

NAME (Print): _____

Chemistry 320M/328M
Dr. Brent Iverson
1st Midterm
September 22, 2022

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. 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 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!!!

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)

PERIODIC TABLE OF THE ELEMENTS

Elementary Subatomic Particles

System	Electron	Proton	Neutron	Photon	Neutrino
Rest mass (kg)	$9.10938291 \times 10^{-31}$	$1.67262161 \times 10^{-27}$	$1.67492729 \times 10^{-27}$	0	0
Rest mass (eV/c ²)	5.1098891×10^{-4}	$1.836152673 \times 10^{-3}$	$1.839397347 \times 10^{-3}$	0	0
Relative electron mass ratio	1	1836.152673(45)	1838.683661(45)	0	0
Relative proton mass ratio	$5.4461791(1) \times 10^{-4}$	1	1.0013076(45)	0	0
Relative neutron mass ratio	$1.836152673(45) \times 10^{-3}$	0.0013076(45)	1	0	0
Spin	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	0	0
Spin quantum number	$\pm \frac{1}{2}$	$\pm \frac{1}{2}$	$\pm \frac{1}{2}$	0	0
Compton wavelength (m)	$2.426310241 \times 10^{-12}$	$1.321409812 \times 10^{-15}$	$1.3195911012 \times 10^{-15}$	—	—
Magnetic moment (J/T)	$9.28476377(45) \times 10^{-24}$	$1.41060760(45) \times 10^{-26}$	$0.88181735(45) \times 10^{-26}$	0	0
In Bohr magneton, μ_B	$1.836152673(45)$	$0.001836152673(45)$	$0.001836152673(45)$	0	0
In nuclear magneton, μ_N	$1836.152673(45)$	$1.836152673(45)$	$1.836152673(45)$	0	0

Summary particles are the fundamental constituents of atoms and nuclei. The proton (p⁺) is a positive particle which has the same mass as an antiproton. The antineutrino ($\bar{\nu}$) is a neutral particle that is the antiparticle of a neutrino. It is emitted in β^- decay and is the antiparticle of a neutrino. The electron (e⁻) is a negative particle which has the same mass as an antielectron (positron). The antiproton (\bar{p}) is a negative particle which has the same mass as a proton. The antineutrino ($\bar{\nu}$) is a neutral particle which has the same mass as a neutrino. It is emitted in β^+ decay and is the antiparticle of a neutrino. The positron (e⁺) is a positive particle which has the same mass as an antielectron. The antiproton (\bar{p}) is a negative particle which has the same mass as a proton. The antineutrino ($\bar{\nu}$) is a neutral particle which has the same mass as a neutrino. It is emitted in β^+ decay and is the antiparticle of a neutrino.

% Ionic Character of a Single Chemical Bond

Percent ionic character describes the nature of a bond. Bonds possessing 50% or greater ionic character are considered ionic. Bonds with less than 50% ionic character are termed covalent. Pauling's equation was modified by Henry H. H. H. H. H.

18 VII O

2	10	18	36	54	86	118	150	182	214	246	278	310	342	374	406	438	470	502	534	566	598	630	662	694	726	758	790	822	854	886	918	950	982	1014	1046	1078	1110	1142	1174	1206	1238	1270	1302	1334	1366	1398	1430	1462	1494	1526	1558	1590	1622	1654	1686	1718	1750	1782	1814	1846	1878	1910	1942	1974	2006	2038	2070	2102	2134	2166	2198	2230	2262	2294	2326	2358	2390	2422	2454	2486	2518	2550	2582	2614	2646	2678	2710	2742	2774	2806	2838	2870	2902	2934	2966	2998	3030	3062	3094	3126	3158	3190	3222	3254	3286	3318	3350	3382	3414	3446	3478	3510	3542	3574	3606	3638	3670	3702	3734	3766	3798	3830	3862	3894	3926	3958	3990	4022	4054	4086	4118	4150	4182	4214	4246	4278	4310	4342	4374	4406	4438	4470	4502	4534	4566	4598	4630	4662	4694	4726	4758	4790	4822	4854	4886	4918	4950	4982	5014	5046	5078	5110	5142	5174	5206	5238	5270	5302	5334	5366	5398	5430	5462	5494	5526	5558	5590	5622	5654	5686	5718	5750	5782	5814	5846	5878	5910	5942	5974	6006	6038	6070	6102	6134	6166	6198	6230	6262	6294	6326	6358	6390	6422	6454	6486	6518	6550	6582	6614	6646	6678	6710	6742	6774	6806	6838	6870	6902	6934	6966	6998	7030	7062	7094	7126	7158	7190	7222	7254	7286	7318	7350	7382	7414	7446	7478	7510	7542	7574	7606	7638	7670	7702	7734	7766	7798	7830	7862	7894	7926	7958	7990	8022	8054	8086	8118	8150	8182	8214	8246	8278	8310	8342	8374	8406	8438	8470	8502	8534	8566	8598	8630	8662	8694	8726	8758	8790	8822	8854	8886	8918	8950	8982	9014	9046	9078	9110	9142	9174	9206	9238	9270	9302	9334	9366	9398	9430	9462	9494	9526	9558	9590	9622	9654	9686	9718	9750	9782	9814	9846	9878	9910	9942	9974	10006	10038	10070	10102	10134	10166	10198	10230	10262	10294	10326	10358	10390	10422	10454	10486	10518	10550	10582	10614	10646	10678	10710	10742	10774	10806	10838	10870	10902	10934	10966	10998	11030	11062	11094	11126	11158	11190	11222	11254	11286	11318	11350	11382	11414	11446	11478	11510	11542	11574	11606	11638	11670	11702	11734	11766	11798	11830	11862	11894	11926	11958	11990	12022	12054	12086	12118	12150	12182	12214	12246	12278	12310	12342	12374	12406	12438	12470	12502	12534	12566	12598	12630	12662	12694	12726	12758	12790	12822	12854	12886	12918	12950	12982	13014	13046	13078	13110	13142	13174	13206	13238	13270	13302	13334	13366	13398	13430	13462	13494	13526	13558	13590	13622	13654	13686	13718	13750	13782	13814	13846	13878	13910	13942	13974	14006	14038	14070	14102	14134	14166	14198	14230	14262	14294	14326	14358	14390	14422	14454	14486	14518	14550	14582	14614	14646	14678	14710	14742	14774	14806	14838	14870	14902	14934	14966	14998	15030	15062	15094	15126	15158	15190	15222	15254	15286	15318	15350	15382	15414	15446	15478	15510	15542	15574	15606	15638	15670	15702	15734	15766	15798	15830	15862	15894	15926	15958	15990	16022	16054	16086	16118	16150	16182	16214	16246	16278	16310	16342	16374	16406	16438	16470	16502	16534	16566	16598	16630	16662	16694	16726	16758	16790	16822	16854	16886	16918	16950	16982	17014	17046	17078	17110	17142	17174	17206	17238	17270	17302	17334	17366	17398	17430	17462	17494	17526	17558	17590	17622	17654	17686	17718	17750	17782	17814	17846	17878	17910	17942	17974	18006	18038	18070	18102	18134	18166	18198	18230	18262	18294	18326	18358	18390	18422	18454	18486	18518	18550	18582	18614	18646	18678	18710	18742	18774	18806	18838	18870	18902	18934	18966	18998	19030	19062	19094	19126	19158	19190	19222	19254	19286	19318	19350	19382	19414	19446	19478	19510	19542	19574	19606	19638	19670	19702	19734	19766	19798	19830	19862	19894	19926	19958	19990	20022	20054	20086	20118	20150	20182	20214	20246	20278	20310	20342	20374	20406	20438	20470	20502	20534	20566	20598	20630	20662	20694	20726	20758	20790	20822	20854	20886	20918	20950	20982	21014	21046	21078	21110	21142	21174	21206	21238	21270	21302	21334	21366	21398	21430	21462	21494	21526	21558	21590	21622	21654	21686	21718	21750	21782	21814	21846	21878	21910	21942	21974	22006	22038	22070	22102	22134	22166	22198	22230	22262	22294	22326	22358	22390	22422	22454	22486	22518	22550	22582	22614	22646	22678	22710	22742	22774	22806	22838	22870	22902	22934	22966	22998	23030	23062	23094	23126	23158	23190	23222	23254	23286	23318	23350	23382	23414	23446	23478	23510	23542	23574	23606	23638	23670	23702	23734	23766	23798	23830	23862	23894	23926	23958	23990	24022	24054	24086	24118	24150	24182	24214	24246	24278	24310	24342	24374	24406	24438	24470	24502	24534	24566	24598	24630	24662	24694	24726	24758	24790	24822	24854	24886	24918	24950	24982	25014	25046	25078	25110	25142	25174	25206	25238	25270	25302	25334	25366	25398	25430	25462	25494	25526	25558	25590	25622	25654	25686	25718	25750	25782	25814	25846	25878	25910	25942	25974	26006	26038	26070	26102	26134	26166	26198	26230	26262	26294	26326	26358	26390	26422	26454	26486	26518	26550	26582	26614	26646	26678	26710	26742	26774	26806	26838	26870	26902	26934	26966	26998	27030	27062	27094	27126	27158	27190	27222	27254	27286	27318	27350	27382	27414	27446	27478	27510	27542	27574	27606	27638	27670	27702	27734	27766	27798	27830	27862	27894	27926	27958	27990	28022	28054	28086	28118	28150	28182	28214	28246	28278	28310	28342	28374	28406	28438	2847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1. (4 points) What is the most important question in Organic Chemistry?

