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McCord CH301   # Exam 4   Nov 14, 2017
50070   Tuesday

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

This print-out should have 20 questions. Multiple-choice questions may continue on the next column or page – find all choices before answering.

001   5.0 points
A solid sample dissolves in water but does not conduct electricity. The sample melts at 433K. Which type of solid is this?

1. Metallic solid

2. Ionic solid

3. Covalent network solid

4. Molecular solid **correct**

Explanation:
Molecular solids have relatively low melting points and do not conduct electricity.

002   5.0 points

What types of intermolecular forces are present in a homogenous mixture of the molecule shown below?
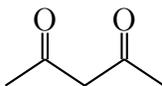
1. dispersion forces, dipole-dipole **correct**

2. dispersion forces only

3. hydrogen bonding only

4. dispersion forces, dipole-dipole, hydrogen bonding

5. dispersion forces, hydrogen bonding

6. dispersion forces, dipole-dipole, ion-dipole

Explanation:
The molecule shown has polar bonds. Therefore, it has dipole-dipole interactions. All molecules are capable of dispersion forces.

003   5.0 points
Rank the following substances in order of freezing point: Ne, Rn, Kr, He

1. $Rn < He < Ne < Kr$

2. $Kr < Ne < Rn < He$

3. $He < Ne < Kr < Rn$ **correct**

4. $Kr < Ne < He < Rn$

5. $He < Ne < Rn < Kr$

Explanation:
When determining the relative IMFs within a group, you should rank based on polarizability (molecular weight). Therefore, the ranking is: $He < Ne < Kr < Rn$

004   5.0 points
Arrange the following substances in order from highest to lowest melting point:

SiO_2 , CH_3CH_2OH , RbF , $CaSO_4$

1. $SiO_2 > CaSO_4 > RbF > CH_3CH_2OH$ **correct**

2. $CH_3CH_2OH > CaSO_4 > RbF > SiO_2$

3. $SiO_2 > RbF > CaSO_4 > CH_3CH_2OH$

4. $SiO_2 > CaSO_4 > CH_3CH_2OH > RbF$

5. $CH_3CH_2OH > RbF > CaSO_4 > SiO_2$

Explanation:
SiO_2 is a network covalent solid. Both $CaSO_4$ and RbF are ionic solids, but $CaSO_4$ has a greater charge density. CH_3CH_2OH is a molecular solid. Thus, arranging the compounds in order from highest to lowest melting point, we get:

$SiO_2 > CaSO_4 > RbF > CH_3CH_2OH$.

005   5.0 points
Which of the following best describes why H_2Te has a higher boiling point than H_2S?

1. H_2Te is more polar than H_2S

2. H_2S is larger than H_2Te

3. H_2Te is capable of hydrogen bonding

4. H_2S is more polarizable than H_2Te

5. H_2Te is more polarizable than H_2S **correct**

6. None of the above

Explanation:
Both H_2Te and H_2S have similar polar molecular structures. However, H_2Te will be more polarizable because Te is larger than S, resulting in a higher BP.

006   5.0 points
State the dominant intermolecular force in each compound, respectively:

CBr_4 , NH_3 , CH_3F , $C_{12}H_{14}$

1. dipole-dipole, hydrogen-bonding, dipole-dipole, hydrogen-bonding

2. dipole-dipole, hydrogen-bonding, hydrogen-bonding, dispersion

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

4. dipole-dipole, dispersion, hydrogen-bonding, dispersion

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

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

Explanation:
CBr_4 consists of polar bonds but the molecule is overall non-polar. Therefore, CBr_4 is dominated by dispersion forces. NH_3 is capable of hydrogen bonding. CH_3F looks like it could have hydrogen bonding, but the fluorine is not connected to a hydrogen. Therefore, CH_3F is dominated by dipole-

dipole interactions. $C_{12}H_{14}$ is an organic, non-polar molecule dominated by dispersion forces.

007   5.0 points
In a molecular orbital diagram for C_2, the LUMO refers to the

1. σ_{2s}^*

2. π_{2p}^*

3. σ_{2p}^*

4. σ_{2s}

5. σ_{2p} **correct**

6. π_{2p}

Explanation:
C_2 has eight valence electrons.

008   5.0 points
Which of the following statements is true regarding molecular orbital theory?

