Chemistry 261: Organic Chemistry

Examination #4

December 2, 2013

Name: ANSWER KEY

Student ID Number:

Exams will be returned via the Chem 261 wall-mount racks outside Lab Sci 300.

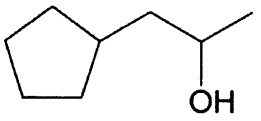
☐ Please check the box if you would prefer to pick up your graded examination directly from Prof. Ponder during office hours.

40101

Problem 1 (10 points)

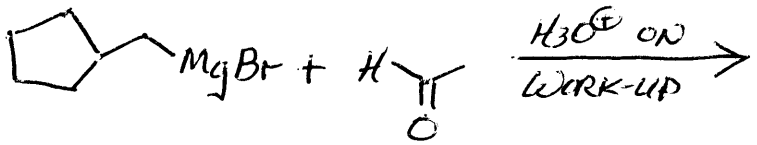
Suggest five different ways to make 1-cyclopentyl-2-propanol in a single step. Each proposed reaction must begin with a different set of starting materials (*i.e.,* none of the five methods can have any organic starting material in common). At least three of your methods must form a carbon-carbon bond, and these three methods must form *different* carbon-carbon bonds.

Show the starting materials and reaction conditions, including workup, for each of your five methods. It is not necessary to provide mechanisms.

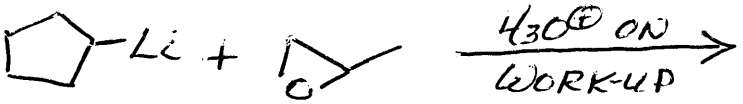


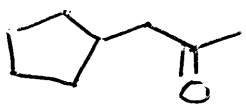
1-Cyclopentyl-2-propanol

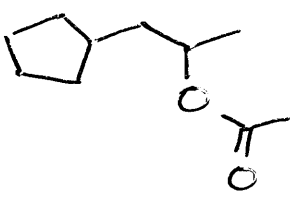
(1) 

(2) 

(+2) FOR EACH CORRECT METHOD

(3) 

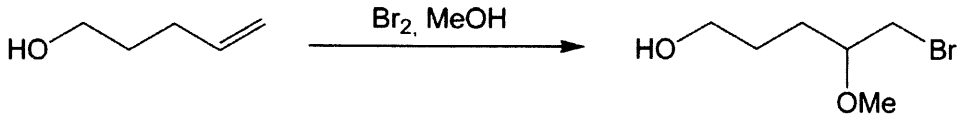
(4) 

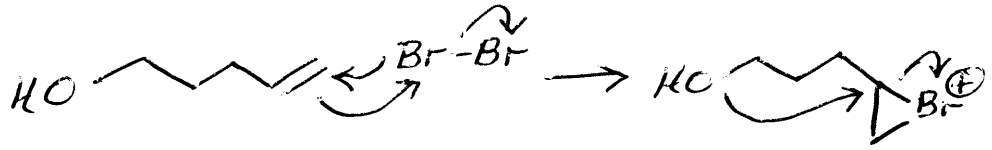
(5) 

MANY OTHER REACTIONS ARE POSSIBLE

Problem 2 (8 points; A & B = 4 points each)

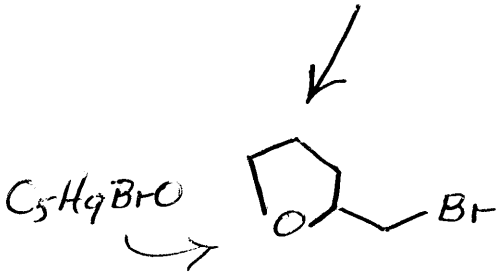
(A) A Chem 261 student attempts to form the product shown below via the indicated reaction. Instead, the reaction makes a product of formula C_5H_9BrO in excellent yield. What is the identity of the observed product, and how is it formed?