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.



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



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



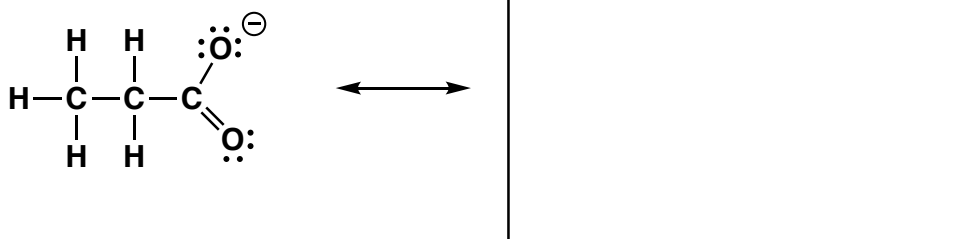
How many different stereoisomers are possible for the above molecule? _____

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.

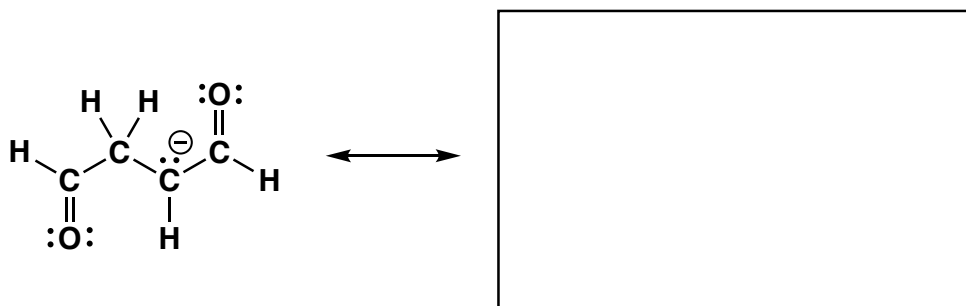


4. (6 pts) The following molecules are best represented as the hybrid of contributing structures. **Draw the second important contributing structure** in the space provided, including all lone pairs and formal charges.

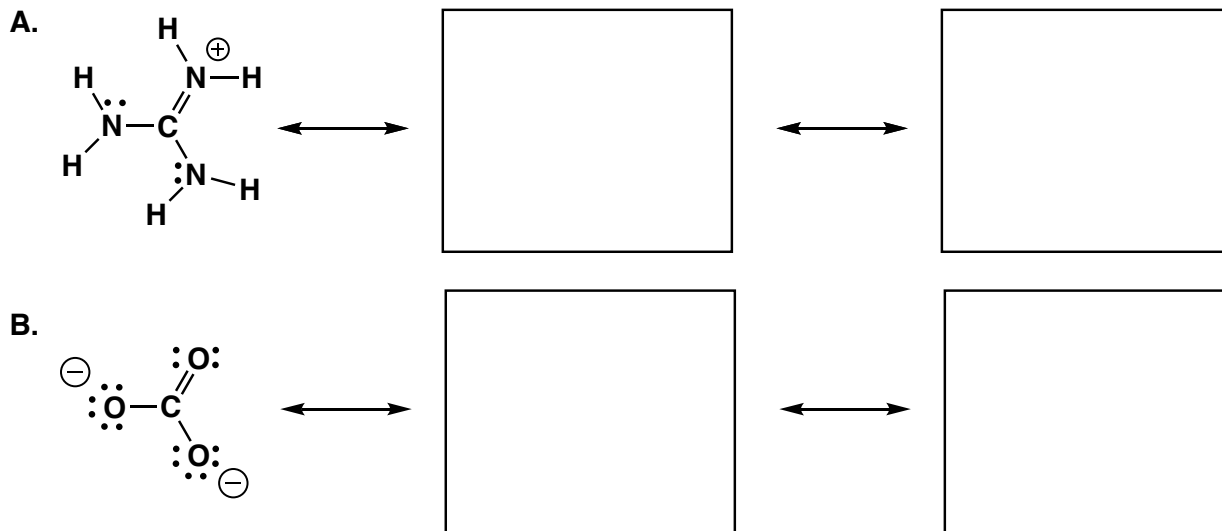
A.



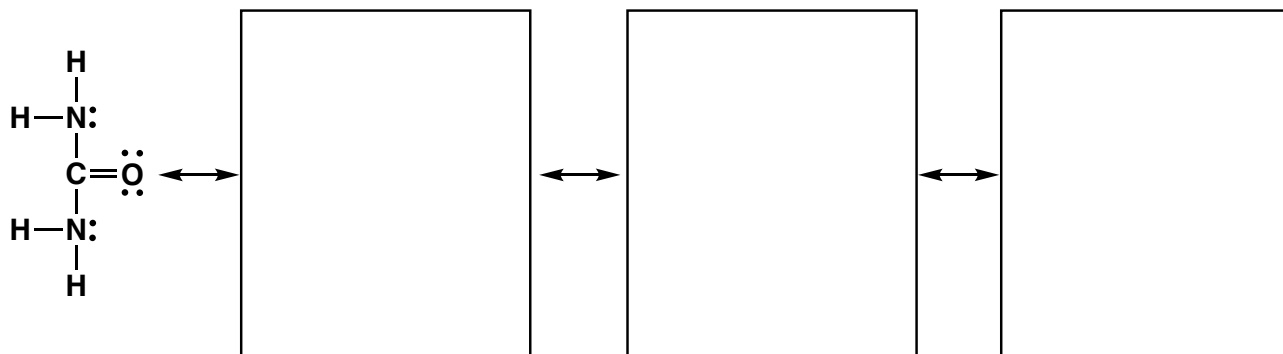
B.



