Chemistry 30B Final Review Problems ANSWER KEY

In this final set of problems, I have tried to include things that will help you on the final exam. These problems have all been adapted from the sophomore organic chemistry course at MIT (though a friend @ Berkeley). I have included sections of problem sets and exams. This being said, the numbering is completely out of order (and doesn't make since). Also, there are some problems crossed out, as they were not covered in our class.

Finally, regarding ANSWER KEYS, I have not yet decided as to whether or not I will provide an answer key online. Please do NOT e-mail me asking about it. If I am going to post a key, it will be done only within a few days of the exam. As you will, or already have seen there is a plethora of office hours available between the last day of class and the final, we are all willing to go over these problems with you.

Note for Doug's Section:

During the Week X discussion section, I would like to cover question (1) on page 2 of 10 (it's buried somewhere in there toward the end with the first three questions asking about pKas). Also work on question (2) on page 4 of 10. Again, not really 4 of 10, but that's what it says on the bottom of the page.

GOOD LUCK ON THE FINAL!

NOTE FOR ANSWER KEY:

You will get the most out of these problems if you try them a few times yourself before looking at the answer key. Also, for many of these problems there are multiple correct answers, just because it's not included here doesn't mean that your answer is wrong. 1. For A you see a strong I+ signal at 127 and the fact it reacts with Mg signifies a halogen. The parent ion is 15 units higher than the I+ hence it is CH_3I .

For C we clearly have an ROH group with the broad absorption at 3350 cm⁻ ¹. No carbonyls and the rest appears to be saturated. We have strong methyene scissor bands at 1469 cm^{-1} and a strong symmetric bend associated the CH₃ at 1385 cm⁻¹. There is also a strong C-O stretch at 1150 associated with the ROH. No other functional groups likely from the cm⁻¹ IR. The 1H-NMR gives a six hydrogen singlet associated with two equivalent methyl groups that is downfield due to neighboring inductive effect, probably the ROH. We also have another methyl group at 0.9 ppm that is clearly attached to an n-alkane that has little or no inductive effects (separated from the ROH by at least one carbon). The is a single methylene that also appears to be desheilded at 1.4 ppm by being next to an oxygen containing carbon. The ROH group in the NMR is identified by exchange with D_2O . Given that there only appears to be one oxygen atom and no unsaturation we can arrive at a emprical formula of $C_5H_{12}O$ for a F.W.=88. The fragmentation shows a stron peak at $OC(CH_3)_2^+$ and confirms that the two methyls are attached to the oxygen bearing carbon. Hence the structure is clearly $CH_3CH_2COH(CH_3)_2$.

Working backwards you can realize that the CH_3 -MgI must be added to $CH_3CH_2COCH_3$ which is B.

2. Compound A is very simple compound based upon its NMR. There is only one type of proton. The position of the resonance is such that it must be connected to an electron withdrawing center either a heteroatom (not oxygen) or a carbon with sp^2 or sp hybridization. Looking at the spectra for compound B it is clear that there has to be a methyl with the 3H signal at 2 ppm. This is likely connected to an electron-withdrawing center. In addition there is another methyl resonance at 1 ppm as a triplet. This is very suggestive of a methyl next to a CH_2 group. The 2 H quartet at 2.4 ppm is typical of a CH_2 connected to a electron withdrawing center. From the IR we see clearly a isolated alkyl carbonyl at 1722 cm-1 . In the mass spectrum we see a very strong signal for the CH_3CO^+ group (FW=43) which is separated from the parent ion M+ by loss of CH_3CH_2 . Similarly we see another signal which differs from the parent ion by 15 mass units (loss of CH_3) that coresponds to the $CH_3CH_2CO^+$ group. This then suggest with the NMR that B is $CH_3CH_2COCH_3$. The reaction we did added 18 mass units to A to make B which is the mass of H_2O . This gives us the molecular formula for A of C_4H_6 . To have the simple NMR clearly this molecule has to have high symmetry and the only possible molecule is CH_3CCCH_3 .