1. Energy is conserved when pure atomic orbitals combine to form bonding and anti-bonding orbitals **correct**

2. Antibonding orbitals lend energetic stability to the overall molecule

3. All diatomic molecules with an even number of total electrons are diamagnetic

4. Molecular orbital theory can only depict the bonding of homonuclear diatomic molecules

Explanation:
Not all diatomic molecules with an even number of total electrons are diamagnetic. An example of this is O_2. Molecular orbital theory is advantageous because complex diagrams can depict the bonding of heteronuclear molcules of all sizes. The only true statement is: Energy is conserved when pure atomic orbitals combine to form bonding and

antibonding orbitals

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009   5.0 points
A liquid poured into a graduated cylinder forms a concave meniscus. Which of the following statements is true regarding this liquid sample?

1. The meniscus is formed to minimize the attractive forces between the liquid molecules and the walls of the container

2. The meniscus is concave because the adhesive forces are lower in energy than the cohesive forces **correct**

3. The meniscus forms to maximize the potential energy of the liquid

4. 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. In this case, a concave meniscus is formed by adhesive forces between liquid molecules and the walls of the container.

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010   5.0 points
Consider the MO diagram for F_2^+. What is the bond order? Is F_2^+ paramagnetic or diamagnetic?

1. 2, paramagnetic

2. 1, diamagnetic

3. 2.5, paramagnetic

4. 2, diamagnetic

5. 2.5, diamagnetic

6. 1.5, diamagnetic

7. 1.5, paramagnetic **correct**

Explanation:

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

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

F_2^+ has unpaired electrons and is therefore paramagnetic.

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011   5.0 points

Which of the following has the lowest surface tension?

1. OH

2. HO OH

3.

4. NH$_2$

5.   **correct**
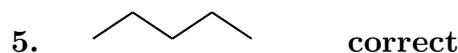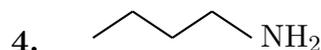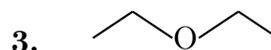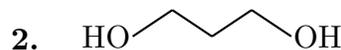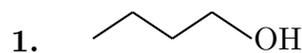
Explanation:
The molecule that has the lowest surface tension will have dispersion forces only. Of the molecules shown, the molecule will the weakest IMF's will exhibit the most hydrogen bonding.

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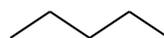
012   5.0 points

Comparing organic molecules, more double bonds correspond to a smaller HOMO-LUMO gap. For example, β-carotene has a pi bond network of 11 bonds and absorbs light in the visible spectrum. An advantage of this is that organic molecules can be selectively synthesized to absorb at specific wavelengths. Based on this information, if you wanted to synthesize a sunscreen that absorbs light in the UV range you would want

1. to absorb at longer wavelengths than β-carotene

2. a larger network of pi bonds than β-carotene

3. none of the above

4. a smaller network of pi bonds than β-carotene **correct**

5. a smaller HOMO-LUMO gap than β-carotene

Explanation:
The question stem states that more double bonds (a larger network of pi bonds) corresponds to a smaller HOMO-LUMO gap. To absorb at the UV range, you would need a large HOMO-LUMO gap. This means you will need fewer double bonds or a small network of pi bonds.

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013   5.0 points
The instability of a bond associated with anti-bonding orbitals is best explained by...

1. Molecular Orbital Theory **correct**

2. Valence Bond Theory

Explanation:
Molecular orbital theory gives us insight into bonding and anti-bonding orbitals.

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014   5.0 points
A theoretical central atom has three bonding regions and two lone pair(s). What is the hybridization of this atom?

1. sp^3

2. sp^3d **correct**

3. sp

4. sp^3d^2

5. sp^2

Explanation:
To determine the valence bond hybridization of a molecule, you must consider all regions of electronic density. Five total electronic regions is sp^3d.

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015   5.0 points

The following structures are constitutional isomers, meaning they share the same molecular formula but the atoms are connected differently.

n-heptane:
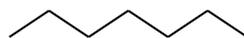
3-ethyl pentane:
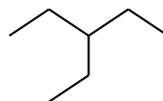
Which of the following best explains why n-heptane has a higher boiling point than 3-ethyl pentane?

1. 3-ethyl pentane is an overall larger molecule, which interferes with intermolecular forces

2. n-heptane has a greater surface area of overlap that can polarize to form instantaneous dipoles **correct**

3. n-heptane is an overall larger molecule, which interferes with intermolecular forces

4. Branched molecules allow dispersion forces to be more tightly packed than linear molecules

5. n-heptane is a more polar molecule

Explanation:
Dispersion forces have a very short range of interaction. Therefore, a molecule that can be more tightly packed will have a higher boiling point. Linear molecules, such as n-heptane have more regions of electron density that can form instantaneous dipoles (dispersion forces).