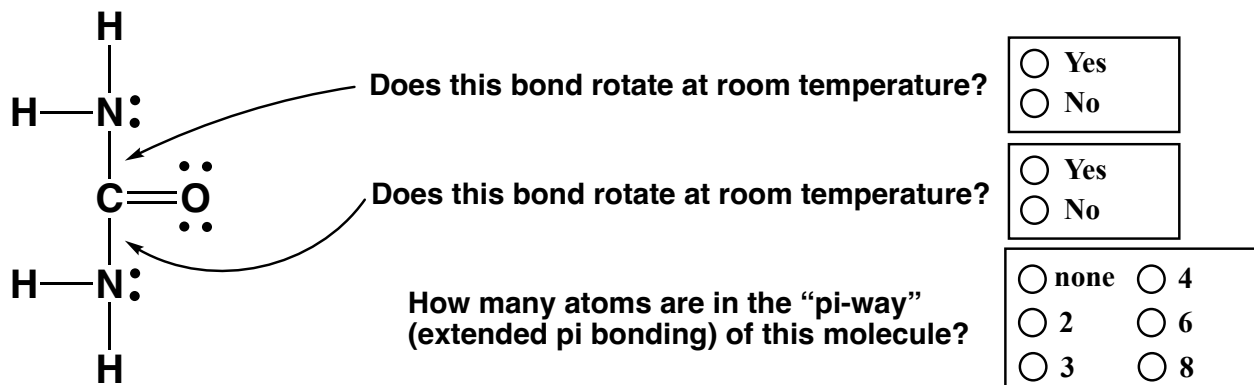
5. (12 pts) The following molecules are best represented as the hybrid of three contributing structures. **Draw the second and third important contributing structures** in the spaces provided, including all lone pairs and formal charges.



6. (9 pts) The following molecule is called urea and is best represented as the hybrid of four contributing structures. **Draw the second, third and fourth important contributing structures** in the spaces provided, including all lone pairs and formal charges.



7. (10 pts) On the following molecule, circle all the atoms that are sp^2 hybridized and answer the three questions in the boxes provided by filling in the circles next to the correct answers.



8. (1 pt each) Fill in each blank with the word or words that best completes the sentences.

For organic chemistry, it is best to think of electrons as _____.

The electron density in molecules can be described mathematically by adding the _____ functions of all the atomic orbitals for all the atoms in the entire molecule, an approach referred to as _____ theory.

The wave functions for the _____ atomic orbitals on each atom can be added together first, a process referred to as _____, before looking for overlap with orbitals from other atoms. This approach is called _____ theory.

You need to be able to think about all _____ bonding in molecules as being derived from the overlap of _____ orbitals and all pi bonding as being derived from overlap of unhybridized _____ orbitals.

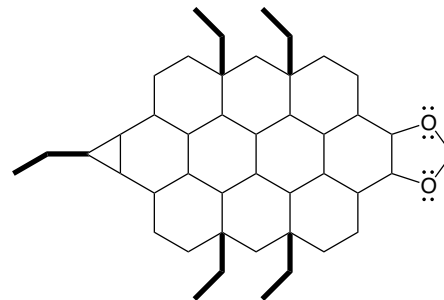
Especially for charged molecules, it is stabilizing to have _____ electron density as well as charges delocalized over more than two atoms. This concept is usually referred to as "stabilization due to _____" or simply "resonance stabilization".

For pi bonding and therefore pi delocalization to occur over more than _____ atoms (i.e. pi-ways), parallel _____ orbitals are needed on ALL of the adjacent atoms involved, explaining why ALL of these atoms must be _____ (or _____) hybridized and why these systems are planar.

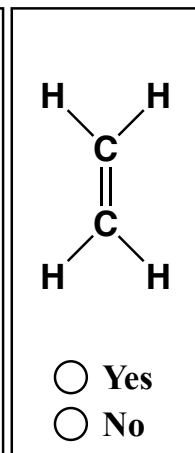
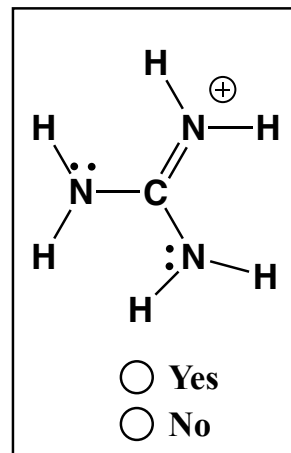
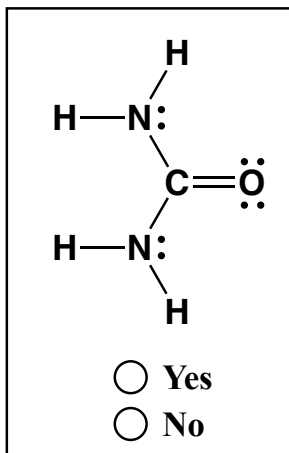
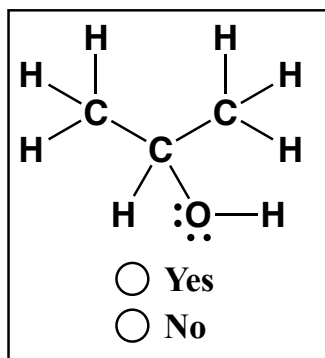
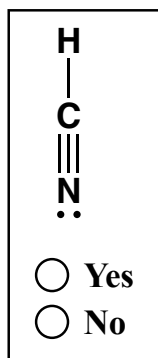
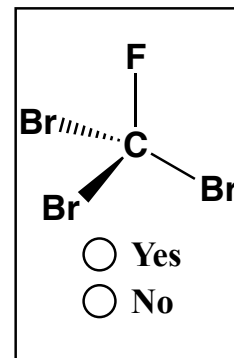
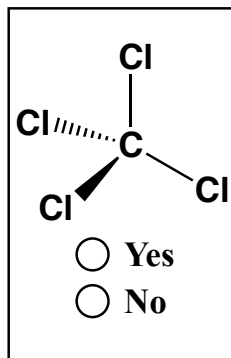
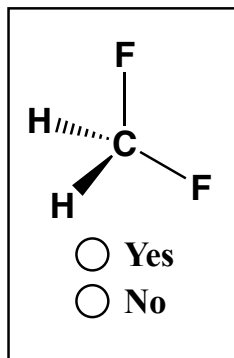
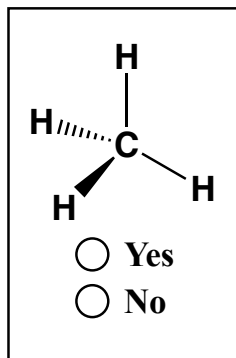
NEWS FLASH: A new species of turtle was just discovered in the turtle pond:

According to IUPAC, its official name is:

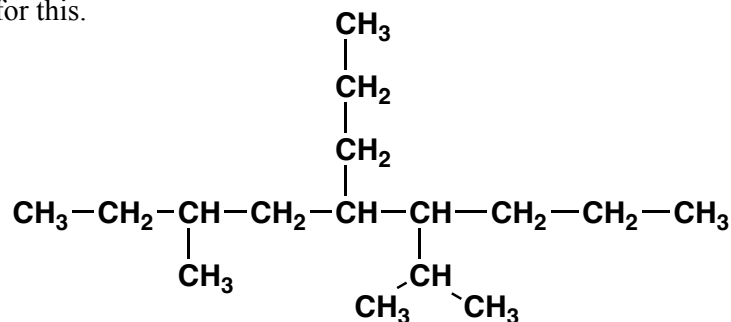
(7a*R*,8a*S*,11*r*,13a*R*,14a*S*)-7a,8a,11,13a,14a-pentaethyltriacontahydro-1*H*-cyclopropa[10,11]ovaleno[3,4-*d*][1,3]dioxole



9. (18 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.

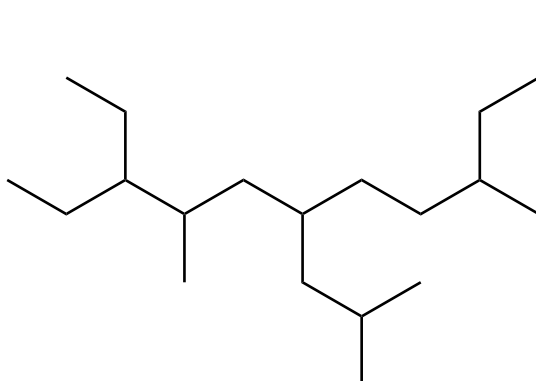


10. (7 pts) In the box below, provide an acceptable IUPAC name for the following molecule. Do not designate R or S for this.



Although stereochemistry is not indicated on the above structure, how many stereoisomers are possible? _____

11. (7 pts) In the box below, provide an acceptable IUPAC name for the following molecule. Do not designate R or S for this.



Although stereochemistry is not indicated on the above structure, how many stereoisomers are possible? _____

12. (10 pts each) For the following IUPAC name, draw the appropriate line angle drawing. You can ignore R and S for this one.

5-isopropyl-2,3,4,7-tetramethylnonane



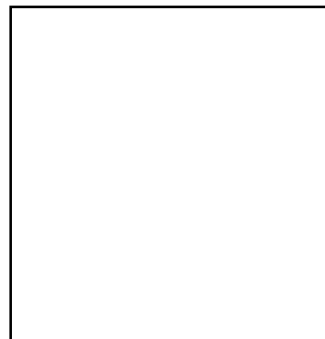
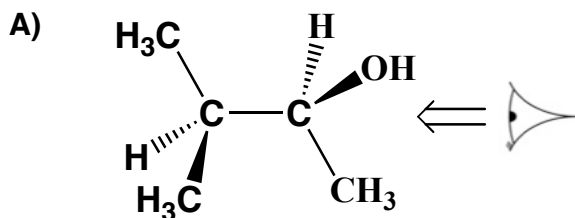
Although stereochemistry is not indicated in the above name or your structure, how many stereoisomers are possible? _____

13. (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*,6*R*,7*S*)-7-ethyl-6-isopropyl-2,5-dimethyldecane

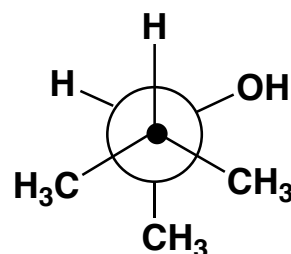
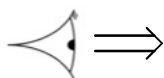


14. (5 pts) Draw the Newman projection for the conformation of 3-methyl-3-butanol as shown.



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

B)

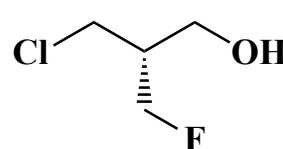
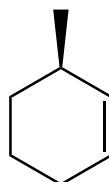
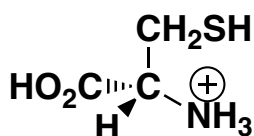
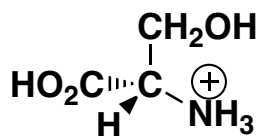
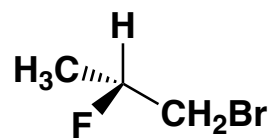
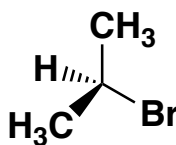
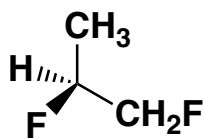
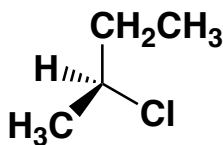


