NAME (Print): _____

EID _____

SIGNATURE: _____

Chemistry 320M/328M
Dr. Brent Iverson
1st Midterm
September 25, 2025

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

Please Note: Please take your time. We are giving you three hours to take this exam even though it is really a one hour exam. The idea is to give you enough time to show us what you know, not how fast you can draw structures. Please take all the time you need to draw the best possible structures that you can! Do not be surprised if you are comfortable leaving the exam long before 9 PM. That is to be expected!

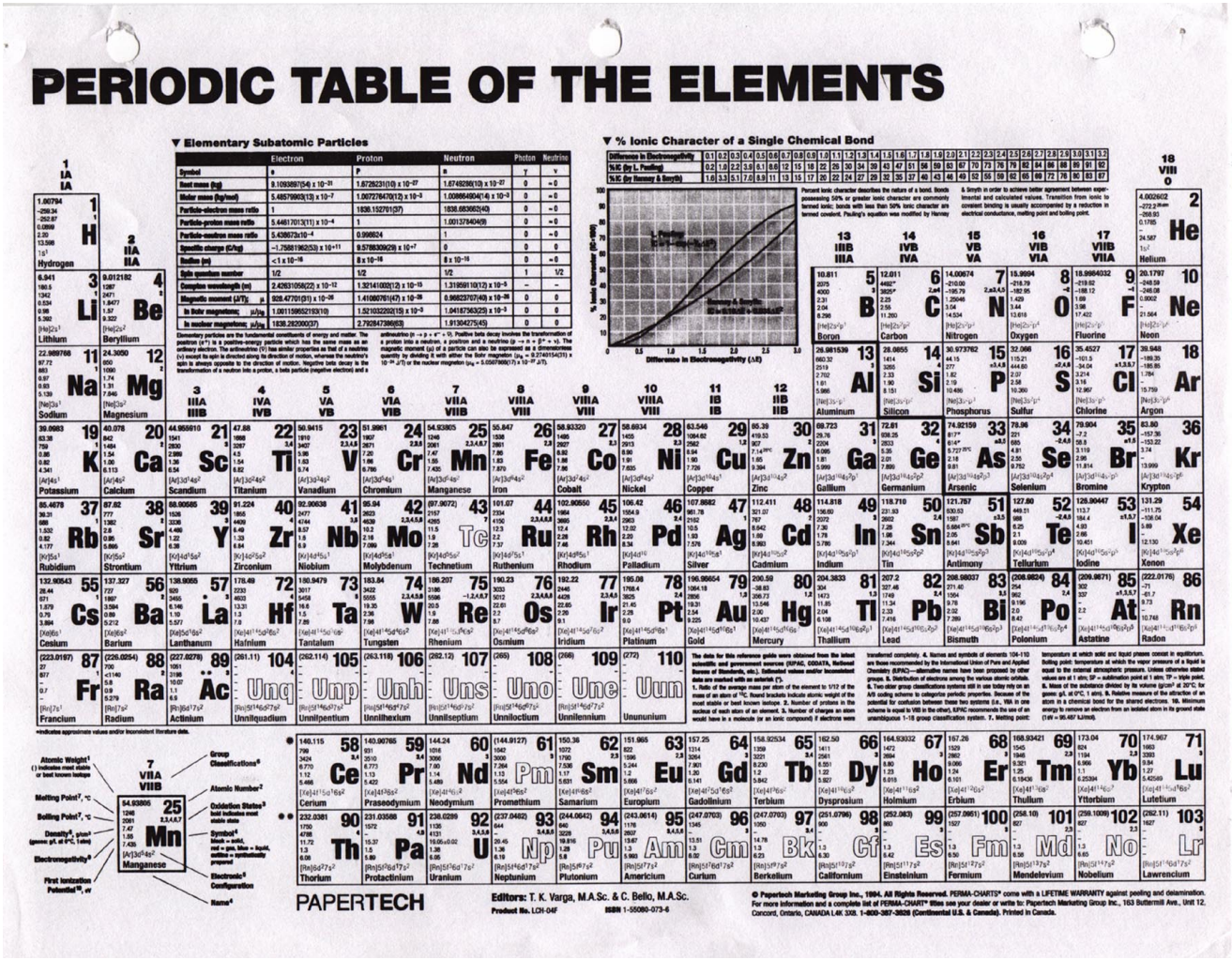
FINALLY, DUE TO SOME UNFORTUNATE RECENT INCIDENCTS YOU ARE NOT ALLOWED TO INTERACT WITH YOUR CELL PHONE IN ANY WAY. IF YOU TOUCH YOUR CELL PHONE DURING THE EXAM YOU WILL GET A "0" NO MATTER WHAT YOU ARE DOING WITH THE PHONE. PUT IT AWAY AND LEAVE IT THERE!!!

Student Honor Code

“As a student of The University of Texas at Austin, I shall abide by the core values of the University and uphold academic integrity.”

_____

(Your signature)



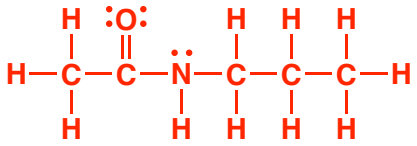
Signature_____ Pg 1 _____(28)

1. (4 points) What is the most important question in Organic Chemistry?

Where are the electrons?

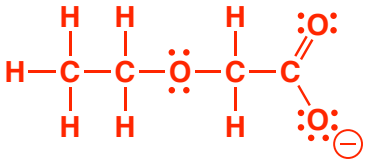
2. (8 pts each) For the following molecular formula, draw complete Lewis line structures in which all atoms (even H atoms) are drawn, lines are used as bonds, all lone pairs are drawn AND ALL FORMAL CHARGES ARE INDICATED. Note you must infer the formal charges as we do not indicate them on the chemical formulas given. You only have to draw one important contributing structure if that is relevant.

