile as shown in the reaction below. Draw the electrophile triflic chloride. (3 pts)

new sulfonium electrophile

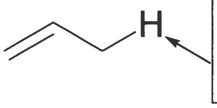


Draw Tf-Cl

5.B. The allylic CH bond is much more acidic than you would expect for a C(sp^3)H bond (expect pKa 50). How would the pKa of the allylic CH bond be compared to 50? Fill in the appropriate bubble. (2 pts)



pKa = 50



pKa ○ > ○ = ● < 50

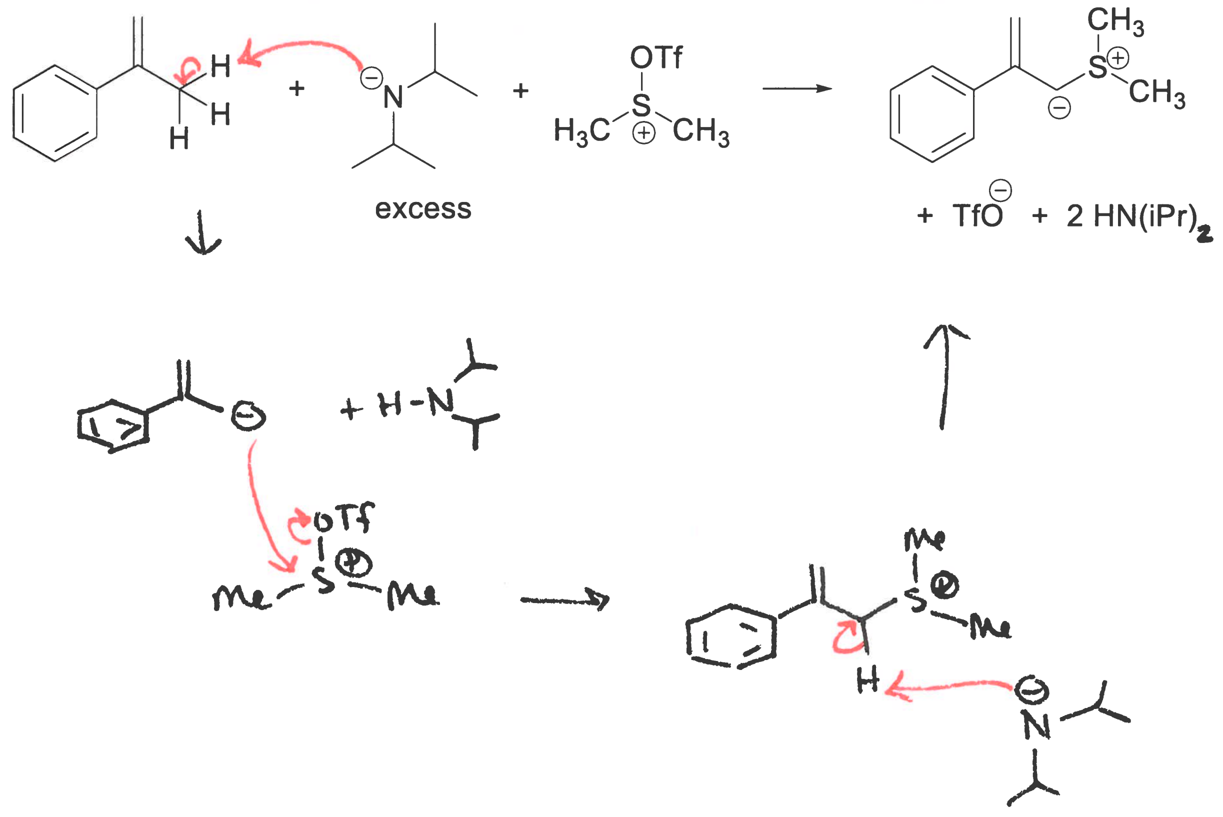
5.C. Why is the allylic CH bond more acidic than a regular C(sp^3)H bond? Explain in 5 words or fewer. (4 pts)

Allylic CH bonds are more acidic than regular alkyl CH bonds because:

resonance of conjugate base.

