

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 12 pages and 19 questions, including this cover sheet. Be sure you have them all. Read each question carefully so that you know exactly what is being asked and what you need to write or draw. Your work on scratch pages will not be graded, so be sure everything you want graded is written on the exam itself.

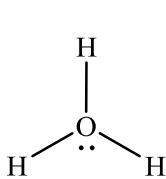
Each multiple choice question (1-16) is worth **4 points** and has **only one correct answer**. Good luck!

PERIODIC CHART OF THE ELEMENTS

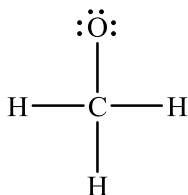
IA	IIA	IIIB	IVB	VB	VIB	VIIIB	VIII	IB	IIB	IIIA	IVA	VA	VIA	VIIA	INERT GASES		
1 H 1.00797														1 H 1.00797	2 He 4.0026		
3 Li 6.939	4 Be 9.0122										5 B 10.811	6 C 12.0112	7 N 14.0067	8 O 15.9994	9 F 18.9984	10 Ne 20.183	
11 Na 22.9898	12 Mg 24.312										13 Al 26.9815	14 Si 28.086	15 P 30.9738	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 (268)	110 ? (271)	111 ? (272)	112 ? (277)						

Circle the single best answer to each multiple choice question (1-16). (4 pts each)

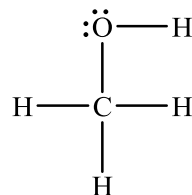
1. What is the formal charge on the oxygen atom in each of the following Lewis structures?



Structure I

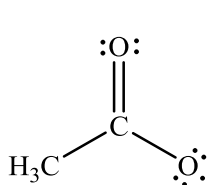


Structure II

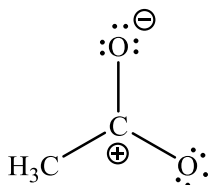


Structure III

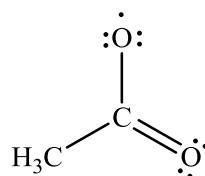
- a. **I**, 0, **II**, 1-, **III**, 1+
 b. **I**, 1+, **II**, 1-, **III**, 0
 c. **I**, 1-, **II**, 1+, **III**, 0
 d. **I**, 1-, **II**, 1-, **III**, 1-
 e. **I**, 1+, **II**, 1+, **III**, 1-
2. Which two of the following are *equivalent* resonance contributors?



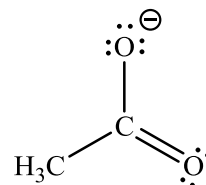
Structure W



Structure X



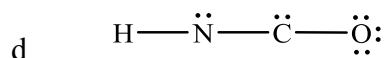
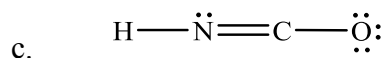
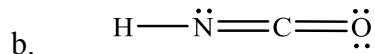
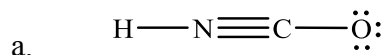
Structure Y



Structure Z

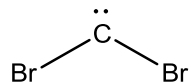
- a. W and X
 b. W and Y
 c. X and Y
 d. W and Z
 e. All the structures are equivalent.
3. In class, we discussed a molecular orbital diagram for pyramidal ammonia that assumed an approximate sp^3 hybridization for nitrogen. Which of the following statements about the molecular orbital diagram for pyramidal ammonia is *false*?
- a. There is one nonbonding orbital.
 b. There are three bonding molecular orbitals.
 c. There are three antibonding molecular orbitals.
 d. All bonding orbitals are occupied.
 e. All nonbonding orbitals are unoccupied.

4. In which of the following structures does the carbon atom have a formal charge that is **not zero**? (All lone pairs are shown.)



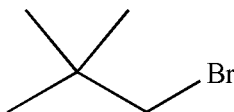
- e. Both c and d

5. Dibromocarbene is an example of a chemical species called a carbene:



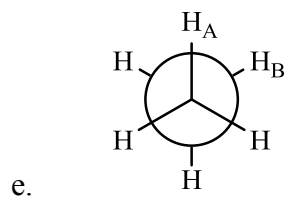
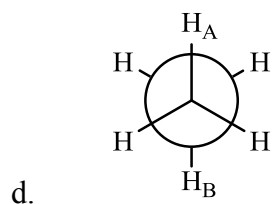
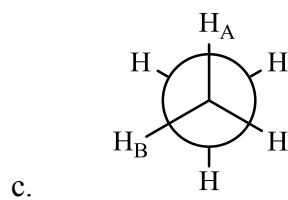
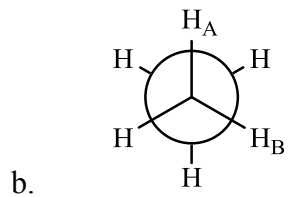
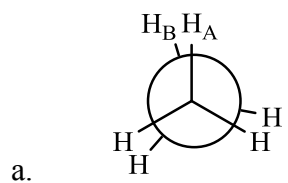
Carbenes exist in one of two forms. In one of these forms, called a singlet, both the nonbonding electrons occupy the same orbital. Approximately what type of orbital does the lone pair occupy?