1) $CH_3CONHCH_2CH_2CH_3$



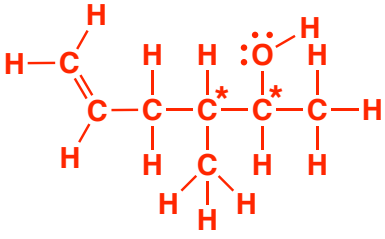
How many different stereoisomers are possible for the above molecule? 1

2) $CH_3CH_2OCH_2CO_2$ **Hint: this one has a 1- overall charge**



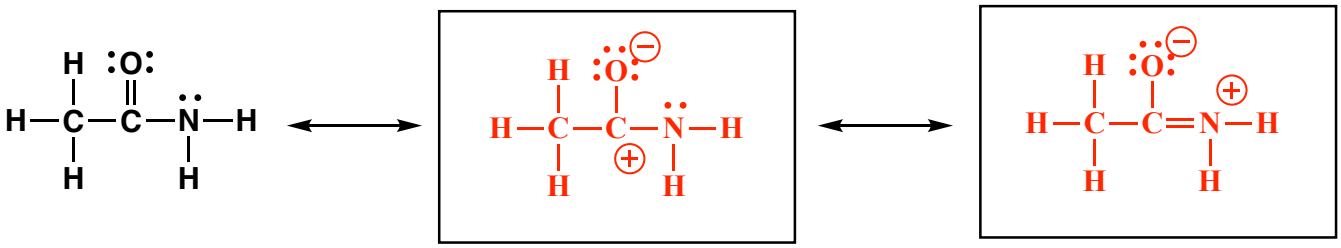
How many different stereoisomers are possible for the above molecule? 1

3) $CH_2CHCH_2CH(CH_3)CHOHCH_3$



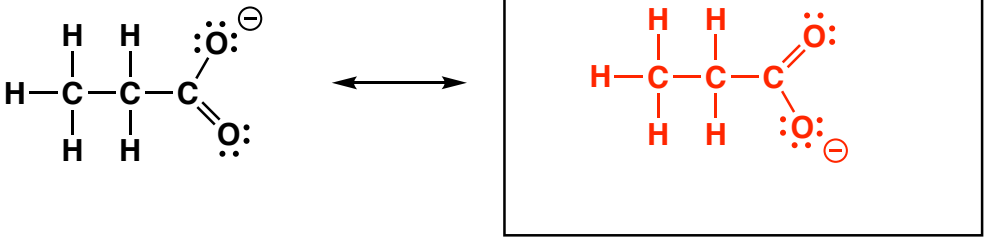
How many different stereoisomers are possible for the above molecule? 4

3. (6 pts) I told you this would be here. The following amide molecule is best represented as the hybrid of three contributing structures. **Draw the second and third important contributing structures** in the spaces provided, including all lone pairs and formal charges.

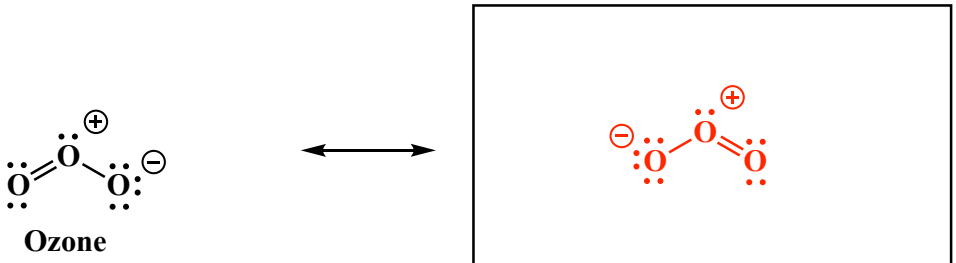


4. (9 pts) The following molecules are best represented as the hybrid of contributing structures. **Draw the second important contributing structure** in the space provided, including all lone pairs and formal charges.

A.

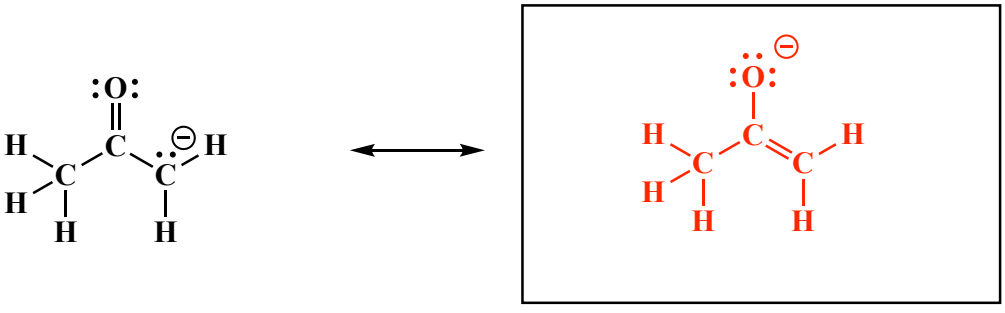


B.

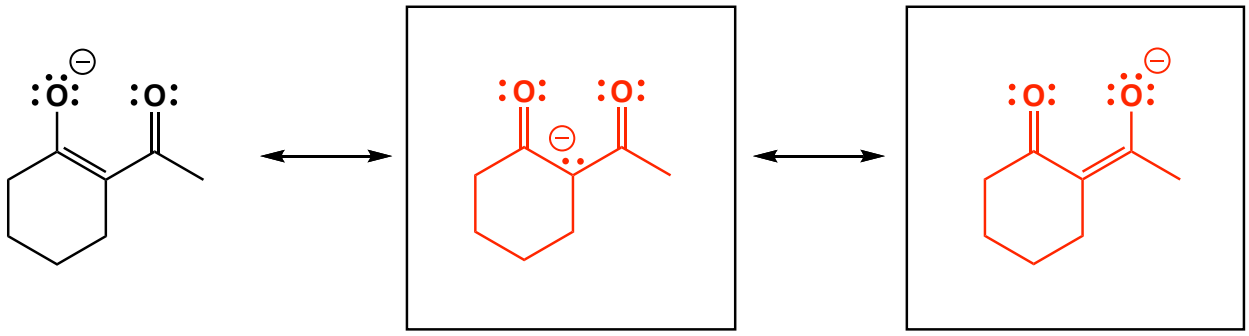


Ozone

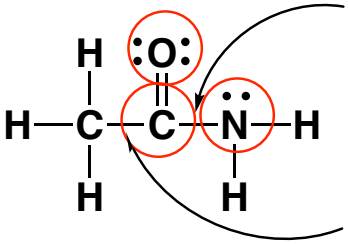
C.