5 words or fewer

5.D. LDA is a strong enough base to deprotonate an allylic CH bond and is non-nucleophilic. Provide a mechanism for the transformation below. Make sure you create all of the products shown. (10 pts)



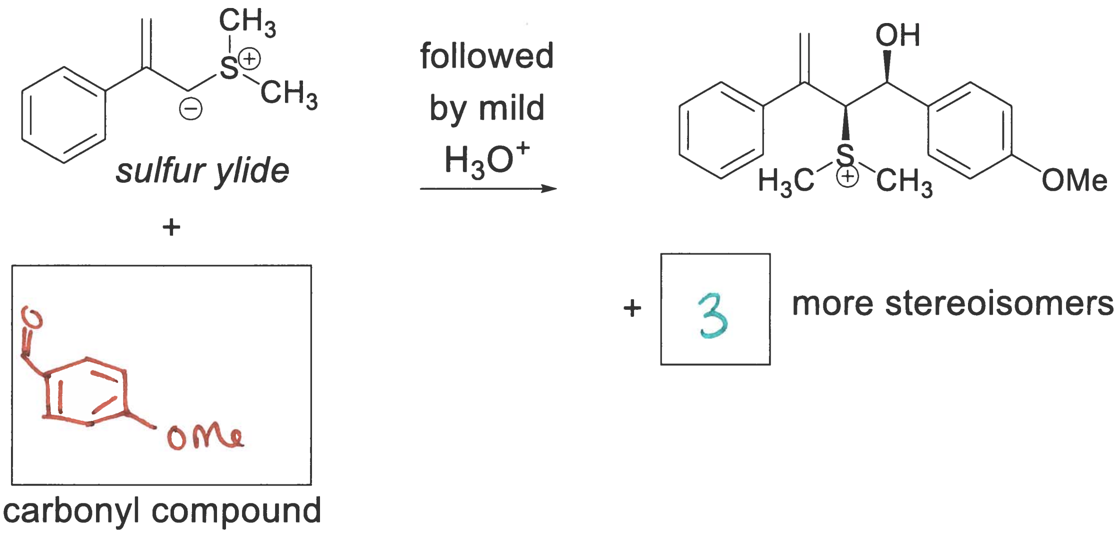
5.E. In mechanism 5.D., LDA acts as a base in the first step and again in the last step. Which time will have the larger K_{eq}? Explain in 10 words or fewer. (4 pts)

The K_{eq} for LDA reacting as a base in the previous mechanism is larger for the ○ first ● last step because: S⊕ pulls e⁻ density. Inductive Effect.

