

Please read and sign the Honor Code statement below:

I pledge that on my honor, as a University of Colorado at Boulder student, I have neither given nor received unauthorized assistance on this exam.

\_\_\_\_\_  
Signature

**General Instructions:** There are 25 questions. Be sure you have them all. Read each question carefully so that you know exactly what is being asked.

Each multiple choice question (1-25) is worth **4 points and has only one correct answer**. Bubble in your answers to these questions on the Scantron provided. Only the Scantron will be graded.

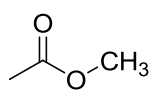
At the end of the exam, turn in your Scantron and this signed cover sheet. You may keep the rest of the exam to check your answers against the key later.

Good luck!

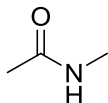
**PERIODIC CHART OF THE ELEMENTS**

IA	IIA	IIIB	IVB	VB	VIB	VIIIB	VIII	IB	IIB	IIIA	IVA	VA	VIA	VIIA	INERT GASES		
1 H 1.00797														1 H 1.00797	2 He 4.0026		
3 Li 6.939	4 Be 9.0122										5 B 10.811	6 C 12.0112	7 N 14.0067	8 O 15.9994	9 F 18.9984	10 Ne 20.183	
11 Na 22.9898	12 Mg 24.312										13 Al 26.9815	14 Si 28.086	15 P 30.9738	16 S 32.064	17 Cl 35.453	18 Ar 39.948	
19 K 39.102	20 Ca 40.08	21 Sc 44.956	22 Ti 47.90	23 V 50.942	24 Cr 51.996	25 Mn 54.9380	26 Fe 55.847	27 Co 58.9332	28 Ni 58.71	29 Cu 63.54	30 Zn 65.37	31 Ga 69.72	32 Ge 72.59	33 As 74.9216	34 Se 78.96	35 Br 79.909	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.905	40 Zr 91.22	41 Nb 92.906	42 Mo 95.94	43 Tc (99)	44 Ru 101.07	45 Rh 102.905	46 Pd 106.4	47 Ag 107.870	48 Cd 112.40	49 In 114.82	50 Sn 118.69	51 Sb 121.75	52 Te 127.60	53 I 126.904	54 Xe 131.30
55 Cs 132.905	56 Ba 137.34	*57 La 138.91	72 Hf 178.49	73 Ta 180.948	74 W 183.85	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.09	79 Au 196.967	80 Hg 200.59	81 Tl 204.37	82 Pb 207.19	83 Bi 208.980	84 Po (210)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	+89 Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (266)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 ? (271)	111 ? (272)	112 ? (277)						

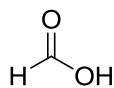
1. Formic acid is the simplest carboxylic acid. Which of these structures is the Lewis structure for formic acid?



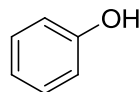
**A**



**B**



**C**



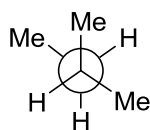
**D**

None of these

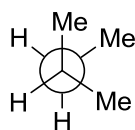
**E**

2. Ethyne (also known as acetylene) is the simplest alkyne, with a formula  $C_2H_2$ . How many  $\sigma$  (sigma) bonds are there in ethyne?

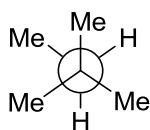
- a. 0  
 b. 1  
 c. 2  
 d. 3  
 e. 4
3. Which of the following is the **least stable staggered conformation** of 2-methylbutane, looking down the C2-C3 bond? (Me = Methyl,  $CH_3$ )



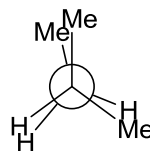
**A**



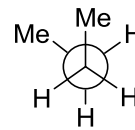
**B**



**C**



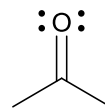
**D**



**E**

Questions 4 and 5 relate to valence bond theory. Valence bond theory describes bonds as overlapping orbitals on adjacent atoms. Each orbital contains one electron, and the sharing of the electrons by the two atoms makes up the bond.

Both question 4 and question 5 involve this structure:



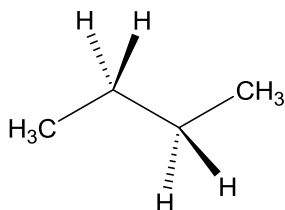
4. What orbitals are overlapping to form the C-O  $\sigma$  bond?

- a.  $p$  on C and  $p$  on O  
 b.  $sp$  on C and  $sp^2$  on O  
 c.  $sp^2$  on C and  $sp^2$  on O  
 d.  $sp^2$  on C and  $p$  on O  
 e.  $p$  on C and  $sp^2$  on O

5. What orbitals are overlapping to form the C-O  $\pi$  bond?

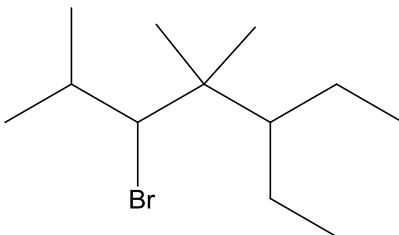
- a.  $p$  on C and  $p$  on O
- b.  $sp$  on C and  $sp^2$  on O
- c.  $sp^2$  on C and  $sp^2$  on O
- d.  $sp^2$  on C and  $p$  on O
- e.  $p$  on C and  $sp^2$  on O

6. What is the torsion angle,  $\theta$ , between the two methyl groups in the structure below (C1 and C4)? (Only consider the conformation shown.)