NOTICE THIS

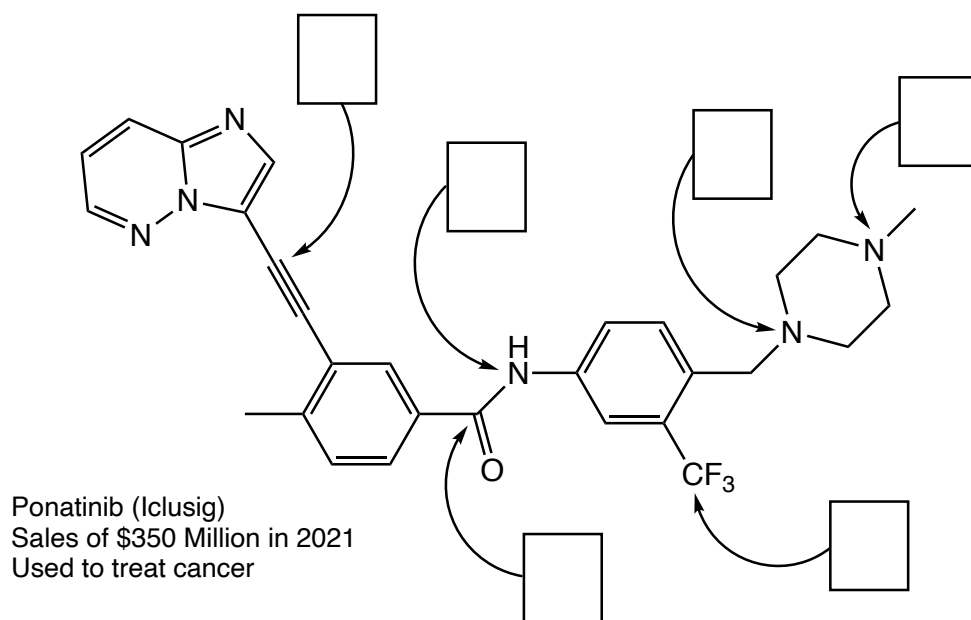
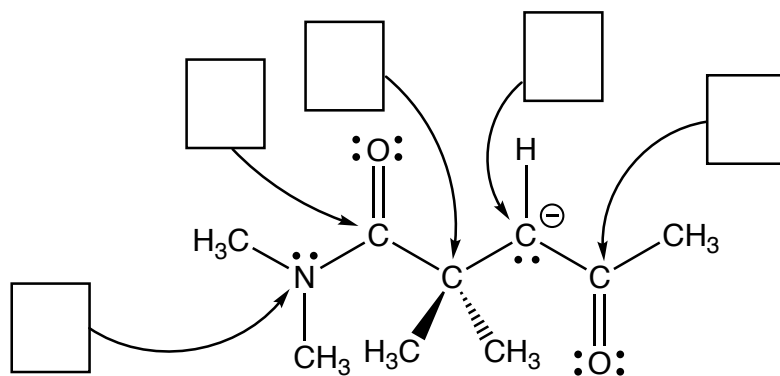
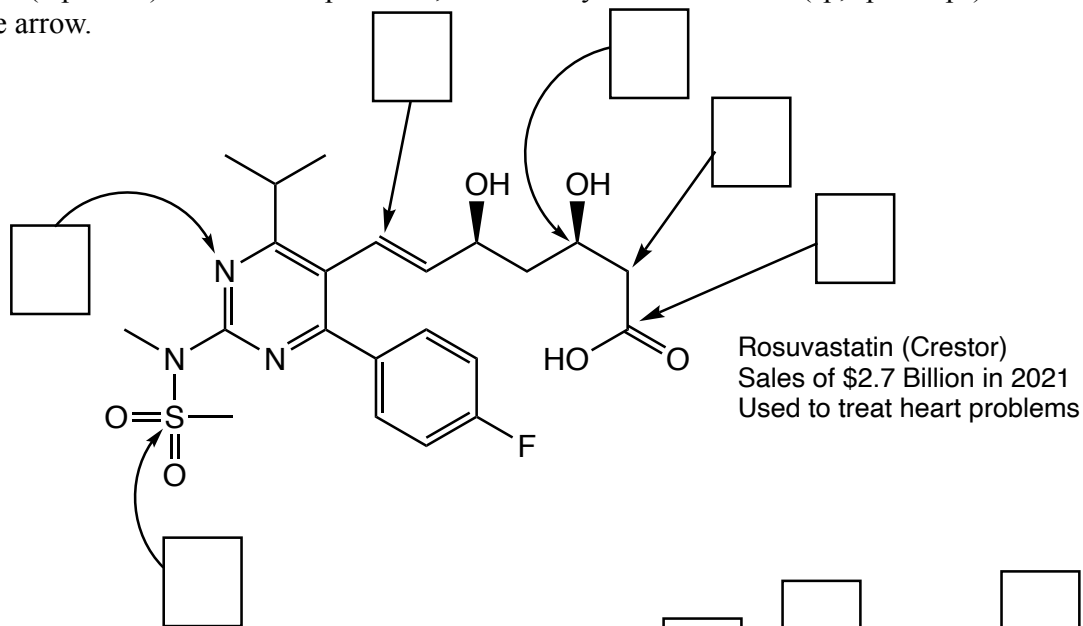


The same molecule was used in both parts of this problem. It is chiral, is it R or S? _____

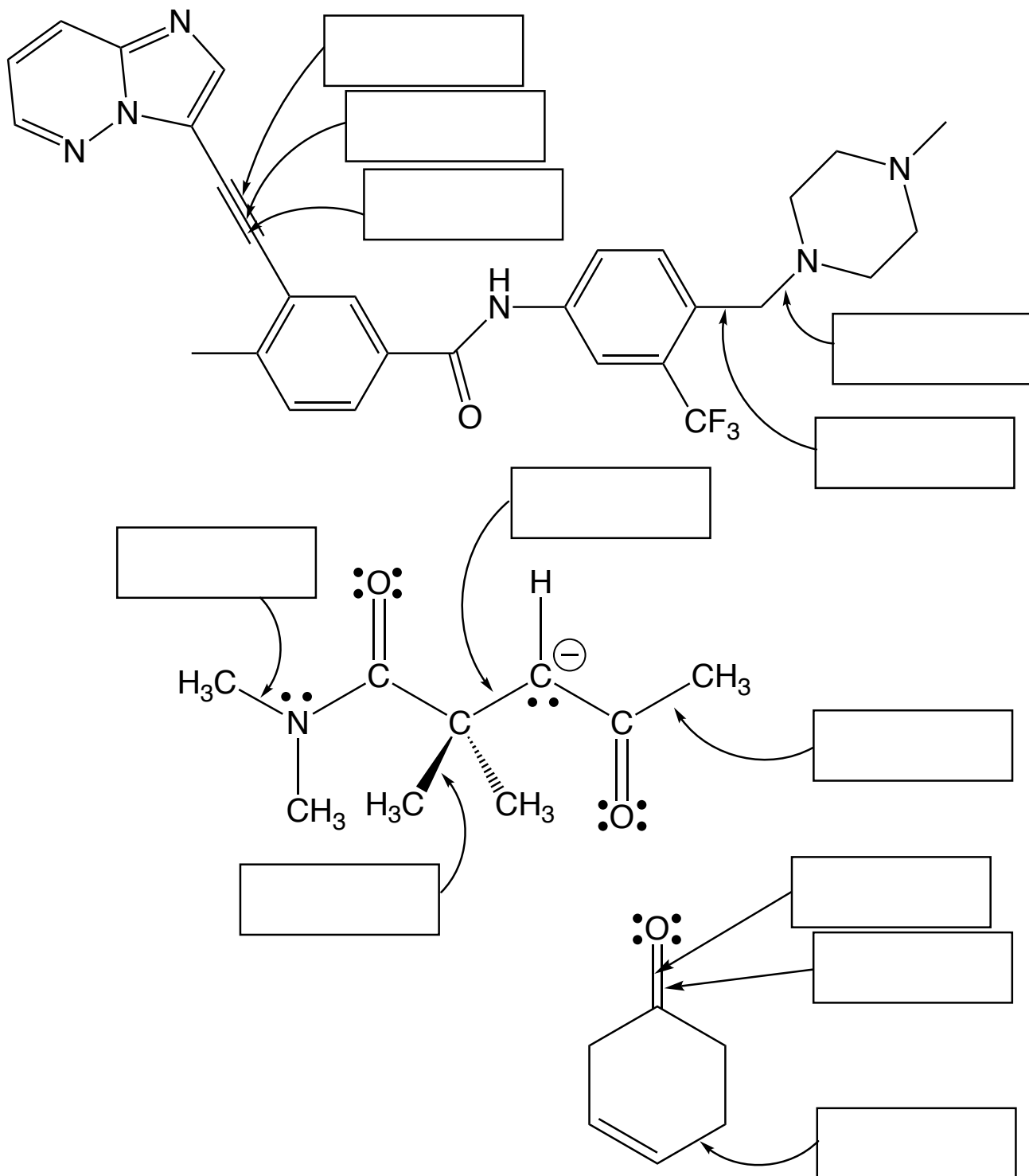
15. (2 pts each) Examine the following structures. For each molecule with a chiral center, assign the stereochemistry then write "R" or "S" as appropriate in the box provided below each structure. For all molecules that have no chiral centers, do not put anything in the box.



