001
version

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McCord CH301

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TTh 9:30 am - 11 am

Exam 3

Nov 5, 2018

Monday 7:30 - 9:00 PM

A - Mi in BUR 106

Mo - Z in JES A121A

Remember to refer to the Periodic Table handout that is separate from this exam copy.

no calculators

NOTE: Please keep this exam copy intact (all pages still stapled - including this cover page). You must turn in ALL the materials that were distributed. This means that you turn in your exam copy (name and signature included), bubble sheet, periodic table handout, and all scratch paper. Please also have your UT ID card ready to show as well.

This print-out should have 25 questions. Multiple-choice questions may continue on the next column or page – find all choices before answering.

001 4.0 points

What is the molecular geometry of nitrogen triiodide, NI_3? Is this molecule polar or nonpolar?

1. Trigonal planar, nonpolar

2. Trigonal pyramid, polar **correct**

3. Trigonal bipyramid, polar

4. T-shaped, polar

5. Tetrahedral, polar

6. Trigonal pyramid, nonpolar

Explanation:
NI_3 has a tetrahedral electronic geometry with 3 bonds and a lone pair. This is a trigonal pyramid molecule geometry that has overall polarity due to the lone pair.

002 4.0 points

Which of the following fully describes the VSEPR geometry of $TeCl_4$?

1. Tetrahedral molecular geometry with zero lone pairs

2. See-saw molecular geometry with one lone pair in the axial position

3. Trigonal bipyramid molecular geometry with one lone pair in the equatorial position

4. See-saw molecular geometry with one lone pair in the equatorial position **correct**

5. Square planar molecular geometry with two lone pairs in the equatorial position

Explanation:
$TeCl_4$ has four bonding regions and one lone pair. This results in a see-saw molecular geometry with one lone pair in the equatorial position.

003 4.0 points

Which of the following angles is the best choice to describe the bond angle in nitrite NO_2^-?

1. 120°

2. slightly less than 120° **correct**

3. 180°

4. slightly less than 109.5°

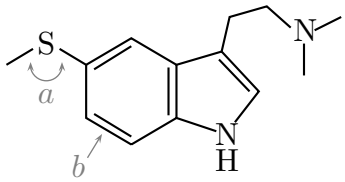
5. slightly less than 180°

6. 109.5°

Explanation:
NO_2^- is a bent molecule on a trigonal planar electronic geometry. So the initial geometry is for 120° bond angles. However, one of the regions is a lone pair, which will push the 2 N-O bonds closer and therefore result in an angle that is less than 120°. The actual bond angle for nitrate is about 115°.

004 (part 1 of 3) 4.0 points

The molecule shown below is a chemical that was discovered to have mild interactions with human HT-2A receptors. Assume all atoms in the structure below obey the octet rule.



What is the correct empirical formula for this compound?

1. $C_{15}H_{17}N_2S$

2. $C_{13}H_{19}N_2S$

3. $C_{13}H_{19}N_2S$

4. $C_{13}H_{12}N_2S$

5. $C_{12}H_{15}N_2S$

6. $C_{13}H_{18}N_2S$ **correct**

Explanation:
The empirical formula is $C_{13}H_{18}N_2S$.

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005 (part 2 of 3) 4.0 points
Which of the following best represents the bond angle labeled a?

1. 118°

2. 90°

3. 178°

4. 109.5°

5. 180°

6. 120°

7. 104.5° **correct**

Explanation:
There are two (not shown) lone pairs on the sulfur atom, which means there are 4 electron regions and therefore a tetrahedral electronic geometry which has a bond angle of 109.5°. The lone pairs are more repulsive than the bonding pairs and therefore pushes the angles down to about 104.5°.

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006 (part 3 of 3) 4.0 points
What is the name of the carbon-carbon bond formed from hybrid orbitals on the internuclear axis, labeled by arrow b?

1. $\pi_{sp^3-sp^3}$

2. σ_{sp-sp^2}

3. $\sigma_{sp^2-sp^2}$ **correct**

4. σ_{2p-2p}

5. π_{2p-2p}

6. σ_{sp-sp}

7. $\pi_{sp^2-sp^2}$

8. σ_{sp^2-2p}

Explanation:
There are two bonds here. One is a pi bond formed based on the overlap of pure 2p orbitals: π_{2p-2p}. However, the one formed on the internuclear axis is the sigma bond, formed from the overlapping hybrids: $\sigma_{sp^2-sp^2}$.