Product has coulombic stability of ⊕ and ⊖ in product

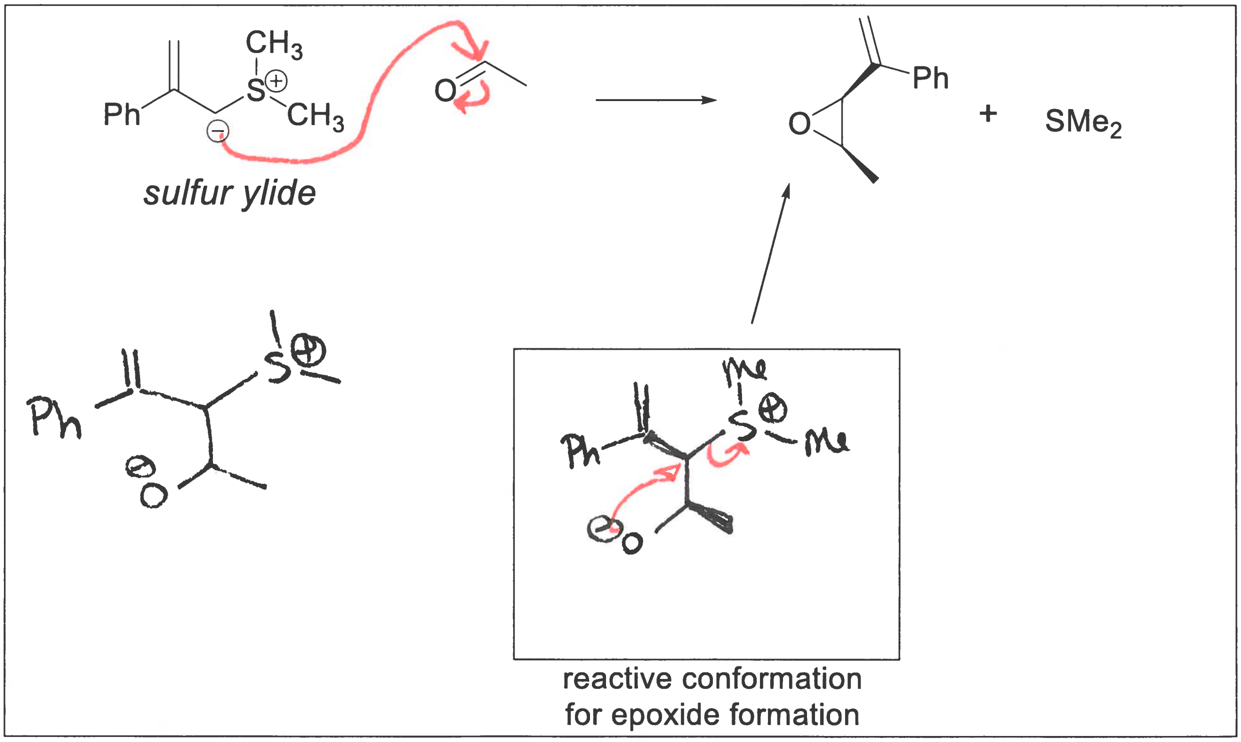
15 words or fewer

5.F. The carbanion product of reaction 5.D., shown below, is known as a sulfur ylide. It acts as a great nucleophile, like other carbanion nucleophiles generated from organo lithiates or Grignard reagents. Fill in the missing carbonyl compound for the reaction below. Also provide how many other stereoisomers you'd expect. (6 pts)