5. (6 pts) The following molecule is best represented as the hybrid of three contributing structures. **Draw the second and third important contributing structures** in the spaces provided, including all lone pairs and formal charges.



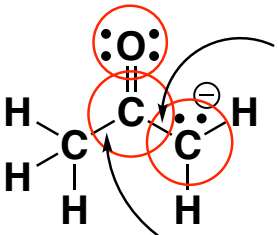
6. (17 pts) Fill in the circle next to the correct answer to each question. **In addition, on all of the following structures, draw a small circle around all atoms that you would describe best as sp^2 hybridized.**



Does this bond rotate at room temperature?
○ Yes it rotates ● No it does not rotate

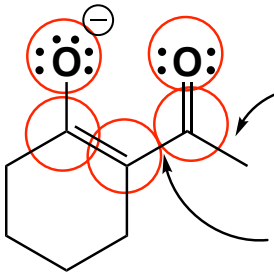
Remember that all the atoms of the pi way must contribute a 2p orbital, so they all must be sp^2

Does this bond rotate at room temperature?
● Yes it rotates ○ No it does not rotate



Does this bond rotate at room temperature?
○ Yes it rotates ● No it does not rotate

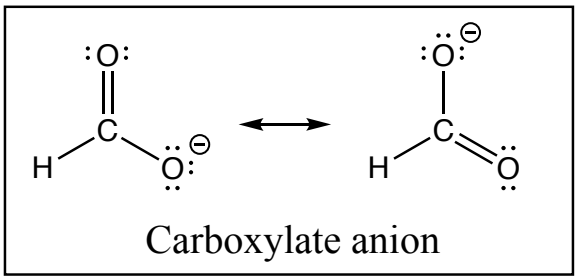
Does this bond rotate at room temperature?
● Yes it rotates ○ No it does not rotate



Does this bond rotate at room temperature?
● Yes it rotates ○ No it does not rotate

Does this bond rotate at room temperature?
○ Yes it rotates ● No it does not rotate

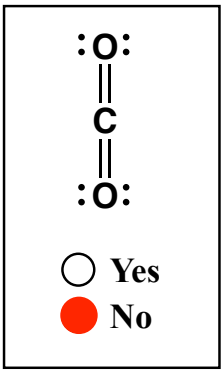
7. (18 pts) The following paragraph refers the carboxylate anion and you may recognize it from a handout we provided in class. Fill in each blank with the word or number that best completes the sentences.



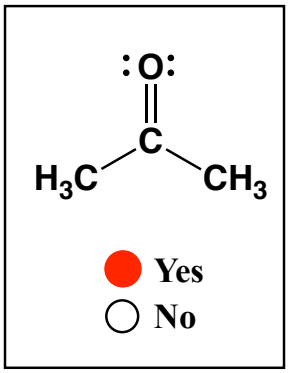
Carboxylate anion

A common situation, and the one many resonance ___contributing___ structures describe, occurs when ___three___ 2p orbitals combine on adjacent atoms. A good example is the carboxylate anion. When ___three___ adjacent 2p orbitals interact (we add the ___three___ 2p orbital ___wave___ functions), ___three___ new molecular orbitals are produced; a low energy ___bonding___ "pi-way" orbital, a ___nonbonding___ orbital and an ___antibonding___ orbital. This pattern of three molecular ___orbitals___ is generally the same whenever ___three___ 2p orbitals interact even if there are different atoms involved, for example the enolate ion or allyl cation. There are ___four___ electrons in the pi system of the carboxylate anion, (you can see this by looking at either of the contributing structures; ___two___ electrons from the pi bond and ___two___ electrons from the third lone pair on the negatively-charged O atom). Note the non-bonding orbital contains the electron density of ___two___ electrons that are paired, do NOT think of it as having one ___unpaired___ electron on each O atom. I know, weird, but remember it is best to think of bonding electrons as ___waves___, not particles. Note the electron density on only the O atoms of the non bonding orbital explains why the ___negative___ charge is localized on the O atoms in the carboxylate anion.

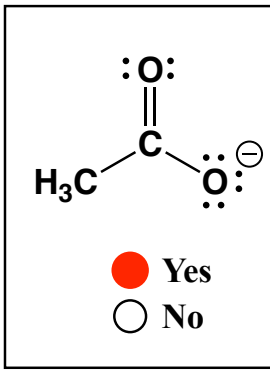
8. (16 pts) Indicate which of the following molecules have an overall molecular dipole moment. You do not need to indicate the direction of the dipole moment, or any of the individual bond dipoles. Fill in the circle next to "Yes" if the molecule has an overall molecular dipole, or "No" if the molecule does not have an overall molecular dipole moment.