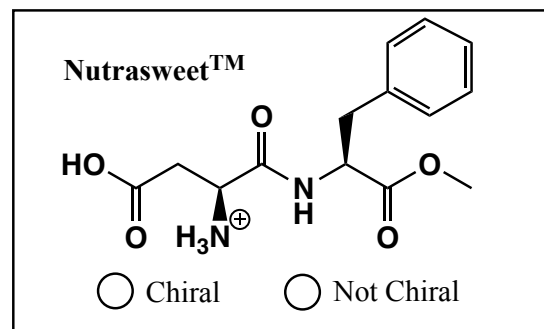
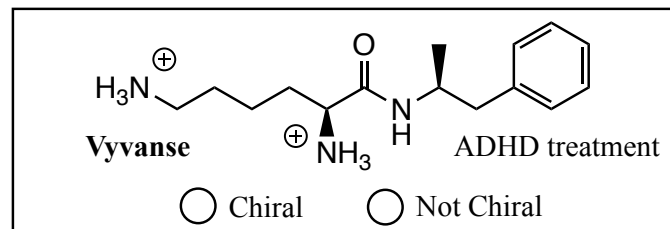
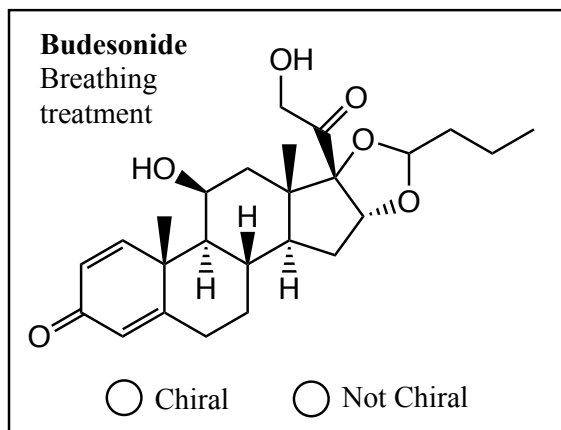
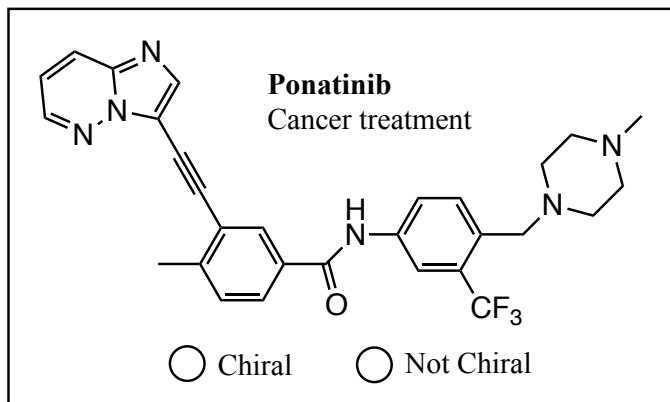
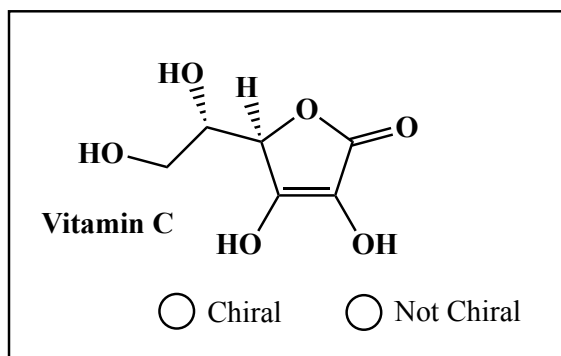
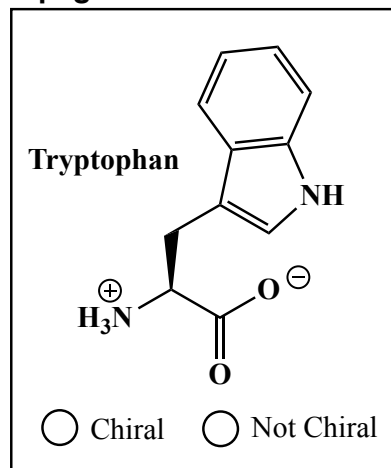
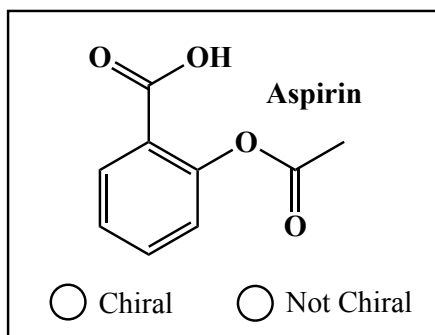
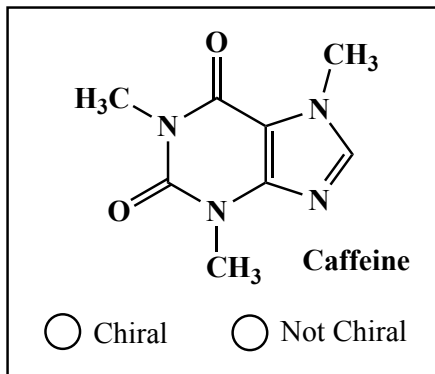
16. (1 pt each) In the boxes provided, write the hybridization state (sp , sp^2 or sp^3) of the atoms indicated by the arrow.



17. (2 pts each) Describe each bond indicated with an arrow as the overlap of hybridized orbitals. For example, an answer might be $\sigma \text{Csp}^3\text{-Csp}^3$



18. (22 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.

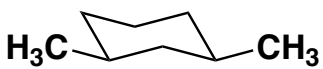
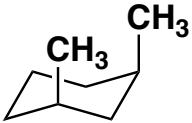
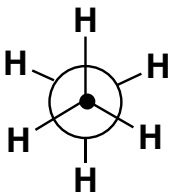
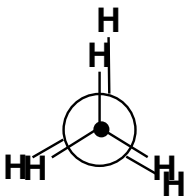
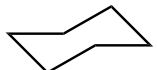

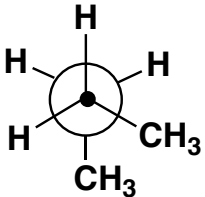
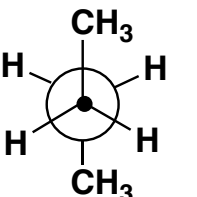
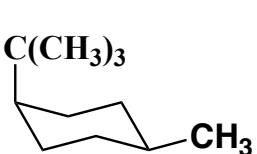
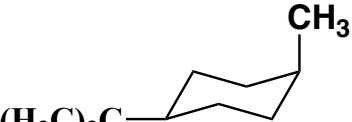
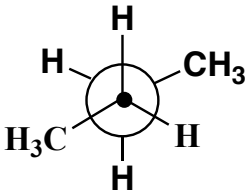
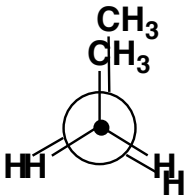


How many stereoisomers of Tryptophan are possible?