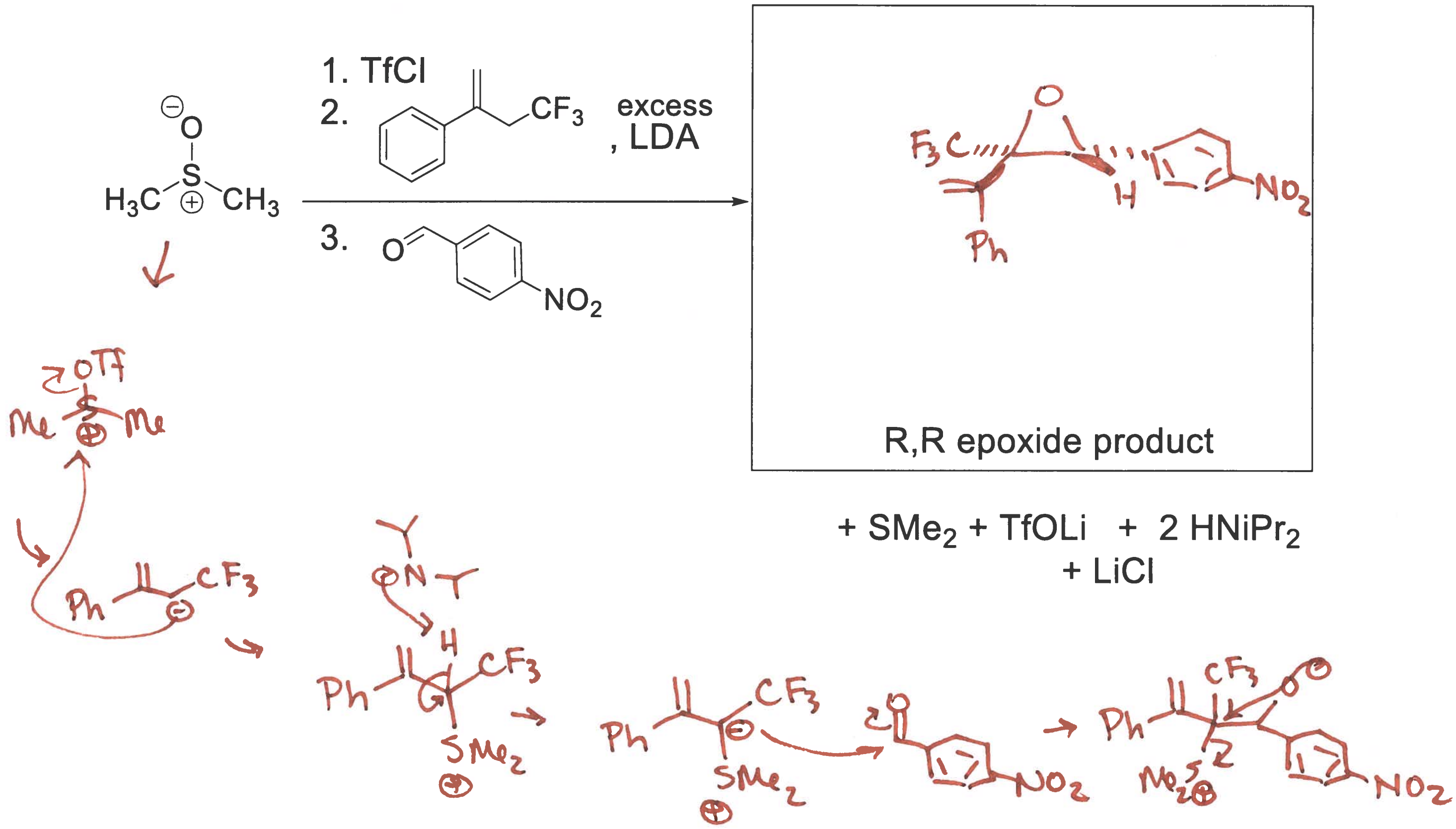


\+ 3 more stereoisomers

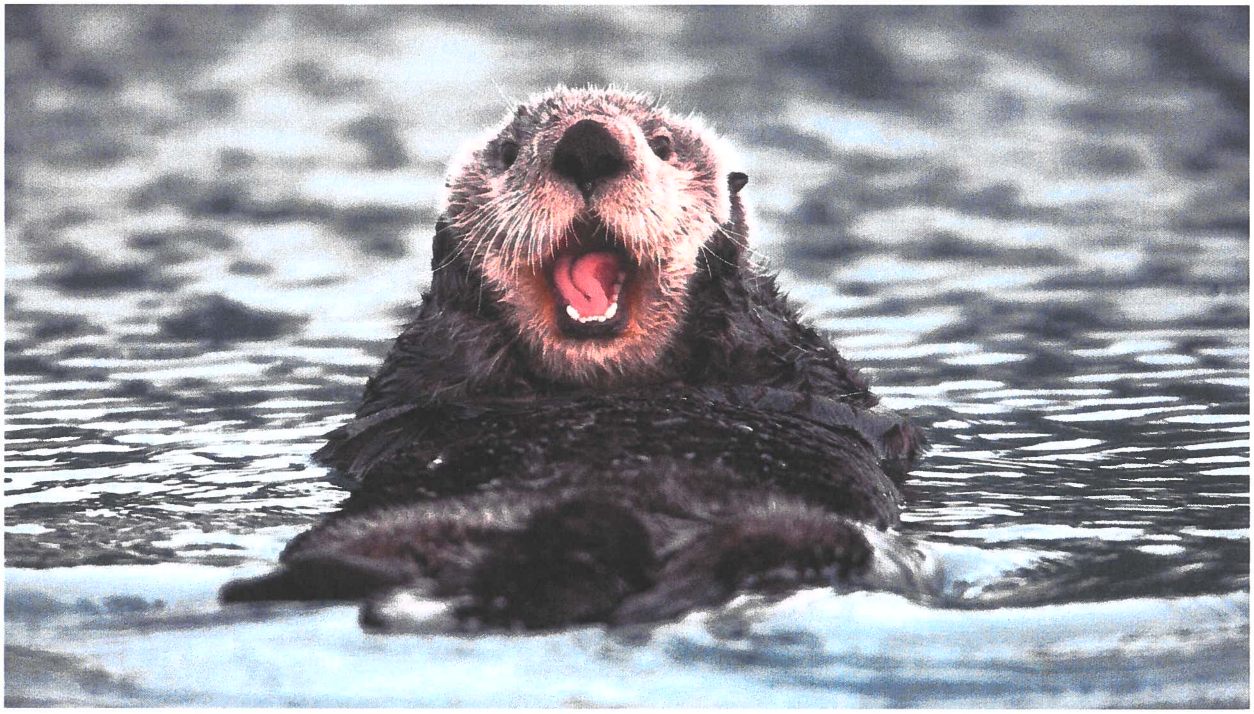
5.G. If the acid step is not done, epoxide products are isolated. Show a mechanism for the reaction below. Specifically show the reactive conformation immediately preceding the epoxide forming step. (8 pts)



5.H. Based on the above sequence of reactions, predict the R,R epoxide isomer of the reaction below. (6 pts)

