

NAME (Print): \_\_\_\_\_

Chemistry 320N  
Final Exam  
May 1, 2025

EID \_\_\_\_\_

SIGNATURE: \_\_\_\_\_

**Please print the  
first three letters  
of your last name  
in the three boxes**

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**Please Note:** Please take your time. You have three hours to take this exam. Please do not rush, we want you to show us everything you have learned during your organic chemistry journey. Making careless mistakes is not good for anyone! If you find yourself getting anxious because of a problem, skip it and come back. Please do not second guess yourself! Keep track of the questions worth a lot of points. (This does not mean they are hard, it just means we think they cover important material.)

**One last thing: I recommend you close your eyes for a moment, then take some nice deep breaths before you begin. YOU GOT THIS!**

**FINALLY, DUE TO SOME UNFORTUNATE RECENT INCIDENTS YOU ARE NOT ALLOWED TO INTERACT WITH YOUR CELL PHONE IN ANY WAY. IF YOU TOUCH YOUR CELL PHONE DURING THE EXAM YOU WILL GET A "0" NO MATTER WHAT YOU ARE DOING WITH THE PHONE. PUT IT AWAY AND LEAVE IT THERE!!!**

“I pledge, as a member of The University of Texas at Austin community, to do my work honestly, respectfully, and through the intentional pursuit of learning and scholarship.”

1. I pledge to be honest about what I create and to acknowledge what I use that belongs to others.
2. I pledge to value the process of learning in addition to the outcome, while celebrating and learning from mistakes.
3. This code encompasses all of the academic and scholarly endeavors of the university community.

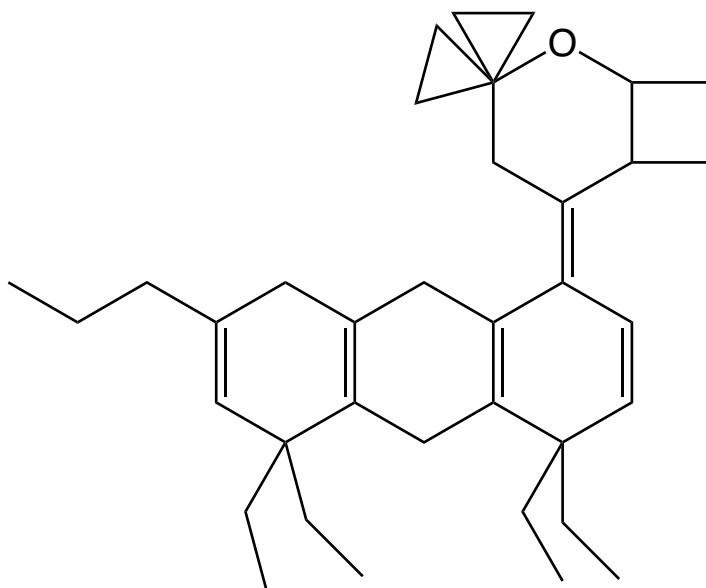
[illegible]

Compound		pK <sub>a</sub>
Hydrochloric acid	$\text{H-Cl}$	-7
Protonated alcohol	$\text{RCH}_2\text{OH}_2^+$	-2
Hydronium ion	$\text{H}_3\text{O}^+$	-1.7
Carboxylic acids	$\text{R}-\overset{\text{O}}{\parallel}{\text{C}}-\text{H}$	3-5
Thiols	$\text{RCH}_2\text{SH}$	8-9
Ammonium ion	$\text{H}_4\text{N}^+$	9.2
β-Dicarbonyls	$\text{RC}-\overset{\text{O}}{\parallel}{\text{C}}-\text{CH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{R}'$	10
Primary ammonium	$\text{H}_3\text{N}^+\text{CH}_2\text{CH}_3$	10.5
β-Ketoesters	$\text{RC}-\overset{\text{O}}{\parallel}{\text{C}}-\text{CH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{OR}'$	11
β-Diesters	$\text{ROC}-\overset{\text{O}}{\parallel}{\text{C}}-\text{CH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{OR}'$	13
Water	$\text{HOH}$	15.7
Alcohols	$\text{RCH}_2\text{OH}$	15-19
Acid chlorides	$\text{RCH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{Cl}$	16
Aldehydes	$\text{RCH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{H}$	18-20
Ketones	$\text{RCH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{R}'$	18-20
Esters	$\text{RCH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{OR}'$	23-25
Terminal alkynes	$\text{RC}\equiv\text{C}-\text{H}$	25
LDA	$\text{H}-\text{N}(\text{i-C}_3\text{H}_7)_2$	40
Terminal alkenes	$\text{R}_2\text{C}=\underset{\text{H}}{\text{C}}-\text{H}$	44
Alkanes	$\text{CH}_3\text{CH}_2-\text{H}$	51

## Golden Rules of Chemistry for your reference

**A. Predicting Structure and Bonding** 1. In most stable molecules, all the atoms will have filled valence shells. 2. Five- and six-membered rings are the most stable. 3. There are two possible arrangements of four different groups around a tetrahedral atom.

**B. Predicting Stability and Properties** 4. The most important question in organic chemistry is "Where are the electrons?" 5. Delocalization of charge over a larger area is stabilizing. 6. Delocalization of unpaired electron density over a larger area is stabilizing. 7. Delocalization of pi electron density over a larger area is stabilizing. **C. Predicting Reactions** 8. Reactions will occur if the products are more stable than the reactants and the energy barrier is low enough. 9. Functional groups react the same in different molecules. 10. A reaction mechanism describes the sequence of steps occurring during a reaction. 11. Most bond-making steps in reaction mechanisms involve nucleophiles reacting with electrophiles.



Hello everyone, Poptart here! Best of luck in your final. You got this! If you were wondering, here is my official IUPAC name: (*E*)-5-(4,4,5,5-tetraethyl-7-propyl-5,8,9,10-tetrahydroanthracen-1(4*H*)-ylidene)-2-oxaspiro[bicyclo[4.2.0]octane-3,1'-cyclopropane]



We are here at the end of your OChem experience (for most of you). ***I have been honored to be on this journey of learning and discovery with you.*** You started by learning about molecular structure and bonding in OChem 1 and now you can carry out sophisticated syntheses to make complex molecules from simpler ones. That technology, the ability to make and break specific chemical bonds, has created what we know as modern life. And now you understand how it works. But that is not all. You also have a solid foundation for understanding the structure and reactivity of the very molecules that are responsible for life on this planet.

And if you have gone through my previous finals you have seen this poem before, but I want you to read this on your own OChem II final exam. This is to each one of you, my sincere wish, taken from the words of one of the great poets of the 20<sup>th</sup> Century, Bob Dylan.

*“May your wishes all come true  
May you always do for others  
And let others do for you  
May you build a ladder to the stars  
And climb on every rung  
May you stay forever young*

*May you always know the truth  
And see the light surrounding you  
May you always be courageous  
Stand upright and be strong  
May you stay forever young*

*May your hands always be busy  
May your feet always be swift  
May you have a strong foundation  
When the winds of changes shift  
May your heart always be joyful  
May your song always be sung  
And may you stay forever young”*

*Here is my original final verse, written specifically for each of you:*

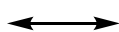
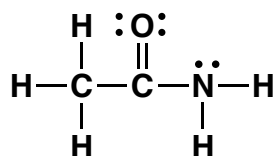
***“Every chance you get,  
You should go out for a run,  
That is the very best way  
For you to stay forever young.”***

**DON'T TEAR OUT THIS PAGE, IT WILL MESS UP OUR SCANS!!!**

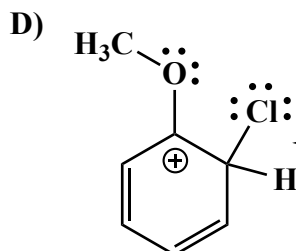
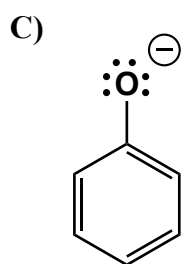
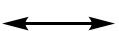
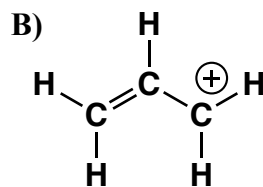
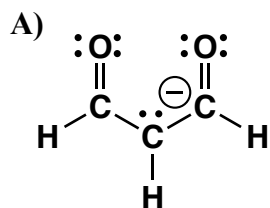
*Use this for scratch paper*

1. (5 pts) What is the most important question in organic chemistry?