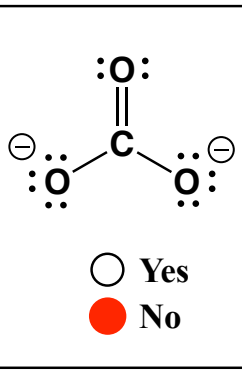
○ Yes
● No



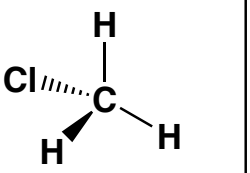
● Yes
○ No



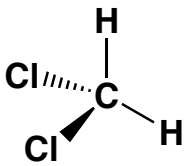
● Yes
○ No



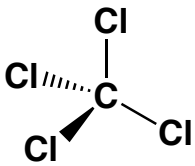
○ Yes
● No



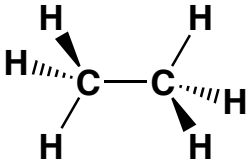
● Yes
○ No



● Yes
○ No

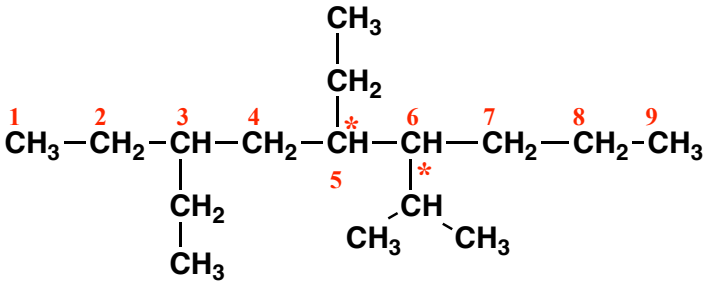


○ Yes
● No



○ Yes
● No

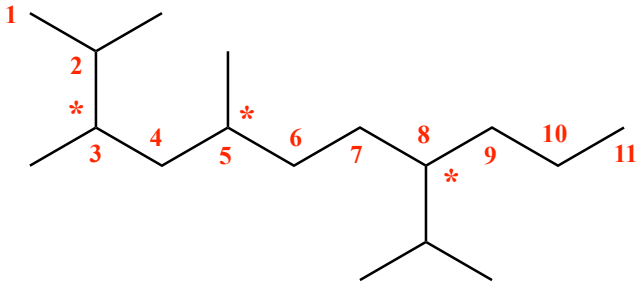
9. (7 pts) Provide an acceptable IUPAC name for the following molecule. Do not designate R or S for this.



3,5-diethyl-6-isopropylnonane
or 3,5-diethyl-6-(1-methylethyl)nonane

Although stereochemistry is not indicated on the above structure, how many stereoisomers are possible? $2^2 = 4$

10. (7 pts) Provide an acceptable IUPAC name for the following molecule. Do not designate R or S for this.

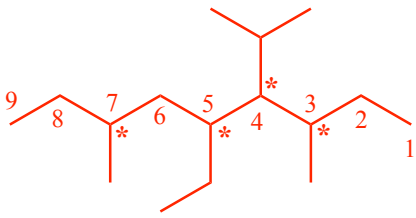


8-Isopropyl-2,3,5-trimethylundecane
or 2,3,5-trimethyl-8-(1-methylethyl)undecane

Although stereochemistry is not indicated on the above structure, how many stereoisomers are possible? $2^3 = 8$

11. (10 pts each) For the following IUPAC name, draw the appropriate line angle drawing. You can ignore R and S for this one.

5-Ethyl-4-isopropyl-3,7-dimethylnonane



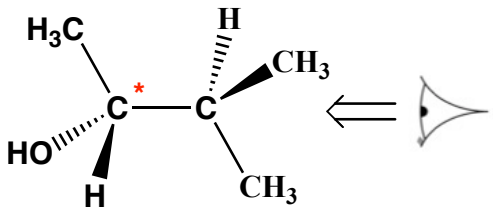
Although stereochemistry is not indicated in the above name or your structure, how many stereoisomers are possible? $2^4 = 16$

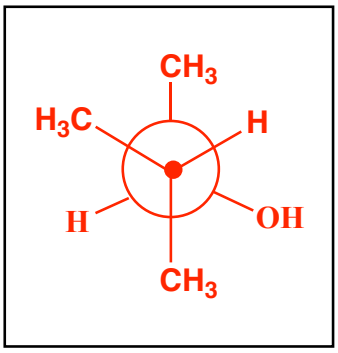
12. (10 pts each) For the following IUPAC name, draw the appropriate line angle drawing. For this one, you need to use wedges and dashes to indicate the appropriate stereochemistry at all chiral centers.

(5*S*,7*S*)-2,5,7-trimethyldecane

13. (5 pts) Draw the Newman projection for the conformation of 3-methyl-2-butanol as shown.

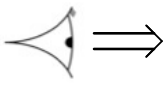
A)

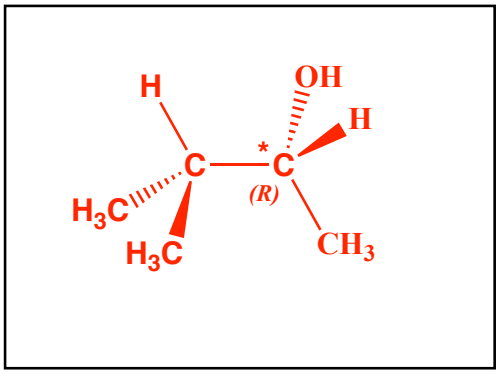


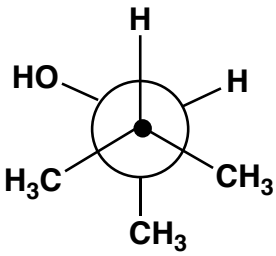


(7 pts) In the empty box draw the conformation of 3-methyl-2-butanol indicated by the Newman projection shown.

B)



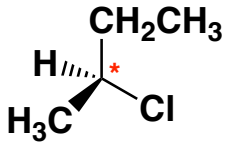




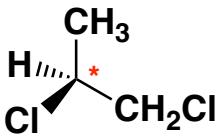
NOTICE THIS

The same molecule was used in both parts of this problem. It is chiral, is it R or S? ***R***

14. (2 pts each) Here it is, the "R" and "S" problem! Examine the following structures. For each molecule with a chiral center, assign the stereochemistry then write "R" or "S" as appropriate in the box provided below each structure. **For all molecules that have no chiral centers, do not put anything in the box.**