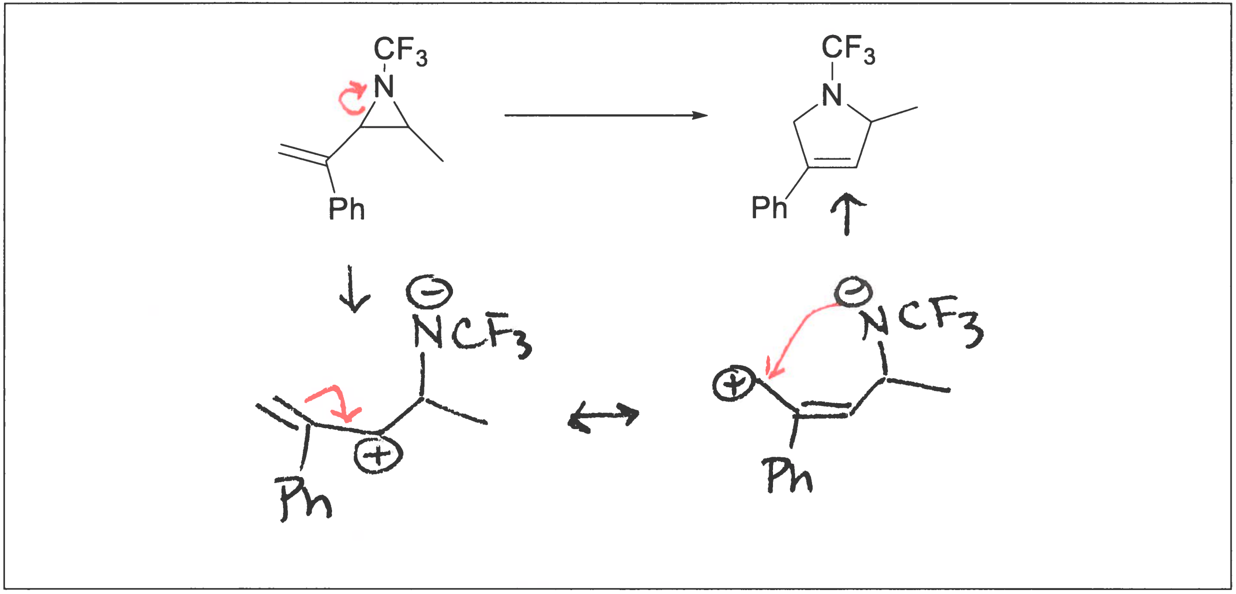


$+ SMe_2 + TfOLi + 2\ HNiPr_2$
$+ LiCl$



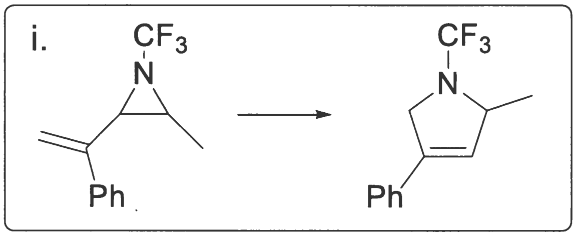
This otter is excited to tell you how close to the end of the exam you are!

5.I. Imines are the nitrogen analogs of carbonyl compounds. When this same chemical sequence happens with imines, the product is called an aziridine (or an aza-cyclopropane). However, there is also an interesting rearrangement that occurs to the aziridine. Provide a mechanism for the unwanted side reaction observed below. (10 pts)

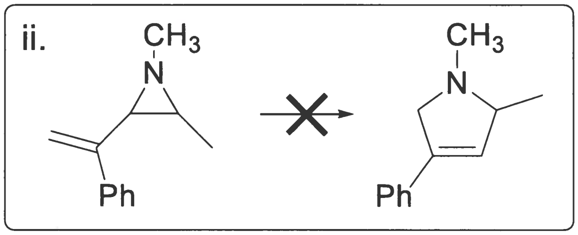


5.J. The side reaction in 5.I. only occurs when the R group on the nitrogen is very electron withdrawing (like a CF_3 group, or a CN group). Explain the observed difference in reactivity. (8 pts)

i.

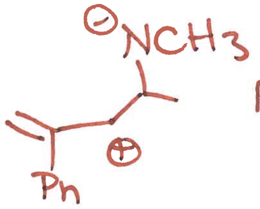


ii.



Reaction (i) proceeds while reaction (ii) does not because:

Forming $N^{\ominus}$ is easier if $\ominus$ is stabilized by adjacent CF_3 group via inductive effect.



no inductive stabilization.

15 words or fewer and a picture for comparison

You're done with Chem 3A! Congrats. Enjoy the next couple of weeks.

Here's some relaxing images of otters holding hands. Obviously.

© John Vargas / Barcroft Media