2. (10 pts) Amides are best represented as the hybrid of three contributing structures. Draw the second and third important contributing structures in the spaces provided. You do **not** have to put arrows on any of the structures.



3. (18 pts) Many other molecules you have seen are best represented as the hybrid of contributing structures. Draw the most important contributing structures for each species in the spaces provided. You do **not** have to put arrows on any of the structures.



4. (2 pts each). Here is an OChem II Crossword puzzle! Fill in the word that is missing in each clue and write it in the appropriate boxes on Page 3. You will likely recognize these as Rules of the Day throughout the semester!

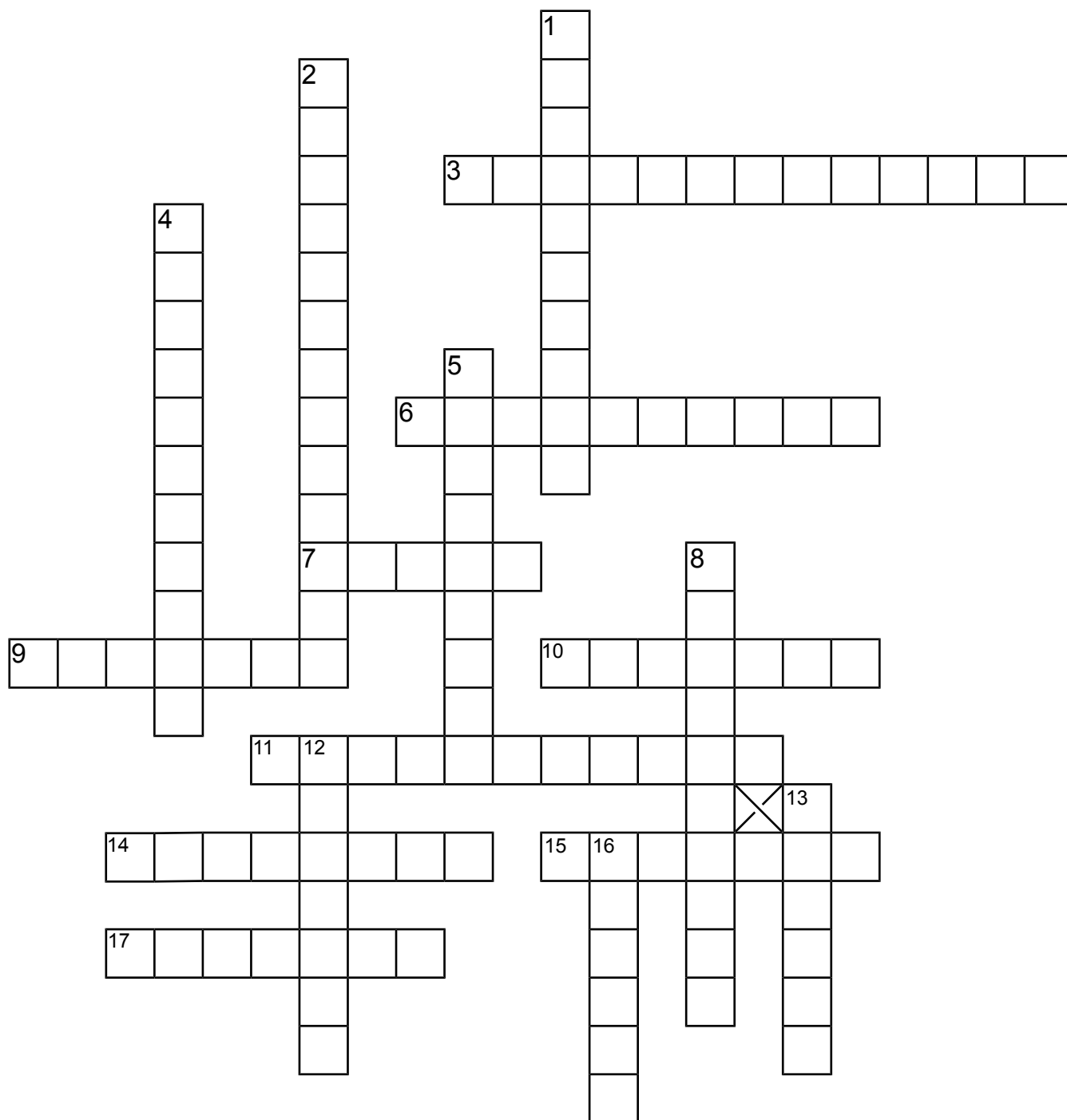
**DOWN**

1. According to Huckel's rules, for a molecule to be aromatic all ring atoms are  $sp^2$  hybridized, the ring must be flat, \_\_\_\_\_ and it must have " $4n + 2$ " pi electrons (2, 6, 10, 14, 18, 22 ....) where  $n = 0, 1, 2, 3, 4, 5, \dots$ ).
2. Protonation of a carbonyl oxygen atom in acid makes the carbonyl carbon atom much more \_\_\_\_\_ (i.e. able to react with weaker nucleophiles).
4. The Z-alkenes and even \_\_\_\_\_ help the membrane bilayers become fluid enough to function.
5. Molecules appear to our eye to be a combination of the wavelengths \_\_\_\_\_ (not absorbed).
8. Carbohydrate monomers can be linked together via acetal bonds and this linkage can be alpha or beta (For glucose alpha is axial). This type of acetal bond is called a \_\_\_\_\_ bond.
12. An \_\_\_\_\_ is formed when a secondary amine reacts with a ketone or aldehyde.
13. A methyl \_\_\_\_\_ is the synthesis key recognition element (KRE) for synthesis by the acetoester synthesis.
16. \_\_\_\_\_ are biological molecules, such as triglycerides and steroids, that are not soluble in water.

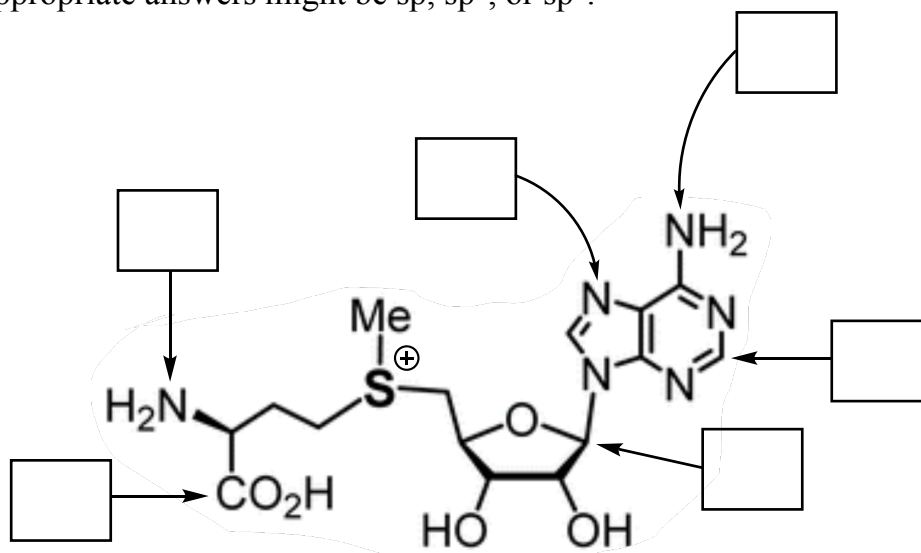
**ACROSS**

3. \_\_\_\_\_ make up biological membranes and are composed of two fatty acid molecules linked to glycerol along with a negatively-charged phosphate connected to a group such as positively-charged choline.
6. Carbohydrates like glucose exist in the cyclic \_\_\_\_\_ form in solution.
7. The stronger the acid, the \_\_\_\_\_ the  $pK_a$  and the more stable the conjugate base.
9. The \_\_\_\_\_ ester synthesis is entirely analogous to the acetoester synthesis, except diethyl malonate is used and a substituted carboxylic acid derivative is the ultimate product following ester hydrolysis in acid ( $H_3O^+$ ) and heating (loss of  $CO_2$ ).
10. High fructose corn syrup is derived from corn starch using \_\_\_\_\_ to convert the poly-D-Glucose polymer to individual D-glucose molecules, then converting some of the D-glucose to D-fructose in analogy to natural bee honey.
11. The Robinson annulation is a Michael reaction followed by an aldol reaction to make a six-membered ring, then the reaction ends with a \_\_\_\_\_.
14. The key to remember is that LDA quantitatively makes \_\_\_\_\_ from aldehydes, ketones and esters.
15. A Dieckmann reaction is a cyclic version of the \_\_\_\_\_ condensation in which a diester reacts to give a 5 or 6-membered ring.
17. Substituents already on the ring influence reactivity and orientation by interacting with the partial positive charges of the \_\_\_\_\_ ion intermediate.