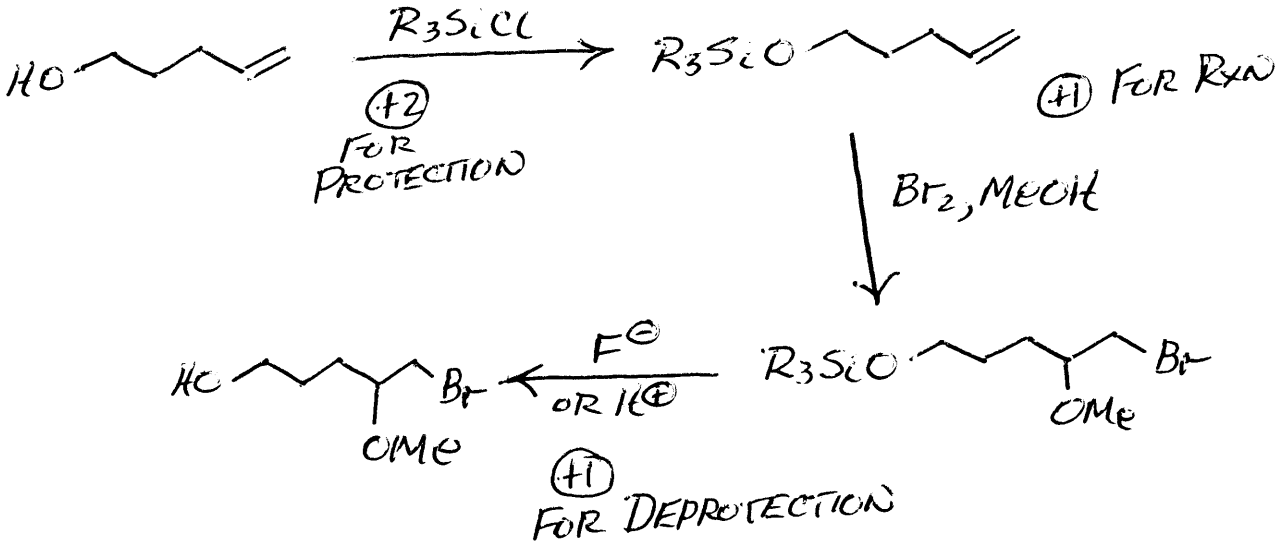


(+2) FOR BROMONIUM ION

(+2) FOR CORRECT PRODUCT

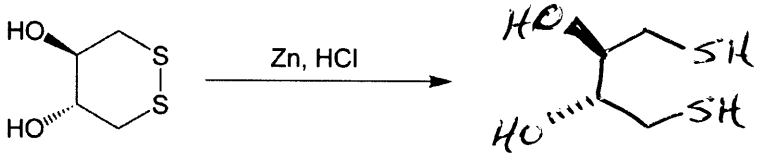


(B) Please help your fellow Chem 261 student by suggesting an alternative synthetic scheme for converting the starting material shown above into the product shown. Your answer may require multiple steps, and you may use any needed reagents.



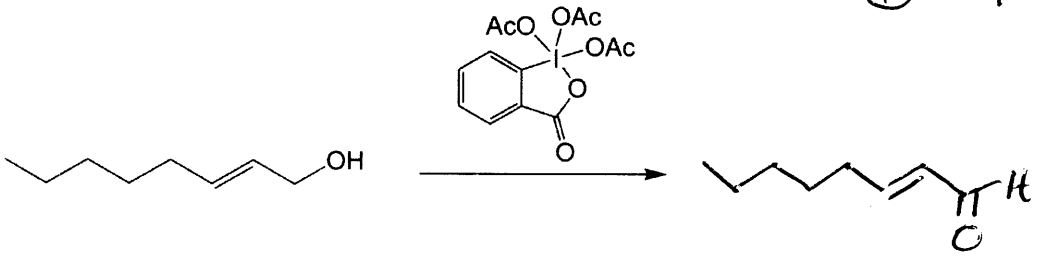
Problem 3 (12 points; A–D = 3 points each) Predict the major product resulting from each of the following reactions. Pay attention to stereochemistry when appropriate. You need not show mechanisms, intermediates or minor products.

