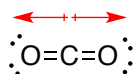


Question 1.

a) Draw a Lewis structure for the molecule CO₂.



b) Add dipole arrows above, showing all polar bonds.

c) Is CO₂ a polar molecule? Yes / **No** (circle your answer)

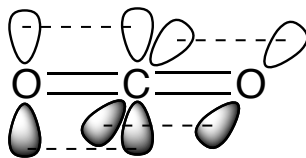
d) What is the hybridization state of the carbon atom in CO₂?

sp

e) Draw a picture that clearly represents the interacting orbitals of all the sigma bonds.

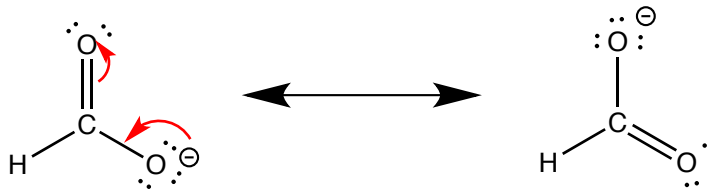


f) Draw a picture that clearly represents the interacting orbitals of all the pi bonds.



Question 2.

a) On the template below, draw two valid Lewis structures for the formate anion (HCO_2^-). Make sure to add all lone pairs and identify any non-zero formal charges.



b) Add curved arrows to the structure on the left (above) showing how it can be converted into the structure on the right.

c) What is the hybridization state of the carbon atom in formate?

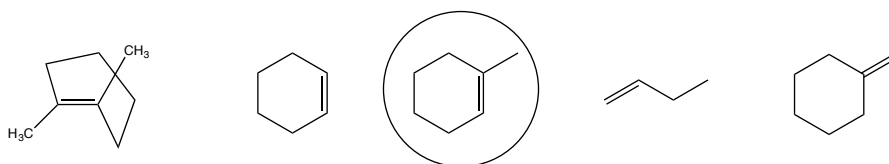


d) Is the formate anion polar? **Yes** / No (circle your answer)

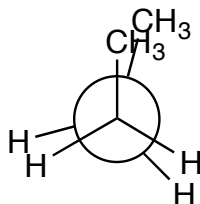
In the space below, briefly explain your answer.

The (large) bond dipoles of the C–O bonds do not fully oppose each other (120° angle between them, not 180°). Thus the molecule cannot fully cancel all the bond dipoles and is polar.

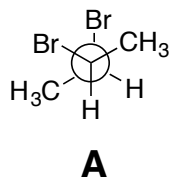
Question 3. Circle the structure with the most stable pi bond:



Question 4. Using a Newman projection, draw butane in the eclipsed conformation as viewed down the $\text{C}_2\text{-C}_3$ bond axis.

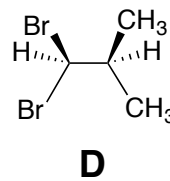
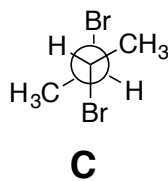
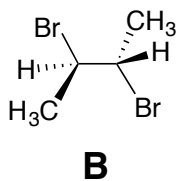


Question 5. Consider the isomer of dibromobutane shown in the Newman projection **A** below.



a) Three isomers of dibromobutane are shown (structures **B-D**). Compare each structure to Newman projection **A**, and describe the relationship of **B-D** as either: structural isomers, conformational isomers, enantiomers, or diastereomers.

Note that conformational isomers must be able to interconvert by single bond rotations.



Relationship between:

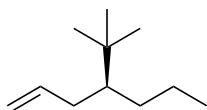
A and B: Diastereomers

A and C: Diastereomers

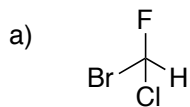
A and D: Structural Isomers

b) For structures **B-D**, circle any that are chiral. (*None are chiral!*)

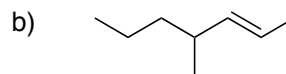
Question 6. Draw (*S*)-4-*tert*-butyl-1-heptene



Question 7. Identify the number of stereoisomers for each of the following compounds.



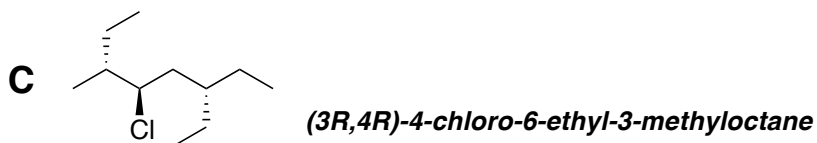
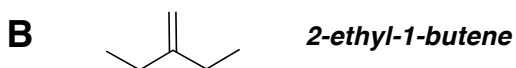
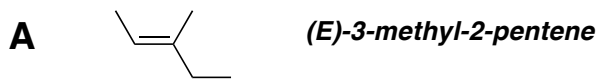
2



4

Question 8.

a) Provide the IUPAC name for each of the following compounds **A-C**:



b) How many signals will appear in the ^1H NMR spectrum of **A** (*in other words, how many hydrogen atom environment/types*)?

5 signals

c) How many signals will appear in the ^1H NMR spectrum of **B** (*in other words, how many hydrogen atom environment/types*)?

3 signals

Question 9. Circle 'soluble' or 'insoluble' to make the following statement accurate:

When performing a recrystallization, the compound that you wish to isolate as a solid crystal should be [**soluble/insoluble**] in the boiling solvent of your choice, and [**soluble/insoluble**] in that solvent when cooled.

Question 10. When separating two compounds X and Y by thin layer chromatography (TLC) with hexanes as the mobile phase, you find that compound X has an R_f of 0.8 and compound Y has an R_f of 0.1.

a) Which compound is more polar? X / Y (circle your answer)

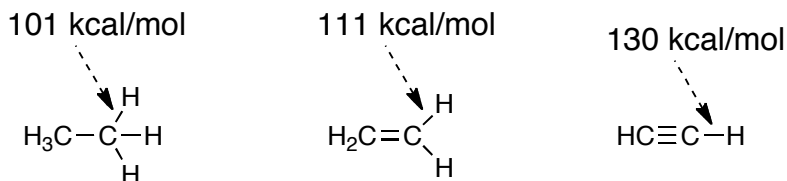
b) Would you expect the R_f of compound Y to be greater in ethyl acetate than in hexanes?

Yes / No (circle your answer)

Give a brief explanation for your answer below:

Ethyl acetate is a more polar solvent than hexanes. Using a more polar eluent will cause all species to travel more rapidly through silica gel, thus increasing the R_f of both X and Y.

Extra Credit. [finish the rest of the test first!] Although the *average* C–H bond dissociation energy (BDE) is about 100 kcal/mol, some trends emerge when we compare specific compounds. Give a clear and complete explanation for the following trend in BDE's for the C–H bonds of ethane, ethylene, and acetylene:



Better orbital overlap will result in a stronger bond from the standpoint of homolytic cleavage (*not* the same as heterolytic cleavage, which has exactly the opposite trend!). The hydrogen $1s$ orbital has better orbital overlap with more spherical orbitals, such as sp -hybrids (50% S) and overlaps more poorly with elongated orbitals, such as sp^3 -hybrids (25% S). The sp -hybrid is also lower in energy, closest in energy to the hydrogen $1s$, and the opposite is true for the sp^3 -hybrid (highest energy, farthest in energy from the hydrogen $1s$). The overlap of orbitals with similar sizes, shapes, and energies give the strongest bonds.