**4 (cont.).** (2 pts each). Here is an OChem II Crossword puzzle! Fill in the words that are missing based on the clues on Page 2. You will likely recognize these as Rules of the Day throughout the semester!



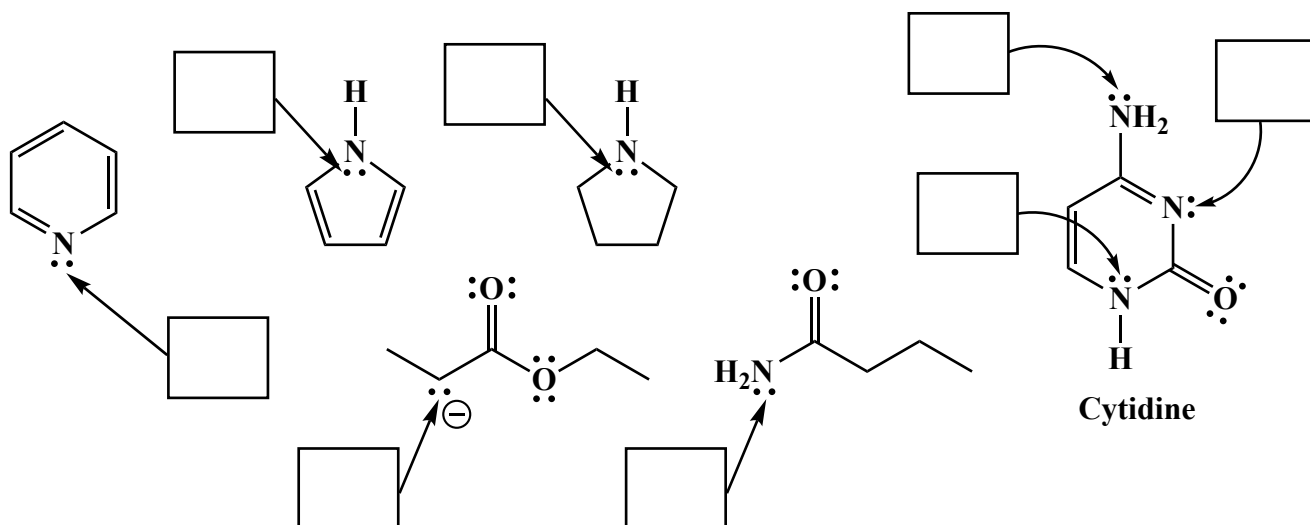
5. (2 pts each) For each arrow, in the box provided write the hybridization state of the atom indicated. Appropriate answers might be  $sp$ ,  $sp^2$ , or  $sp^3$ .



**S-Adenosylmethionine (SAM)** An enzyme cofactor used when a methyl group is transferred.  
(I copied this structure off of the internet)

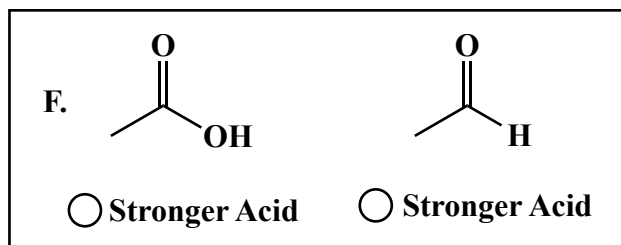
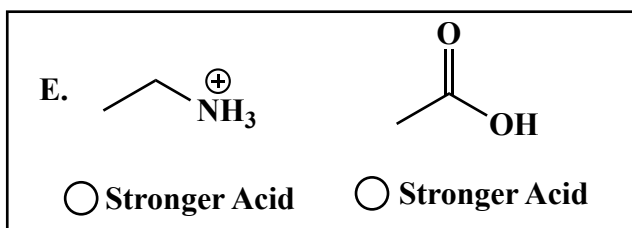
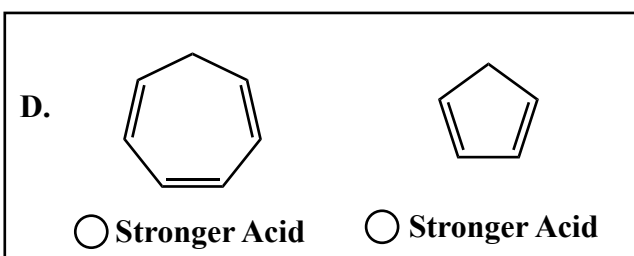
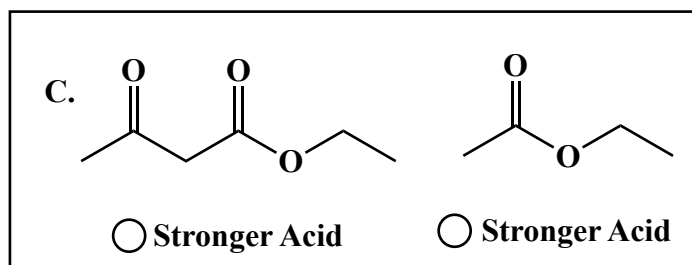
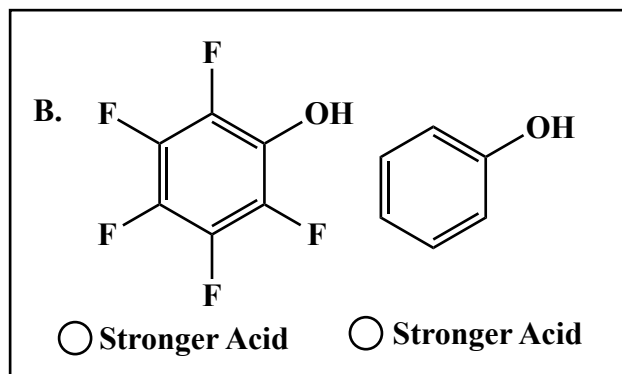
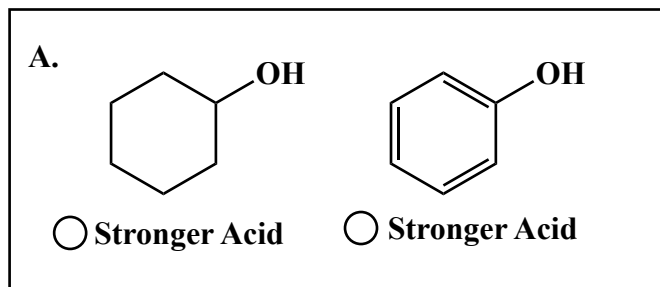
(4 pts) The above structure was copied from the internet. In the box provided, briefly explain what is chemically incorrect about this structure.

6. (1 pt each) For each arrow, on the line provided write the type of atomic orbital that contains the lone pair of electrons indicated. Appropriate answers might be  $sp$ ,  $sp^2$ ,  $sp^3$  or  $2p$ .

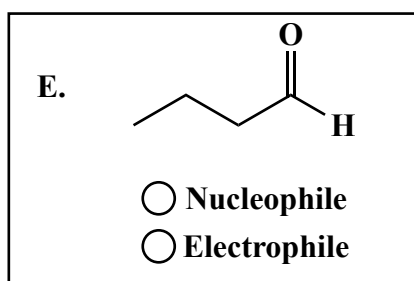
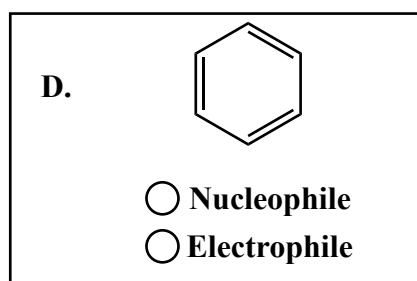
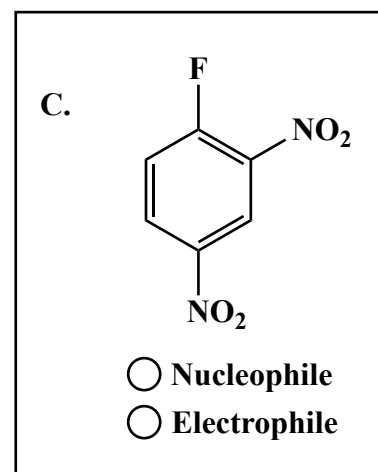
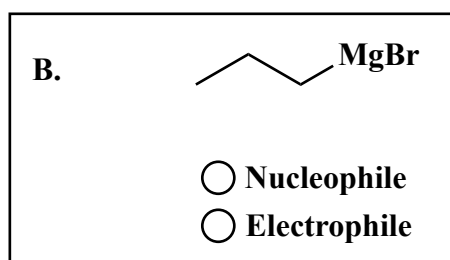
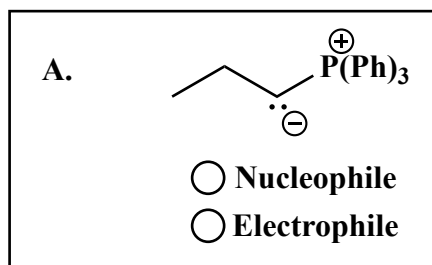




7. (2 pts each) For each pair of molecules, fill in the circle to indicate which one is the stronger acid (lower  $pK_a$ ).