(A)

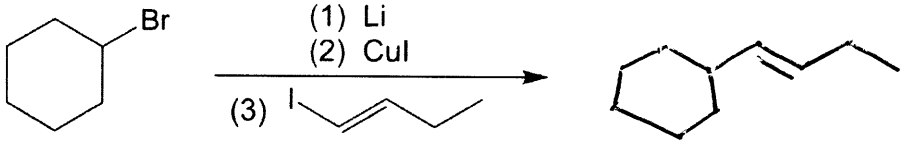


(+3) FOR EACH FULLY CORRECT ANSWER
(+2) IF STEREOCHEM IS WRONG

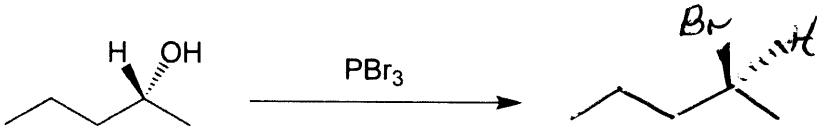
(B)



(C)

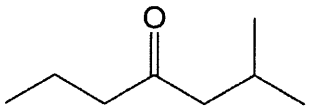


(D)

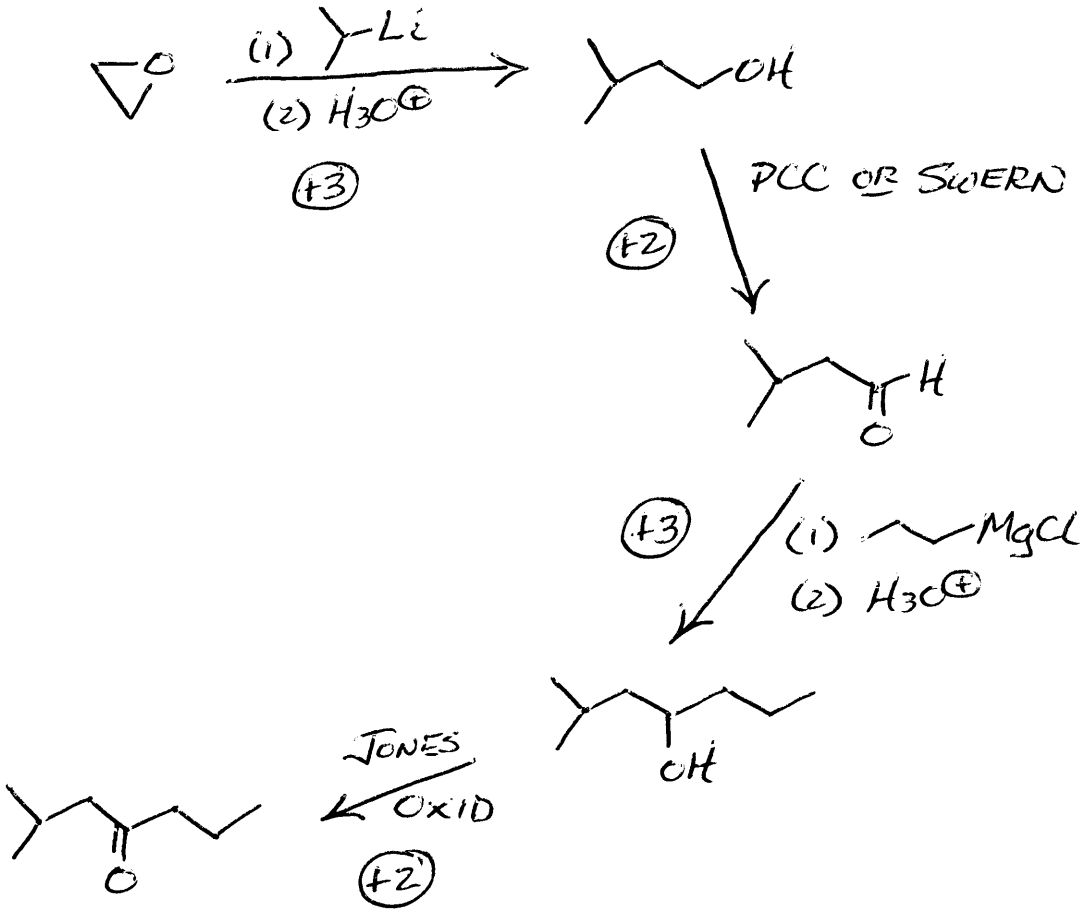


Problem 4 (10 points)

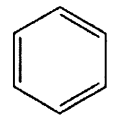
2-Methylheptan-4-one is an important alarm pheromone for the ant species *Tapinoma nigerrimum*, which is relatively common in tropical and warmer temperate regions. Starting from any organic molecules containing three or fewer carbons, and any needed inorganic reagents, propose a synthetic route to this compound. Your synthesis will be evaluated on the total number of steps, the yield of the individual steps, and their selectivity.

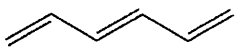


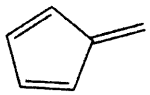
2-Methylheptan-4-one

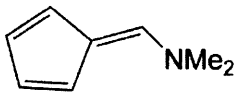


Problem 5 (12 points; A = 5 points, B = 4 points, C = 3 points)


Benzene


Hexatriene


Fulvene



6-Dimethylaminofulvene

Hückel π Molecular Orbital (MO) Energies:

Benzene	$\alpha+2\beta$	$\alpha+\beta$	$\alpha+\beta$	$\alpha-\beta$	$\alpha-\beta$	$\alpha-2\beta$
