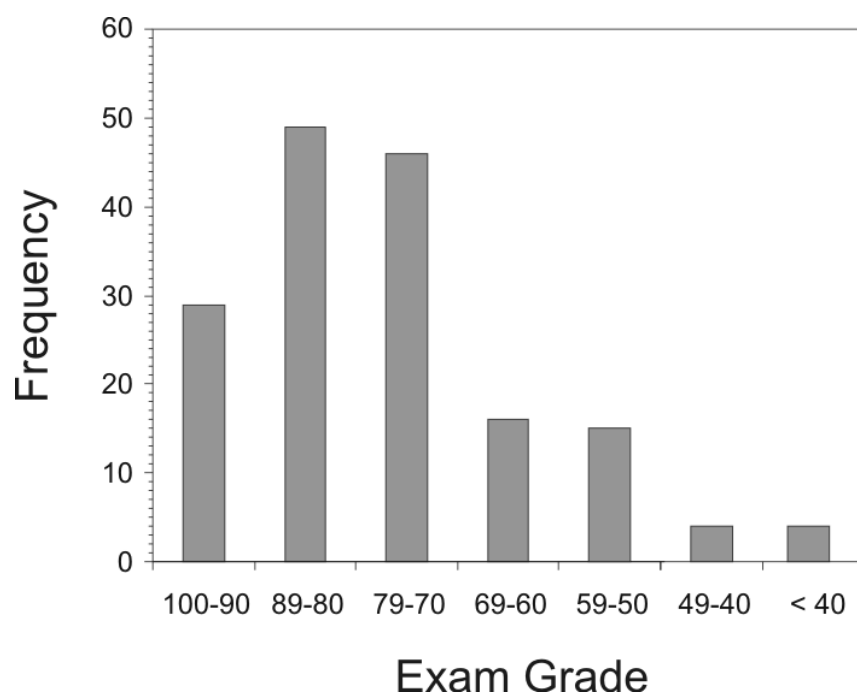


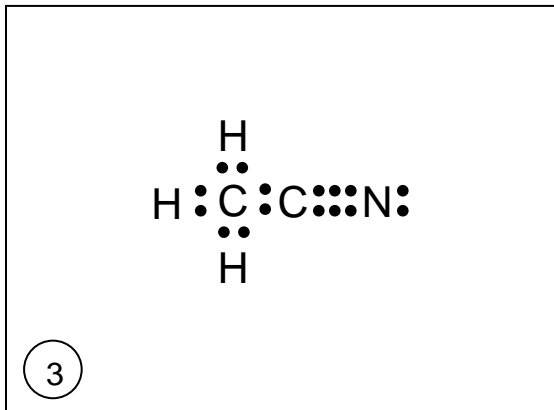
**Exam 1
Answer Key**

Exam 1 Mean: 78
Exam 1 Median: 80
Exam 1 St. Dev.: 15

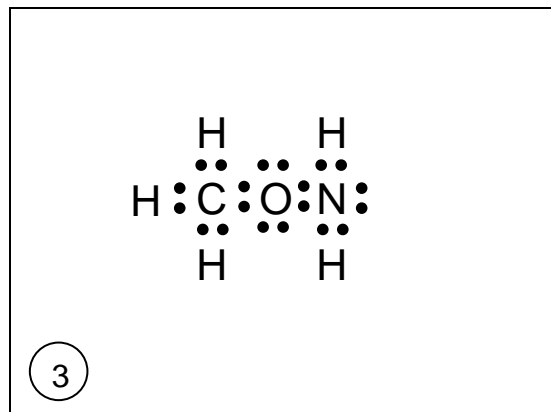


1. (9 pts) **Draw Lewis dot structures** for each of the molecules below. Draw all valence electrons as dots. If there are formal charges, draw them on the appropriate atoms.

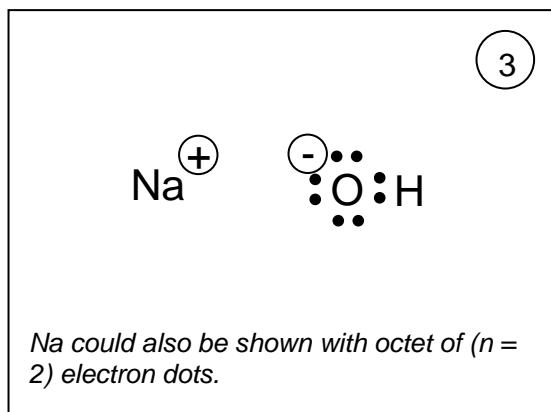
(a) acetonitrile, CH_3CN



(b) methoxyamine, CH_3ONH_2



(c) sodium hydroxide, NaOH



Rubric:

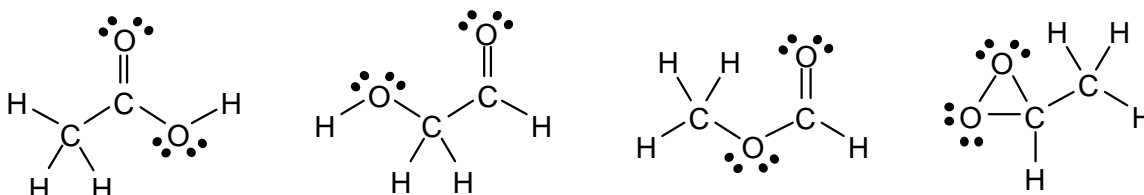
3 points each box.

-1 point for each missing or incorrectly assigned charge or electron pair.

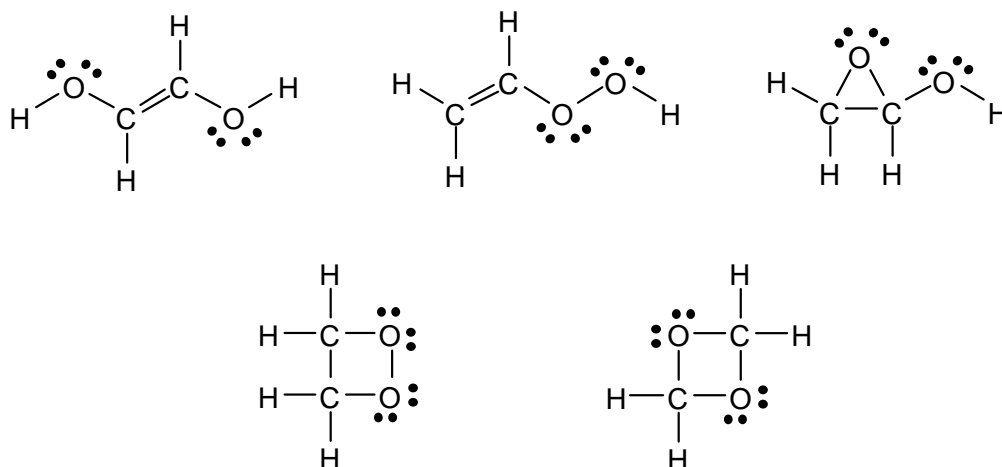
1 point partial for drawing bonds as lines instead of dots.

2. (6 pts) **Draw Lewis dash-bond structures** for two constitutional isomers that have molecular formula $C_2H_4O_2$, and that have **no formal charges** on any atom. Draw all atoms and lone pairs of electrons.

Holy buckets there were a bunch of possible answers to this problem. They all have something in common though—all of the answers either have one double bond or one cycle. Some stable versions include:



Some structures a chemist wouldn't ordinarily see (but you wouldn't know this, so they are perfectly acceptable as answers to this problem):



Rubric:

3 points each correct structure.