8. (2 pts each) For each of the following molecules we have seen in reaction mechanisms, fill in the circle to indicate whether the molecule acts as a nucleophile or electrophile. For this one, you can ignore acid or base considerations and just focus on the nucleophile/electrophile properties of the molecules.



9. (2, 3 or 4 pts each) For each set of molecules, fill in the circles that correctly describe the situation.

**A)**

$$\begin{array}{c} \text{CHO} \\ | \\ \text{H} - \text{C} - \text{OH} \\ | \\ \text{CH}_2\text{OH} \end{array}$$
**D-Glyceraldehyde**

$$\begin{array}{c} \text{CHO} \\ | \\ \text{H} - \text{C} - \text{OH} \\ | \\ \text{HO} - \text{C} - \text{H} \\ | \\ \text{HO} - \text{C} - \text{H} \\ | \\ \text{H} - \text{C} - \text{OH} \\ | \\ \text{CH}_2\text{OH} \end{array}$$

$$\begin{array}{c} \text{CHO} \\ | \\ \text{HO} - \text{C} - \text{H} \\ | \\ \text{H} - \text{C} - \text{OH} \\ | \\ \text{HO} - \text{C} - \text{H} \\ | \\ \text{HO} - \text{C} - \text{H} \\ | \\ \text{CH}_2\text{OH} \end{array}$$

☐ D-Carbohydrate
 ☐ D-Carbohydrate
 ☐ Not a D-carbohydrate
 ☐ Not a D-Carbohydrate

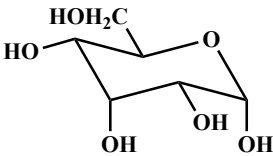
**B)**

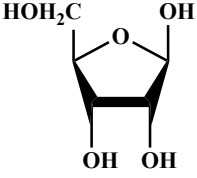
$$\begin{array}{c} \text{CHO} \\ | \\ \text{H} - \text{C} - \text{OH} \\ | \\ \text{H} - \text{C} - \text{OH} \\ | \\ \text{H} - \text{C} - \text{OH} \\ | \\ \text{CH}_2\text{OH} \end{array}$$

$$\begin{array}{c} \text{CHO} \\ | \\ \text{HO} - \text{C} - \text{H} \\ | \\ \text{H} - \text{C} - \text{OH} \\ | \\ \text{HO} - \text{C} - \text{H} \\ | \\ \text{CH}_2\text{OH} \end{array}$$

☐ Enantiomers
 ☐ Diastereomers

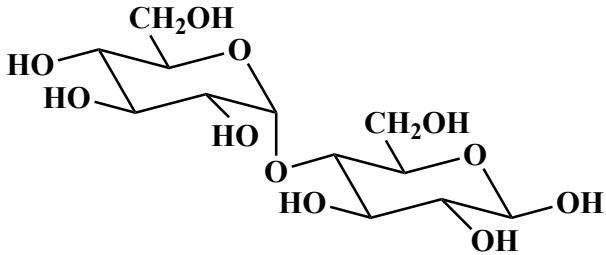
**C)**





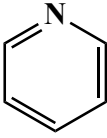
☐ Furanose
 ☐ Furanose
 ☐ Pyranose
 ☐ Pyranose

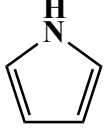
**D)**



☐ This molecule has an  $\alpha(1,6)$  glycosidic bond
 ☐ This molecule has a  $\beta(1,6)$  glycosidic bond
 ☐ This molecule has an  $\alpha(1,4)$  glycosidic bond

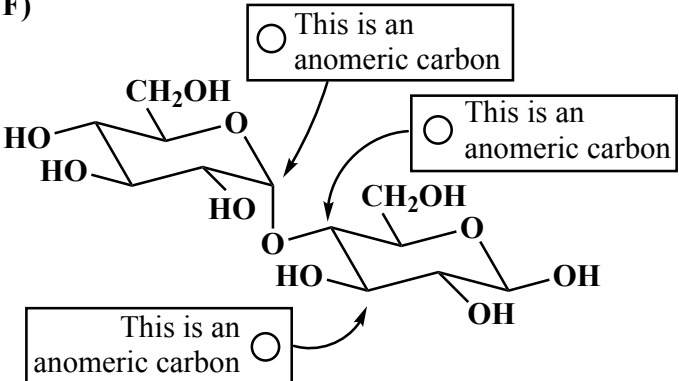
**E)**





☐ Can be used as a base
 ☐ Can be used as a base
 ☐ Not a base
 ☐ Not a base

**F)**



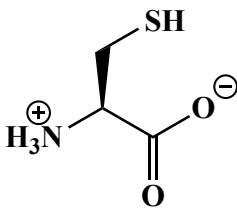
☐ This is an anomeric carbon

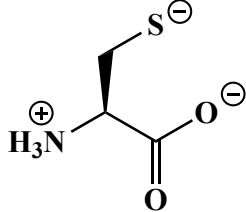
☐ This is an anomeric carbon

☐ This is an anomeric carbon

**G)**

The  $\text{pK}_a$  of  $\text{R-NH}_3^+$  is about 10  
 The  $\text{pK}_a$  of  $\text{R-CO}_2\text{H}$  is about 3.5  
 The  $\text{pK}_a$  of  $\text{R-CH}_2\text{SH}$  is about 8.3

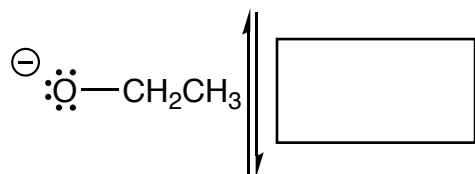
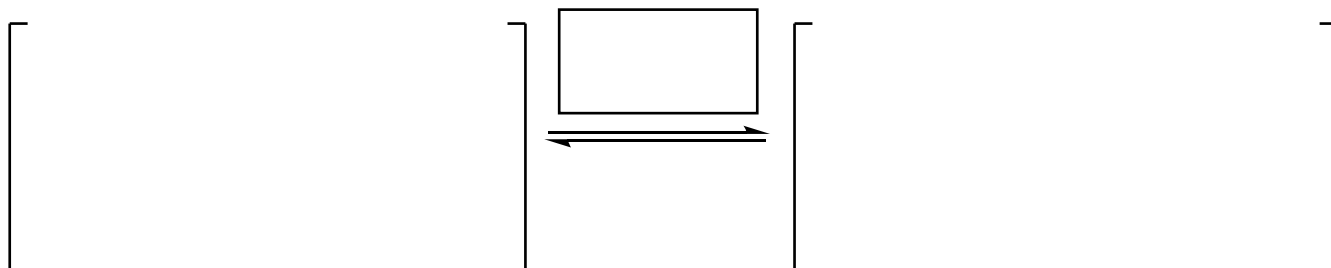
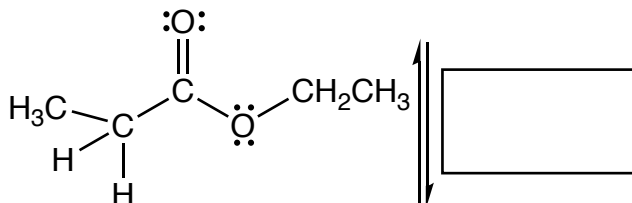
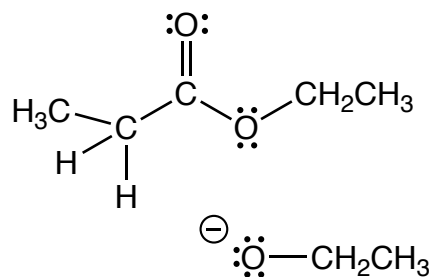




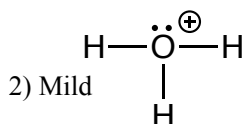
☐ This is correct for pH 2.0  
☐ This is correct for pH 7.0  
☐ This is correct for pH 9.0  
☐ This is never correct

☐ This is correct for pH 2.0  
☐ This is correct for pH 7.0  
☐ This is correct for pH 9.0  
☐ This is never correct

10. (30 pts) Complete the mechanism for the following Claisen reaction. **Be sure to show arrows to indicate movement of all electrons, write all lone pairs, all formal charges, and all the products for each step.** Remember, I said all the products for each step. **IF A NEW CHIRAL CENTER IS CREATED IN AN INTERMEDIATE OR PRODUCT, MARK IT WITH AN ASTERISK AND LABEL THE MOLECULE AS RACEMIC IF APPROPRIATE.** In the boxes provided, write which of the 4 mechanistic elements describes each step (make a bond, break a bond, etc.).