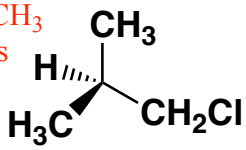


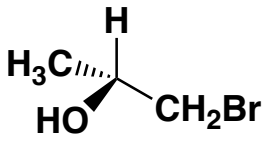
S



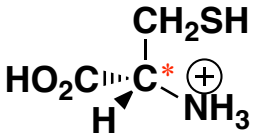
S

two -CH_3 groups

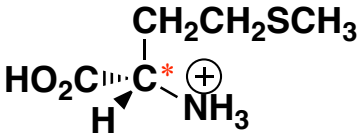




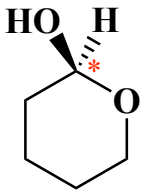
R



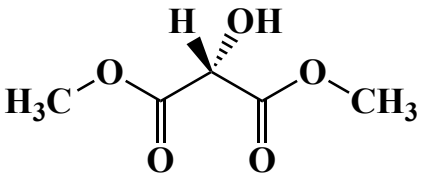
R

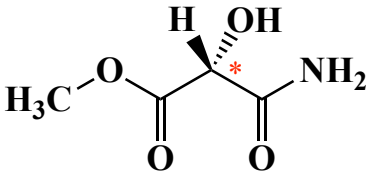


S



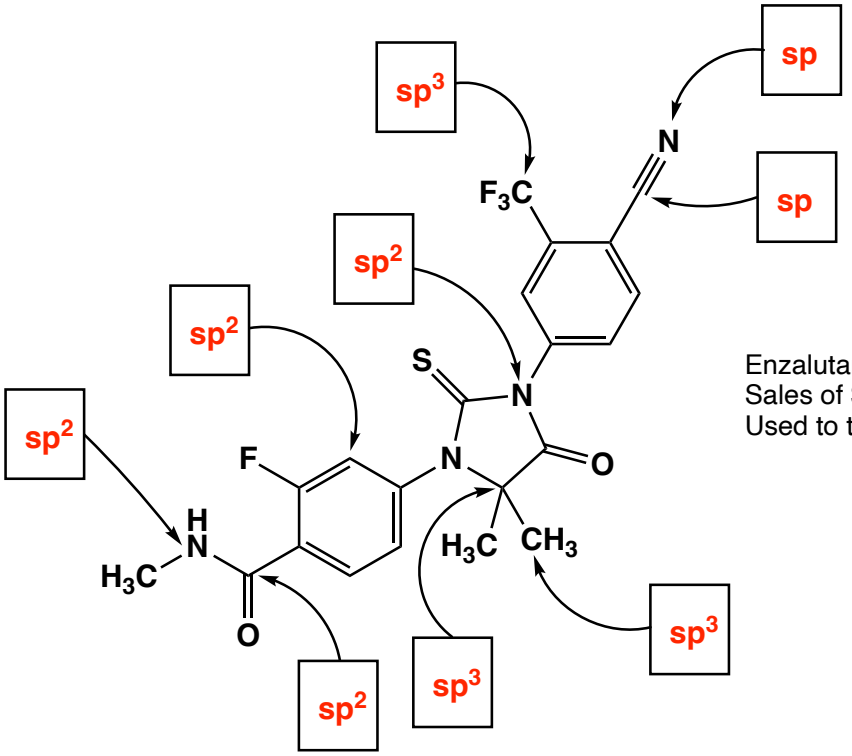
S



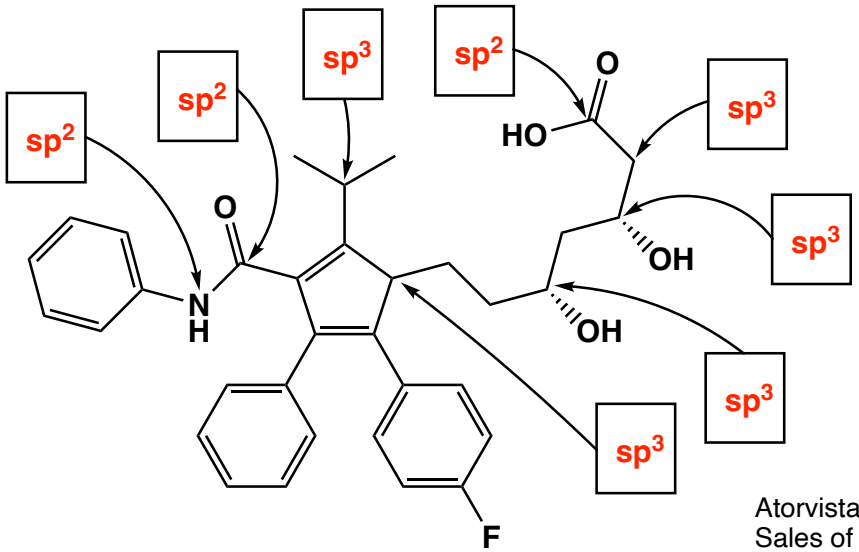


R

15. (1 pt each) In the boxes provided, write the hybridization state of the atoms indicated by the arrow.