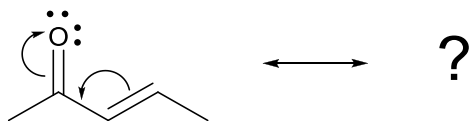
- a.  $0^\circ$
  - b.  $60^\circ$
  - c.  $120^\circ$
  - d.  $180^\circ$
  - e. None of these
7. Still considering the structure in Question 6, what types of strain are present in this structure? (Only consider the conformation shown.)
- a. Torsional strain
  - b. Van der Waals (steric) strain
  - c. Both
  - d. Neither
  - d. None of these choices is correct

8. What is the correct IUPAC (systematic) name for this molecule?

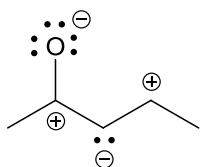


- a. 3-bromo-5-ethyl-2,4,4-trimethylheptane
- b. 2,4,4-trimethyl-3-bromo-5-ethylheptane
- c. 5-bromo-3-ethyl-4,4,6-trimethylheptane
- d. 5-bromo-3-ethyl-4,4,6-methylheptane
- e. None of these

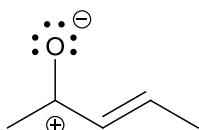
9. The structure below was converted to a new resonance contributor using the curved arrows shown:



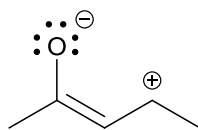
Which of these structures is the correct result of the arrows shown in the picture above?



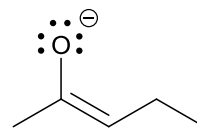
**A**



**B**



**C**



**D**

None of these structures

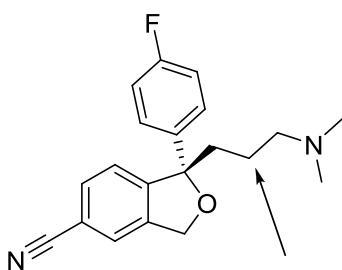
**E**

10. Consider the molecule 1-chloro-3-isopropyl-5-methylcyclohexane. In this molecule, what is the hybridization of C2?

- a.  $sp$
- b.  $sp^2$
- c.  $sp^3$
- d. The orbitals on C2 are not hybridized
- e. Not enough information is given to answer the question

11. Consider the ion  $\text{H}_2^-$ . How many electrons are in the antibonding orbital for this ion?
- 0
  - 1
  - 2
  - 3
  - Cannot be determined from the information given

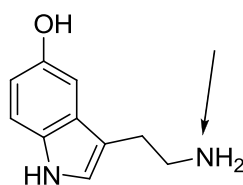
Questions 12, 13 and 14 are about the structure of Lexapro, a commonly prescribed antidepressant of the SSRI (selective serotonin reuptake inhibitor) class.



**Lexapro (Escitalopram)**

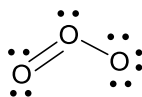
12. Which one of the following functional groups is present in Lexapro?
- ester
  - amide
  - anhydride
  - carboxylic acid
  - nitrile
13. What is the molecular geometry around the carbon indicated by the arrow?
- linear
  - trigonal planar
  - tetrahedral
  - bent
14. What is the correct classification of the carbon designated by the arrow?
- primary
  - secondary
  - tertiary
  - none of these

15. What is the bond order for  $\text{He}_2^+$ ?
- a. 0
  - b. 0.5
  - c. 1.0
  - d. 1.5
  - e. None of these
16. Here is the structure of serotonin, a neurotransmitter associated with regulation of mood, appetite, and sleep.



**Serotonin**

- What is the percentage s character in the hybrid orbitals on the nitrogen indicated by the arrow? Note that the lone pairs are not shown in this structure, but all atoms are neutral (zero formal charge).
- a. 25%
  - b. 33.3%
  - c. 50%
  - d. 66.7%
  - e. 75%
17. What are the formal charges on each of the oxygen atoms in ozone? All lone pairs are shown.