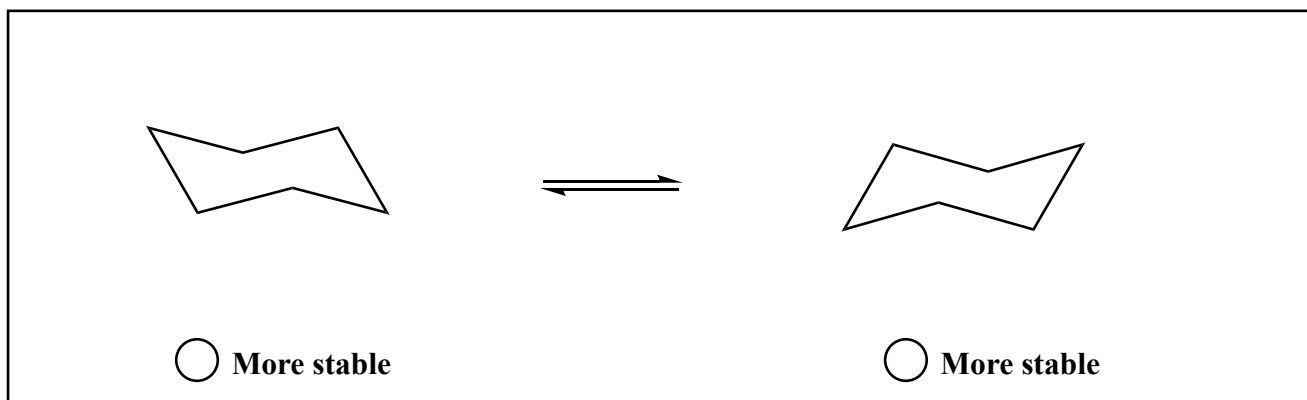
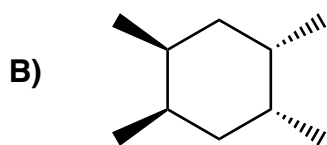
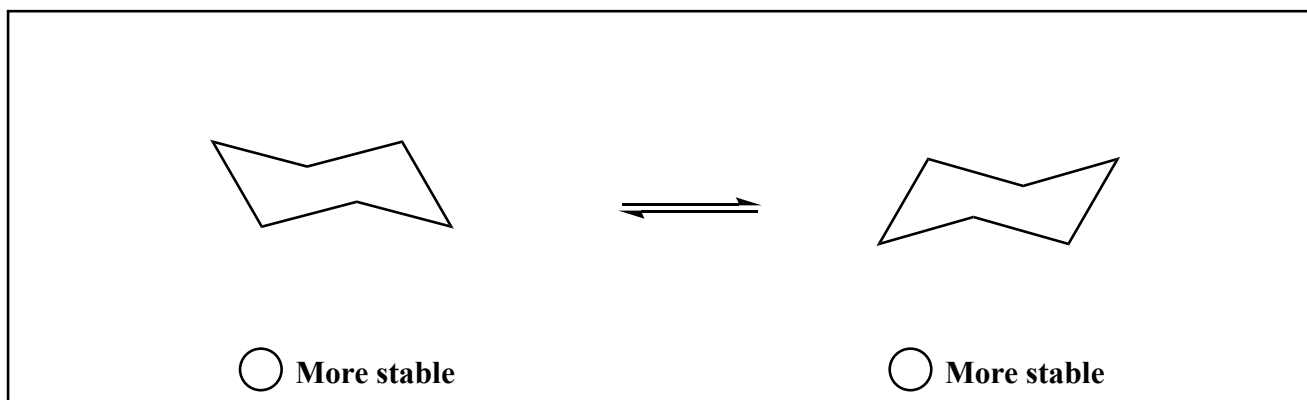
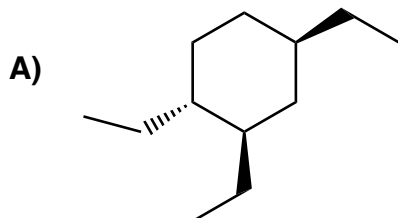
How many stereoisomers of aspirin are possible?

How many stereoisomers of Nutrasweet™ are possible?

19. (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:

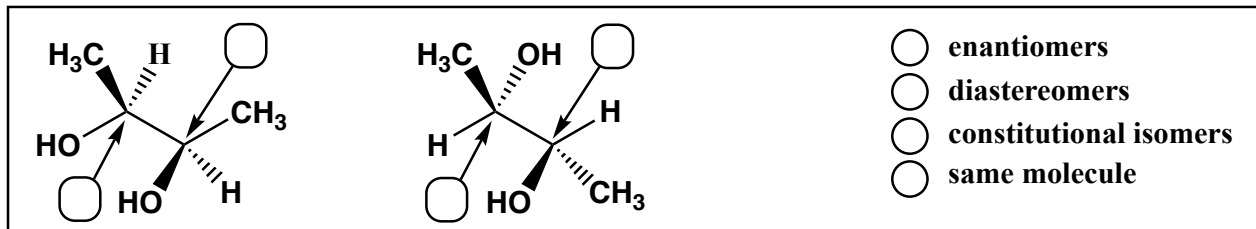
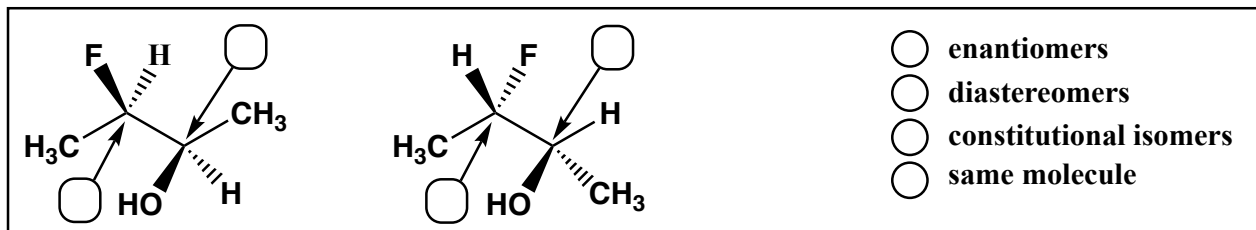
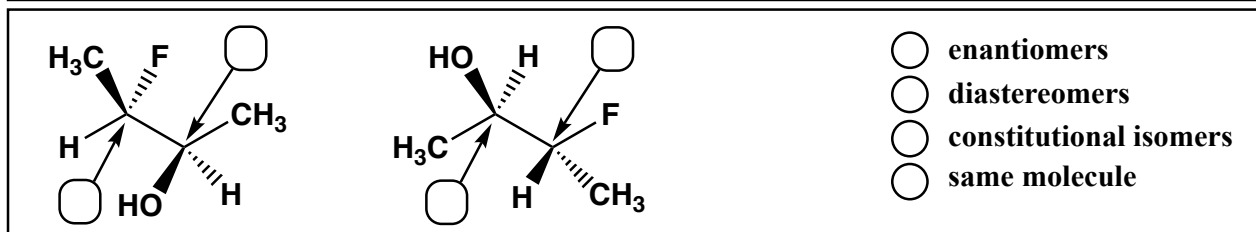
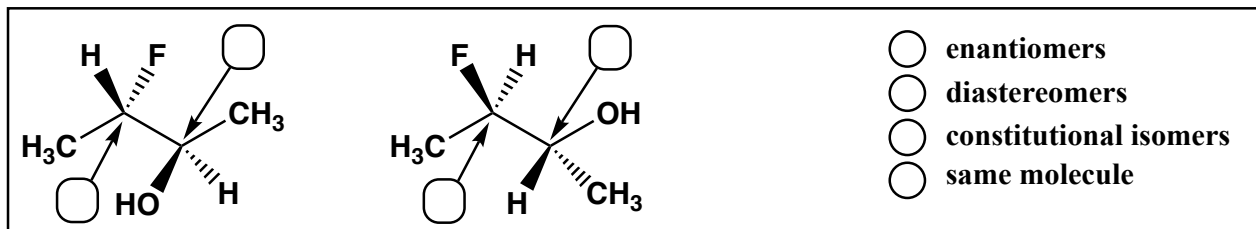
		Angle strain	Torsional strain	Steric strain
 <input type="radio"/> More stable	vs.			
 <input type="radio"/> More stable				
 <input type="radio"/> More stable	vs.			
 <input type="radio"/> More stable				
 <input type="radio"/> More stable	vs.			
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 <input type="radio"/> More stable	vs.			
 <input type="radio"/> More stable				

20. (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.

