

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 65.38	Gallium 31 Ga 69.723	Germanium 32 Ge 72.64	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	Sr 87.62	Yttrium 39 Y 88.906	Zirconium 40 Zr 91.224	Niobium 41 Nb 92.906	Molybdenum 42 Mo 95.94	Technetium 43 Tc [98]	Ruthenium 44 Ru 101.07	Rhodium 45 Rh 101.07	Palladium 46 Pd 106.32	Silver 47 Ag 107.87	Cadmium 48 Cd 112.41	Indium 49 In 114.82	Tin 50 Sn 118.71	Antimony 51 Sb 121.76	Tellurium 52 Te 127.60	Iodine 53 I 126.90	Xenon 54 Xe 131.29	
Cesium 55 Cs 132.91	Barium 56 Ba 137.33	57-70	Lanthanum 57 Lu 138.91	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	Pt 78 Pt 195.08	Au 79 Au 196.97	Hg 80 Hg 200.59	Tl 81 Tl 204.38	Pb 82 Pb 207.2	Bi 83 Bi 208.98	Po 84 Po [209]	At 85 At [210]	Rn 86 Rn [222]
Francium 87 Fr [223]	Radium 88 Ra [226]	89-102	Lr 103 Lr [260]	Rf 104 Rf [261]	Db 105 Db [262]	Sg 106 Sg [263]	Bh 107 Bh [264]	Hs 108 Hs [265]	Mt 109 Mt [266]	Uun 110 Uun [267]	Uuu 111 Uuu [268]	Uub 112 Uub [269]	Uuq 114 Uuq [270]					

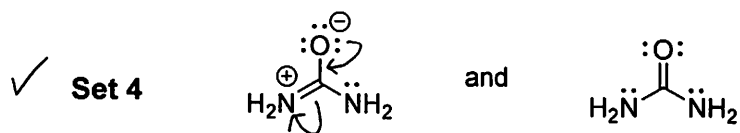
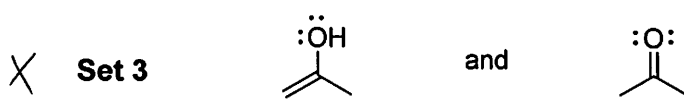
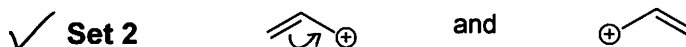
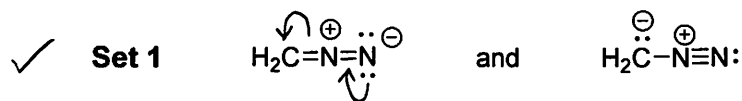
* Lanthanide series

57	58	59	60	61	62	63	64	65	66	67	68	69	70
La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb
138.91	140.12	140.91	144.24	[145]	150.36	151.96	157.25	158.93	162.50	164.93	167.26	168.93	173.04
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No
[227]	232.04	231.04	238.03	[237]	[244]	[243]	[247]	[247]	[251]	[252]	[257]	[258]	[259]

** Actinide series

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

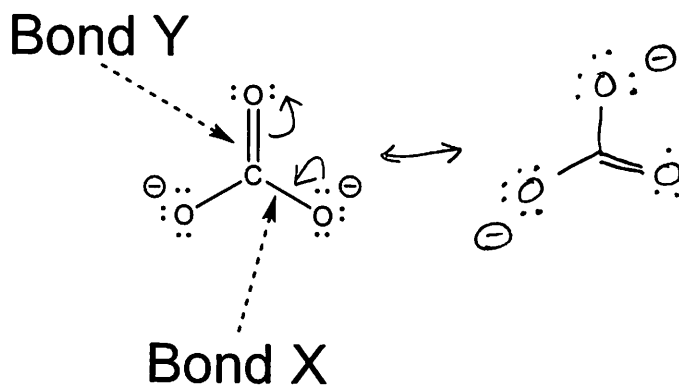
C



- 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, CO_3^{2-} . Would you expect bond Y to be shorter, longer, or the same length as bond X?

C

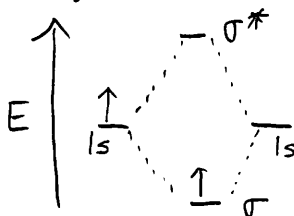


- a. Shorter
 b. Longer
 c. The same length

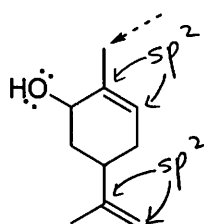
3. Consider the ion H_2^+ . How many electrons are in the bonding molecular orbital for this ion?

B

- 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?

C

- 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?

C

- a. trigonal planar
- b. linear
- c. tetrahedral
- d. octahedral
- e. bent

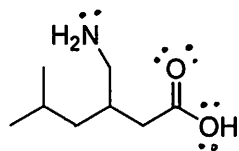
6. How many sp^2 carbon atoms are there in carveol?