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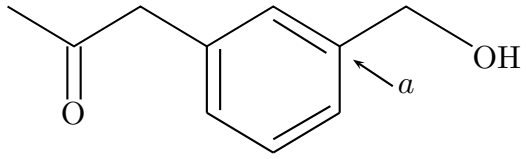
007 (part 1 of 2) 4.0 points
Consider the organic line structure shown below:



How many sigma and pi bonds are in this molecule?

1. $\sigma = 24$, $\pi = 3$

2. $\sigma = 12$, $\pi = 3$

3. $\sigma = 24$, $\pi = 12$

4. $\sigma = 26$, $\pi = 12$

5. $\sigma = 24$, $\pi = 4$ **correct**

6. $\sigma = 12$, $\pi = 4$

Explanation:
There are 20 single bonds and 4 double bonds: $\sigma = 24$, $\pi = 4$

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008 (part 2 of 2) 4.0 points
What is the hybridization around the carbon labelled a?

1. sp^2 **correct**

2. sp^4

3. $2p$

4. sp^3

5. $2s$

6. sp

Explanation:
This carbon has three regions of electron density. Therefore, it is sp^2.

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009 4.0 points

What is the hybridization around krypton in KrF_2?

1. sp^3d **correct**

2. sp

3. sp^3

4. sp^2

5. sp^3d^2

Explanation:
KrF_2 is a linear molecule with two bonds and three lone pairs. Krypton has a total of 5 regions of high electron density, meaning it has sp^3d hybridization.

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010 4.0 points

According to valence bond theory, which of the following best describes the π-bond between the carbon and oxygen in formaldehyde, CH_2O?

1. sp^2 hybrid orbitals overlap above and below the internuclear axis

2. The sp^2 hybrid orbital of oxygen overlaps with the p-orbital of carbon on the internuclear axis

3. p-orbitals overlap above and below the internuclear axis **correct**

4. p-orbitals overlap on the internuclear axis

5. p-orbitals overlap either above or below the internuclear axis

Explanation:
π-bonds are formed by the side-to-side overlap of p orbitals which results in electron density above and below the bond axis but not on the axis. σ-bonds have their densities on the bond axis.

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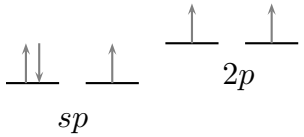
011 4.0 points

Consider the valence bond configuration for a central atom:



This atom belongs to which of the following molecules?

1. NH_3

2. CN^- **correct**

3. CO_3^{2-}

4. CO_2

5. NO_2^-

Explanation:
The valence bond configuration shows one lone pair, one sigma bond, and two pi-bonds. This could be either the carbon or the nitrogen on CN^-.

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012 4.0 points

Which of the following is an advantage specific to molecular orbital theory?

1. The magnetic properties of molecules are accurately predicted in molecular orbital diagrams **correct**

2. Molecular orbital diagrams prove that p-electrons can only form pi bonds and s-electrons can only form sigma bonds

3. Molecular orbital theory provides the hybrid orbitals for localized electrons in a molecule

4. The incredibly complex nature of molecular orbital theory allows for easy navigation of large organic molecules

Explanation:
Evaluating each statement, the only true advantage of MO theory that is listed is that the magnetic properties of molecules can be accurately predicted in MO diagrams.

Disadvantage: The incredibly complex nature of molecular orbital theory actually makes navigation of large organic molecules difficult, which is why organic chemists often use VB theory to quickly describe the bonding of central atoms.

Untrue statements: Molecular orbital theory provides the hybrid orbitals for localized electrons in a molecule, molecular orbital diagrams prove that *p*-electrons can only form pi bonds and *s*-electrons can only form sigma bonds.

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013 4.0 points

According to molecular orbital theory, antibonding orbitals...

1. are lower in energy than bonding orbitals and are therefore populated with electrons prior to bonding orbitals

2. increase the electron density between two bonding atoms when populated with electrons

3. decrease the stability of a bonding region when populated with electrons **correct**

4. are higher in energy than bonding orbitals and are therefore populated with electrons prior to bonding orbitals

Explanation:
Antibonding orbitals form from the overlap of atomic orbitals, are higher in energy than bonding orbitals, are populated with electrons after the corresponding bonding orbitals are populated and lend instability to the molecule when populated with electrons.

