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Answer Key: The Resonance of Molecular Geometry: A College Chemistry Challenge

Scholars analyze lattice energy, calculate formal charges, and predict hybridization patterns to explain the stability of complex polyatomic ions and crystal structures.

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1. Which of the following factors is primarily responsible for the increased lattice energy of Aluminum Nitride (AlN) compared to Magnesium Oxide (MgO)?

Answer: C) The increase in the product of ionic charges (Q1Q2)

According to Coulomb's Law, lattice energy is directly proportional to the product of the charges (Q1Q2). AlN involves +3 and -3 charges, whereas MgO involves +2 and -2, leading to a significantly higher lattice energy for AlN.

2. In the polyatomic ion Phosphate (PO4^3-), the formal charge on the phosphorus atom when drawn with an expanded octet to minimize formal charges is _____.

Answer: B) 0

To minimize formal charges in PO4^3-, phosphorus forms one double bond and three single bonds with oxygen. Phosphorus has 5 valence electrons and in this state has 5 bonds and no lone pairs, resulting in a formal charge of 0.

3. According to Valence Bond Theory, the central iodine atom in the triiodide ion (I3-) utilizes sp3d hybridization to accommodate its lone pairs and bonding pairs.

Answer: A) True

The triiodide ion has 5 electron domains around the central iodine (2 bonding pairs and 3 lone pairs), which requires five hybrid orbitals, characteristic of sp3d hybridization.

4. When examining the Molecular Orbital (MO) diagram for Nitrogen (N2), why are the sigma-2p orbitals higher in energy than the pi-2p orbitals?

Answer: A) Due to significant s-p mixing occurring in lighter diatomic molecules

In homonuclear diatomic molecules like Li2 through N2, the energy gap between 2s and 2p orbitals is small enough that s-p mixing occurs, which pushes the sigma-2p orbital higher in energy than the pi-2p orbitals.

5. The molecular geometry of Xenon Tetrafluoride (XeF4) is best described as _____.

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Answer: C) Square Planar

XeF4 has 6 electron domains (4 bonding and 2 lone pairs). The electron geometry is octahedral, but the lone pairs position themselves 180 degrees apart to minimize repulsion, resulting in a square planar molecular geometry.

6. Metallic bonding strength generally decreases across a period from left to right as the number of delocalized electrons increases.

Answer: B) False

Metallic bonding strength generally *increases* across a period because the number of delocalized electrons increases and the atomic radius decreases, causing stronger attraction between the 'sea' of electrons and the nuclei.

7. What is the bond order of the Oxygen molecule ion (O_2^+) based on Molecular Orbital Theory?

Answer: C) 2.5

Neutral O_2 has a bond order of 2. Removing an electron from an antibonding pi-star orbital to form O_2^+ increases the bond order by 0.5, resulting in a bond order of 2.5.

8. In a polar covalent bond, the vector quantity representing the partial charge separation and distance is known as the _____.

Answer: B) Dipole moment

The dipole moment is a quantitative measure of a bond's polarity, calculated as the product of the charge magnitude and the distance between the charges.

9. The Conductivity of a substance can always be used to definitively distinguish between ionic and covalent solids without further testing.

Answer: B) False

While many covalent solids are insulators, some (like graphite) conduct electricity. Furthermore, ionic solids do not conduct in the solid state, only when molten or dissolved, requiring more than a single simple conductivity test for distinction.

10. Which molecule exhibits a net dipole moment of zero despite containing polar bonds?

Answer: C) CCl_4

CCl_4 has four polar C-Cl bonds, but because the molecule is perfectly tetrahedral and symmetrical, the individual bond dipoles cancel each other out, resulting in a nonpolar molecule.

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