Chemistry 1A

Midterm Exam #2

Tuesday, October 16, 2018

Name: ________________________________

SID: __________________________________

GSI Name: _____________________________

Write your name on all the pages of the exam.

For multiple choice questions, fill in the bubble (◯) completely.

Unless otherwise specified, multiple choice questions have only one correct answer.

For short-answer questions, answers outside the boxes provided will not be graded.

Show all relevant work.

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1. Select the molecule that possesses a dipole.

- ◯ CCl_4
- ◯ SeF_6
- ◯ CO_2
- ◯ NH_3

2. The temperature of an ideal gas increases 5-fold, while the volume decreases 2-fold. How does the pressure change?

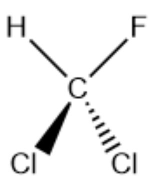
- ◯ Increases 10-fold
- ◯ Increases 2.5-fold
- ◯ Decreases 10-fold
- ◯ Decreases 2.5-fold

3. What is the H-C-H bond-angle of ethylene (below).

$$H_2C{=}CH_2$$

- ◯ 180 degrees
- ◯ 120 degrees
- ◯ 109.5 degrees
- ◯ 107 degrees

4. Identify the chiral molecule.



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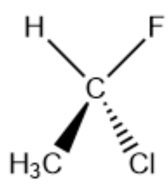

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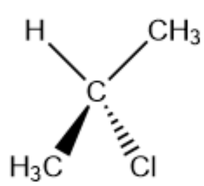

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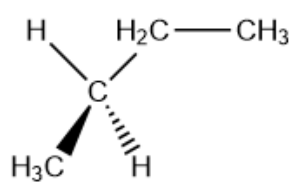

◯

5. Choose the diatomic molecule with the greatest bond order.

- ◯ N_2
- ◯ H_2
- ◯ O_2
- ◯ F_2

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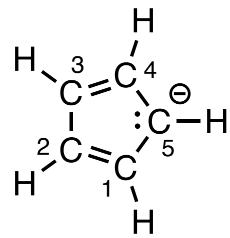
6. Consider the planar molecule cyclopentadienyl anion ($C_5H_5^-$), with the carbon atoms numbered from 1-5, as sketched in the diagram below. Complete the following questions. Please reason your answers and show your work:

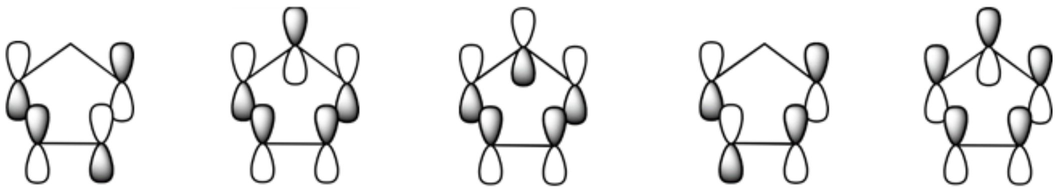


a. $C_5H_5^-$ has 5 *equivalent* Lewis dot structures. Draw 2 other Lewis dot structures of $C_5H_5^-$. Please number your carbons.

b. What is the hybridization of the carbon atoms? Hint: All carbon atoms are identical and the geometry of $C_5H_5^-$ is planer.

- ◯ sp
- ◯ sp^2
- ◯ sp^3

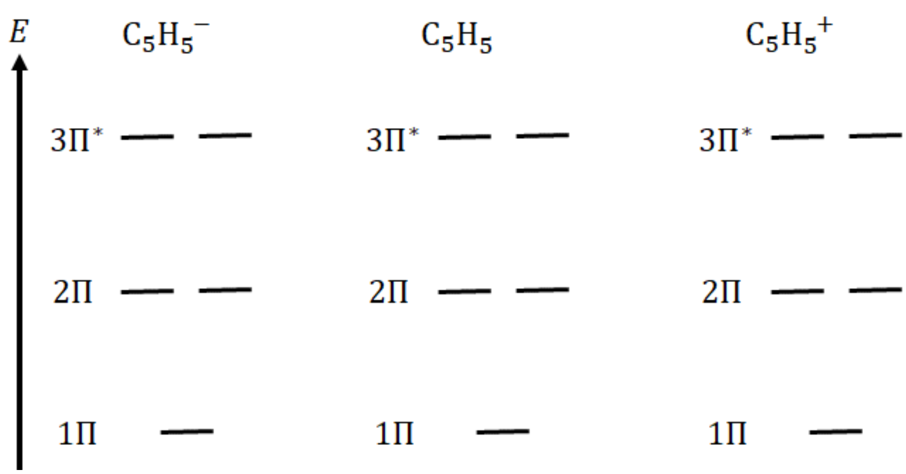
c. Consider the pi molecular orbitals hybridized from the $2p_z$ on each carbon atom, as shown in the diagram below. The $2p_z$ orbitals are perpendicular to the plane of the molecule. Which is/are the lowest energy molecular orbital(s)? Which is/are the highest energy molecular orbital(s). You may select more than one.