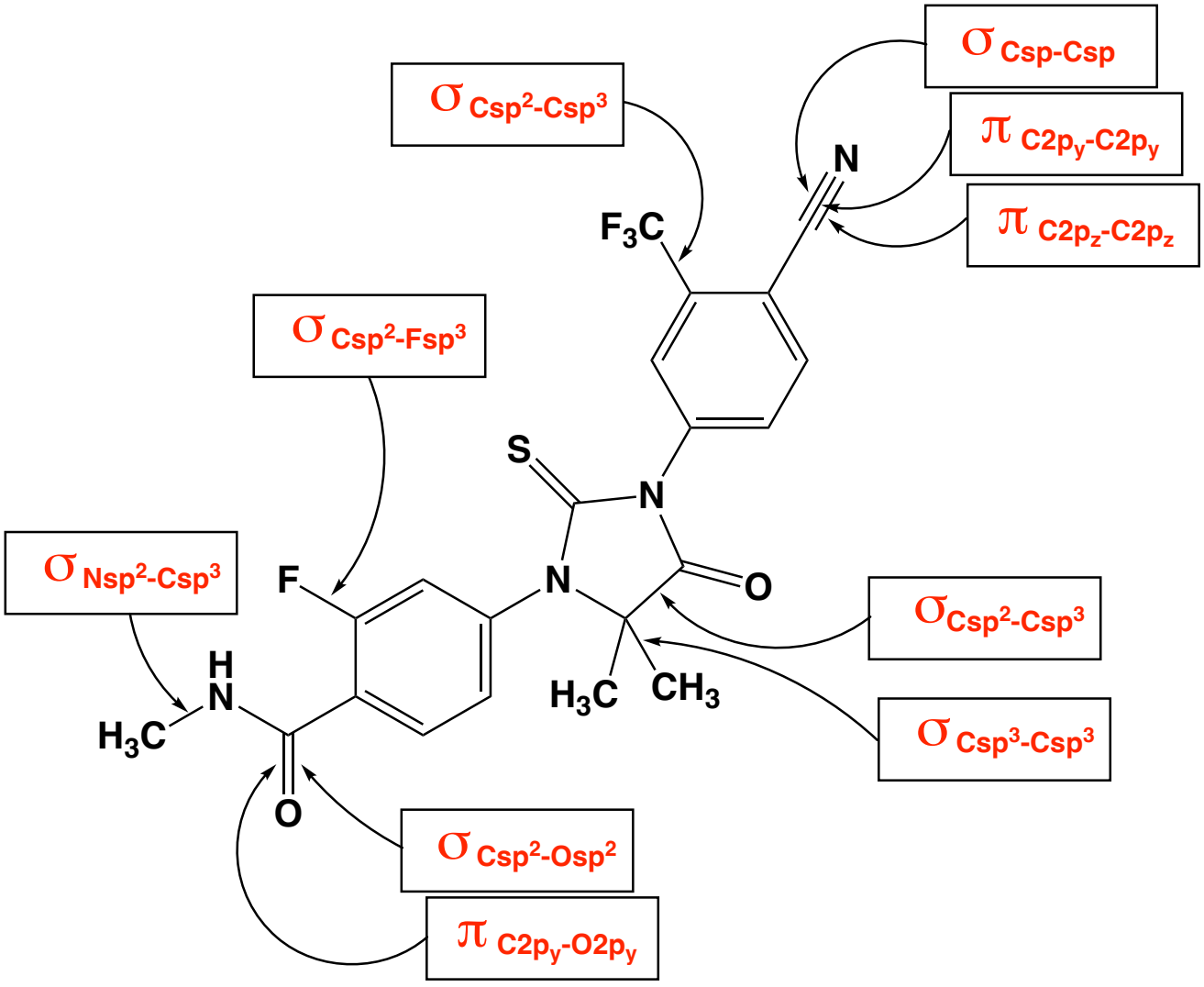


Enzalutamide (Xtandi)
Sales of $7.8 Billion in 2024
Used to treat cancer



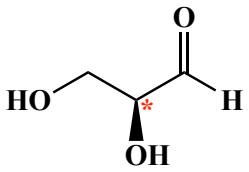
Atorvistatin (Lipitor)
Sales of $1.5 Billion in 2024
Used to lower cholesterol by over 200 million people worldwide (not a typo, that many people really do take this drug or its generic version!)

16. (2 pts each) Describe each bond indicated with an arrow as the overlap of orbitals. For example, an answer might be $\sigma_{Csp^3\text{-}Csp^3}$

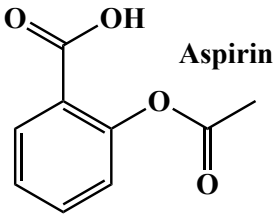


17. (24 pts) **Fill in the appropriate circle to indicate whether the molecule is chiral or not chiral. Then answer the three questions at the bottom of the page.**

Glyceraldehyde

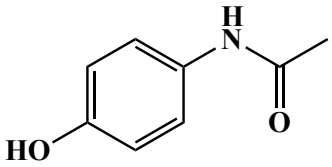


● Chiral ○ Not Chiral

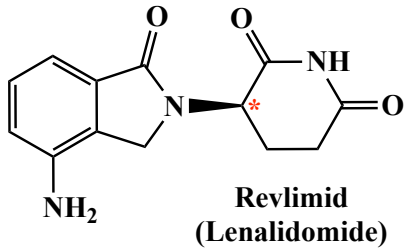


○ Chiral ● Not Chiral

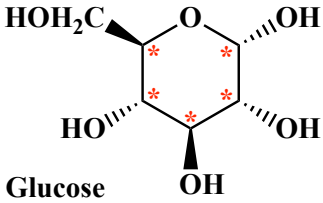
Tylenol (Acetomenophen)



