

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

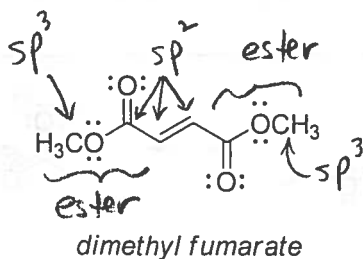
Hydrogen 1 H 1.008																	Helium 2 He 4.003				
Lithium 3 Li 6.941	Beryllium 4 Be 9.012															Boron 5 B 10.811	Carbon 6 C 12.011	Nitrogen 7 N 14.007	Oxygen 8 O 15.999	Fluorine 9 F 18.998	Neon 10 Ne 20.180
Sodium 11 Na 22.990	Magnesium 12 Mg 24.305															Aluminum 13 Al 26.982	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 72.61	Arsenic 33 As 74.922	Selenium 34 Se 78.96	Bromine 35 Br 79.904	Krypton 36 Kr 83.8				
Rubidium 37 Rb 85.468	Sr 38 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 102.91	Palladium 46 Pd 106.42	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 127.6	Iodine 53 I 126.905	Xenon 54 Xe 131.29				
Cesium 55 Cs 132.91	Ba 56 Ba 137.32	* 57-70	Lanthanum 57 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	Po 84 Po [209]	Astatine 85 At [210]	Radon 86 Rn [222]			
Francium 87 Fr [223]	Ra 88 Ra [226]	* * 89-102	Lr 103 Lr [261]	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 [271]								

* Lanthanide series

57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 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
89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No
[227]	232.04	231.04	238.03	[237]	[244]	[247]	[251]	[254]	[259]	[264]	[267]	[271]	[285]

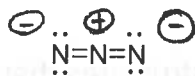
* Actinide series

1. Dimethyl fumarate, shown below, was approved in March 2013 by the Food and Drug Administration for the treatment of patients with multiple sclerosis.



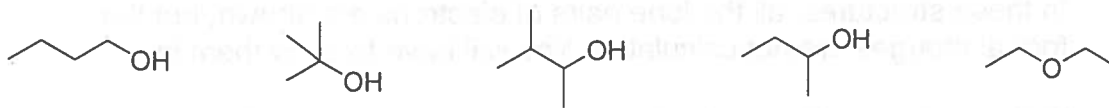
Which of these statements about dimethyl fumarate is true?

- a. All the carbon atoms are sp^2 hybridized.
 b. All the carbon atoms are sp^3 hybridized.
 c. Dimethyl fumarate contains at least one carboxylic acid.
 d. Dimethyl fumarate contains at least one ester.
 e. There are six (6) hydrogen atoms in dimethyl fumarate. *There are 8*
2. What is the overall charge on this chemical species?



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

3. Which of these structures is not a constitutional isomer of the others?



A

B

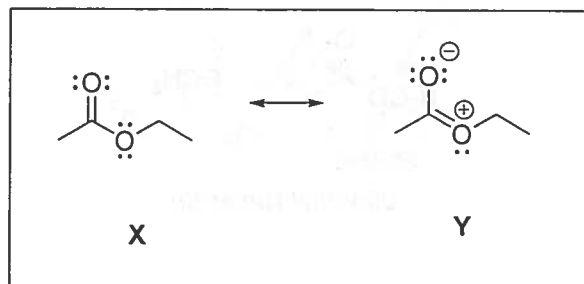
C

D

E

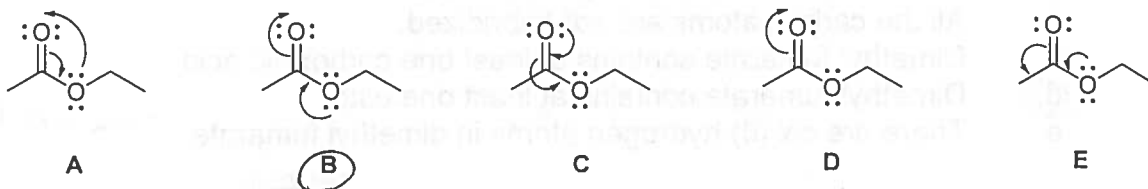
Has 5 c's
 - The others
 have 4

4. Curved arrows are used to convert one resonance contributor (resonance structure) to another. In this picture, X and Y are contributors to the same resonance hybrid:

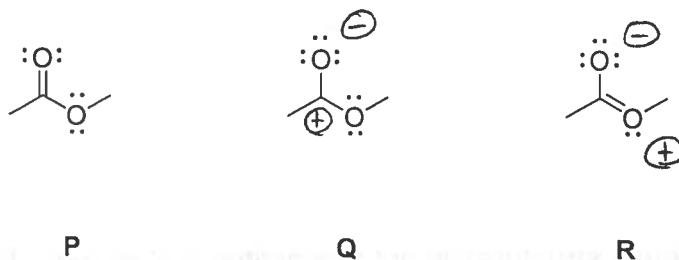


B

Which of these structures shows the correct arrows to convert X to Y?



5. Here are three resonance structures that belong to the same resonance hybrid:



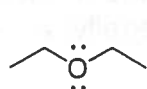
In these structures, all the lone pairs of electrons are shown, but the formal charges are not calculated. You will have to draw them in.

D

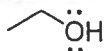
Which of these statements about the structures is correct?

- P is the most minor contributor and R is the major contributor
- P is the most minor contributor and Q is the major contributor
- R is the most minor contributor and P is the major contributor
- Q is the most minor contributor and P is the major contributor
- R is the most minor contributor and Q is the major contributor

6. Which of these structures contains an oxygen atom with sp^3 hybridization?



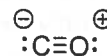
W ✓



X ✓



Y X

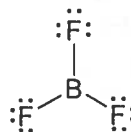
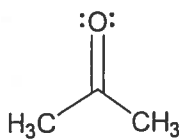
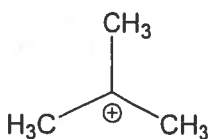


Z X

B

- a. W
- b. W and X
- c. W, X and Y
- d. X
- e. Y

7. What do these three structures have in common?



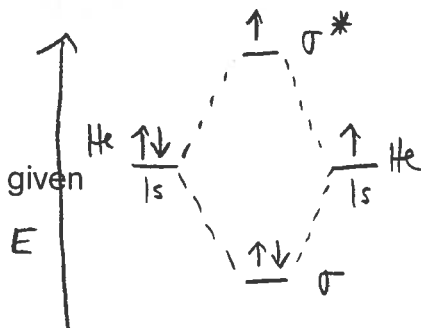
C

- a. There is tetrahedral geometry around the central atom. *Trigonal planar*
- b. All three structures have at least two other *reasonable* resonance structures (e.g., structures with minimized formal charges)
- c. Each structure has at least one atom with an unhybridized p orbital.
- d. All three structures are polar.
- e. The three structures do not share any of the common features listed in choices "a" through "d".

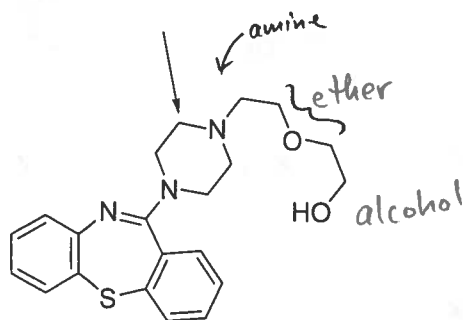
8. Consider the ion He_2^+ . How many electrons are in the antibonding orbital for this ion?

B

- a. 0
- b. 1
- c. 2
- d. 3
- e. Cannot be determined from the information given



Questions 9, 10 and 11 relate to Seroquel, a medication prescribed as an anti-psychotic. Here is the structure of Seroquel:



Seroquel (Quetiapine)

9. What is the geometry around the carbon indicated by the arrow?

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

10. What is the hybridization of the atom indicated by the arrow?

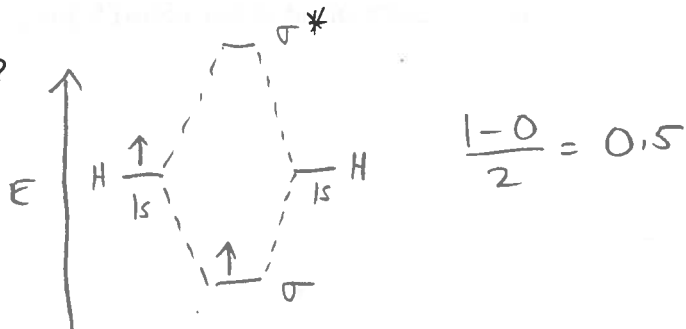
- C
- a. sp
 - b. sp^2
 - c. sp^3
 - d. The indicated atom is not hybridized.