- a. sp
b. sp^2
c. sp^3
d. $2s$
e. $2p$
6. What is the systematic (IUPAC) name of this compound?

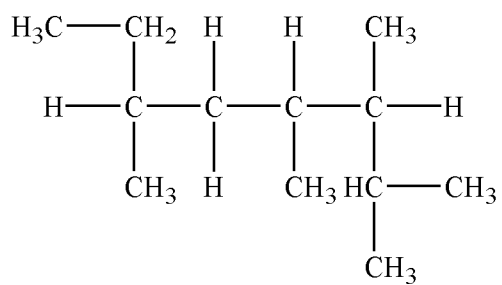


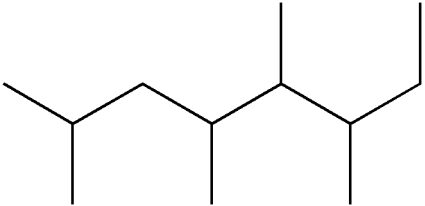
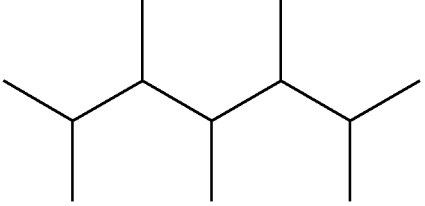
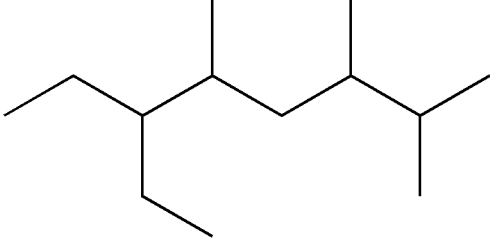
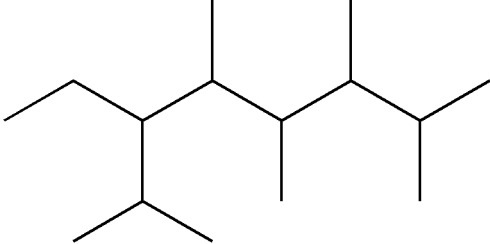
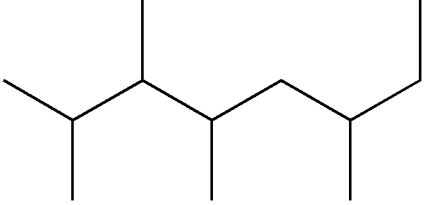
- a. 1-bromobutane
b. 1-bromo-2-methylbutane
c. 1-bromo-2-methylpropane
d. 1-bromo-2,2-dimethylpropane
e. 3-bromo-2,2-dimethylpropane

7. Which of the following Newman projections shows a dihedral angle of 60° between H_A and H_B ?

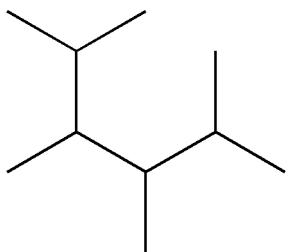


8. Which of the following skeletal structures corresponds to the Lewis structure shown?

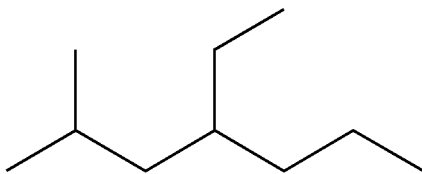


- a. 
- b. 
- c. 
- d. 
- e. 

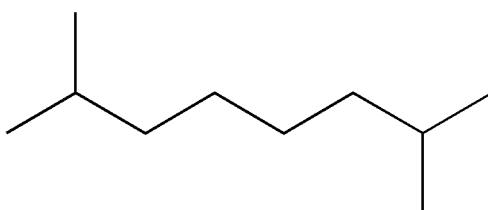
9. Which of the following compounds is *not* a constitutional isomer of the others?



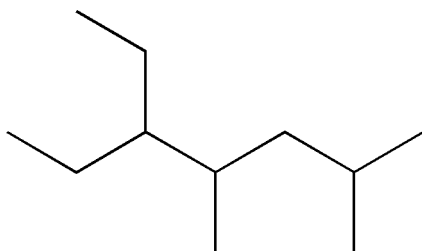
a.



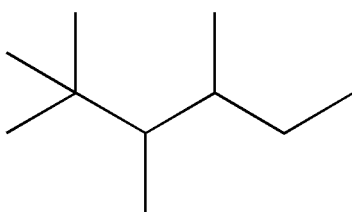
b.



c.