Fulvene	$\alpha+2.11\beta$	$\alpha+\beta$	$\alpha+0.62\beta$	$\alpha-0.25\beta$	$\alpha-1.62\beta$	$\alpha-1.86\beta$
Hexatriene	$\alpha+1.80\beta$	$\alpha+1.25\beta$	$\alpha+0.45\beta$	$\alpha-0.45\beta$	$\alpha-1.25\beta$	$\alpha-1.80\beta$

Gas Phase Heat of Formation Values (kcal/mol):

Benzene	19.8	Hexane	-39.9
Cyclohexane	-29.8	Hexatriene	40.2
Fulvene	53.3	Methylcyclopentane	-25.3

(A) What is the total Hückel π-electron energy for fulvene? Compare this value to corresponding values for three isolated C=C bonds, for hexatriene and for benzene. Based upon the Hückel MO results, is fulvene best described as aromatic, conjugated, or something in between?

(+3) FULVENE $\pi e^{\ominus}$ ENERGY $= 6\alpha + 7.46\beta$ — AROMATIC

(+2) THUS, FULVENE IS BETWEEN AROMATIC AND CONJUGATED — CONJ.

BENZENE $6\alpha + 8\beta$

HEXATRIENE $6\alpha + 7\beta$

3x ETHENE $6\alpha + 6\beta$

(B) Use the heat of formation data to compare the π-stabilization of fulvene, benzene and hexatriene. Based upon the thermodynamic data, is fulvene best described as aromatic, conjugated, or something in between?