(Chemist opens flask and adds a mild acid)



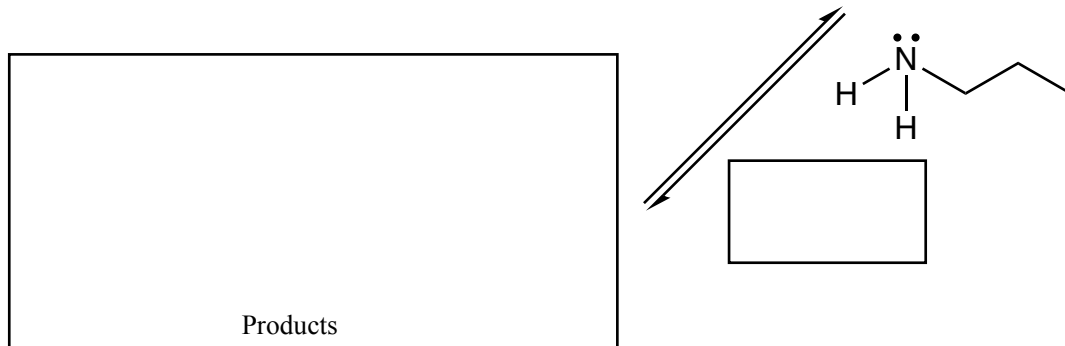
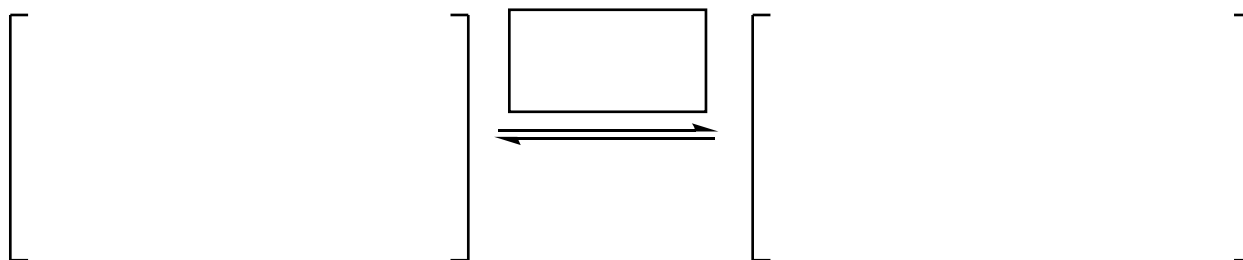
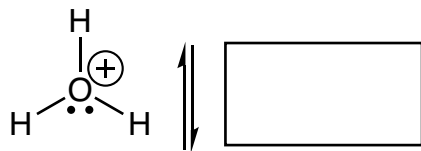
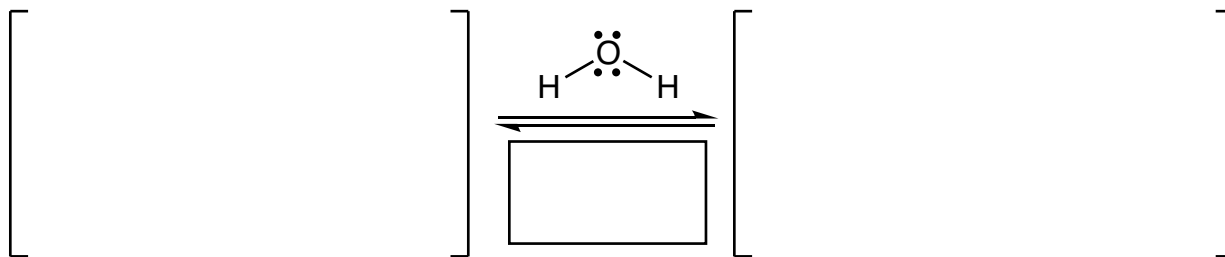
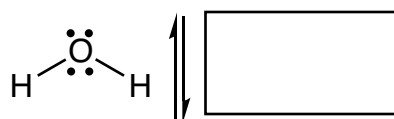
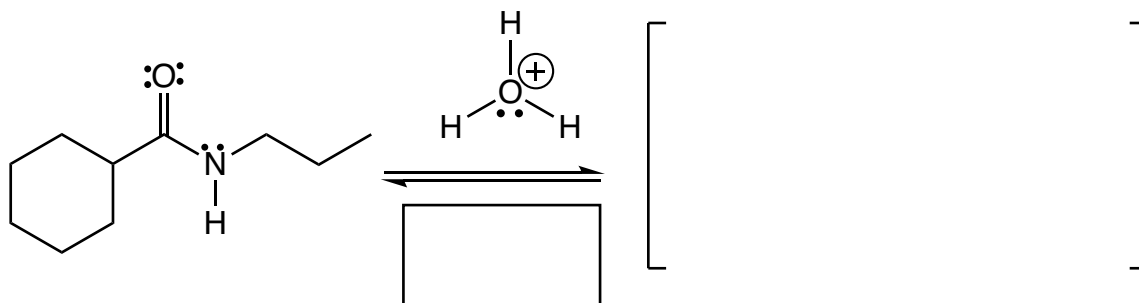
2) Mild



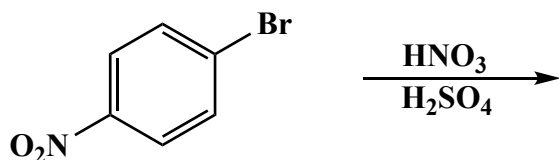
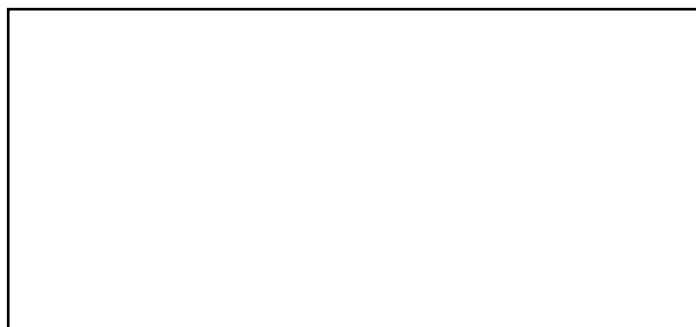
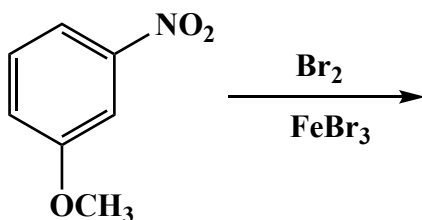
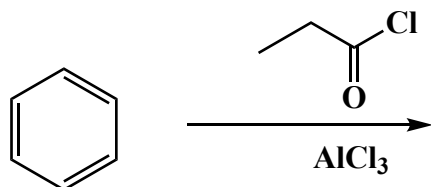
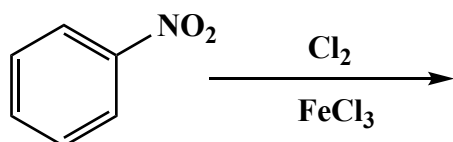
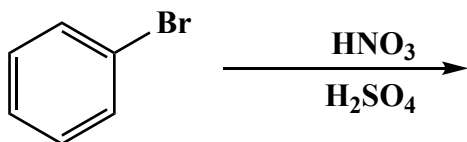
Initial Products