3. Compound B is a very simple one with a single NMR signal indicative of a methyl group bound either to an N or Halogen. By subtracting 15 mass units from the parent ion it is clear that the heteroatom is Br and A must be methyl bromide. Triphenylphosphene is a very good nucleophile and makes a cationic complex which is $Ph_3PCH_3^+Br^-$. This reagent when activated by strong base is know to react with ketones to give alkenes. Compound C has a typical carbonyl at 1717 cm⁻¹ that is clearly substituted by alkyl groups. There is no other evidence of functional groups in the IR. There is a strong methylene scissor at 1449 cm⁻¹ and there is no CH3 symmetric bend at 1385 cm⁻¹. Considering the mass and that there has to be one oxygen you can deduce that with the number of hydrogens given in the NMR of 10 that there must be two degrees of unsaturation with the C=O and a ring (no alkene). In the NMR the 4 H signal is clearly next to the carbonyl and the other Hs are removed. The only structure with the proper mass and the necessary NMR is cyclohexanone. Clearly the carbonyl goes away to give an alkene (new 2H resonance at 4.5 ppm and 3100 cm⁻¹ (C-H stretch), and 1649 cm⁻¹ (C=C stretch)). The NMR of the remaining signals remains very similar to C as we still have a six membered ring in D which is methylene cyclohexane.



D

C

4. There are six different kinds of protons in this structure. The olefin protons, H_4 , are clearly at 6 ppm. All of the other protons are on alkyl groups. The bridgehead protons H_3 have an sp2 group attached and have high s character due to orbital hybridization and are at 2.9 ppm. The other hydrogens can be assigned can be assigned using the ring current ideas discussed in class. The signals at 1.6 and 0.9 are for two hydrogens and clearly must be H_5 or H_6 . The one at 0.9 is too far up field for a normal CH_2 group and hence this one is feeling the shielding region generated by the ring current of the olefin. If you make a molecule you will see this. Hence H_6 if the peak at 0.9 and H_5 is the signal at 2.9 ppm. Using the similar argument we would assign H_1 to the signal at 1.1 ppm and H_2 to be the signal at 1.3 ppm.



5. Compound A clearly has an alkene with a C-H stretching band at 3100 cm-1 and a weak C=C stretch at 1660 cm⁻¹. There is a strong methylene scissor mode at 1466 cm⁻¹ and there doesn't appear to be any methylgroups in the IR or other functional groups. Oxidation by warm concentrated KMnO₄ is know to cleave double bonds to give carboxylic acids. For an internal double bond this would add 4 oxygen atoms in total or a mass of 64. Indeed the mass increases in B by 64 units and the IR indicates the presence of CO₂H groups in with the broad O-H band and the carbonyl band at about 1790 cm⁻¹. The fact that we didn't cleave the molecule in two and lower the molecular weight indicates that the olefin was part of a ring structure. Considering the molecular weigh and two degrees of unsaturation (ring and alkene) we can arrive at cyclooctene as A and $HO_2C(CH_2)_6CO_2H$ as B.

6. These compounds have high symmetry and the fact that they are aromatic they must have a para orientation of identical functional groups. Compound A has an exchangeable H, which is likely a phenol group. Upon oxidation a

carbonyl appears with a strong band at 1651 cm^{-1} suggestive of a conjugated variety. This makes sense as we have an unsaturated system. The loss of two mass units can only be rationalized by loss of two protons. Hence the system when oxidized looses two electrons and two protons. The singlet for B is down field of typical olefins however if we have conjugated ketones this will shift them to that resonance. Given the mass and these conditions the only plausible compounds are:





3. Show all of the intermediates and the mechanism for each step in the following transformation.



 \times

3

4. Compound A (F.W. = 90.1) is oxidized by pyridinium chlorochromate (PCC) in CH_2Cl_2 to give compound B (F.W. = 86) which is then treated sequentially with CH_3ONa , and CH_3I to give compound C (F.W. = 132.2) with the spectra shown and a proton NMR of 4.5 (2H, t); 3.5 (6H, s), 1.35 (4H, m). Propose structures for A, B, and C and detail the reactions. Explain your structural assignment.





5. Give a detailed mechanism for the following reaction.



6. The following spectra are from a compound that is produced by the product of the acid catalyzed reaction with benzene and the epoxide formed from propene. Propose a structure, provide a detailed reaction mechanism, and assign the NMR signals to the best of your ability.



2. Consider the TsOH and LDA initiated reactions of this epoxide under anhydrous conditions. Give the potential products and detailed mechanisms for both and show detailed stereochemistry with all absolute assignments (i.e. R or S).