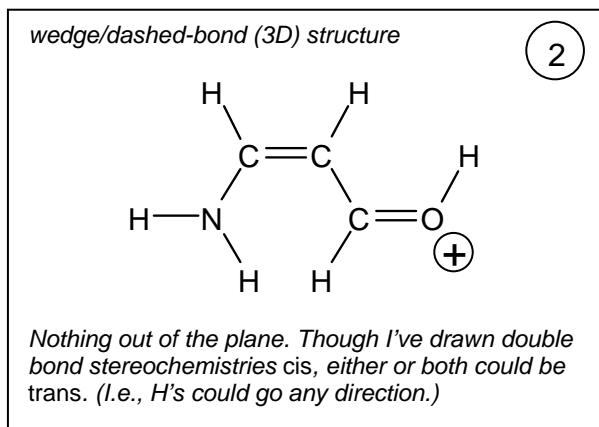
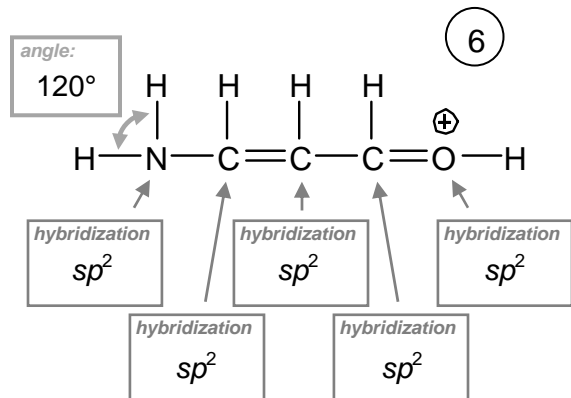
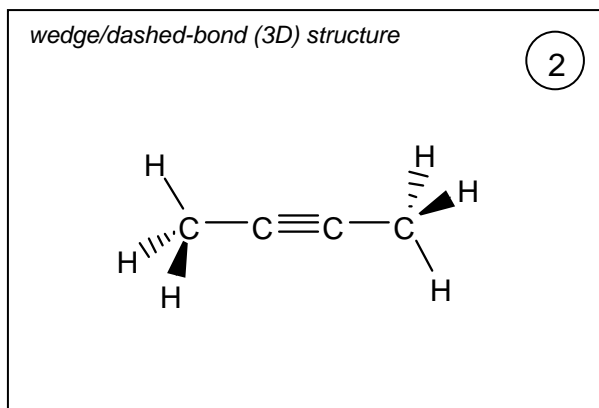
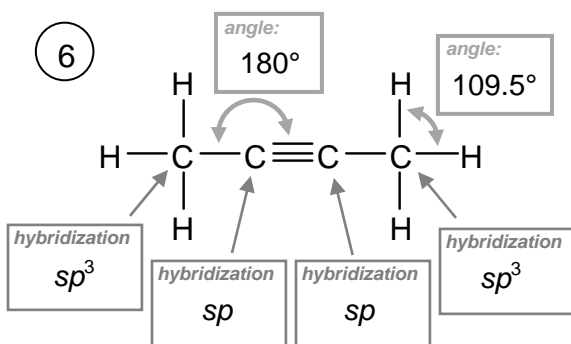
-1 point for each missing electron pair, dot, or bond.

Structures that have formal charges, or that should have formal charges, receive no credit.

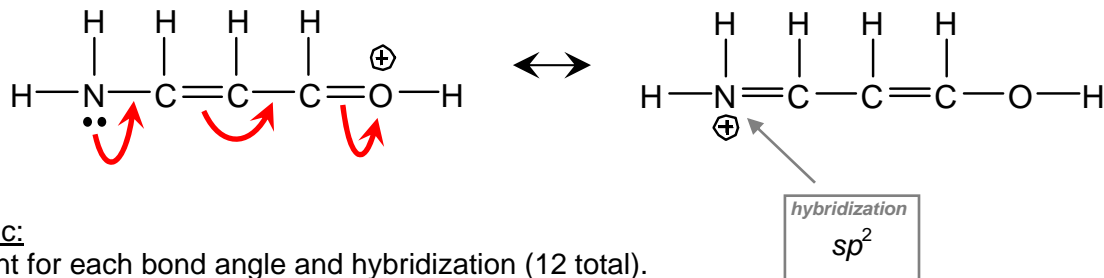
1 point partial for drawing a structure with incorrect molecular formula (say, C_2H_4O), but otherwise completely correct (and with no formal charges).

If you drew same structure twice (e.g., as resonance structures), or you drew stereoisomers instead of constitutional isomers, we gave you credit for one but not the other.

3. (16 pts) For each of the Lewis structures drawn below, in the boxes provided:
- Draw Lewis wedge/dashed-bond structures that illustrate the three-dimensional structure of the molecule. Draw all atoms, but feel free to omit lone pairs.
 - In the boxes provided, write the hybridization state for any atom heavier than hydrogen.
 - In the boxes provided, give any bond angle indicated by curved arrows in the original Lewis structure.



On the second structure, the left-most nitrogen is sp^2 -hybridized because its lone pair participates in resonance:



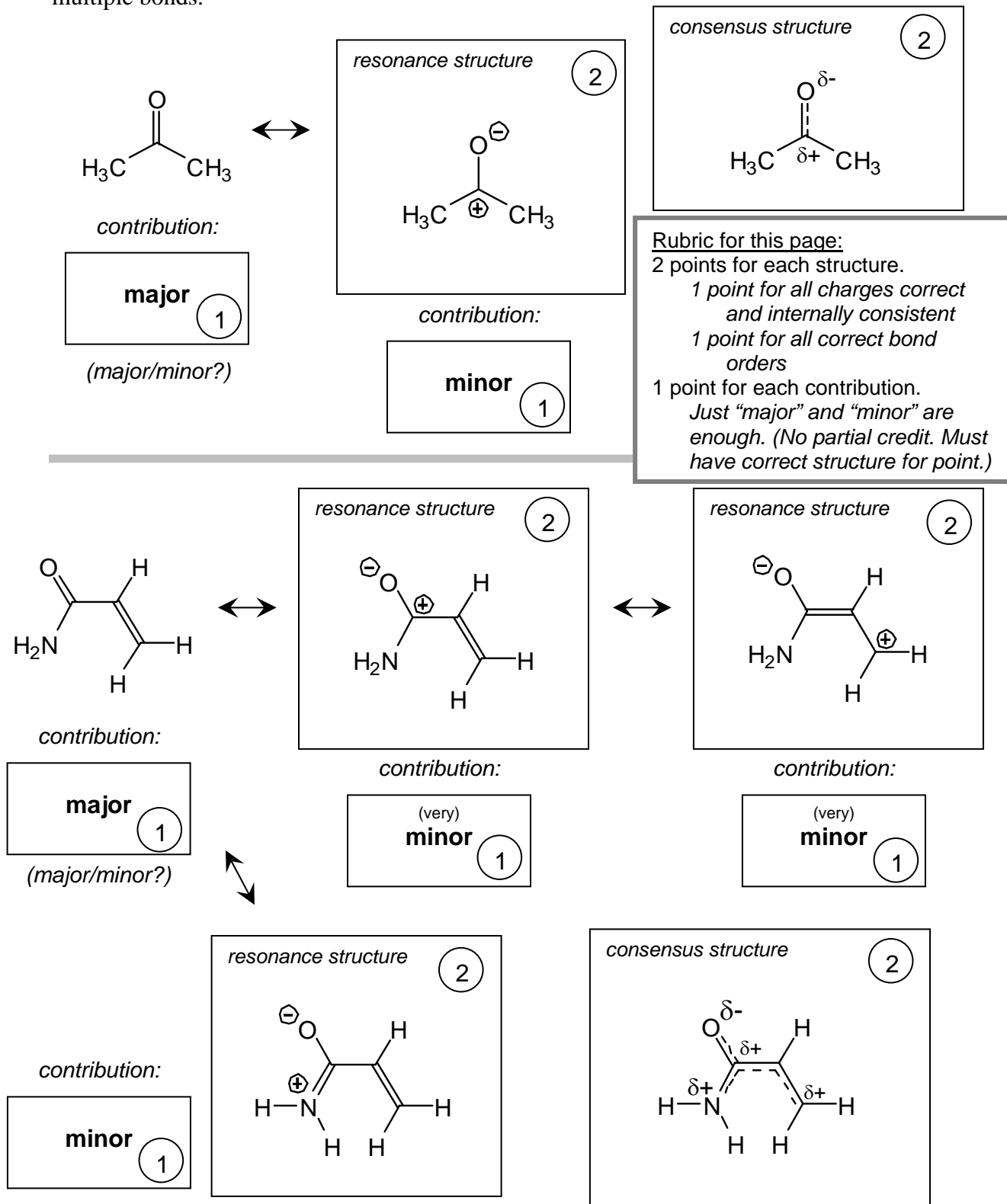
Rubric:

1 point for each bond angle and hybridization (12 total).

2 points for each 3-D structure (4 total).