C

- 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.)

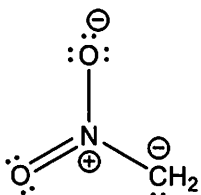
E



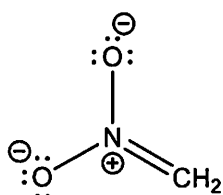
Pregabalin (Lyrica)

- a. 1
- b. 2
- c. 3
- d. 4
- e. 5

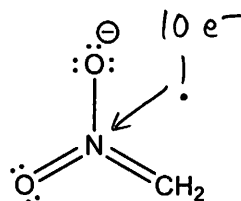
8. Which of the structures is NOT an acceptable resonance contributor to the resonance hybrid represented by the others?



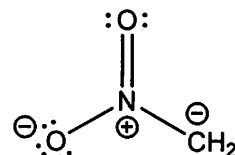
A



B



C



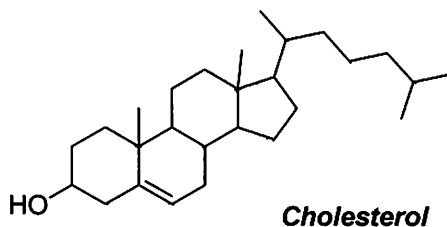
D

C

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

9. The constitution of cholesterol is shown here:

A



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 σ bond in cholesterol?

E

- 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

O sp^3 and C sp^3

11. According to valence bond theory, which orbitals are overlapping to form the C-C π bond in cholesterol?

A

- 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

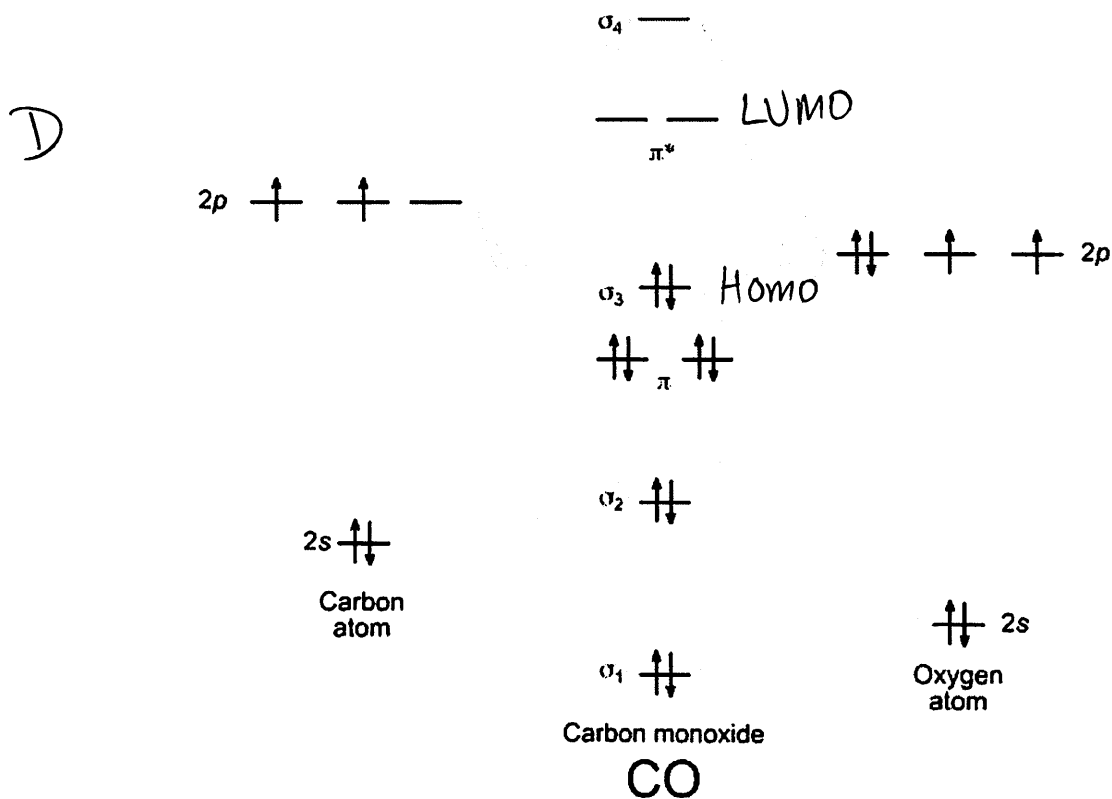
12. Which of these molecular orbitals would you not expect to exist in cholesterol?

