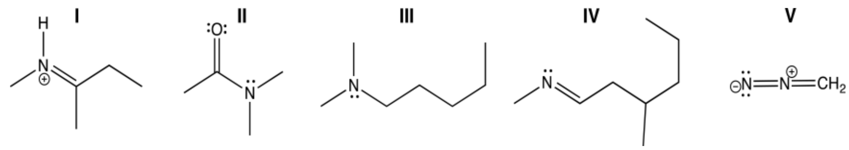
ESC OrgChem I - Practice exam 1

Multiple Choice
Identify the choice that best completes the statement or answers the question.

____ 1. How many valence electrons are assigned to oxygen when determining formal charge in the ionic compound sodium methoxide, $NaOCH_3$?
a. 4
b. 5
c. 6
d. 7
e. 8

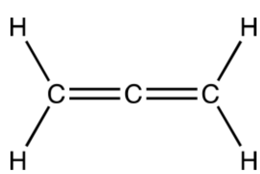
____ 2. Which of the following molecules contains a nitrogen atom with linear geometry?



a. I
b. II
c. III
d. IV
e. V

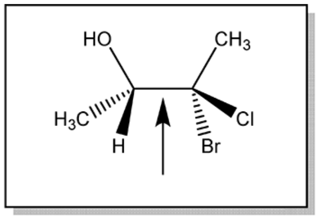
____ 3. What is the strongest intermolecular attractive force between an alcohol and a ketone?
a. hydrogen bond
b. ion–dipole
c. ion–ion
d. dipole-induced dipole
e. induced dipole–induced dipole

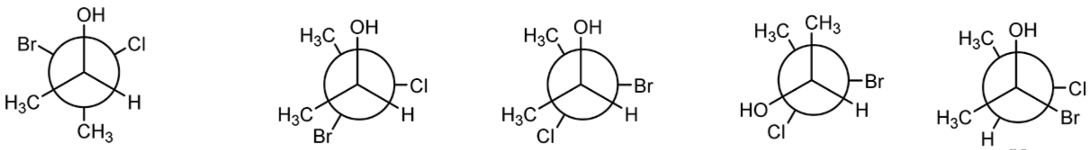
____ 4. From left to right, identify the hybridization of the three carbon atoms in the following interesting organic structure. These structures are called cumulenes.



a. sp^3, sp^2, sp^3
b. sp^3, sp, sp^3
c. sp^2, sp, sp^2
d. sp, sp, sp^2
e. sp^2, sp^2, sp^2

____ 5. The Newman projection looking down the indicated bond in the following species is best represented by which of the following (I, II, III, IV, or V)?

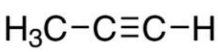




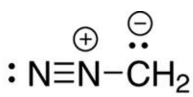
I II III IV V

a. I
b. II
c. III
d. IV
e. V

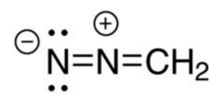
____ 6. Which of the following Lewis structures violates the octet rule and is therefore incorrect?



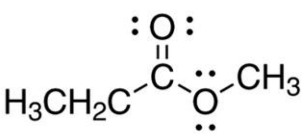
I



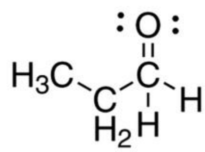
II



III



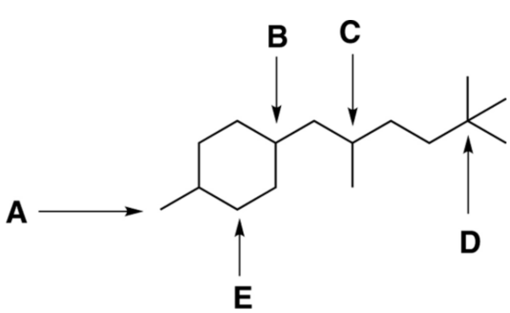
IV



V

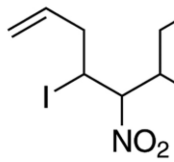
a. Structure I
b. Structure II
c. Structure III
d. Structure IV
e. Structure V