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014 4.0 points

Consider the MO diagram for F_2^+. What is the bond order? Is F_2^+ paramagnetic or diamagnetic?

1. 2.5, diamagnetic

2. 2, diamagnetic

3. 1.5, paramagnetic **correct**

4. 2.5, paramagnetic

5. 1.5, diamagnetic

6. 1, diamagnetic

7. 2, paramagnetic

Explanation:
F_2^+ has 8 bonding electrons and 5 antibonding electrons.

$$\text{BO} = \frac{1}{2}[(\text{bonding e}^-) - (\text{antibonding e}^-)]$$
$$= \frac{1}{2}(8 - 5) = 1.5$$

F_2^+ has unpaired electrons and is therefore paramagnetic.

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015 4.0 points

A solar farm utilizes the cadmium telluride class of photovoltaics (CdTe) because of their thin size, cost-effectiveness, and efficient photon absorption at around 824 nm. However, the peak efficiency for a solar cell is around 700 nm. Which of the following materials would be a more efficient alternative to CdTe?

1. A crystalline silicon cell with a longer wavelength of absorption than CdTe

2. A mono-silicon cell that has a larger HOMO-LUMO gap than CdTe **correct**

3. None of the choices will increase the efficiency of the solar farm

4. An amorphous silicon cell with a smaller frequency of asborption than CdTe

5. A multi-silicon cell that has a smaller HOMO-LUMO gap than CdTe

Explanation:
While CdTe is an efficient photovoltaic, you could increase efficiency by selecting a material with a HOMO-LUMO gap closer to the peak photon emission of the sun. This would be a shorter wavelength, or higher energy (bigger HOMO-LUMO gap). The only material in the answer choices that fits this description is the mono-silicon cell.

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016 4.0 points

The HOMO-LUMO gap of C_2 refers to the energy difference between which two orbitals?

1. σ^*_{2p} and π^*_{2p}

2. π^*_{2p} and σ_{2p}

3. σ^*_{2s} and π^*_{2p}

4. σ_{2s} and π_{2p}

5. π_{2p} and σ_{2p} **correct**

6. σ^*_{2s} and π_{2p}

Explanation:
C_2 has eight total electrons valence electrons. The highest occupied orbital (HOMO) is the π_{2p} and the next orbital available (LUMO) is the σ_{2p}.

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017 4.0 points

Polarizability is...

1. how easily a molecule maintains a permanent dipole based on its geometry

2. a measurement of the total resonance in a molecule

3. how easily a molecule maintains a permanent dipole based on the size of its electron clouds

4. how easily a molecule induces a dipole based on the size of its electron clouds **correct**

5. the net formal charge on a bonding atom

Explanation:
The more electrons a molecule has and the farther they are from all the nuclei will affect how easily a dipole can be induced in the electron cloud (aka: polarized).

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018 4.0 points

State the dominant intermolecular force possible for each compound, respectively:

O_3 , SF_6 , NH_3 , C_6H_6

1. dipole-dipole, dispersion, hydrogen-bonding, dispersion **correct**

2. dispersion, dipole-dipole, dipole-dipole, dispersion

3. dipole-dipole, dipole-dipole, dipole-dipole, hydrogen-bonding

4. dispersion, dispersion, hydrogen-bonding, dispersion

5. dipole-dipole, dispersion, hydrogen-bonding, dipole-dipole

6. dispersion, dipole-dipole, hydrogen-bonding, dispersion

Explanation:
O_3 has non-polar bonds, but lone pairs, resonance, and unequal formal charge that create a polar molecule. Therefore, it has dipole-dipole interactions.

SF_6 has polar bonds but perfect symmetry in the octahedral molecular geometry. Therefore, it has dispersion forces.

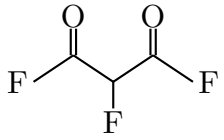
NH_3 has hydrogen bonds.

C_6H_6 has only non-polar bonds and three-

dimensional symmetry.

019 4.0 points

What types of intermolecular forces are present in a homogenous mixture of the molecule shown below?