11. Which of the following functional groups is present in Seroquel (i.e., which of these names would be a reasonable way to classify this structure)?

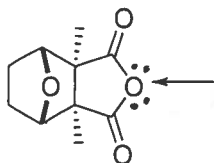
- B
- a. ester
 - b. ether
 - c. ketone
 - d. carboxylic acid
 - e. amide

12. What is the bond order for H_2^+ ?

- B
- a. 0
 - b. 0.5
 - c. 1.0
 - d. 1.5
 - e. None of these



13. Here is the structure of cantharidin, a poisonous compound excreted by blister beetles. Although it has medicinal uses for humans when applied appropriately, it has also been used historically (and illegally) as an aphrodisiac.

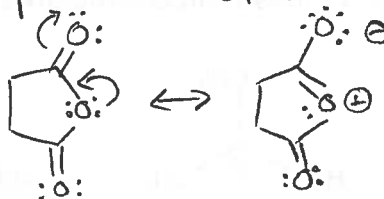


Cantharidin

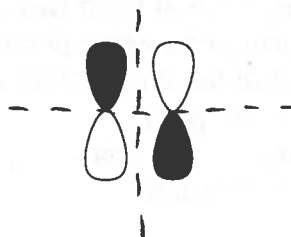
What is the percentage s character in the hybrid orbitals on the oxygen indicated by the arrow? Note that the lone pairs are not shown in this structure, but all atoms are neutral (zero formal charge).

- a. 25%
 b. 33.3%
 c. 50%
 d. 66.7%
 e. 75%

It is sp^2 because of resonance

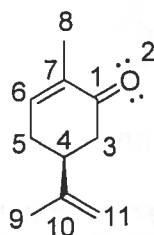


14. How many nodes are there in this orbital? (The picture represents one orbital.)



- a. 0
 b. 1
 c. 2
 d. 3
 e. Cannot be determined from the picture

Questions 15, 16 and 17 involve the structure of carvone. Carvone is a naturally occurring oil found in spearmint, caraway and dill. It is used extensively in food because of its flavor. (According to Wikipedia, Wrigley's spearmint gum is soaked in carvone and coated with sugar.) Use the numbering system on the structure to answer questions.