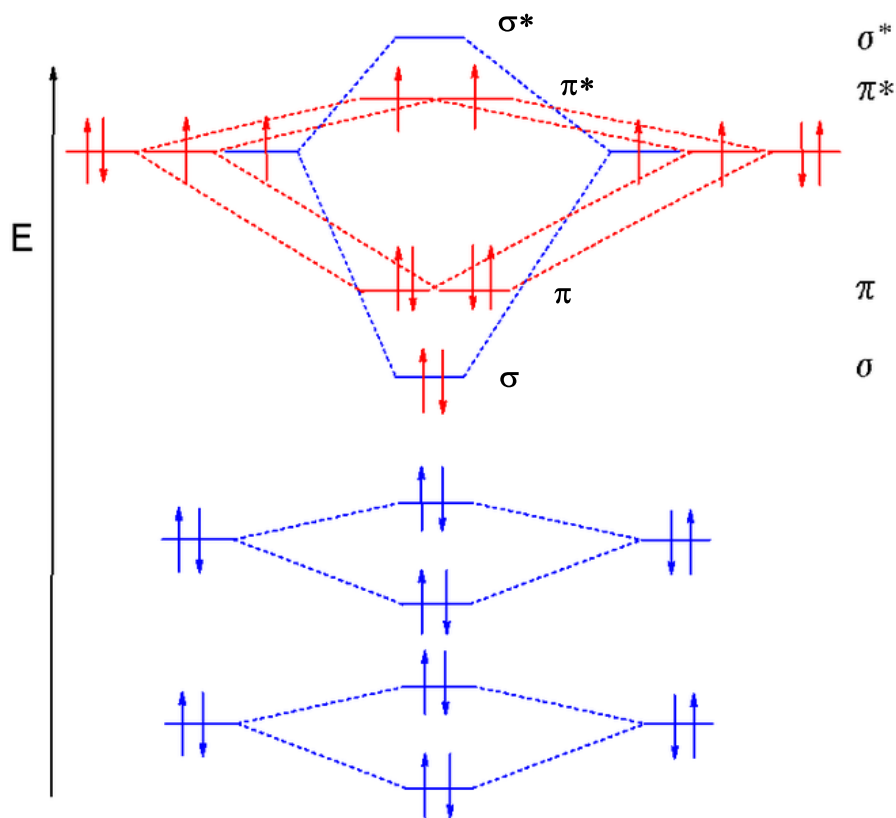
From left to right, the formal charges are:

- a. 1-, 1+, 0
- b. 1+, 0, 1+
- c. 0, 0, 1+
- d. 0, 0, 0
- e. 0, 1+, 1-

18. How many constitutional isomers exist for the formula  $C_4H_9Br$ ?

- a. 2
- b. 3
- c. 4
- d. 5
- e. Billions

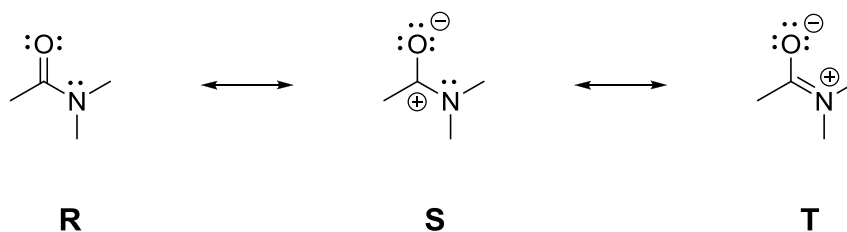
19. Here is a molecular orbital diagram for  $O_2$ . The relevant molecular orbitals have been labeled for you.



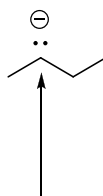
What is the LUMO in  $O_2$ ?

- a.  $\sigma$
- b.  $\sigma^*$
- c.  $\pi$
- d.  $\pi^*$
- e. None of these

20. Rank these three resonance contributors in order of increasing importance: least important (most minor contributor) to most important (major contributor).



- R is the most important and S is the least important.
  - R is the most important and T is the least important.
  - S is the most important and R and T are equivalent (they contribute equally to the hybrid)
  - T is the most important and S is the least important
  - None of these statements is true
21. What is the hybridization of the carbon indicated by the arrow in this structure? (Note that the hydrogens are not explicitly shown.)



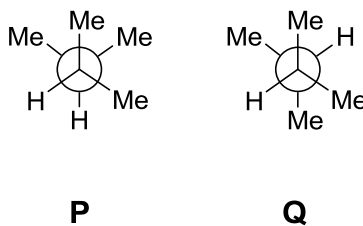
- $sp$
  - $sp^2$
  - $sp^3$
  - The orbitals on this carbon are not hybridized
  - Not enough information
22. How many nodes are there in this orbital? (The picture represents one orbital.)



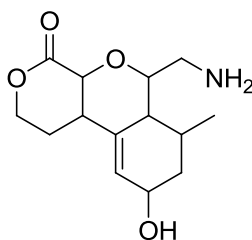
- 0
- 1
- 2
- 3
- Cannot be determined from the picture



23. What is the difference in energy, in kcal/mol, between the two conformations shown? (Me = Methyl, CH<sub>3</sub>)



- a. 0.8, and P is higher in energy than Q  
 b. 0.8, and P is lower in energy than Q  
 c. 1.6, and P is higher in energy than Q  
 d. 1.6, and P is lower in energy than Q  
 e. Not enough information to answer the question
24. True or False. In the bonding orbital in the MO diagram for H<sub>2</sub>, there is one node.
- a. True  
 b. False
25. The interesting but deadly molecule Kardashanine, shown below, has been found in dangerously high concentrations in blood samples taken from people who appear in and watch reality television shows. Really.



Which of the functional groups listed below does NOT appear in this compound?

- a. ester  
 b. amine  
 c. epoxide  
 d. alkene  
 e. alcohol