C

- a. C-H σ
- b. C-C π^*
- c. C-O π
- d. Nonbonding
- e. All of these orbitals exist in cholesterol

There are no C-O π bonds

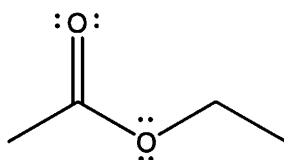
13. Here is a molecular orbital diagram for CO, carbon monoxide. The atomic and molecular orbitals are labeled. Even though it is more complicated than the diagrams you have seen, the same principles apply.



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

- a. σ^3
- b. σ^4
- c. $2p$
- d. π^*
- e. None of these

14. Ethyl acetate is the compound shown here:



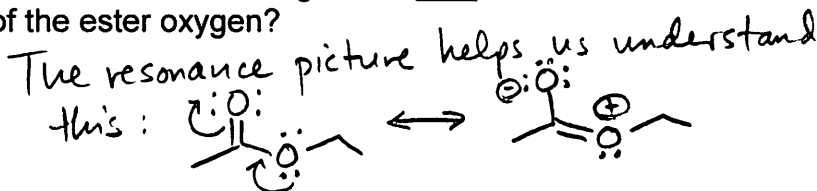
Ethyl acetate

To what class of compounds does ethyl acetate belong?

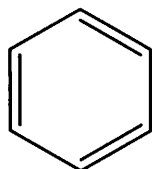
- a. carboxylic acid
- b. ether
- c. ester
- d. alcohol
- e. anhydride

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?

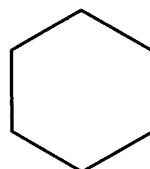
- a. sp
- b. sp^2
- c. sp^3
- d. The ester oxygen is not hybridized.



16. Consider the structures of benzene and cyclohexane:



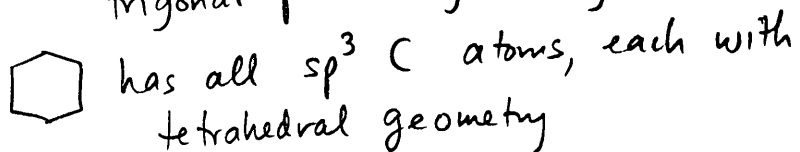
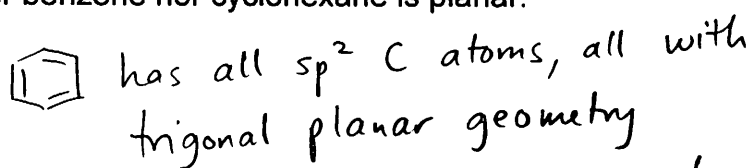
benzene



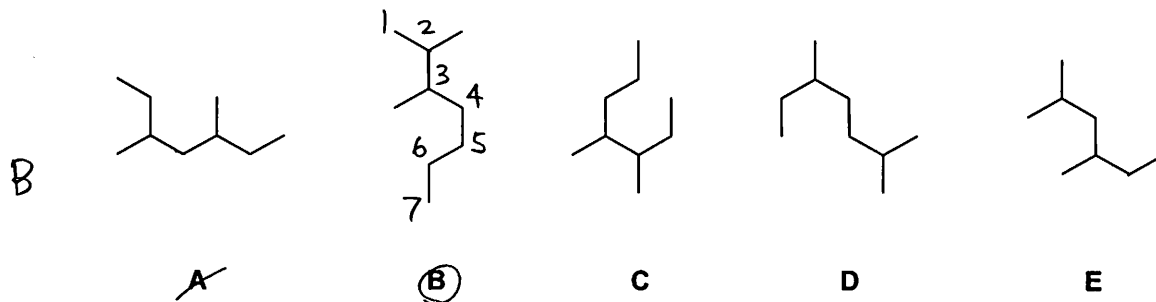
cyclohexane

Which of these statements is true?