Final Products

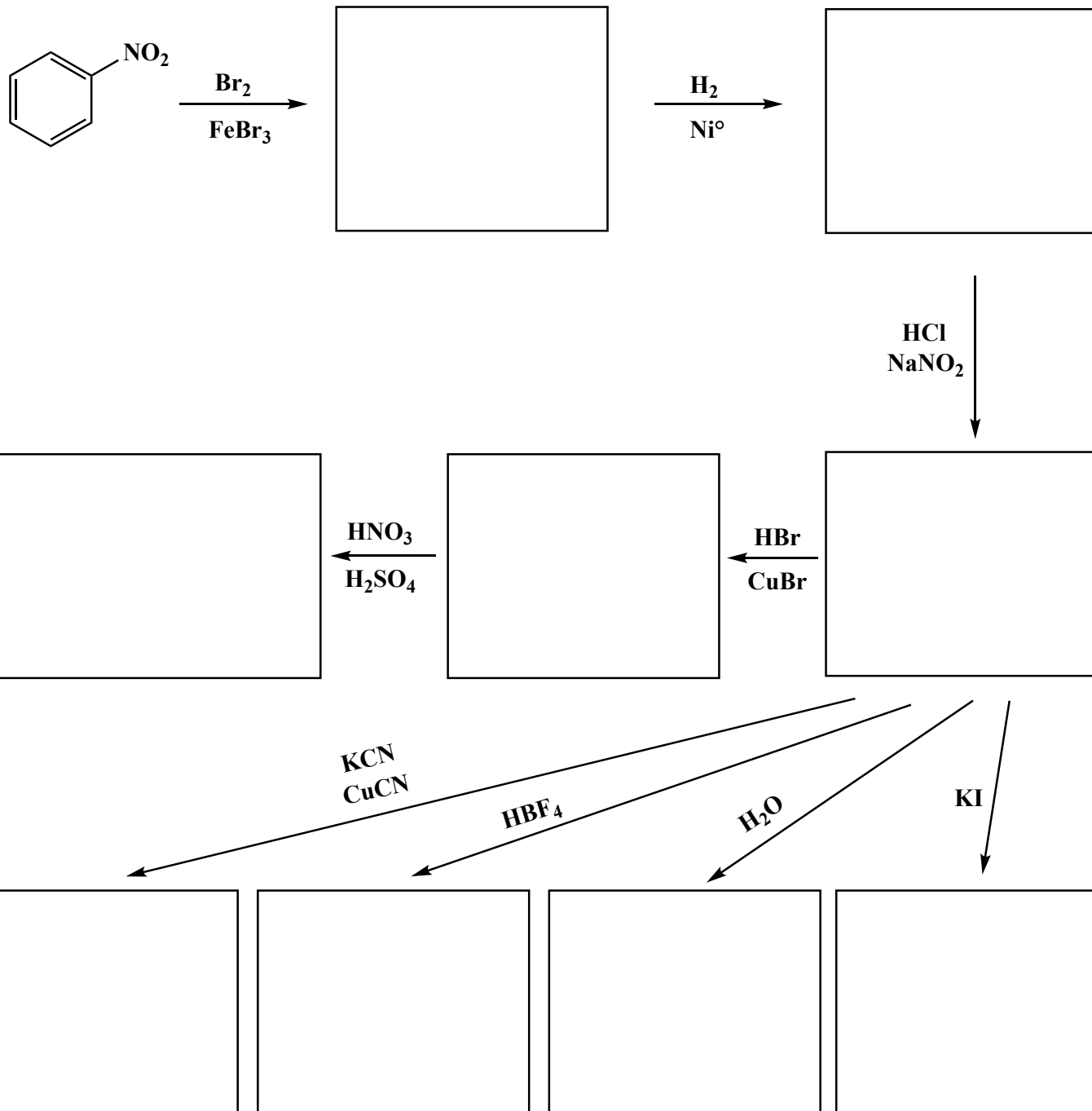
11. (34 pts) Complete the mechanism for the following amide hydrolysis. **Be sure to show arrows to indicate movement of all electrons, write all lone pairs, all formal charges, and all the products for each step.** Remember, I said all the products for each step. **IF A NEW CHIRAL CENTER IS CREATED IN AN INTERMEDIATE OR PRODUCT, MARK IT WITH AN ASTERISK AND LABEL THE MOLECULE AS RACEMIC IF APPROPRIATE.** In the boxes provided, write which of the 4 mechanistic elements describes each step (make a bond, break a bond, etc.).



12. (3 or 5 pts.) Write the predominant product(s) that will occur for each transformation. If a new chiral center is created and a racemic mixture is formed, you must draw both enantiomers and write "racemic" under the structure. Use wedges (  $\blacktriangle$  ) and dashes (  $\cdots$  ) to indicate stereochemistry. For these, only write the principle organic products, do not include side products like ethanol,  $\text{CO}_2$  or metal salts. **For all aldol reactions, we only want you to draw the dehydrated products.**

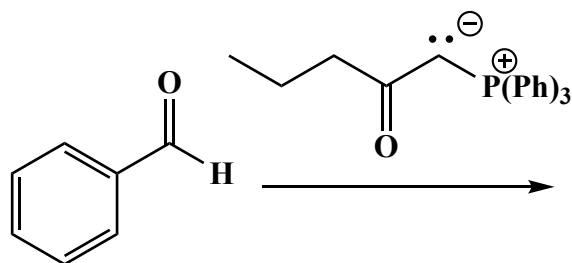
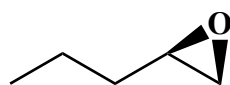
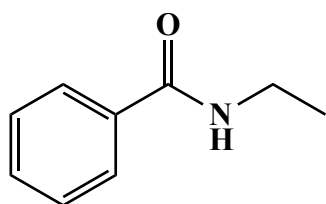
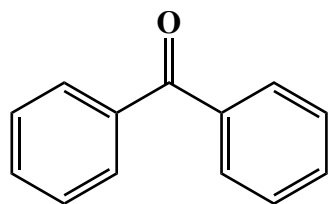


**12 (cont.) (3 or 5 pts.)** Write the predominant product(s) that will occur for each transformation. If a new chiral center is created and a racemic mixture is formed, you must draw both enantiomers and write "racemic" under the structure. Use wedges (  $\blacktriangle$  ) and dashes (  $\cdots$  ) to indicate stereochemistry. For these, only write the principle organic products, do not include side products like ethanol, CO<sub>2</sub> or metal salts. **For all aldol reactions, we only want you to draw the dehydrated products.**

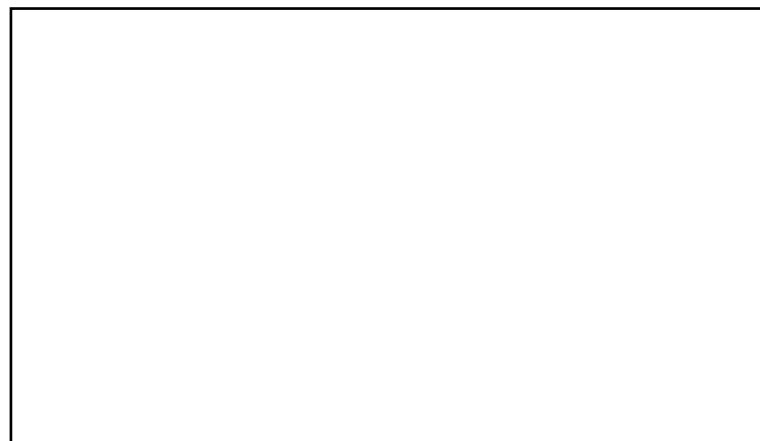
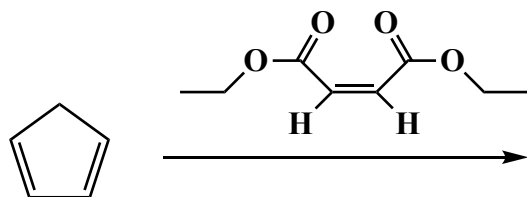
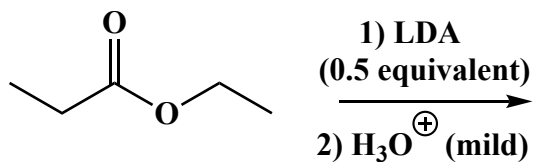
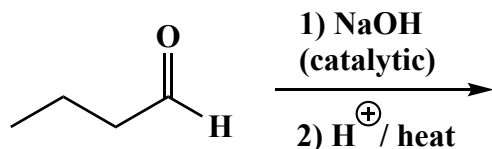
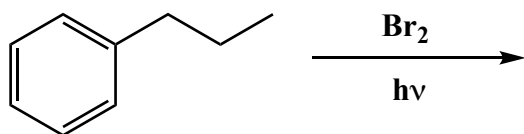
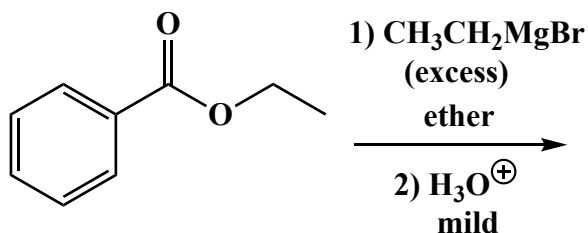