____ 7. Which of the labeled carbon atoms can be classified as a 2° carbon?



a. A
b. B
c. C
d. D
e. E

____ 8. What is the IUPAC name for the following molecule?

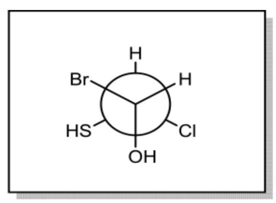


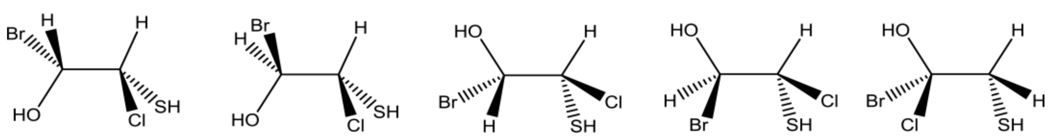
a. 2-ethyl-3-nito-4-iodohep-6-ene
b. 2-ethyl-4-iodo-3-nitohep-6-ene
c. 6-ethyl-4-iodo-5-nitrohept-1-ene
d. 6-ethyl-4-iodo-5-nitrohept-1-ene
e. 4-iodo-6-methyl-5-nitrooct-1-ene

____ 9. Which of the following α–amino acids possesses two hydrogen atoms adjacent to the carboxylic acid?

a. serine
b. phenylalanine
c. glycine
d. tryptophan
e. lysine

____ 10. Which of the following dash–wedge structures best represents the following Newman projection?

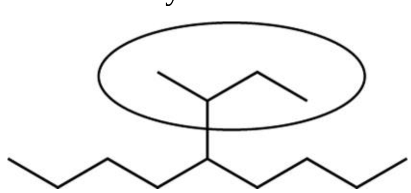




I II III IV V

a. I
b. II
c. III
d. IV
e. V

____ 11. What is the trivial name for the circled alkyl substituent?



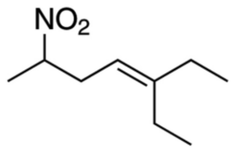
a. *n*-butyl
b. 2-butyl
c. *sec*-butyl
d. *tert*-butyl
e. isobutyl

____ 12. An alkene contains a double bond. Why is the C=C of an alkene rigid and unable to freely rotate?

a. The C=C bond is very strong, and it is impossible to break it.
b. The σ bond becomes blocked by the hydrogen atoms.

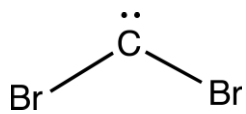
c. The sp^2 hybrid orbitals of carbon take up too much room.
d. The π electrons are delocalized through the σ bonds.
e. The 2*p* orbitals of the π bond overlap above and below the C—C plane to restrict rotation.

____ 13. What is the IUPAC name for the following molecule?



a. 2-nitro-5-ethylhept-4-ene
b. 5-ethyl-2-nitrohept-4-ene
c. 3-ethyl-6-nitrohept-3-ene
d. 6-nitro-3-ethylhept-3-ene
e. 5-ethyl-2-nitrooct-4-ene

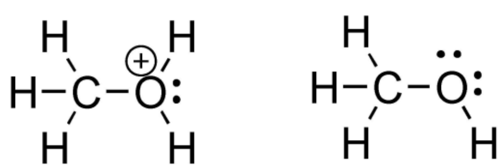
____ 14. Consider the interesting structure below, called a dibromocarbene. The carbon of the dibromocarbene has one lone electron pair and two separate covalent bonds to individual bromine atoms. What is the formal charge on the carbon atom of the dibromocarbene?



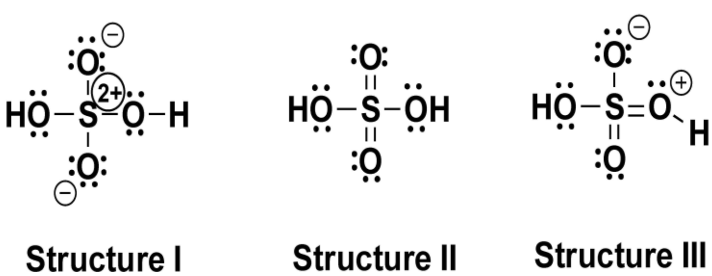
a. +2
b. +1
c. 0
d. –1
e. –2

Short Answer

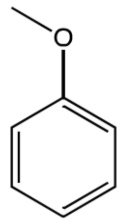
1. Oxygen is an important heteroatom found in many organic molecules. Consider methanol and its protonated derivative, shown below. How does an oxygen with a positive charge, called an oxonium species, influence the magnitude of the partial positive charge on the carbon atom? Which oxygen–carbon bond do you think is more difficult to break? Explain.



2. Are the following Lewis structures for sulfuric acid related as resonance structures? Explain.



3. Draw all possible resonance forms for anisole using appropriate arrow notation. Which resonance structure is most stable? Which is least stable? Draw the resonance hybrid for anisole, indicating all partial charges.