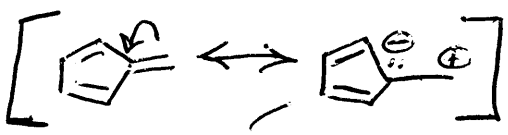
BENZENE + $3H_2$ → CYCLOHEXANE $\Delta H = -49.6$ KCAL/MOL

HEXATRIENE + $3H_2$ → HEXANE $\Delta H = -80.1$

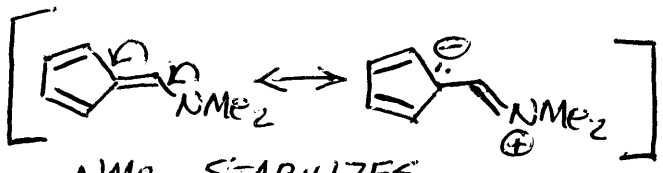
FULVENE + $3H_2$ → MeCYCLOPENTANE $\Delta H = -78.6$

THUS, FULVENE IS MUCH CLOSER TO CONJUGATED (HEXATRIENE) THAN TO AROMATIC (BENZENE)

(C) Fulvene has an unusually large dipole moment for a hydrocarbon at 1.1 Debye (D). The fulvene derivative, 6-dimethylaminofulvene (shown above), has an extremely large dipole moment of 4.5 D. Explain.

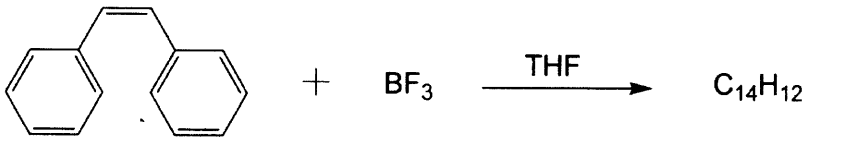


← + DIPOLE



Problem 6 (10 points; A-C = 2 points each, D = 4 points)

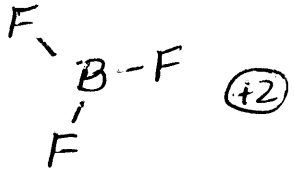
Compound I (0.50 g of a colorless liquid) and boron trifluoride, BF_3, (0.40 g) were dissolved in 4 ml of tetrahydrofuran (THF) in a test tube. The tube was covered with aluminum foil and kept at room temperature for 24 hours. At the end of the reaction time, the THF solution was washed thoroughly with aqueous sodium carbonate to remove boron trifluoride. Then the THF was removed by evaporation, and the remaining solid was recrystallized from ethanol to give white crystalline Compound II (0.19 g, m.p. 124-125°C). The molecular formula of Compound II was determined to be $C_{14}H_{12}$.



Compound I

Compound II

(A) Draw the Lewis dot structure for BF_3.

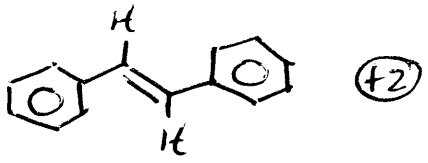


(B) What is the percent yield of product for this reaction?

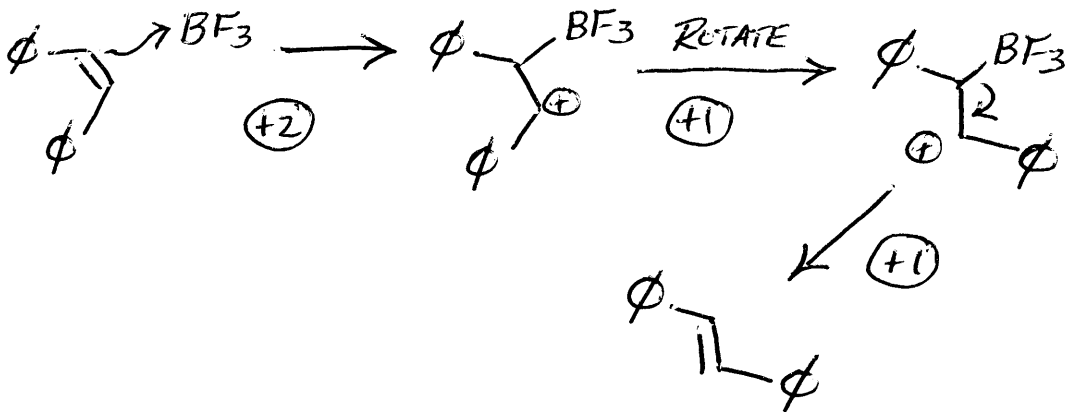
$0.19/0.50 = 38\%$ (+2)

ALL-OR-NONE

(C) What is the structure of Compound II?