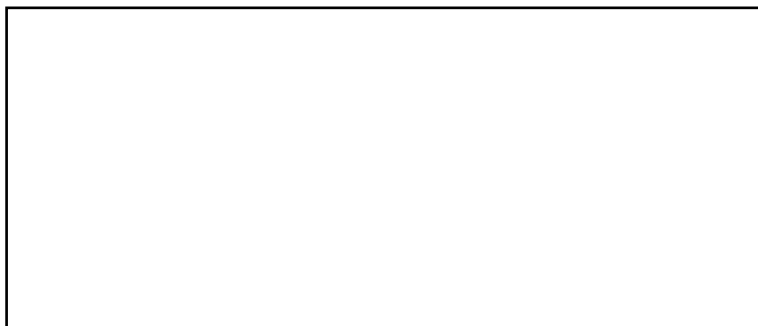
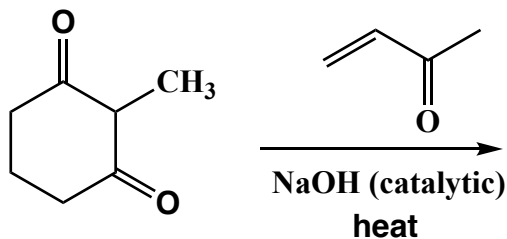
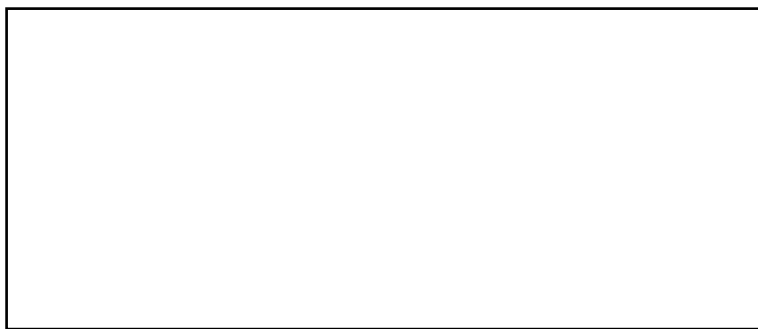
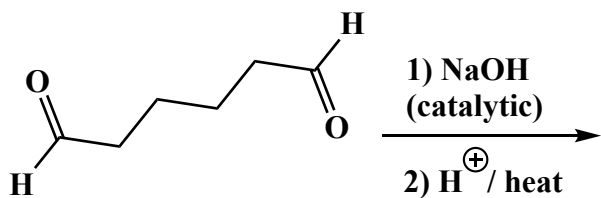
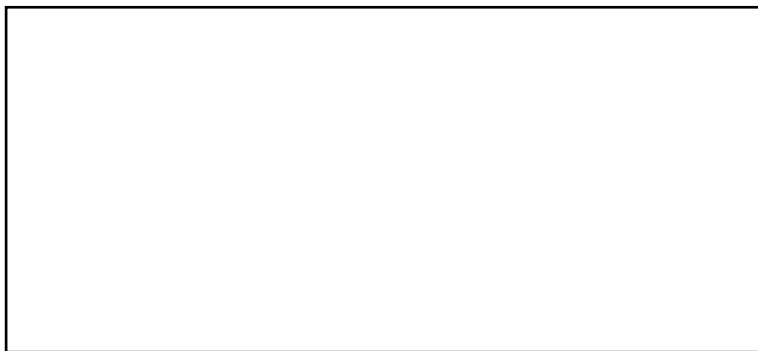
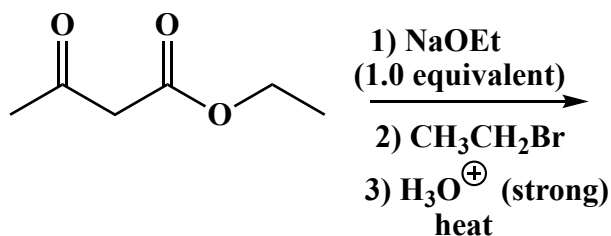
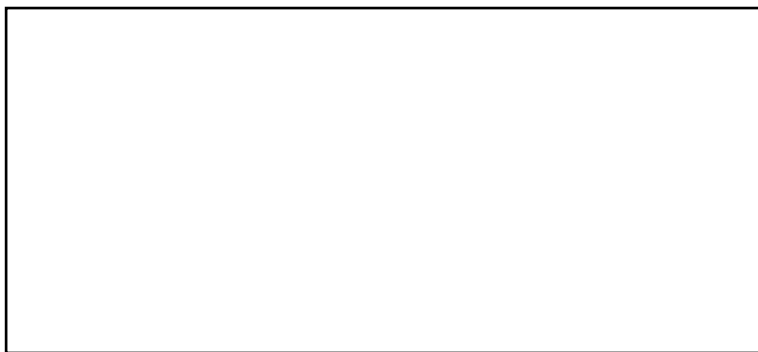
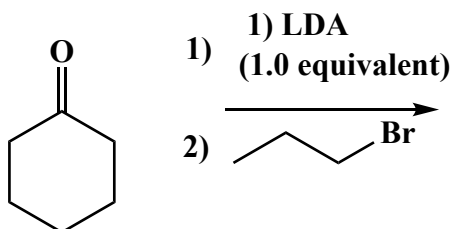
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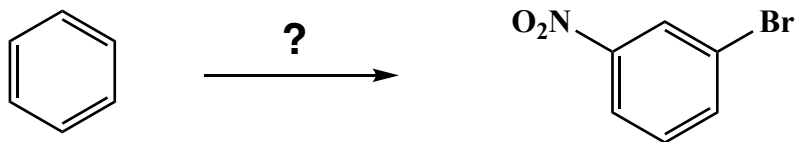


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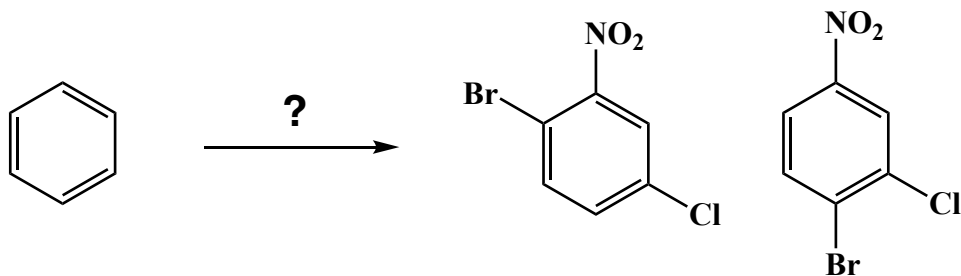
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A) (4 pts)



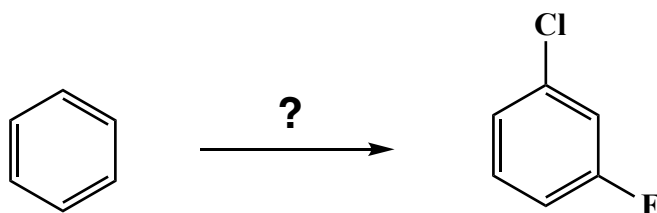
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B) (7 pts)



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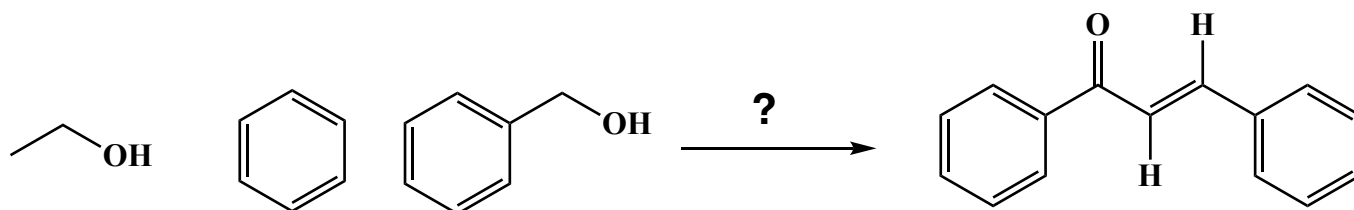
C) (13 pts)