4. Add substituents using dash–wedge notation to achieve the structure specified.
   a. An alkene that has a fluorine atom pointing back on the leftmost carbon and a methyl group coming out on the rightmost carbon. Assume that hydrogen fills the valence of carbon.
   b. A tetrahedral carbon with two chlorine atoms pointing down on the plane of the paper, a bromine atom pointing out, and a hydrogen atom pointing back.

5. The solvent *tert*-butyl methyl ether (MTBE) is used as a "greener" replacement for the organic solvent diethyl ether, because it has less propensity to form peroxides upon standing. Draw the line structures of both diethyl ether and MTBE. Look up the physical properties (boiling point and flash point) of both solvents. Explain why the boiling point of diethyl ether is lower.

6. (a) Group I cations are common ions found in organic salts. Write the electron configuration for the Group I cations below. In the fourth column, use circles to represent the relative size of each cation conceptually. Define the term ionic radius and label the ionic radius of each cation.

Cation	**Electron configuration of cation**	**Ionic radius (nanometer)**	**Draw schematic of cation, and label ionic radius**	**Calculate ionic diameter (picometer [pm])**
K^+		0.138 nm		
Na^+		0.102 nm		
Li^+		0.076 nm		

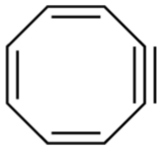
(b) Organic molecules called crown ethers (refer to the box titled "Phase Transfer Catalysts" in Chapter 2 of your text) can sequester a cation of specific size to make the organic anion more reactive. Charles Pedersen, in fact, shared the 1987 Nobel Prize in Chemistry for contributions to the synthesis of crown ethers. Suppose you wanted to use a crown ether to selectively remove each individual cation from a solution of sodium, lithium, and potassium. For each cation, which crown ether might you add?

Select cation (Na^+, K^+, Li^+)	**Crown ether cavity diameter (picometer [pm])**	**Crown ether**
	260–320 pm	18-crown-6
	170–220 pm	15-crown-5
	120–140 pm	12-crown-4

7. Draw line structures of a molecule with the formula C_4H_6O that has the characteristics outlined in (a), (b), and (c).
   (a) two *sp*-hybridized carbon atoms, a methyl group, and a primary alcohol
   (b) an epoxide and one carbon–carbon bond formed from the overlap of 2*p* orbitals

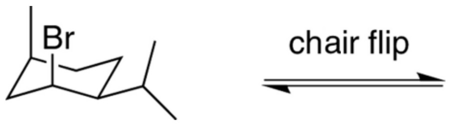
(c) a cyclopropane ring connected to only one substituent via a σ bond, which was formed from the overlap of one Csp^3 and one Csp^2 orbital.

8. How many total electrons reside in MOs of π symmetry in the following molecule?

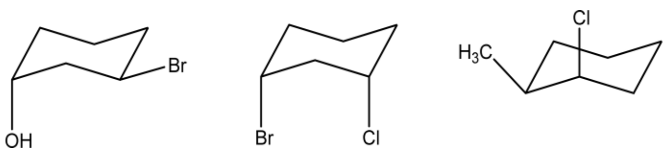


9. Draw the most stable Newman projection for 1-iodobutane looking down the C1—C2 bond.

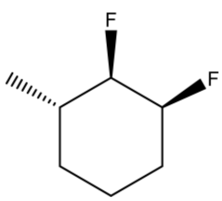
10. Draw the following molecule after it undergoes a chair flip.