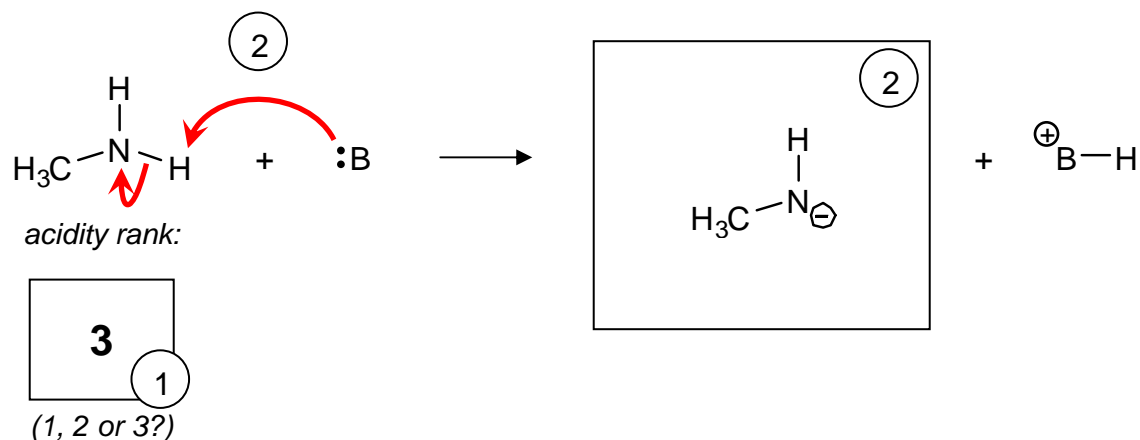
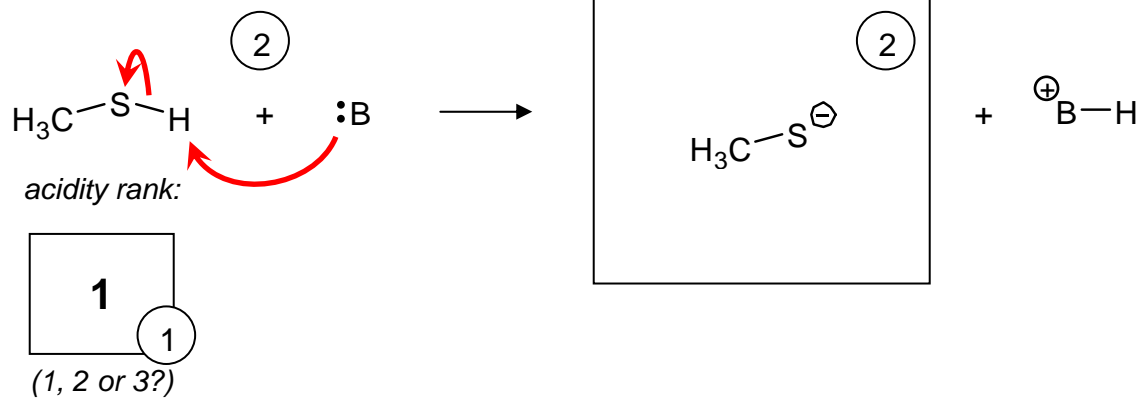
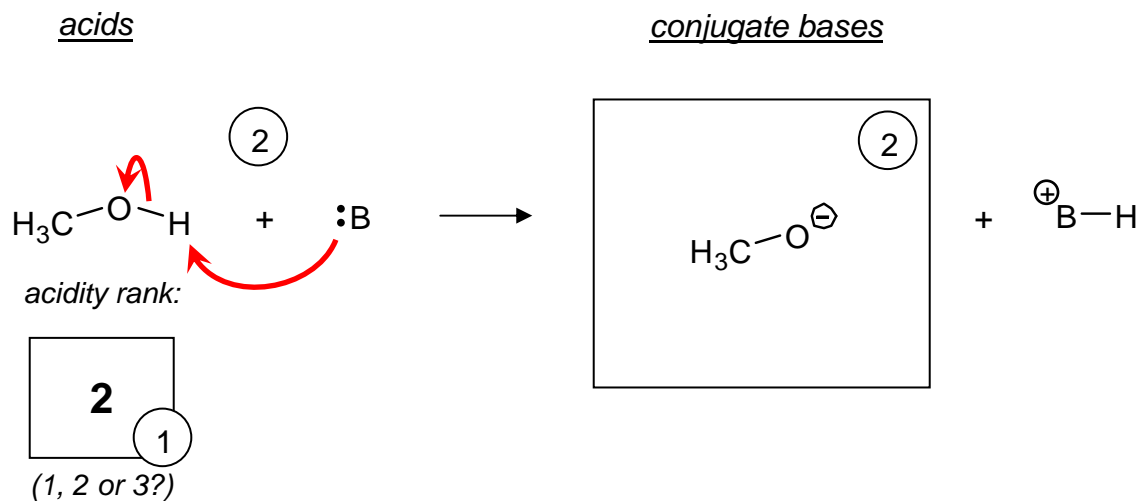
-1 for each incorrect center (up to 2).

4. (18 pts) For each of the molecules on the left, draw as many Lewis dash-bond resonance structures as there are boxes. (Feel free to omit lone pairs and C-H's, or draw them—your choice.) Then, below each resonance structure, describe whether each would be a major or minor contributor. Finally, draw a consensus structure that illustrates partial charges and multiple bonds.



5. (15 pts) For each of the acid-base reactions below:

- Using “electron pushing” (with double-barbed arrows), show how each acid on the left would react with a generic base “B:”.
- In the box on the right, draw the conjugate base product of each reaction.
- Rank the acids in terms of acidity, from “1” for the most acidic to “3” for the least acidic.