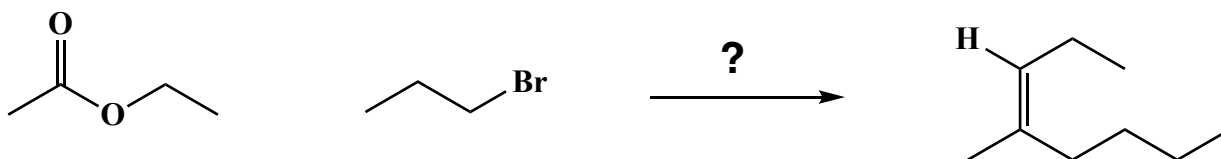
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D) (13 pts)



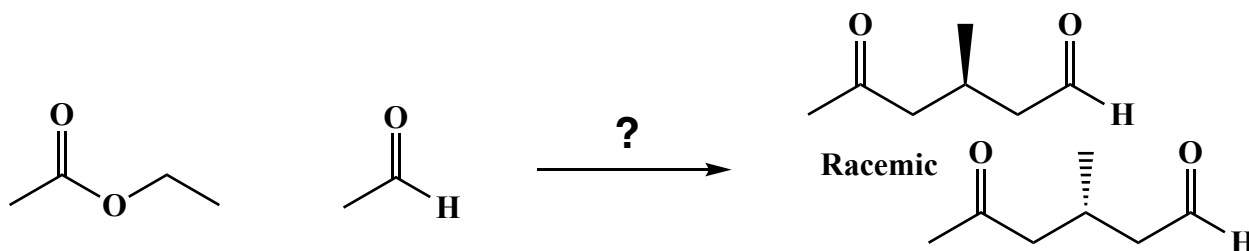
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E) (13 pts)



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F) (13 pts)



14. (8 pts) Here is an “apply what you know” problem with an important message. There is a long history of beverage companies selling drinks with addictive components before those components were studied and laws written to make the practice illegal. Coca cola started as a drink with around 9 milligrams of actual cocaine in it! Of course, that was outlawed and there is no cocaine in Coca Cola products today. The problem is that there are many different possible drinks or teas that can be made from plants that have pharmacologically active ingredients, and it takes a while for the science and the laws to catch up! **Currently, a number of these drinks, with known dangerous chemicals that are not yet illegal, are disguised and marketed as energy drinks.** One that is currently being marketed to college students like you is called Feel Free. *Until recently it was a sponsor of UT Athletics despite several of us raising concerns with the UT President at the time.* I wish I was making that up! Feel Free is packaged and marketed to college students to look exactly like a Red Bull or 5-Hour energy drink and the advertisements sound the same as well. BUT FEEL FREE IS NO ENERGY DRINK. Instead of caffeine and B vitamins, which are safe in reasonable amounts (do not drink too many energy drinks in one day, know your caffeine limits!), Feel Free has only dangerous plant extracts from Kava roots and Kratom leaves. These are very bad news as will be explained below.



feel free.

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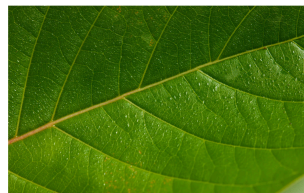
### feel free. CLASSIC product ingredients

Discover the two powerful botanic ingredients inside our feel free CLASSIC products.



#### Kava Root

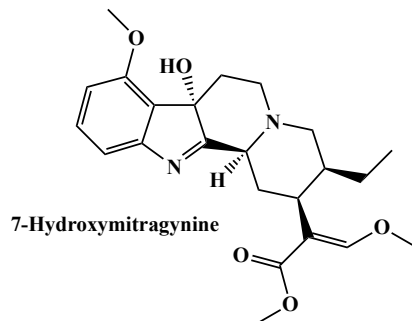
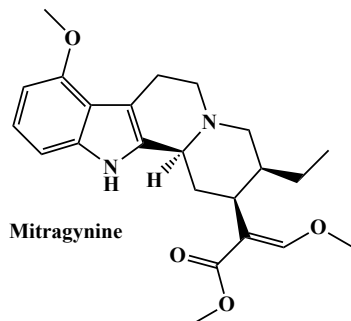
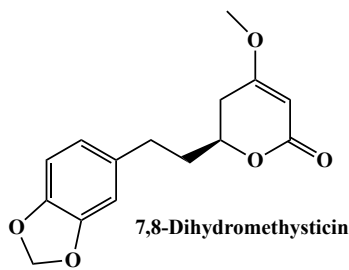
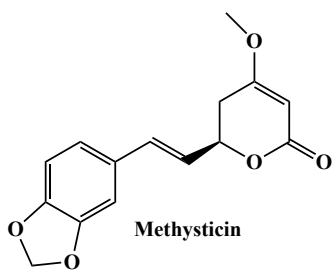
Kava kava, or *Piper methysticum*, is a plant native to the South Pacific. The root of the plant is used as an herbal remedy with various effects. Traditionally, the kava root was ground into a paste and added to liquid for consumption as a kava drink.



#### Leaf Kratom

Kratom, whose scientific name is *Mitragyna speciosa*, is a tropical evergreen tree in the coffee family that is native to Southeast Asia, particularly Indonesia, Thailand, and Malaysia. Kratom leaves have been traditionally used in these regions for centuries.

Both Kava and Kratom are well known to the people of the South Pacific Islands and Indonesia, respectively. Kava has a series of active ingredients, especially methysticin and 7,8-dihydromethysticin. Kratom has mitragynine, which is metabolized in your body to produce 7-hydroxymitragynine.



Methysticin and 7,8-dihydromethysticin are known to interact with GABA neurons, just like serious medications such as vallium and other so-called benzodiazepines, which are psychoactive and therefore only available legally with a doctor's prescription. Mitragynine and especially 7-hydroxymitragynine are known to bind to the mu-opioid receptor, the exact target of the opioids morphine and fentanyl! Many people have reported being addicted to Feel Free, including experiencing serious withdrawal symptoms that are similar to opioid withdrawal. And at about \$13 dollars per bottle, Feel Free is as expensive as a drug habit, with addicts needing several bottles a day to avoid withdrawal symptoms.

Various Kava extracts are also known to cause serious liver damage as well as increasing your chances of cancer. And Feel Free will block the metabolism of other drugs by interacting with your  $P_{450}$  enzymes, thereby increasing the potency of these other drugs, so accidental overdoses involving Feel Free in combination with other drugs are all too common. Very sad.

Here are the questions:

Methysticin and 7,8-dihydromethysticin have two different functional groups that make the rings on either end of the molecule. Look at the structures on the previous page and fill in the circle that accurately describes the two functional groups that make two rings of methysticin and 7,8-dihydromethysticin. (Ignore the benzene ring)

- ☐ hemiacetal and lactone
- ☐ acetal and lactone
- ☐ hemiacetal and acetal
- ☐ two acetals

Mitragynine and 7-hydroxymitragynine are chiral compounds. Look at the two structures and determine the number of chiral centers in each. **Note, for this one you need to realize that a nitrogen bonded to three different carbon atoms cannot be chiral (the lone pair can move so the chirality of the N atom is not fixed)!** In other words, only the carbon atoms of mitragynine and 7-hydroxymitragynine can be chiral centers.

- ☐ Mitragynine has 3 chiral centers and 7-hydroxymitragynine has 3 chiral centers
- ☐ Mitragynine has 4 chiral centers and 7-hydroxymitragynine has 3 chiral centers
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If you know someone who is drinking these so-called “botanical tonics” like Feel Free as if they were energy drinks, you should consider getting them help by calling SHIFT here at UT or any other substance misuse resource. **My friends at SHIFT tell me there has been a recent increase in the number of students trying to reduce their Kratom use, but they are having difficulty because of dependency (addiction).** And remember, you can get a dose of Narcan at the PCL circulation desk. It is free of charge and no questions will be asked. Please do this even if you don’t think you will ever need it. **You could save a life.** As I mentioned last week, a former student in the class took my advice and saved their brother’s life because when it was needed, they happened to have the very same dose of Narcan I had told them how to obtain from PCL.

Like I said at the beginning of this exam, it has been an honor to be on this journey of Organic Chemistry discovery and learning with you. Have a wonderful summer break and remember: **Go see something that truly takes your breath away and also....run every chance you get!**