(i) (ii) (iii) (iv) (v)

Lowest energy	Highest energy
◯ i	◯ i
◯ ii	◯ ii
◯ iii	◯ iii
◯ iv	◯ iv
◯ v	◯ v

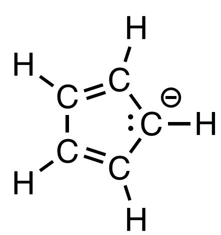
d. The energy level diagrams below show the positioning of the orbitals for cyclopentadienyl. Complete the electronic configuration ***for the pi bond system*** using Aufbau, Pauli, and Hund rules for the cyclopentadienyl anion ($C_5H_5^-$), neutral (C_5H_5), and cation ($C_5H_5^+$). Do not account for electrons in sigma bonds.

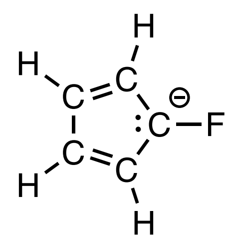


e. Which molecule(s) is/are magnetic?

- ◯ $C_5H_5^-$
- ◯ C_5H_5
- ◯ $C_5H_5^+$

f. The molecule 1-floro-2,4-cyclopentadienide anion ($C_5H_4F^-$) is identical to cyclopentadienyl anion ($C_5H_5^-$) with one of the hydrogens replaced with florin atom (see the figure below). Circle the molecule that has a dipole moment and draw an arrow pointing in the direction of the dipole (from negative to positive charge).





7. Consider the molecule beryllium hydride, BeH_2. Assume that Be (electronic configuration $1s^2\ 2s^2$) and H (electronic configuration $1s^1$) are covalently bonded and answer the following questions:

a. Write the best Lewis structure for this molecule. Using VSEPR explain in 1-2 sentences why the geometry of BeH_2 is linear and why BeH_2 has no dipole moment.

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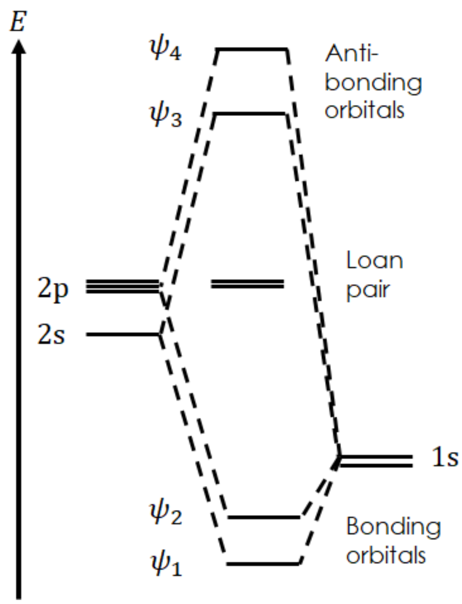
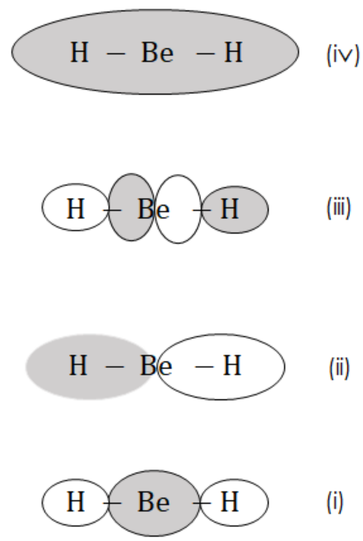
b. The energy level diagram below describes the molecular orbital energies of BeH_2. The two lowest molecular orbitals are bonding, and the two highest molecular orbitals are anti-bonding. The molecular orbitals shown on the right diagram were formed by hybridizing the 1s orbital of each hydrogen atom with the 2s and the $2p_z$ orbitals of Be (color code: dark is positive; bright is negative). The $2p_x$ and $2p_y$ orbitals of Be are load pair (often called “non-bonding”) and do not participate in bond formation. Assign the molecular orbital (i)-(iv) to the corresponding orbital energies ($\psi_1 - \psi_4$).





c. Use the diagram above (in b.) to complete the electronic configuration of BeH_2. What is the bond order for each Be-H bond?

