

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, not anything that you write on the exam.**

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!

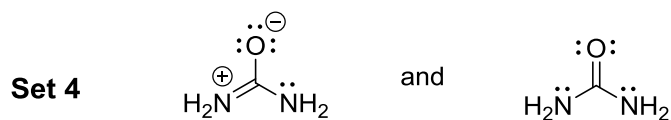
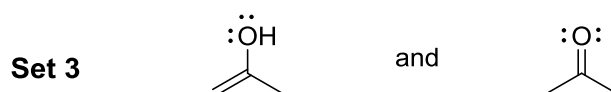
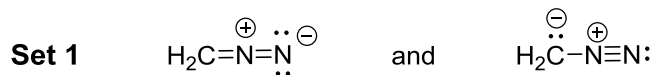
1A 2A 3A 4A 5A 6A 7A 8A

hydrogen 1 H 1.0079																	helium 2 He 4.0026								
lithium 3 Li 6.941	beryllium 4 Be 9.0122																boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180			
sodium 11 Na 22.990	magnesium 12 Mg 24.305																aluminum 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948			
potassium 19 K 39.098	calcium 20 Ca 40.078	scandium 21 Sc 44.956	titanium 22 Ti 47.867	vanadium 23 V 50.942	chromium 24 Cr 51.996	manganese 25 Mn 54.938	iron 26 Fe 55.845	cobalt 27 Co 58.933	nickel 28 Ni 58.693	copper 29 Cu 63.546	zinc 30 Zn 65.39	gallium 31 Ga 69.723	germanium 32 Ge 72.61	arsenic 33 As 74.922	selenium 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.80								
rubidium 37 Rb 85.468	strontium 38 Sr 87.62	yttrium 39 Y 88.906	zirconium 40 Zr 91.224	niobium 41 Nb 92.906	niobium 41 Nb 92.906	niobium 41 Nb 92.906	niobium 41 Nb 92.906	niobium 41 Nb 92.906	niobium 41 Nb 92.906	niobium 41 Nb 92.906	niobium 41 Nb 92.906	niobium 41 Nb 92.906	niobium 41 Nb 92.906	niobium 41 Nb 92.906	niobium 41 Nb 92.906	niobium 41 Nb 92.906	niobium 41 Nb 92.906	niobium 41 Nb 92.906	niobium 41 Nb 92.906	niobium 41 Nb 92.906	niobium 41 Nb 92.906	niobium 41 Nb 92.906	niobium 41 Nb 92.906		
cesium 55 Cs 132.91	barium 56 Ba 137.33	57-70 *	lutetium 71 Lu 174.97	hafnium 72 Hf 178.49	tantalum 73 Ta 180.95	tungsten 74 W 183.84	rhenium 75 Re 186.21	osmium 76 Os 190.23	iridium 77 Ir 192.22	platinum 78 Pt 195.08	gold 79 Au 196.97	mercury 80 Hg 200.59	thallium 81 Tl 204.38	lead 82 Pb 207.2	bismuth 83 Bi 208.98	polonium 84 Po [209]	astatine 85 At [210]	radon 86 Rn [222]							
francium 87 Fr [223]	radium 88 Ra [226]	89-102 * * *	lawrencium 103 Lr [262]	rutherfordium 104 Rf [261]	dubnium 105 Db [262]	seaborgium 106 Sg [269]	bohrium 107 Bh [264]	hassium 108 Hs [269]	meitnerium 109 Mt [269]	ununnium 110 Uun [271]	ununium 111 Uuu [272]	unubium 112 Uub [272]		ununium 114 Uuq [289]											

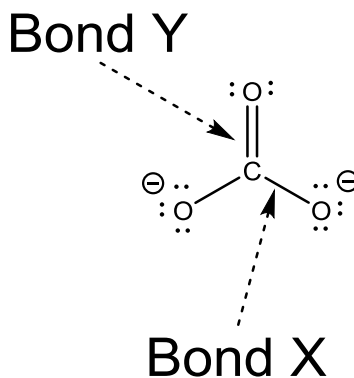
\* Lanthanide series

lanthanum 57 La 138.91	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.04
actinium 89 Ac [227]	thorium 90 Th 232.04	protactinium 91 Pa 231.04	uranium 92 U 238.03	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]

1. Which of the following pairs of structures does NOT represent a pair of resonance contributors?



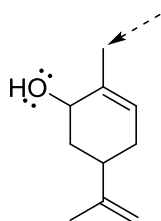
- a. Set 1  
 b. Set 1 and Set 3  
 c. Set 3  
 d. Set 4  
 e. All of these sets represent pairs of resonance contributors
2. Here is the structure of the carbonate anion,  $\text{CO}_3^{2-}$ . Would you expect bond Y to be shorter, longer, or the same length as bond X?