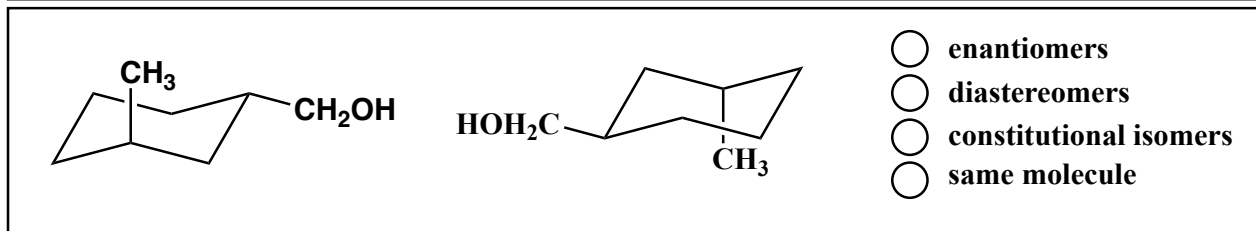
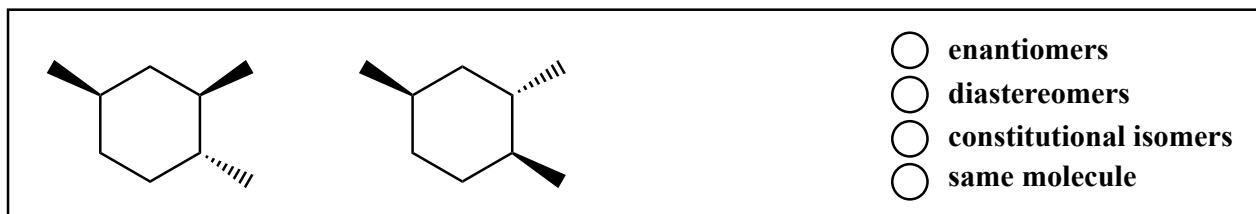


21. (38 pts) For each pair of molecules, on the line provided state the relationship between the two structures. Possible answers could be **enantiomers**, **diastereomers**, **constitutional isomers**, or **same molecule**. Fill in the circle to indicate the correct relationship between the molecules shown. In the boxes provided next to each chiral center, write "R" or "S" to indicate the absolute stereochemistry present.

Relationship:

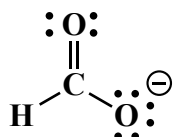


You do not need to label the chiral centers with "R" or "S" on these last two.

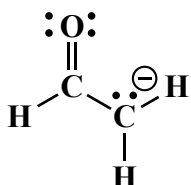


22. (22 points total). Here is an “apply what you know” problem in the form of an MCAT style passage.

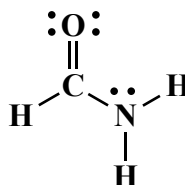
We have seen a number of molecules that contains a three-atom, delocalized pi bond (a “pi-way”). In particular, we have seen a carboxylate ion, enolate ion, and of course, amides. Each of the three atoms donates a 2p orbital that overlap.



Carboxylate Ion

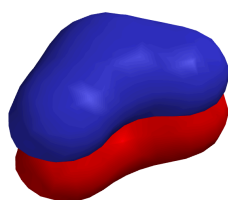


Enolate Ion

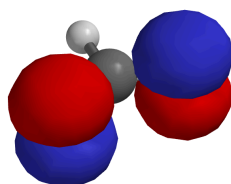


Amide

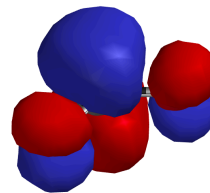
When the three 2p orbitals overlap, there are three pi molecular orbitals formed that extend over all three atoms. You have seen these before, and they are shown below:



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

One of the more difficult parts of the analysis of delocalized pi bonding concerns how many electrons are involved in the pi molecular orbitals. Each of the ions shown above, the carboxylate ion, the enolate ion, and the amide, have the same number of pi electrons in the pi molecular orbitals.

22 (cont).

2. (4 pts) Fill in the circle for the answer that **lists how many electrons reside in these pi molecular orbitals in the carboxylate ion, the enolate ion and the amide?**

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

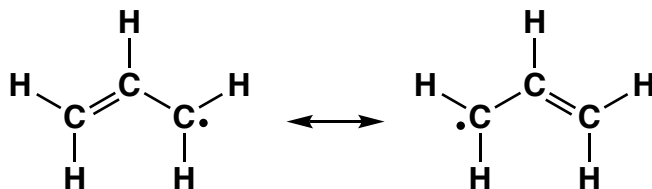
3. (4 pts) Fill in the circle for the answer that lists **which of the orbitals are filled by the electrons you listed in part two above.**

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

Your answer to part 3. explains the properties of the carboxylate ion, the enolate ion and the amide.

For example, let's consider the carboxylate ion. By understanding which of these orbitals are filled, it explains why there is partial double bond character over all three atoms (O-C-O) and why the negative charge is located on only the two oxygen atoms.

Later this semester you will learn that there are some highly reactive intermediates that have an unpaired electron in their valence shell, and these are called "radicals". One example is shown below, it is called the "allyl radical" and it is best described as the resonance hybrid of two contributing structures. Note that radicals have no formal charge!



The allyl radical

It turns out that all of the carbon atoms of the allyl radical are sp^2 hybridized and the three 2p orbitals overlap to create the same three pi molecular orbitals shown above in this problem.

22 (cont).

4. (4 pts) Fill in the circle for the answer that lists **how many electrons reside in these pi molecular orbitals in the allyl radical?**

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

One of the pi molecular orbitals of the allyl radical is only half-filled, containing the electron density for only a single electron, not a pair of electrons! That is why radicals are so reactive, they react to make bonds that fully fill their valence shell.

5. (4 pts) Given everything you know about delocalized pi molecular orbitals, fill in the circle for the answer that correctly lists **the pi molecular orbital that is half-filled in the allyl radical.**

- Orbital A
 Orbital B
 Orbital C
 Yay! Only one more 2pt question and you will be finished with the exam!

6. (2 pts) Examine the contributing structures for the allyl radical above, does the orbital you selected in part 5. make sense to you?

- No, there is no correlation between the molecular orbitals and contributing structures
 Yes, the orbital I chose and the contributing structures place the unpaired electron density on the same atoms.

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!!!