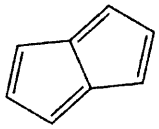
(D) Provide a "curved arrow" mechanism to account for the formation of Compound II.



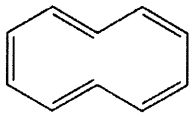
Problem 7 (8 points; A-H = 1 point each part)

For each of the molecules shown below, indicate whether the structure is aromatic, antiaromatic, or nonaromatic.

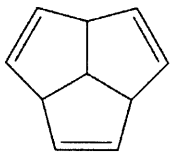
(A) ANTIAROMATIC



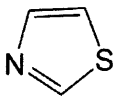
(B) NONAROMATIC



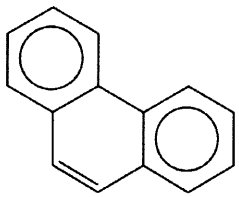
(C) NONAROMATIC



(D) AROMATIC

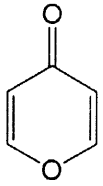


(E) AROMATIC

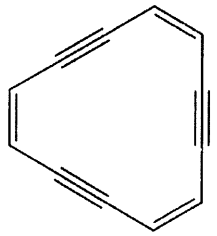


(F) NONAROMATIC

(G) AROMATIC

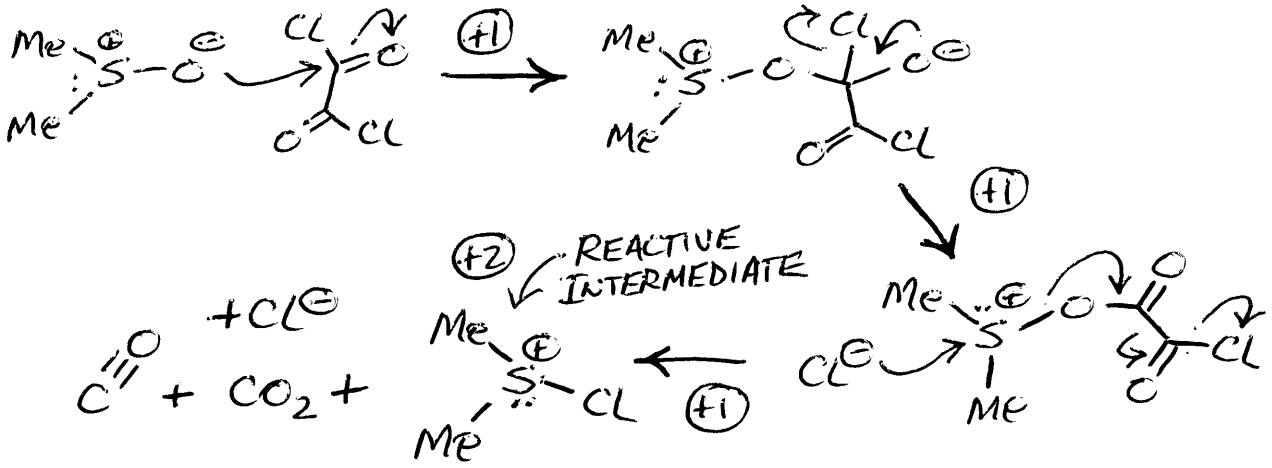


(H) ANTIAROMATIC

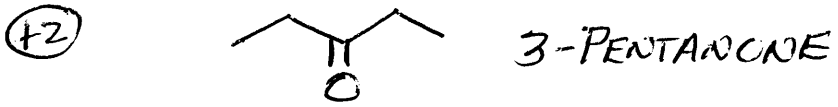


Problem 8 (12 points; A = 5 points, B = 2 points, C = 5 points)

