

Name: \_\_\_\_\_ Date: \_\_\_\_\_

## Answer Key: Vibrating Valence: Advanced Bonding Theory for 12th Grade Pros

Calculate formal charges and predict molecular geometries as if designing new semiconductor materials for the next generation of tech hardware.

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**1. Which transition metal complex exhibits Jahn-Teller distortion as a direct consequence of electronic degeneracy in its octahedrally coordinated d-orbitals?**

**Answer:** C)  $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$

$\text{Cu}^{2+}$  is a d9 system; in an octahedral field, the  $e_g$  orbitals are unevenly occupied, leading to a geometric distortion that lowers the symmetry and energy of the complex.

**2. In Molecular Orbital (MO) theory, the bond order of the dioxygen cation ( $\text{O}_2^+$ ) is \_\_\_\_\_, which explains its increased stability compared to neutral  $\text{O}_2$ .**

**Answer:** C) 2.5

Removing an electron from the antibonding  $\pi^*$  orbital of neutral  $\text{O}_2$  (bond order 2.0) increases the bond order to 2.5, resulting in a stronger, shorter bond.

**3. Based on VSEPR theory and hybridization in hypervalent molecules, Xenon tetrafluoride ( $\text{XeF}_4$ ) adopts a tetrahedral molecular geometry.**

**Answer:** B) False

$\text{XeF}_4$  has an  $\text{AX}_4\text{E}_2$  configuration ( $\text{sp}^3\text{d}^2$  hybridization), resulting in an octahedral electron geometry but a square planar molecular geometry due to the two lone pairs.

**4. Using Fajan's Rules, which of the following compounds displays the highest degree of covalent character despite being classified as an ionic halide?**

**Answer:** C)  $\text{LiI}$

$\text{LiI}$  combines a small, highly polarizing cation ( $\text{Li}^+$ ) with a large, highly polarizable anion ( $\text{I}^-$ ), which results in significant electron cloud overlap (covalency).

**5. In the context of Band Theory, a material where the valence band and conduction band overlap slightly, as seen in semi-metals like Bismuth, is known as a \_\_\_\_\_.**

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**Answer:** B) Semimetal

Semimetals possess a small overlap between the bottom of the conduction band and the top of the valence band, leading to unique electronic transport properties.

**6. The boiling point of Phosphine (PH<sub>3</sub>) is higher than that of Ammonia (NH<sub>3</sub>) because Phosphorus is heavier than Nitrogen.**

**Answer:** B) False

Ammonia (NH<sub>3</sub>) has a higher boiling point than PH<sub>3</sub> because NH<sub>3</sub> experiences strong intermolecular hydrogen bonding, which PH<sub>3</sub> lacks due to Nitrogen's higher electronegativity.

**7. The molecule Boron Trifluoride (BF<sub>3</sub>) is a powerful Lewis Acid. What is the hybridization of the Boron atom and the resulting bond angle?**

**Answer:** B) sp<sup>2</sup>, 120°

Boron in BF<sub>3</sub> has three valence electrons and forms three sigma bonds with no lone pairs, leading to sp<sup>2</sup> hybridization and a trigonal planar geometry.

**8. According to the LCAO-MO method, the mixing of 2s and 2p atomic orbitals occurs in homonuclear diatomic molecules of elements with atomic numbers Z d\_\_\_\_, affecting the order of sigma and pi levels.**

**Answer:** B) 7

For Li<sub>2</sub> through N<sub>2</sub> (Z=7), s-p mixing is significant enough that the sigma-2p molecular orbital is higher in energy than the pi-2p orbitals.

**9. Which of the following compounds contains a coordinate covalent bond (dative bond)?**

**Answer:** B) NH<sub>4</sub><sup>+</sup>

In the ammonium ion, the Nitrogen atom donates both electrons to a Hydrogen ion (H<sup>+</sup>) that has no electrons of its own, forming a coordinate covalent bond.

**10. In a metallic lattice, the 'Sea of Electrons' model explains the ductility of metals because the non-directional nature of the bonds allows layers of atoms to slide over each other without breaking.**

**Answer:** A) True

Unlike ionic crystals, where sliding causes repulsion between like-charged ions, delocalized electrons in metals maintain the bond during physical deformation.

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