- a. Shorter  
 b. Longer  
 c. The same length

3. Consider the ion  $\text{H}_2^+$ . How many electrons are in the bonding molecular orbital for this ion?
- a. 0
  - b. 1
  - c. 2
  - d. 3

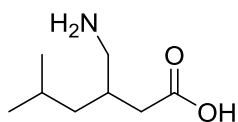
Questions 4, 5 and 6 relate to carveol, a naturally occurring compound called a terpenoid that is found in many essential oils. Here is the structure of carveol. (Note that one of the carbon atoms is indicated by an arrow.)



**Carveol**

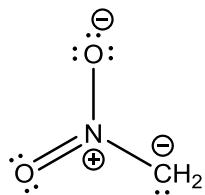
4. What is the hybridization of the carbon indicated by the arrow?
- a.  $sp$
  - b.  $sp^2$
  - c.  $sp^3$
  - d. The indicated carbon is not hybridized.
5. What is the approximate electronic geometry around the oxygen atom?
- a. trigonal planar
  - b. linear
  - c. tetrahedral
  - d. octahedral
  - e. bent
6. How many  $sp^2$  carbon atoms are there in carveol?
- a. 2
  - b. 3
  - c. 4
  - d. 5
  - e. 6

7. Here is the constitution of a compound called pregabalin, an anticonvulsant which is marketed under the trade name Lyrica. The lone pairs of electrons are not shown in this structure. To complete the structure, how many lone pairs of electrons must be added? (The formal charge is zero on all atoms.)

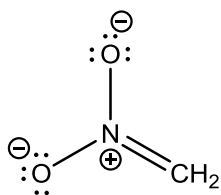


**Pregabalin (Lyrica)**

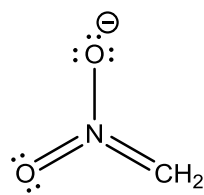
- a. 1  
b. 2  
c. 3  
d. 4  
e. 5
8. Which of the structures is NOT an acceptable resonance contributor to the resonance hybrid represented by the others?



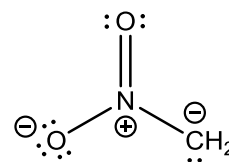
**A**



**B**



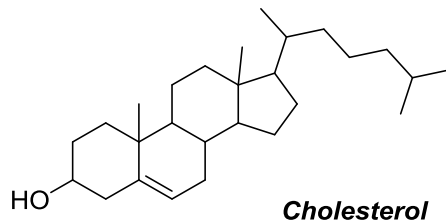
**C**



**D**

- a. A  
b. B  
c. C  
d. D  
e. All are acceptable resonance contributors

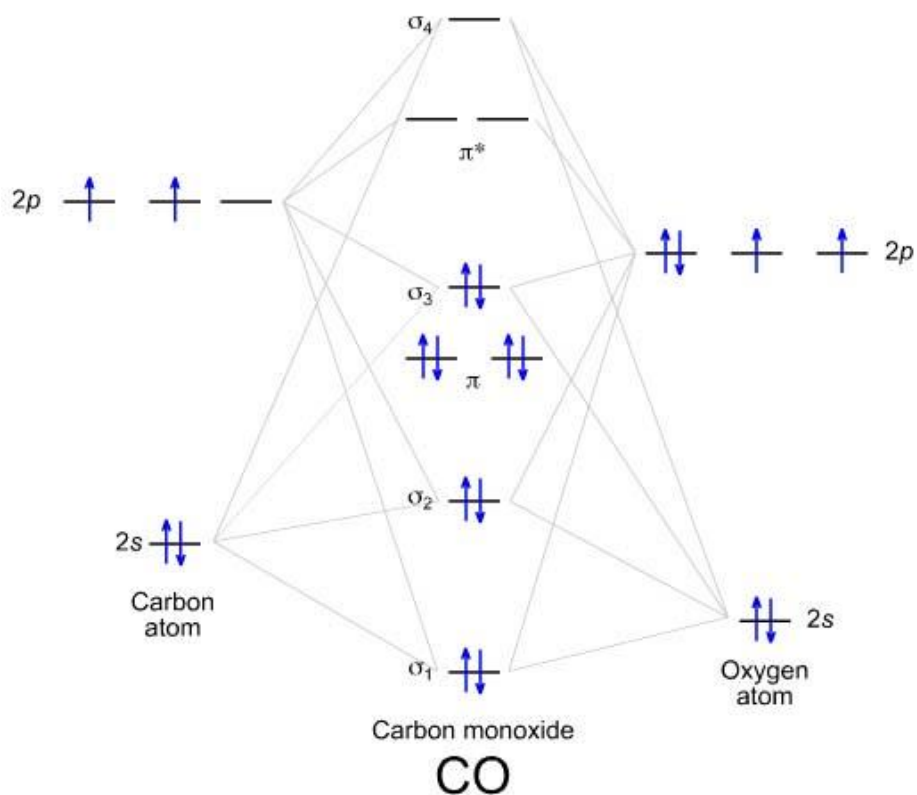
9. The constitution of cholesterol is shown here:



Cholesterol can be classified as a(n):

- a. alcohol
  - b. amide
  - c. ester
  - d. ketone
  - e. anhydride
10. According to valence bond theory, which orbitals are overlapping to form the C-O  $\sigma$  bond in cholesterol?
- a.  $p$  and  $p$
  - b.  $sp^2$  and  $sp^2$
  - c.  $p$  and  $sp^2$
  - d.  $sp^2$  and  $sp^3$
  - e.  $sp^3$  and  $sp^3$
11. According to valence bond theory, which orbitals are overlapping to form the C-C  $\pi$  bond in cholesterol?
- a.  $p$  and  $p$
  - b.  $sp^2$  and  $sp^2$
  - c.  $p$  and  $sp^2$
  - d.  $sp^2$  and  $sp^3$
  - e.  $sp^3$  and  $sp^3$
12. Which of these molecular orbitals would you not expect to exist in cholesterol?
- a. C-H  $\sigma$
  - b. C-C  $\pi^*$
  - c. C-O  $\pi$
  - d. Nonbonding
  - e. All of these orbitals exist in cholesterol

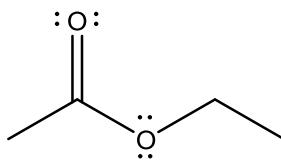
13. Here is a molecular orbital diagram for CO, carbon monoxide. The atomic and molecular orbitals are labeled. Even though it is more complicated than the diagrams you have seen, the same principles apply.



According to this diagram, what is the LUMO in CO?

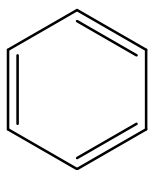
- $\sigma^3$
- $\sigma^4$
- $2p$
- $\pi^*$
- None of these

14. Ethyl acetate is the compound shown here:

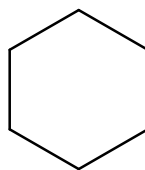


***Ethyl acetate***

- To what class of compounds does ethyl acetate belong?
- carboxylic acid
  - ether
  - ester
  - alcohol
  - anhydride
15. Ethyl acetate contains two oxygen atoms: the carbonyl oxygen, and the ester oxygen. Which of the following labels best describes the hybridization of the ester oxygen?
- $sp$
  - $sp^2$
  - $sp^3$
  - The ester oxygen is not hybridized.
16. Consider the structures of benzene and cyclohexane:



***benzene***

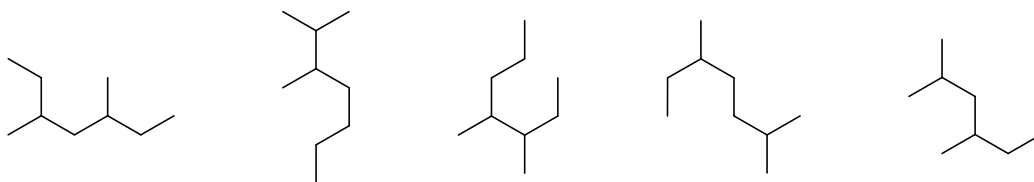


***cyclohexane***

Which of these statements is true?

- Both molecules are planar (all atoms are in one plane).
- Benzene is planar, but cyclohexane is not.
- Cyclohexane is planar, but benzene is not.
- Neither benzene nor cyclohexane is planar.

17. Which of these compounds is 2,3-dimethylheptane?



**A**

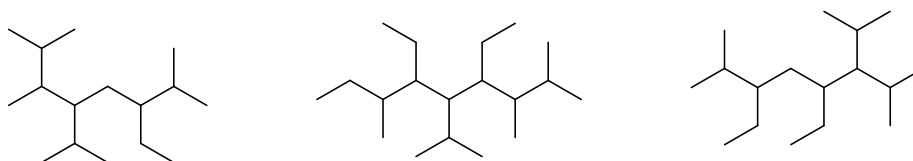
**B**

**C**

**D**

**E**

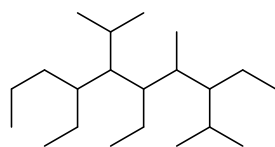
18. Which of these compounds has an isopropyl group at the 4 position?