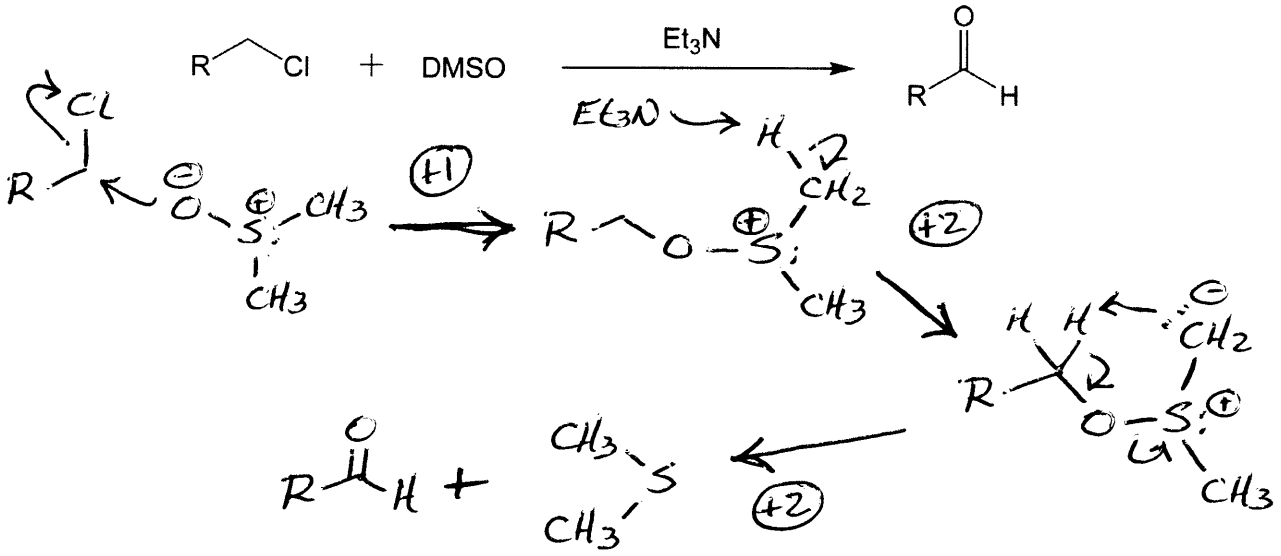
(A) In the first step of the Swern oxidation, dimethyl sulfoxide (DMSO) reacts with oxalyl chloride (Cl–CO–CO–Cl) at low temperature to form a reactive intermediate. Identify this intermediate, and provide a complete mechanism for its formation.



(B) The second part of the Swern oxidation is addition of the alcohol substrate, such as 3-pentanol, and at least two equivalents of triethyl amine to the preformed reactive intermediate. What is the final product if 3-pentanol is the alcohol reacted?

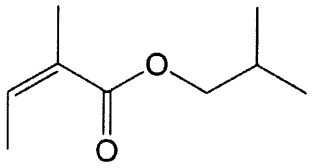


(C) The Kornblum oxidation is an analogous DMSO-based reaction used to convert primary alkyl halides into aldehydes. Suggest a full "curved arrow" mechanism for this reaction. *Hint: Nucleophilic attack by DMSO on the halide is followed by steps similar to Swern oxidation, and proceeds via a sulfur ylide intermediate.*