1. dispersion forces only

2. hydrogen bonding only

3. dispersion forces, dipole-dipole **correct**

4. dispersion forces, dipole-dipole, ion-dipole

5. dispersion forces, dipole-dipole, hydrogen bonding

6. dispersion forces, hydrogen bonding

Explanation:
The molecule shown has polar bonds and three dimensional asymmetry in its connectivity, despite how symmetrical it appears in the two-dimensional Lewis structure. Therefore, it has dipole-dipole interactions. All molecules are capable of dispersion forces.

020 4.0 points

Which of the following can form hydrogen bonds with another molecule of itself?

I. CH_3F

II. CH_3CH_2OH

III. CH_3OCH_3

IV. CH_2O

1. I, III, and IV only

2. II only **correct**

3. I and II only

4. I only

5. I, II, III, and IV

Explanation:
The only molecule listed capable of making a hydrogen bond is ethanol, CH_3CH_2OH.

021 4.0 points

Consider the two molecules: H_2S and SiH_4. Which of these hydrides has the higher vapor pressure and why?

1. H_2S, because it is less polarizable

2. SiH_4, because it is more polarizable

3. H_2S, because it is more polar

4. H_2S, because it can hydrogen bond

5. SiH_4, because it is a symmetrical molecule with only dispersion forces **correct**

Explanation:
These two hydrides are in the same period. Compare the IMFs based on shape. Because SiH_4 is a symmetrical molecule, it will be dominated by dispersion forces. This means it will have lower IMFs and a higher vapor pressure.

022 4.0 points

Consider the following boiling point data:

$$\text{HBr, } T_b = -66^\circ\text{C}$$

$$\text{HI, } T_b = -35^\circ\text{C}$$

Which of the following explains why HI has a higher boiling point than HBr?

1. HI is more polarizable than HBr **correct**

2. The highly polarizable dispersion forces of HBr are stronger than the dipole-dipole forces of HI

3. The dipole-dipole forces of HBr are stronger than the dipole-dipole forces of HI

4. The highly polar dipole-dipole forces of HI are stronger than the dipole-dipole forces of HBr

Explanation:
Br is more electronegative than I, even though the boiling point for HI is higher. This can only be explained by having dispersion forces as the dominant force present. I is larger and more polarizable than Br, which is why the dispersion forces are greater for HI.

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023 4.0 points

A liquid poured into a graduated cylinder has stronger cohesive forces than adhesive forces. Which of the following best describes the meniscus formed?

1. The meniscus is concave because the forces between the liquid and the walls of the container are stronger than forces between the liquid molecules

2. The meniscus is convex because the forces between the liquid and the walls of the container are stronger than forces between the liquid molecules

3. The meniscus is convex because the liquid molecules on the surface are more attracted to each other than the walls of the container **correct**

4. The meniscus is concave because the liquid molecules on the surface are more attracted to each other than the walls of the container

Explanation:
A meniscus is always formed to maximize attractions and minimize the potential energy. The convex meniscus is formed by cohesive forces between liquid molecules.

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024 4.0 points

Consider a solid that has a molar mass of 180.2 g/mol and a melting point of 423 K. This solid is a terrible electrical conductor, even when fully dissolved in an aqueous medium. What type of solid is this compound?

1. Molecular **correct**

2. Metallic

3. Ionic

4. Covalent network

Explanation:
Since the solid has a relatively small molar mass and low melting point, and it is not a conductor in solution, it is most likely molecular compound.

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025 4.0 points

Arrange the following substances in order from lowest to highest theoretical melting point:

SiO_2 , H_2O , $NaNO_3$, LiF , BCl_3

1. $H_2O < NaNO_3 < BCl_3 < LiF < SiO_2$

2. $BCl_3 < H_2O < NaNO_3 < LiF < SiO_2$ **correct**

3. $BCl_3 < H_2O < LiF < NaNO_3 < SiO_2$

4. $BCl_3 < SiO_2 < LiF < NaNO_3 < H_2O$

5. $SiO_2 < LiF < H_2O < BCl_3 < NaNO_3$

Explanation:
SiO_2 is a network covalent solid. Both LiF and $NaNO_3$ are ionic solids, but LiF has a greater charge density. H_2O is a molecular substance capable of hydrogen bonding. BCl_3 is a nonpolar molecular substance. Thus, arranging the compounds in order from lowest to highest melting point, we get:

$BCl_3 < H_2O < NaNO_3 < LiF < SiO_2$