Why are the rankings the way they are? The acidity of all three acids is determined by the relative stabilities of charged species in the acid-base reaction—in this case, by the relative stabilities of the anionic conjugate bases. (All of the cationic conjugate acids are the same, “ BH^+ ”, so that doesn’t generate a difference we can judge.) Looking at the first two anions, one places a negative charge on oxygen, and the other places the charge on sulfur. Oxygen is indeed more electronegative than sulfur, so we might expect it to accommodate the charge better. BUT, we said in class that differences between charged atoms in a group (on the periodic table, between atoms in the same vertical column) are frequently determined more by size than by electronegativity. Sulfur is larger than oxygen, and as a result the charge is distributed over a larger volume/surface than it is on smaller oxygen. This stabilizes the charge on sulfur relative to oxygen. So, we’d expect CH_3S^- to be a more stable conjugate base than CH_3O^- , and therefore that CH_3SH would be a stronger acid than CH_3OH .

Nitrogen and oxygen are in the same period, so there’s no real size difference between them, but oxygen is more electronegative than nitrogen. So we’d expect CH_3O^- to be a more stable conjugate base than CH_3NH^- , and for CH_3OH to be a stronger acid than CH_3NH_2 .

Rubric: For each acid-base reaction,

2 points for electron pushing (one point each curved arrow).

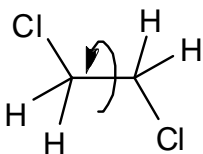
1 point total for the set of 2 arrows if you drew the lines in the correct place, but arrow heads were incorrect.

1 point for rank. *No partial credit.*

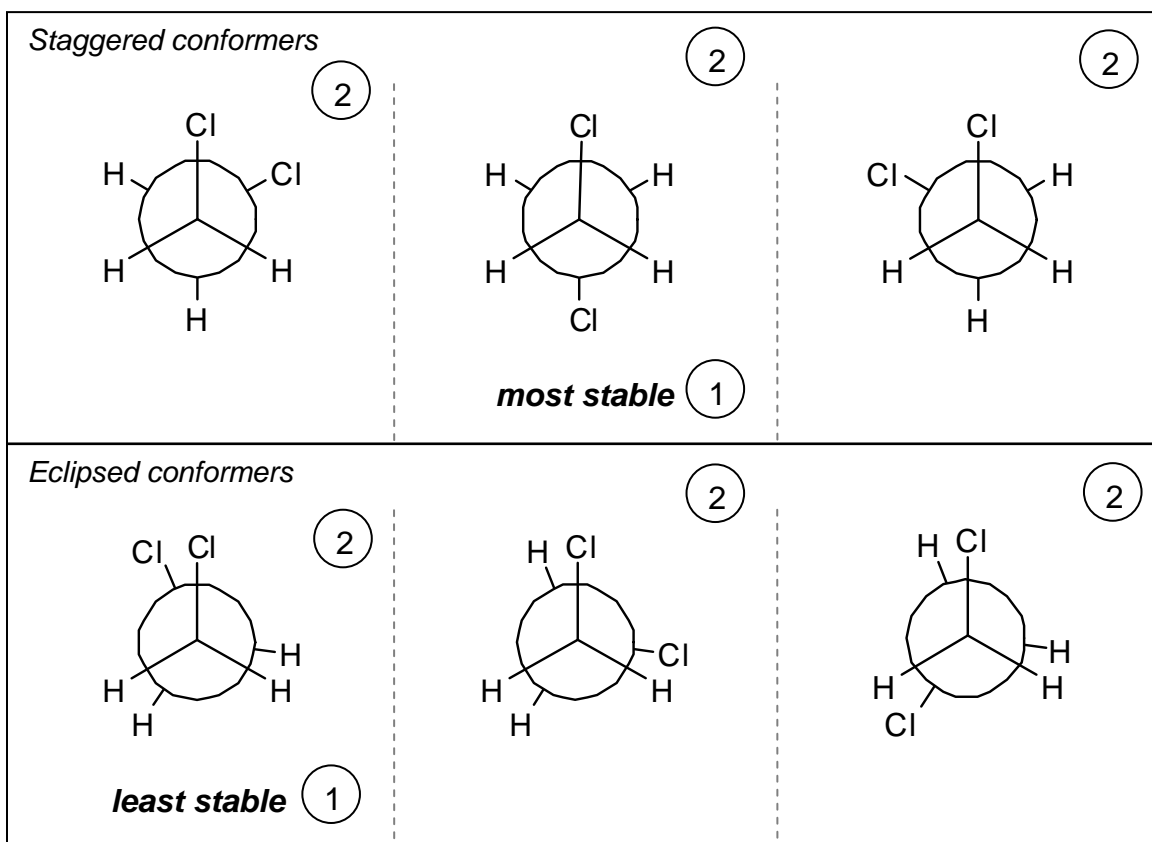
2 points for structure of conjugate base.