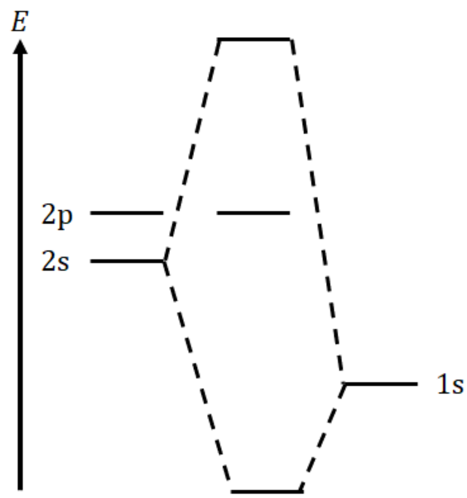
bond order: ________

d. Would Be-H bond in BeH_2 be shorter or longer than the O-H bond in water? Use periodic trends and reason your answer in 1-2 sentences.

◯ BeH_2 bonds would be shorter ◯ BeH_2 bonds would be longer	Explain:

e. Consider the reaction $\mathrm{BeH_2} \rightarrow \mathrm{H}\cdot + \cdot\mathrm{BeH}$ (the "·" symbol for a radical). Write the Lewis dot structure of BeH· radical (remember: radicals have odd number of electrons and thus, are an exception to the complete shell rule).

f. The electronic configuration of BeH· can be explained by hybridizing the 1s orbital on H with the 2s and 2p orbitals on Be (see diagram below). Label each MO as "bonding", "anti-bonding," or "non-bonding" (complete your answer on the diagram).



g. What is the bond order of BeH·?

bond order: _______

8) Consider a model of a hypothetical single-electron atom that is different from the hydrogen atom. This atom has two quantum numbers, n and ℓ. There is one orbital for each combination of n and ℓ.

n can be any positive integer: $n = 1, 2, 3, \ldots$
The possible values of ℓ depend on n: $\ell = -(n-1), \ldots, 0, \ldots, n-1$
The energy of a state depends only on n: $E_n = -\frac{Ry}{(2n-1)^2}$, where Ry is Rydberg's constant.

i. By filling in the table below, indicate the energy and degeneracy of each level, up to $n = 4$. (Recall that degeneracy is the number of states with the same energy.)

n	E_n/Ry	possible ℓ values	degeneracy
1	$-Ry$	0	1
2			
3			
4			

ii. A certain transition of this atom causes a photon with energy $hv = 0.0196\ Ry$ to be emitted. The initial state in this transition has $n_{\text{init}} = 4$. What is the value of n in the final state?

_______________ Final Answer

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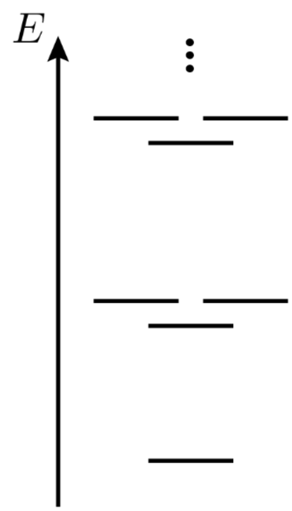
The orbitals of this model can be filled with electrons to make hypothetical multi-electron atoms. Due to screening, the $\ell = 0$ orbitals have slightly lower energy than those with $\ell \neq 0$ for the same value of n. The energy level diagram below shows the positioning of these orbitals.



Aufbau, Pauli, and Hund's rules apply to the filling of these orbitals.

iii. Write the electronic configuration of an atom with 6 electrons. By analogy with the hydrogen atom, use "s" to refer to orbitals with $\ell = 0$, and use "p" to refer to orbitals with $\ell = \pm 1$.

iv. For this model, an atom with 8 electrons is extremely stable and non-reactive. Explain this observation using its electron configuration.