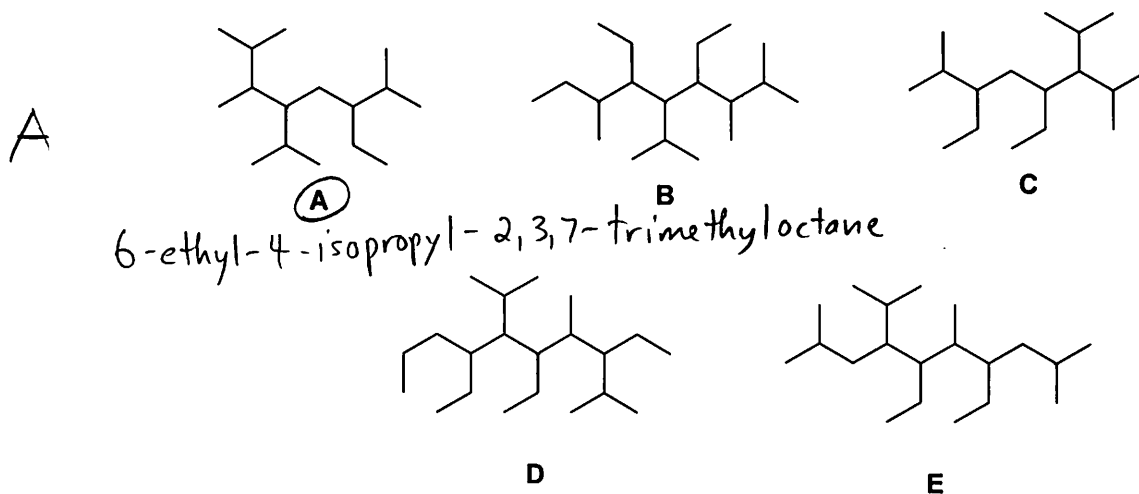
- ~~a.~~ Both molecules are planar (all atoms are in one plane).
- b. Benzene is planar, but cyclohexane is not.
- c. Cyclohexane is planar, but benzene is not.
- d. Neither benzene nor cyclohexane is planar.



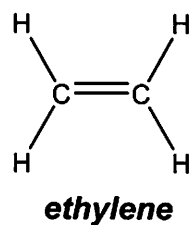
17. Which of these compounds is 2,3-dimethylheptane?



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

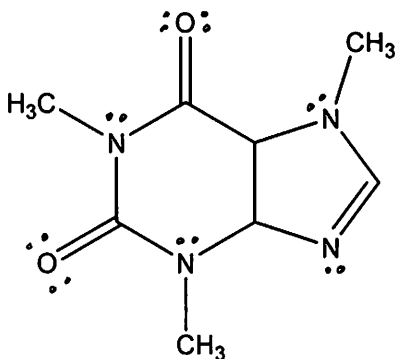


19. How many nodes are there in the C-C π^* molecular orbital in ethylene?



- a. 0
 b. 1
c. 2
 d. 3
 e. Ethylene does not contain a π^* 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%

sp^3 is 25% s, 75% p

22. Which of these compounds is pentane?



A



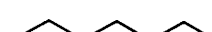
B



C



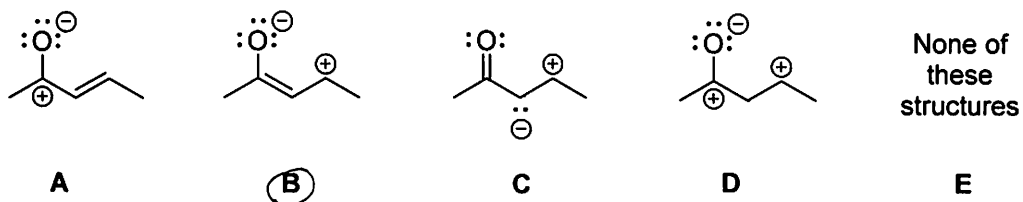
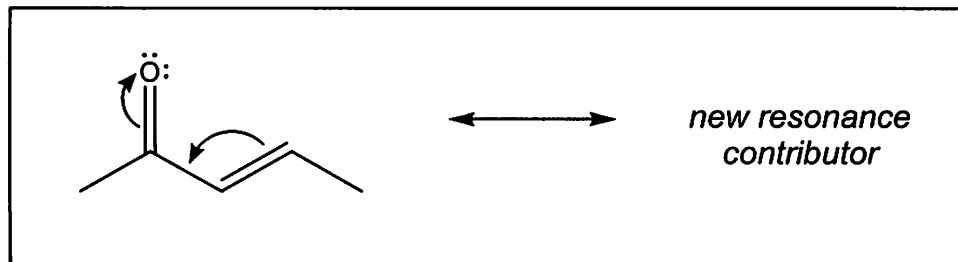
D



E

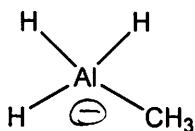
23. Curved arrows are used to convert one resonance contributor (resonance structure) to another. Examine the curved arrows shown on the structure below. Which of the choices is the resonance structure that would result from those arrows?

B



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

B

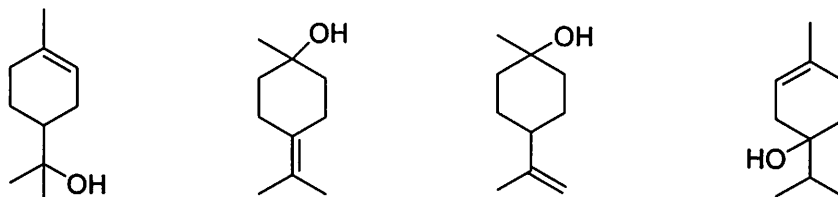


$$3 - (4 + 0) = -1$$

- 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:

A



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?

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

Same formula,
different
connectivity