-1 point for each missing charge or atom.

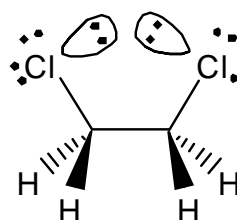
6. (22 pts) For the molecule 1,2-dichloroethane (below):



- (a) Draw Newman projections for the six conformers—three staggered and three eclipsed—accessed by rotation of the central C-C bond.
- (b) Label which conformer you would expect to be most stable, and which you would expect to be least stable. If there are multiple conformations that are equally most or least stable, label them all.



Electron-pair repulsion between lone pairs on the two chlorine atoms cause the chlorines to avoid each other. As a result, the totally eclipsed and gauche conformations are higher in energy than the anti- and simple eclipsed conformations (just as was true for butane).



Rubric for (a/b):

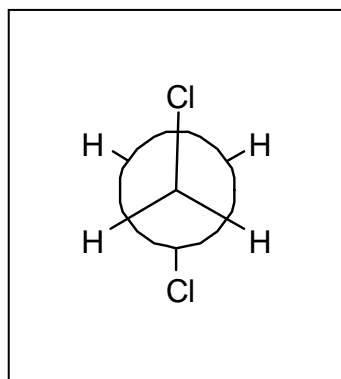
2 points for each conformer. *No partial credit.*

Two of the staggered conformers and two of the eclipsed conformers are mirror images of each other. They have identical characteristics, but they are technically not the same. You need to draw each one. If, instead of drawing the two, you draw the same one twice, you get 2 points for one of them and not the other.

1 point for each assignment of most/least stable. Must be exactly correct.

- (c) Different conformations can contribute different polarities to the overall, average polarity of a molecule. In the boxes below, re-draw two of your most stable (and thus most prevalent) Newman projections from the previous page. Then, circle whether the molecule is polar or non-polar when it is in that conformation. If you circle "polar", also draw a dipole arrow (\rightarrow) that shows the total dipole moment for that conformer.

When the molecule is in this conformation



it is
(circle one)

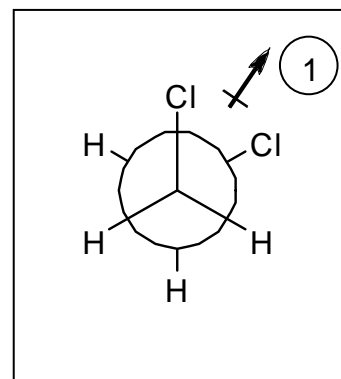
POLAR

or

NON-POLAR

2

When the molecule is in this conformation



it is

POLAR

or

NON-POLAR

1

Only one conformer is non-polar: the anti-conformer. All others are polar. Our grading on this problem was independent of what conformer you chose—we didn't grade you on what you drew in the box. (So, if you chose eclipsed conformers instead of the more stable staggered ones, well, you could still get full credit.)

Rubric for (c): For each conformer,

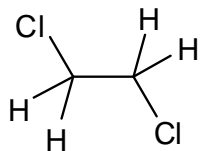
2 points for circling "non-polar", if drawn conformer is anti.

If drawn conformer is not anti,

1 point for circling "polar",

1 point for drawing dipole arrow in average direction of two chlorine atoms.

(d) Would you say that 1,2-dichloroethane should be more or less polar than, or equally polar compared to, *trans*-1,2-dichloroethene? (Circle one answer.) Then, *briefly* explain why.



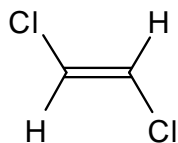
should be

2

**MORE
POLAR**
than

**LESS
POLAR**
than

**EQUALLY
POLAR**
compared to



Why?

Dichloroethane is **sometimes** in a conformation that makes it polar.

But the central C=C bond of dichloroethene doesn't rotate, so it is **never** in a conformation that makes it polar.

So, we'd expect dichloroethane to be more polar than dichloroethene.