1. (12 points, 1 point per box) In the boxes below, write the product of the reaction indicated or the reagent or reagents (e.g. not "Jones Reagent") required for the transformations shown. Where relevant, clearly indicate stereochemistry. If no reaction occurs, write "no reaction" in the box.







2. (20 points) In the reaction shown below, an epoxide is converted to a hydroxyketone in two steps. Write the structure of the epoxide-derived product of the first reaction (compound A) in the box below. In the space below the reaction, clearly write an arrow-pushing mechanism for both steps (i.e. starting materials -> compound A -> products). Clearly draw all intermediates and reaction by-products in your mechanism.



···

3. (36 points, 6 points each) As part of a Ph.D. thesis, an MIT graduate student performed a reaction in the lab in which a foul-smelling organic molecule (compound A) was treated with NaOH and CH₃I, giving compound B, which had a slightly less offensive odor. Some of the spectral data for compound B are listed below. If applicable, clearly indicate the geometry of all alkenes (e.g. cis or trans). (MW of S = 32.06)

EA: C, 67.69%; H, 6.49%; S, 25.82%

MS: M⁺ = 124

¹H NMR (ppm) 7.18 (2H, dd, J = 2, 8), 7.16 (2H, dd, J = 7, 8), 7.02 (1H, dd, J = 2, 7), 2.47 (3H, s)

a. What is the molecular formula of compound B?

b. What is the "index of hydrogen deficiency" of compound **B**? (Hint: Treat sulfur as you would oxygen in such a calculation)

c. How many chemically nonequivalent carbon atoms does compound B have?

5

4

- d. How many chemically nonequivalent hydrogen atoms does compound B have?
- e. Draw the structure of compound B.



f. Draw the structure of compound **A** (the foul-smelling starting material).



4. (32 points) In the box below, draw the structure of the unknown compound having MF C₁₃H₁₆O and the ¹H NMR data below. If applicable, clearly indicate the geometry of all alkenes (e.g. cis or trans).

¹H NMR (ppm) 7.54 (1H, d, J = 16), 7.30 (2H, dd, J = 2, 8), 7.21 (2H, dd, J = 7, 8), 7.14 (1H, dd, J = 2, 7), 6.67 (1H, d, J = 16), 1.21 (9H, s)

Your proposed structure:	
The second secon	K
trans	doubte bond.

(1) (2 points each, 30 points total) Please provide the requested answer/data/reagents. If no reaction is expected, write "NR". Note: n-Bu = n-Butyl = -CH₂CH₂CH₂CH₃.





(2) (9 points) Consider the experiment outlined below:

$$\begin{array}{c|c} & & & H_2 \varnothing \\ \hline Me & & \Theta & H_2 \end{array} \qquad stop the reaction at 50% conversion and examine the recovered anhydride for incorporation of \varnothing \end{array}$$

Ø = isotopically labeled oxygen

In analogy with the discussion in class regarding the labeling studies of acid chloride, amides, etc., carefully explain what level ("high" or "low") of Ø incorporation you expect to observe in the recovered anhydride. Your explanation should include the mechanism for this hydrolysis reaction.

- (3) (18 points total) Methyl acetimidate (A) is hydrolyzed in aqueous sodium hydroxide to (initially) give mainly acetamide and methanol (eq 1). In aqueous acid, A hydrolyzes to (initially) give primarily methyl acetate and the ammonium ion (eq 2).
 - (a) (7 points) Write a detailed mechanism for the illustrated process. Please show all arrow pushing.



(b) (7 points) Write a detailed mechanism for the illustrated process. Please show all arrow pushing.



(c) (4 points) Briefly explain why the two reactions provide different products.

Basically NHZ is a poor LG SD the basic medium always gives the ande However under acidic conditions. "NHY is a very weak nucleophile so the ester formation of 10" be inversible. (6) (11 points each, 22 points total) Synthesize the indicated compounds from the allowed starting materials shown below. All of the carbons of the target compounds should be derived from the allowed starting materials.



(10) (2 points each, 42 points total) Please provide the requested answer/data/reagents. If no reaction is expected, write "NR".







(11) (12 points) Provide the best mechanism. Please show all arrow pushing.