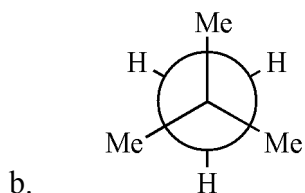
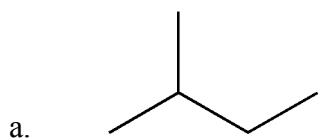


d.

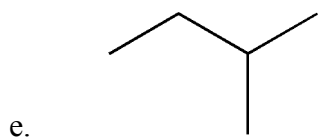
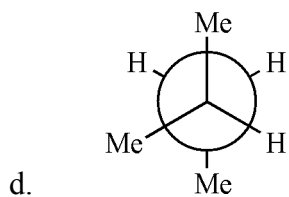


e.

10. Which of the following structures is *not* a representation of 2-methylbutane?



c. $(\text{CH}_3)_2\text{CHCH}_2\text{CH}_3$



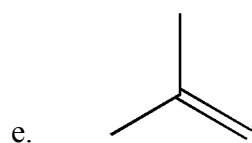
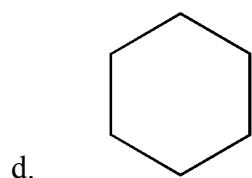
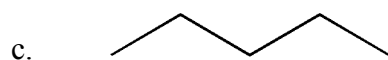
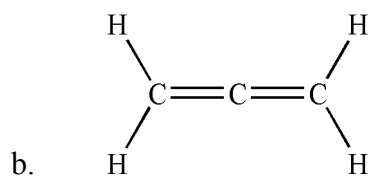
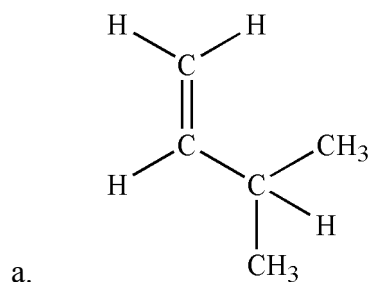
11. In which of the following molecules can a methyl group be eclipsed by either a chlorine atom or by a bromine atom?

- a. 1-bromo-3-chloropropane
- b. 1-bromo-1-chloropropane
- c. 1-bromo-2-chloropropane
- d. 2-bromo-1-chloropropane
- e. 2-bromo-2-chloropropane

12. How many molecular orbitals are generated from all possible linear combinations of one $2p$ orbital on carbon and one $2p$ orbital on oxygen?

- a. 0
- b. 1
- c. 2
- d. 3
- e. 4

13. Which of the following structures contains a hybrid orbital with the *greatest* percentage of *s* character?



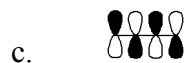
14. A certain orbital interaction diagram has four bonding molecular orbitals and four antibonding molecular orbitals. How many atomic orbitals were mixed to create all these molecular orbitals?

- a. 2
b. 4
c. 8
d. 16
e. It cannot be determined from the information given.

15. Which of the following statements about the orbital interaction diagram for H_2^- is *false*?

- a. There are two atomic orbitals that mix to produce molecular orbitals.
- b. There is one bonding molecular orbital.
- c. There is one antibonding molecular orbital.
- d. All bonding orbitals are occupied.
- e. All antibonding orbitals are unoccupied.

16. A set of π molecular orbitals were generated by various linear combinations of p orbitals. Which of the following π molecular orbitals is highest in energy?



- e. All four orbitals shown are degenerate.

17. (15 pts) Draw an orbital interaction diagram for borane, BH_3 , assuming a trigonal planar geometry. Your diagram should include the following:

Show all orbitals at their correct energy levels, including any and all bonding orbitals, antibonding orbitals, nonbonding orbitals, and atomic orbitals. Note that B is slightly *less* electronegative than H.

Label each orbital (e.g. s , p , sp , sp^2 , sp^3 , σ , σ^* , π , π^* , n).

Label the HOMO and the LUMO.

You do not have to draw the orbitals.

18. (15 pts) Define each of the following terms:

Torsional strain:

Van der Waals strain:

Which of these types of strain is present in each of the following conformations?
For each conformation, circle ALL types of strain that are present:

Eclipsed ethane	Torsional	Van der Waals	Neither
Staggered ethane	Torsional	Van der Waals	Neither
Anti butane (methyl groups anti)	Torsional	Van der Waals	Neither
Gauche butane	Torsional	Van der Waals	Neither
Eclipsed butane (methyl groups eclipsed)	Torsional	Van der Waals	Neither

19. (6 pts) Draw two more reasonable resonance contributors for the following structure (all lone pairs are shown). Show the interconversion of your structures using curved arrow notation. Include all non-zero formal charges.