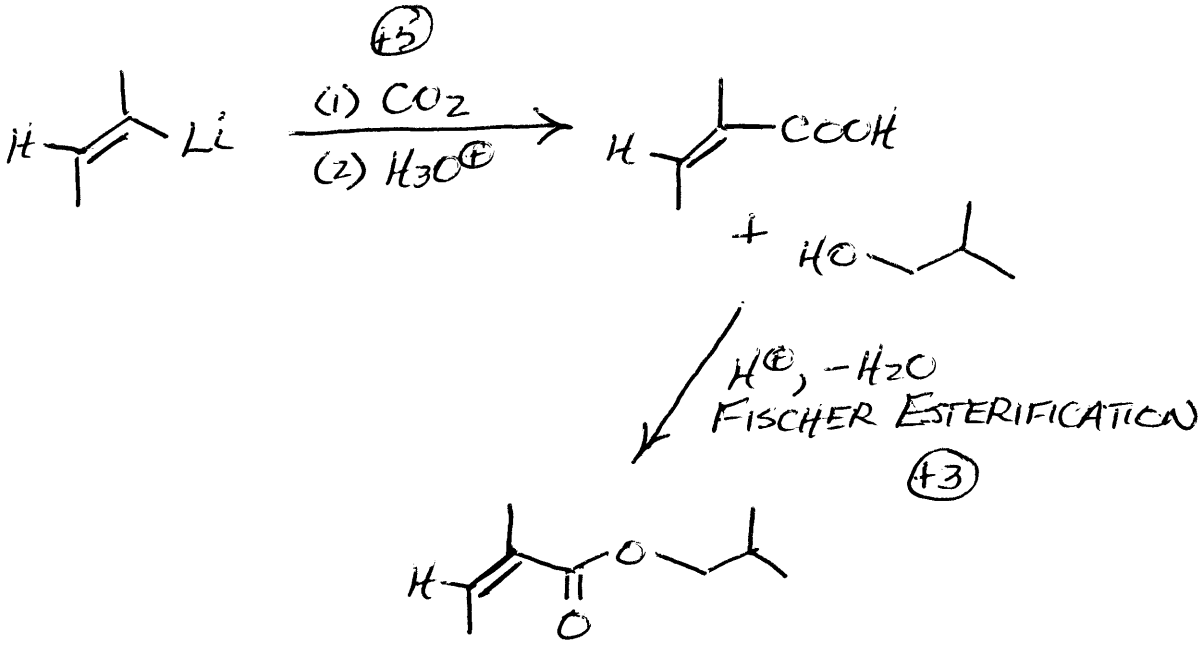


Problem 9 (8 points)

Isobutyl angelate is a major component of Roman chamomile, an essential oil which is an ingredient in a variety of perfumes, cosmetics and processed foods. Devise a synthesis of this molecule, starting from any compound of four carbons or less and any needed reagents. Your synthesis will be evaluated on the total number of steps, the yield of the individual steps, and their selectivity.



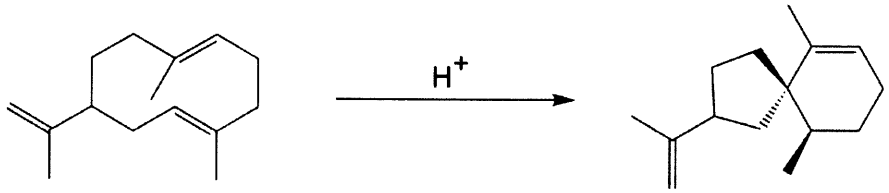
Isobutyl Angelate



OTHER, MULTI-STEP ROUTES ARE POSSIBLE IN PLACE OF EACH STEP ABOVE

Problem 10 (10 points)

Hysocyamus muticus (Egyptian henbane) is a medicinal plant of the nightshade family found in desert environments. The plant contains a sesquiterpene synthase enzyme that catalyzes the conversion of germacrene A to vetispiradiene. While this reaction is enzyme mediated, it is thought to proceed through a series of intermediates consistent with an acid-catalyzed rearrangement. Provide a complete "curved arrow" mechanism for the process below. Please show all intermediates along your proposed pathway.



Germacrene A

Vetispiradiene