11. Label each of the following molecules as cis or trans.



12. Draw a Haworth projection for the following trisubstituted cyclohexane



13. A molecule has two rings, three double bonds, and two triple bonds. How many IHD units does this molecule have?

14. Draw all alkyne-containing isomers of C_5H_8.

ESC OrgChem I - Practice exam 1
Answer Section

MULTIPLE CHOICE

1. ANS: D PTS: 1 DIF: Easy REF: 1.3 | 1.9
   OBJ: Determine the number of valence and/or core electrons for an atom or ion.
   MSC: Analyzing
2. ANS: E PTS: 1 DIF: Moderate REF: 2.1
   OBJ: Determine an atom’s molecular geometry. MSC: Applying
3. ANS: A PTS: 1 DIF: Moderate REF: 2.6
   OBJ: Identify the relative strength of the common intermolecular forces as they apply to organic molecules.
   MSC: Analyzing
4. ANS: C PTS: 1 DIF: Moderate REF: 3.8
   OBJ: Determine atomic hybridization. MSC: Applying
5. ANS: B PTS: 1 DIF: Moderate REF: 4.2
   OBJ: Convert dash–wedge drawings to Newman projections. MSC: Applying
6. ANS: E PTS: 1 DIF: Moderate REF: 1.5
   OBJ: Assess the validity of a Lewis structure. MSC: Analyzing
7. ANS: E PTS: 1 DIF: Easy REF: A.7
   OBJ: Classify carbon types.MSC: Remembering
8. ANS: E PTS: 1 DIF: Moderate REF: B.1
   OBJ: Name alkenes using IUPAC nomenclature. MSC: Analyzing
9. ANS: C PTS: 1 DIF: Easy REF: 1.14
   OBJ: Identify the key structural features of amino acids, saccharides, and nucleotides.
   MSC: Remembering
10. ANS: A PTS: 1 DIF: Moderate REF: 4.2
    OBJ: Convert Newman projections to dash–wedge drawings. MSC: Analyzing
11. ANS: C PTS: 1 DIF: Easy REF: A.7
    OBJ: Identify and name trivial alkyl groups. MSC: Remembering
12. ANS: E PTS: 1 DIF: Moderate REF: 3.9
    OBJ: Explain why double and triple bonds are unable to freely rotate.
    MSC: Understanding
13. ANS: C PTS: 1 DIF: Easy REF: B.1
    OBJ: Name alkenes using IUPAC nomenclature. MSC: Analyzing
14. ANS: C PTS: 1 DIF: Easy REF: 1.9
    OBJ: Apply knowledge of chemical structure to determine the formal charge of an unknown species.
    MSC: Understanding

SHORT ANSWER

1. ANS:
   The C–O bond in the oxonium species would have the greatest bond dipole. Consequently, this bond would be weaker and easier to break than the C–O bond of methanol.

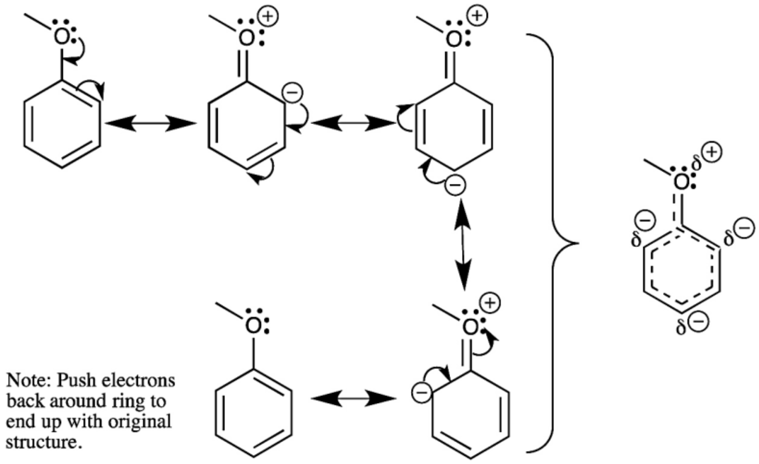
   PTS: 1 DIF: Difficult REF: 1.4 | 1.5 | 1.9
   OBJ: Predict the properties of a covalent bond based on known periodic trends, and vice versa.

MSC: Evaluating

2. ANS:
Yes, they are all resonance structures. The structures differ in the position of lone pairs and π bonds. Atoms are in the same position and no sigma bonds have been broken. The structures have different potential energies due to structural and electrostatic differences.

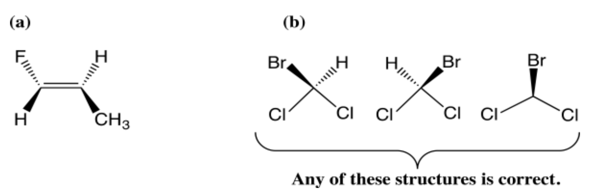
PTS: 1 DIF: Moderate REF: 1.5 | 1.9 | 1.10
OBJ: Compare a series of structures to determine if they are resonance structures.
MSC: Analyzing

3. ANS:
The neutral structure is most stable. The two structures with the partial negative charge closest to the oxygen are equal in energy. These structures are also more stable than the structure with the charges farther apart; thus, they contribute a greater degree to the hybrid.