016   5.0 points

Consider the valence bond configuration for a central atom:

$$\underline{\uparrow\downarrow} \quad \underline{\uparrow} \quad \underline{\uparrow} \quad \underline{\uparrow}$$
$$sp^3$$
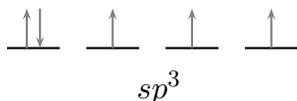
This central atom belongs to which of the following molecules?

1. $\left[\ddot{\text{O}}=\ddot{\text{N}}-\ddot{\text{O}}:\right]^{-}$

2. $\text{H}-\overset{\displaystyle\cdot\cdot}{\underset{\displaystyle|}{\text{P}}}-\text{H}$ **correct**
$\qquad\quad\text{H}$

3. $\ddot{\text{O}}=\text{C}=\ddot{\text{O}}$

4. $\text{H}-\overset{\displaystyle\text{H}}{\underset{\displaystyle|}{\underset{\displaystyle\text{H}}{|}}}\overset{|}{\text{C}}-\ddot{\text{O}}\text{H}$

5. $\text{H}-\overset{\displaystyle\text{H}}{\underset{\displaystyle|}{\underset{\displaystyle\text{H}}{|}}}\overset{|}{\text{C}}-\text{H}$
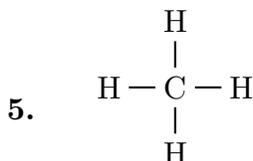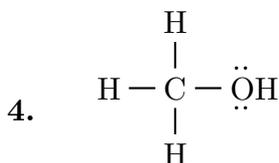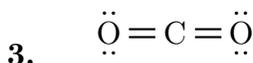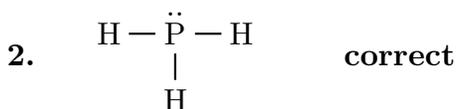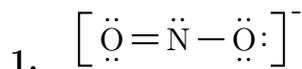
Explanation:

The valence bond configuration shows one lone pair and three sigma bonds. This is PH_3.

017   5.0 points

You are able to extract two saturated hydrocarbons, octane and decane, from a liquid organic mixture. Both molecules are linear hydrocarbons (i.e. there is no branching). Compared to octane, decane appears more viscous. You can conclude that decane also has:

I. a higher molecular weight

II. a smaller surface area

III. a higher boiling point

IV. a higher vapor pressure

1. III only

2. I, II and III only

3. none of the above

4. I and III only **correct**

5. II and III only

6. I, II, III, and IV

Explanation:
Viscosity is a qualitative way of determining the relative strength of IMF's. Because decane is more viscous, we know that it has stronger IMF's. Therefore, it will be expected to have a higher boiling point and a lower vapor pressure. A more branched structure will weaken the overall IMFs, so we cannot make this conclusion with the information provided. Because both structures are saturated hydrocarbons, we can conclude that decane has a higher MW.

018 (part 1 of 2) 5.0 points
Consider the following organic line structure:
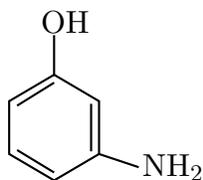
According the valence bond theory, how many sigma and pi bonds are in the organic structure above?

1. 3 σ and 12 π

2. 14 σ and 3 π

3. 18 σ only

4. 18 σ and 3 π

5. 15 σ and 3 π **correct**

Explanation:
Accounting for the "understood" hydrogen atoms, there are a total of 12 single bonds and 3 double bonds. This is a total of 15 σ and 3 π.

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019 (part 2 of 2) 5.0 points
For the structure shown above, what is the hybridization around oxygen?

1. sp^2

2. None of the above

3. sp^3 **correct**

4. sp

5. sp^3d^2

6. sp^3d

Explanation:
In this structure, oxygen has four regions of electron density, corresponding to a sp^3 hybridization.

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020   5.0 points
Name the bond in carbon dioxide (CO_2) that overlaps above and below the internuclear axis.

1. σ_{sp-sp}

2. σ_{sp^2-2p}

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

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

5. σ_{2p-2p}

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

7. π_{2p-2p} **correct**

8. σ_{sp^2-sp}

Explanation:
Pi bonds consist of overlapping p orbitals off the internuclear axis. For carbon dioxide, the $2p$ atomic orbitals overlap above and below the internuclear axis.