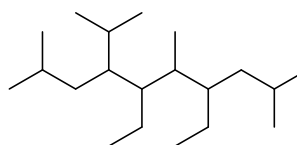
**A**

**B**

**C**

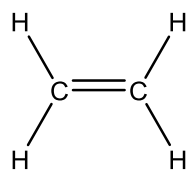


**D**



**E**

19. How many nodes are there in the C-C  $\pi^*$  molecular orbital in ethylene?

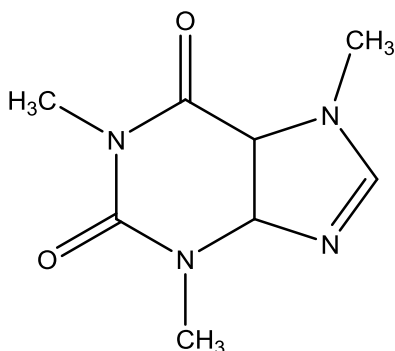


**ethylene**

- a. 0
- b. 1
- c. 2
- d. 3
- e. Ethylene does not contain a  $\pi^*$  orbital.



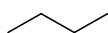
20. The structure of caffeine is shown. Lone pairs are not explicitly drawn, but all atoms are neutral (formal charge = zero).



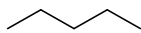
**Caffeine**

- How many nonbonding molecular orbitals are there in caffeine?
- a. 2
  - b. 4
  - c. 6
  - d. 8
  - e. Millions
21. There are three methyl groups in caffeine. What is the percentage of *p* character for the orbitals on a carbon in a methyl group?
- a. 25%
  - b. 33.3%
  - c. 50%
  - d. 66.7%
  - e. 75%

22. Which of these compounds is pentane?



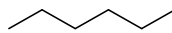
**A**



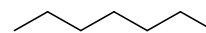
**B**



**C**

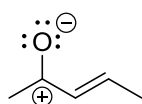
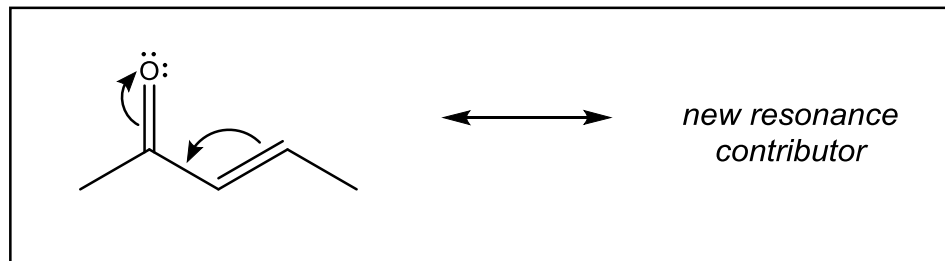


**D**

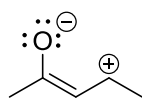


**E**

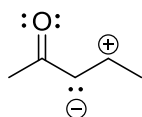
23. Curved arrows are used to convert one resonance contributor (resonance structure) to another. Examine the curved arrows shown on the structure below. Which of the choices is the resonance structure that would result from those arrows?



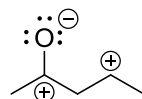
**A**



**B**



**C**

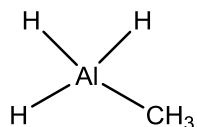


**D**

None of these structures

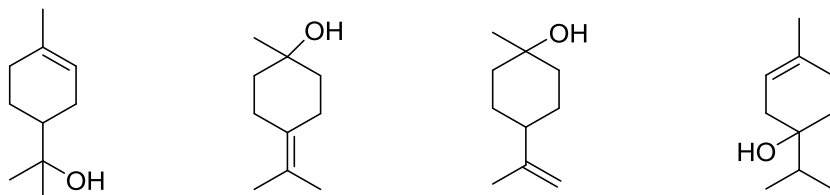
**E**

24. What is the formal charge on aluminum in this structure?



- a. 1+  
 b. 1-  
 c. 0  
 d. 2+  
 e. 2-

25. Recently, tabloids reported that there was a heated altercation between Solange and Jay Z in an elevator in a New York hotel. While the exact nature of this argument has not been revealed, insiders claim that Solange became furious with Jay Z because he kept insisting that the four compounds shown below were constitutional isomers:



Solange claimed, loudly, that the four were resonance structures contributing to the same resonance hybrid. She then physically attacked Jay Z. Witnesses indicate that during the attack she screamed “You can’t call yourself an organic chemist!”

Who was correct, Jay Z or Solange?

- Jay Z. The four compounds are constitutional isomers.
- Solange. The four compounds are contributors to the same resonance hybrid.
- Neither Jay Z nor Solange were correct. The four compounds have no relationship to one another.
- Both Jay Z and Solange were correct. The four compounds are constitutional isomers AND resonance contributors to the same hybrid.