carvone

15. What orbitals overlap to form the pi bond between C1 and O-2?

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

16. What orbitals overlap to form the sigma bond between C1 and C3?

D

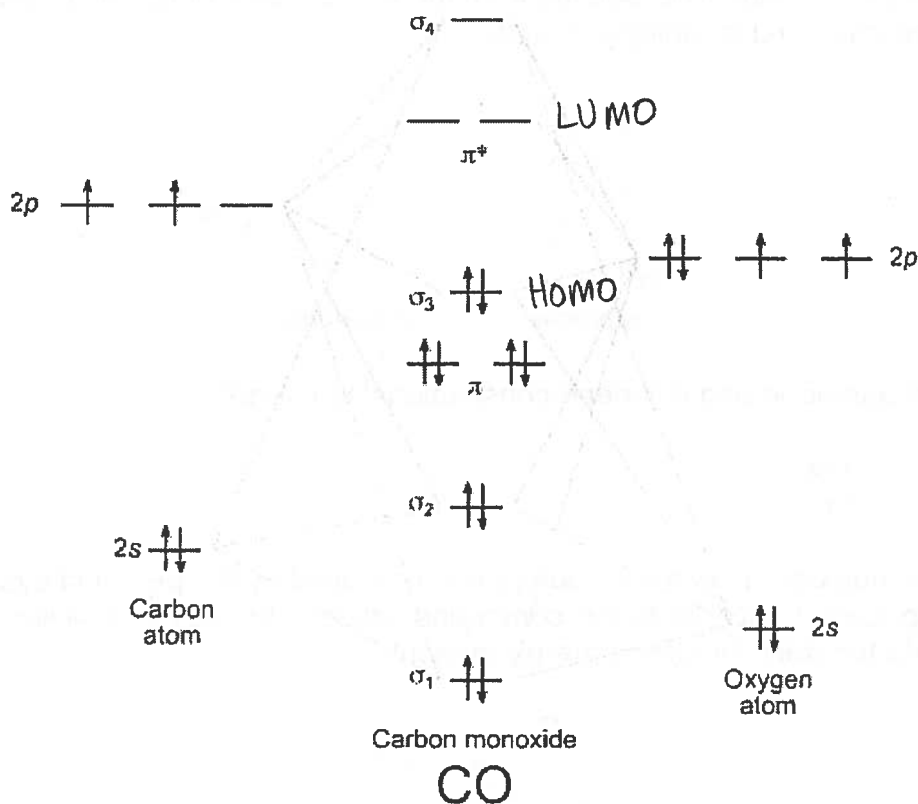
- a. p and p
- b. sp^2 and sp^2
- c. p and sp^2
- d. sp^2 and sp^3
- e. sp^3 and sp^3

17. Each of the lone pairs on O2 is contained in what type of orbital?

D

- a. s
- b. p
- c. sp
- d. sp^2
- e. sp^3

18. 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.

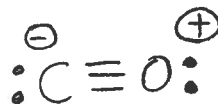


According to this diagram, what is the HOMO in CO?

- B
- a. σ^1
 - b. σ^3
 - c. $2p$
 - d. π^*
 - e. None of these

19. For the major resonance contributor for CO, what are the formal charges?

- B
- a. + on carbon, - on oxygen
 - b. + on oxygen, - on carbon
 - c. zero on carbon, zero on oxygen
 - d. + on carbon, zero on oxygen
 - e. zero on carbon, + on oxygen



20. How many hydrogen atoms are on the carbon indicated by the arrow in this structure?

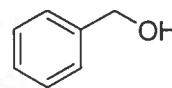
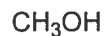
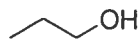
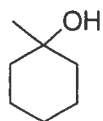
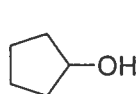


B

- a. Zero
- b. One
- c. Two
- d. Three
- e. Not enough information

21. Which of these structures is a secondary alcohol?

A



A

B

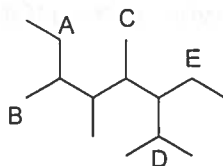
C

D

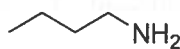
E

22. Some of the carbons in this structure are labeled. Which of them is a tertiary carbon?

D



23. How is this amine classified?

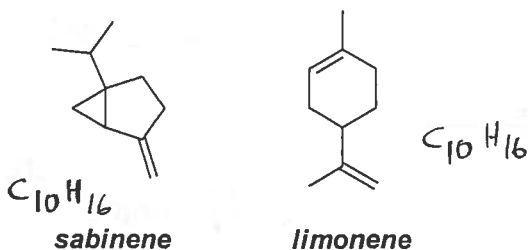


A

- a. Primary
- b. Secondary
- c. Tertiary
- d. None of these

24. Sabinene and limonene are compounds called "terpenes" that are commonly produced by plants. For example, sabinene is isolated from oak and spruce oils and is also responsible for some of the flavor of black pepper. Limonene is isolated from the rind of citrus fruits and is used in perfumes and cleaning products.

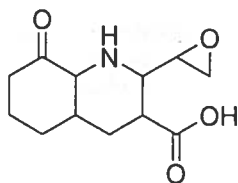
A



Are sabinene and limonene constitutional isomers?

- a. Yes
 b. No
25. Justinbieberone is a toxic compound produced by the pet monkeys of teen pop stars. Exposure to this compound causes obnoxious behavior. Unfortunately, its effects are permanent.

A



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

- a. ester
 b. amine
 c. epoxide
 d. ketone
 e. carboxylic acid