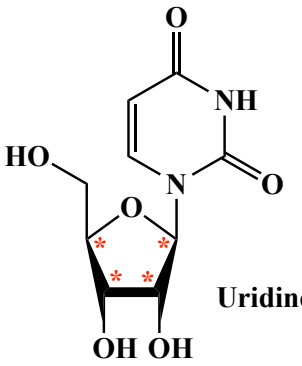
○ Chiral ● Not Chiral



● Chiral ○ Not Chiral

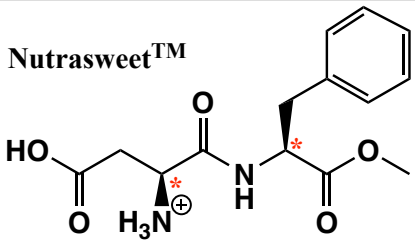


● Chiral ○ Not Chiral



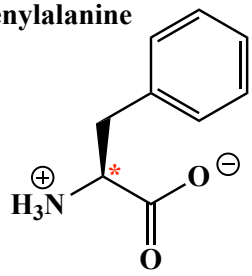
● Chiral ○ Not Chiral

Nutrasweet™

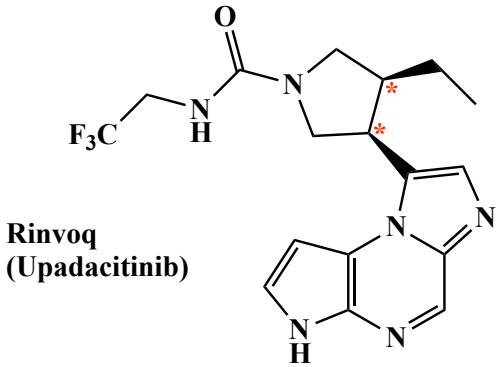


● Chiral ○ Not Chiral

Phenylalanine



● Chiral ○ Not Chiral



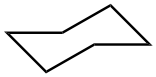
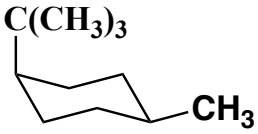
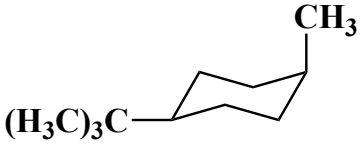
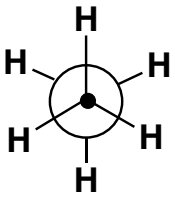
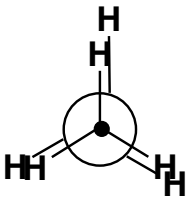
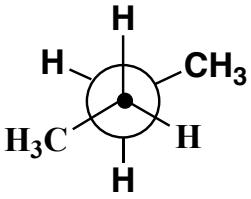
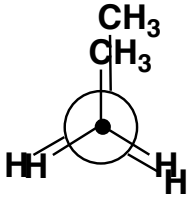
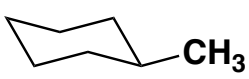
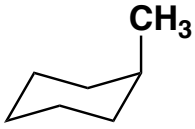
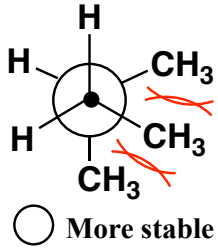
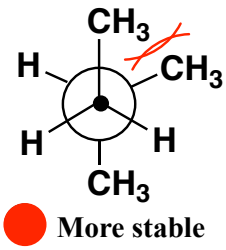
● Chiral ○ Not Chiral

How many stereoisomers of Phenylalanine are possible? **2**

How many stereoisomers of Tylenol are possible? **1**

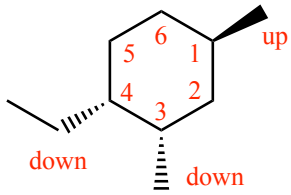
How many stereoisomers of Revlimid are possible? **2**

18. (4 pts each) For each pair of molecules, fill in the circle under the one that is more stable of the two, then put an "X" in the box under all the types of strain that explain(s) your answer:

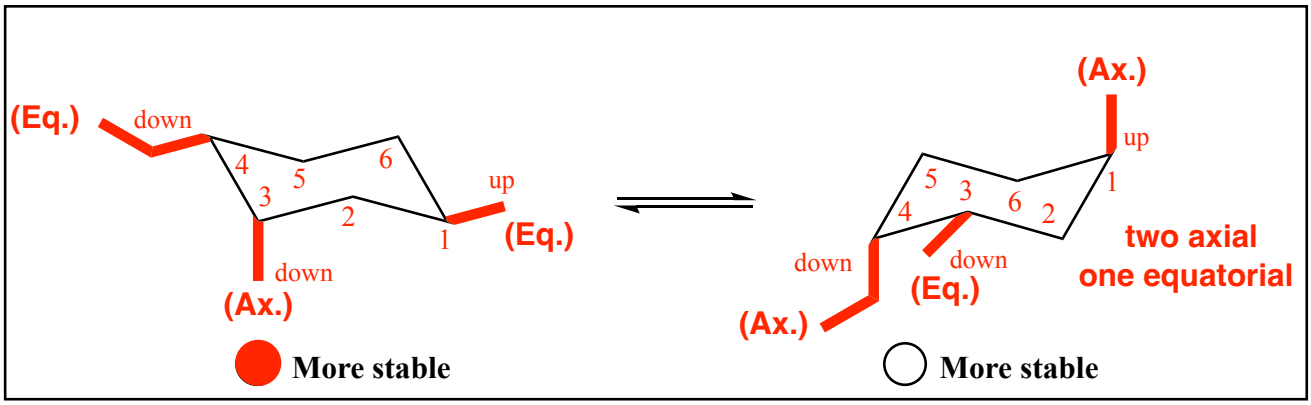
		Steric strain	Torsional strain	Angle strain
 ● More stable vs. ○ More stable 			X	X
 ○ More stable vs. ● More stable 		X		
 ● More stable vs. ○ More stable 			X	
 ● More stable vs. ○ More stable 		X	X	
 ● More stable vs. ○ More stable 		X		
 ○ More stable vs. ● More stable 		X		

19. (20 pts) For the following cyclohexane derivatives, draw the two alternative chair conformations. IF there is a difference in stability, fill in the circle that says "More stable". If there is not any difference in stability, do not fill in any circle.

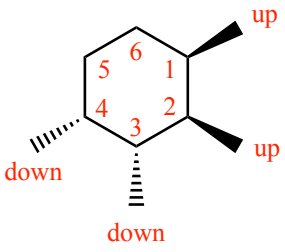
A)



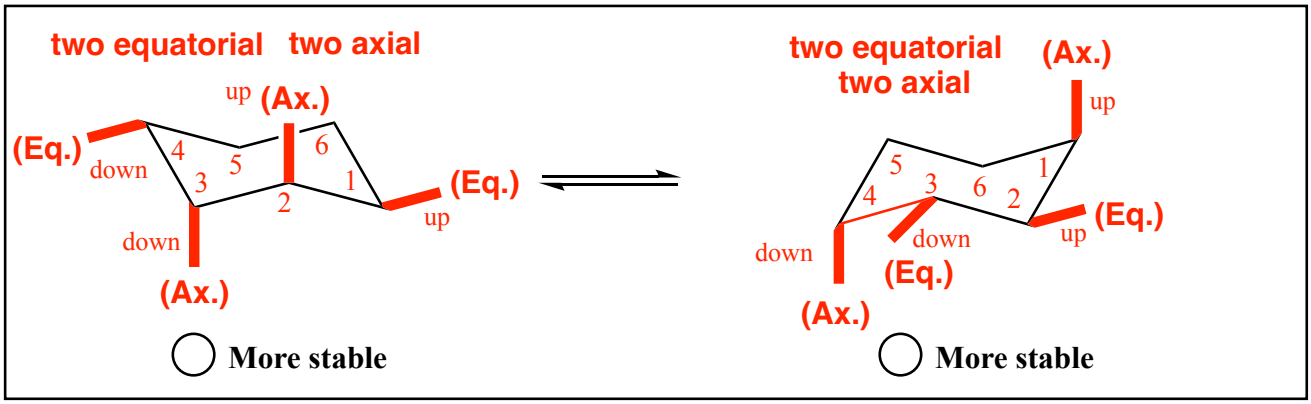
It is critical that you number in the same direction on all structures, I numbered clockwise here



B)

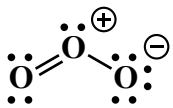


It is critical that you number in the same direction on all structures, I numbered clockwise here

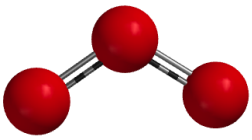


20. (22 points total). Here is an "apply what you know" problem in the form of an MCAT style passage.