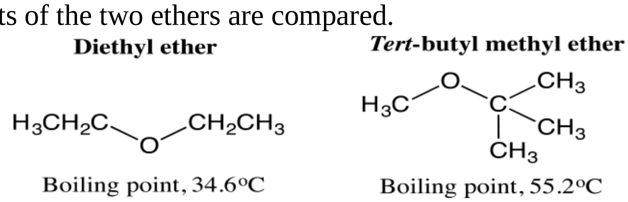
PTS: 1 DIF: Moderate REF: 1.9 | 1.10
OBJ: Deduce and draw the resonance structures that contribute to the resonance hybrid, and vice versa.
MSC: Creating

4. ANS:



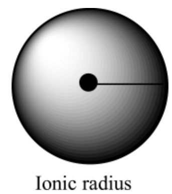
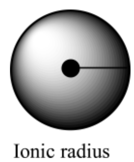
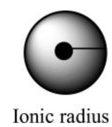
PTS: 1 DIF: Moderate REF: 2.2
OBJ: Correctly depict the three-dimensional structure of a molecule using dash–wedge notation.
MSC: Creating

5. ANS:
Diethyl ether has a smaller molecular weight and thus fewer intermolecular attractive forces when equal amounts of the two ethers are compared.



PTS: 1 DIF: Easy REF: 2.6
OBJ: Identify the relative strength of the common intermolecular forces as they apply to organic molecules.
MSC: Understanding

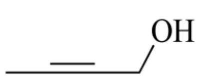
6. ANS:

Cation	**Electron configuration of cation**	**Ionic radius (picometer [pm])**	**Draw schematic of cation, and label ionic radius**	**Calculate ionic diameter (picometer [pm])**
K^+	$1s^22s^22p^63s^23p^6$	138 pm		276 pm
Na^+	$1s^22s^22p^6$	102 pm		204 pm
Li^+	$1s^2$	70 pm		140 pm

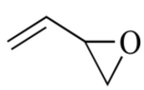
Select cation (Na^+, K^+, Li^+)	**Crown ether cavity diameter (picometer [pm])**	**Crown ether**
K^+	260–320 pm	18-crown-6
Na^+	170–220 pm	15-crown-5
Li^+	120–140 pm	12-crown-4

PTS: 1 DIF: Difficult REF: 2.9
OBJ: Evaluate the solvation of an ion or molecule by a protic or an aprotic solvent.
MSC: Evaluating

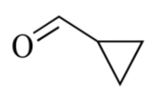
7. ANS:

(a)


Chemical formula
C_4H_6O

(b)


Chemical formula
C_4H_6O

(c)


Chemical formula
C_4H_6O

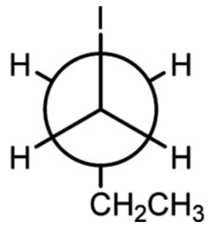
PTS: 1 DIF: Moderate REF: 3.4 OBJ: Determine atomic hybridization.
MSC: Creating

8. ANS:

10 electrons.

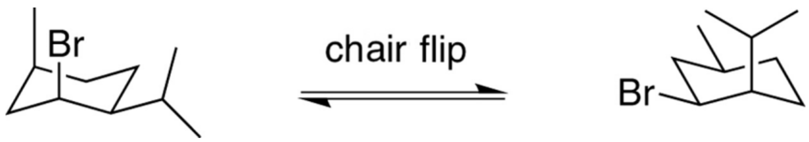
PTS: 1 DIF: Difficult REF: 3.8 OBJ: Map electrons to molecular orbitals.
MSC: Understanding

9. ANS:



PTS: 1 DIF: Moderate REF: 4.3
OBJ: Identify which Newman projection conformations are the most/least stable.
MSC: Analyzing

10. ANS:

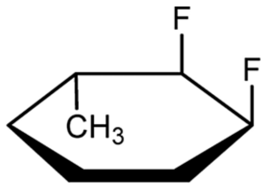


PTS: 1 DIF: Easy REF: 4.6
OBJ: Complete chair flips on a substituted cyclohexane ring. MSC: Understanding

11. ANS:
Trans, cis, cis

PTS: 1 DIF: Moderate REF: 4.9
OBJ: Identify the cis–trans relationships on substituted cyclohexanes.
MSC: Understanding

12. ANS:

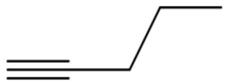


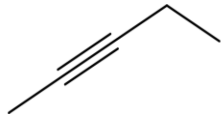
PTS: 1 DIF: Difficult REF: 4.9
OBJ: Draw Haworth projections to show cis–trans relationships.
MSC: Applying

13. ANS:
Nine

PTS: 1 DIF: Moderate REF: 4.12
OBJ: Calculate the IHD for a formula or structure. MSC: Analyzing

14. ANS:





PTS: 1 DIF: Easy REF: 4.13
OBJ: Draw all the constitutional isomers for a given formula. MSC: Creating