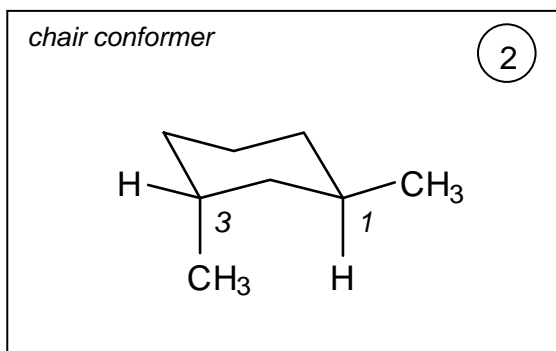
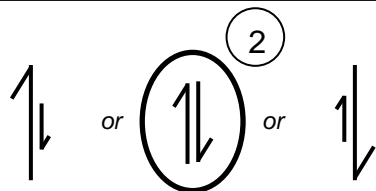
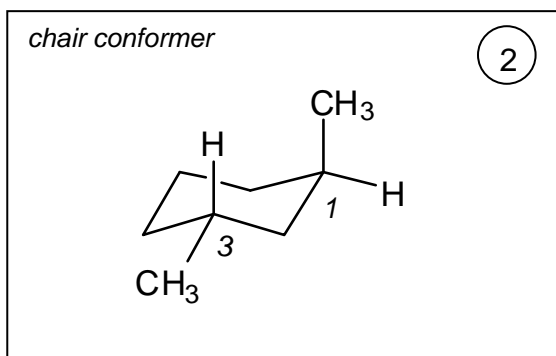
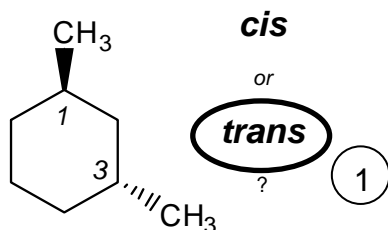
2

Rubric for (d):

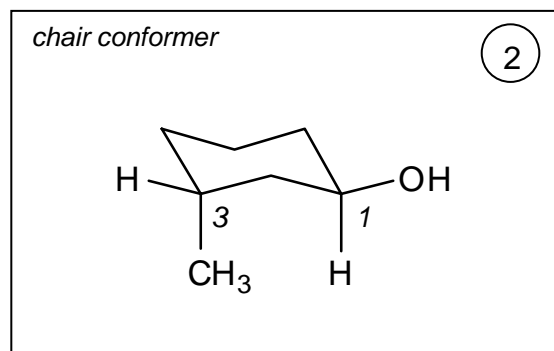
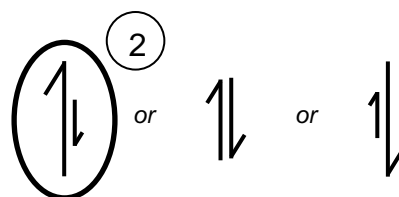
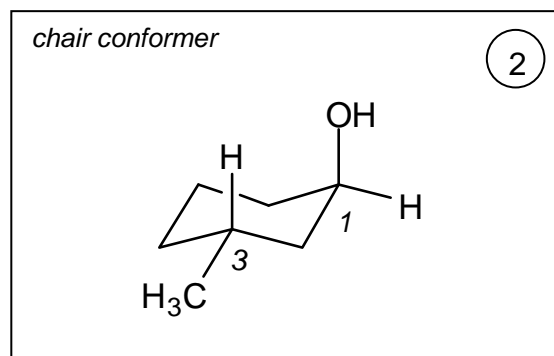
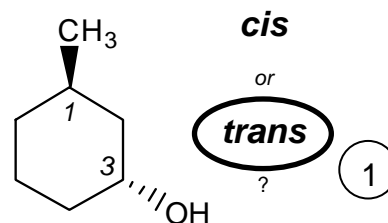
2 points for circling "more polar". *No partial credit.*

2 points for explanation. Latitude on these two points is given to the grader—we did not create a point-by-point rubric for this question.

7. (14 pts) For each of the 1,3-disubstituted cyclohexanes below,
- Circle whether you would call the substitution pattern “*cis*” or “*trans*”.
 - Draw two chair conformations that interconvert via chair flipping. On your chairs, label carbons 1 and 3 with the appropriate numbers.
 - Circle one of the three equilibrium arrows to indicate which conformation would be more stable, or to indicate they are equally stable.



Each chair has one equatorial and one axial methyl group. So, they have equal energy, and neither should be favored over the other.



-OH is less sterically demanding than -CH₃. So, the chair that puts the -CH₃ in the equatorial position should be more stable, and the equilibrium should favor that chair.

Rubric:

1 point for each circled "trans".

2 points for each conformer structure.

1 point for drawing a chair.

1 point for drawing one axial substituent, and then one equatorial substituent two carbons away.

You only get this second point if you got the first one (if chair is correctly drawn).

If you draw same substitution pattern twice, you only get the point for one of them.

2 points for each circled equilibrium arrow.

You can only get these points if both chairs are correct. (I.e., if we can make sense of what the equilibrium arrow is referring to.)