On the second page you drew the second contributing structure of the ozone molecue, O_3. You no doubt have heard of ozone for maybe a couple of reasons, but I can assure you ozone is far more interesting than you probably know! Below is one of the two most important contributing structures of ozone.

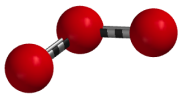


Ozone

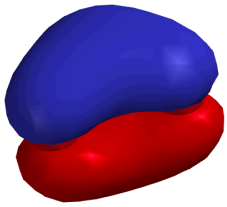


Ozone

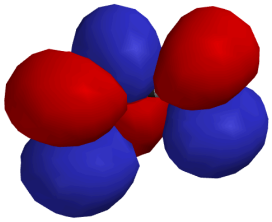
By now, I hope you recognize that a molecule like ozone has a three atom pi-way, based on the overlap of three unhybridized 2p orbitals.



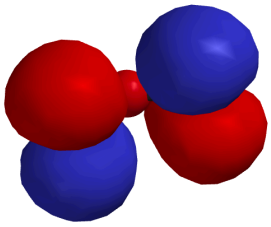
Ozone



Orbital A



Orbital B



Orbital C

1. (4 pts) From the following choices, fill in the circle for the answer that accurately **lists the three molecular orbitals in order from lowest to highest energy**:

- ◯ Orbital A Orbital B Orbital C
- ◯ Orbital B Orbital C Orbital A
- ● Orbital A Orbital C Orbital B
- ◯ Orbital C Orbital B Orbital A

2. (4 pts) One of the more difficult parts of the analysis of delocalized pi bonding concerns how many electrons are involved in the pi molecular orbitals. Fill in the circle for the answer that **lists how many total electrons reside in all of these pi molecular orbitals in ozone**.

- ◯ 2 pi electrons total
- ◯ 3 pi electrons total
- ● 4 pi electrons total
- ◯ 6 pi electrons total

20 (cont).

3. (4 pts) Fill in the circle for the answer that lists **which of the orbitals are filled by the electrons you listed in part two above**.

- ○ Orbitals A, B and C
- ○ Orbitals A and B
- ○ Orbital A only
- ● Orbitals A and C

4. (4 pts) Based on the structure of ozone, **what must be the hybridization state of each O atom of ozone**?

- ○ The O atoms on both ends of ozone are sp^3, the middle O atom is sp^2
- ○ The O atoms on both ends of ozone are sp^2, the middle O atom is sp
- ○ Only one of the O atoms on the end of ozone is sp^3, the other two O atoms are sp^2
- ● All three O atoms of ozone are sp^2

In the upper atmosphere, the ozone molecule is made when O_2 molecules react because of solar radiation to give ozone, O_3. Because of this, in the upper atmosphere there is an entire layer of relatively high ozone (O_3). It turns out the ozone layer is essential for life on our planet, as ozone absorbs harmful ultraviolet radiation coming from the sun that would otherwise harm every living creature if all of the sun's ultraviolet radiation was allowed to pass through the atmosphere down to the surface. However, ozone is also very reactive with other molecules. The reason is that there are too many lone pairs of electrons too close to each other on the ozone molecule, and as we will soon see this semester, too many lone pairs too close together weakens bonds and makes molecules very reactive. It is this reactivity that can be a problem. Down on the surface, ozone is produced as a pollutant by combustion engines, so that especially on hot, sunny days the concentration of ozone gets high and in Austin we have "Ozone action days". On those days it is dangerous for sensitive people to exercise outside. The reason is that the highly reactive ozone attacks molecules in our lungs!

As we will learn in a few weeks, ozone reacts with alkenes, or molecules with C=C bonds. Ozone attacks molecules with C=C bonds in our lungs and that is why it is dangerous. Although the overall ozone molecule is neutral, the mechanism of the reaction of C=C bonds with ozone can be understood by looking at the charges on the atoms of the ozone molecule. You will learn that C=C bonds react with atoms having full or partial positive charges.

20 (cont).

4. (4 pts) Based on BOTH of the most important contributing structures of ozone from page 2, which atom(s) of ozone carry a significant postive charge?

- ◯ The O atoms on both ends of ozone
- ● The middle O atom of ozone only
- ◯ Only one of the O atoms on the end of ozone
- ◯ All three O atoms of ozone share the postive charge evenly

A remarkable development has been the discovery that reacting ozone with natural oils such as olive oil creates ointments that simultaneously kill bacteria and also help heal wounds. In the manufacturing process for these ointments, the ozone reacts with the C=C bonds of olive oil to create a therapeutic molecule. You will likely be hearing more about this very interesting discovery.

A good way to get ready for a 5K race is to remember that avoiding a running injury means being patient and increasing your distance slowly. Start by running as far as you can comfortably. Do not push it at the beginning. Let's say you can run 1 mile before feeling too out of breath. Run that 1 mile 2-3 times a week at first, making sure you have no foot or leg pain. If you do have foot/leg issues, try new running shoes fit by a professional (The Loop or Rogue Running are great running stores for this). After you are comfortable running 1 mile for a week, try 1.25 miles for 2-3 times the next week. Then run to 1.5 miles, then 2.0 miles, then 2.5 miles each 2-3 times for a week. It will then be time for the race and you will make it!!!