Part I. Short Answer: 4 points each (answer ALL 8 questions).

1. Match each orbital in the list below with the correct description: 3s, 2p, 4d, 1s
   - 1s Has the lowest energy
   - 2p Has one planar (or angular) node
   - 3s Has 2 total nodes
   - 4d Is one of a set of 5 degenerate orbitals

2. Of the following species, ______ has the largest radius.
   a) Rb+
   b) Sr^{2+}
   c) Br^-
   d) Kr
   e) Ar

3. Of the following atoms, which has the largest first ionization energy?
   a) K
   b) Rb
   c) Sr
   d) Ca
   e) Ba

4. Which of the following kinds of electromagnetic radiation has the highest energy per photon?
   a) visible light
   b) ultraviolet light
   c) infrared light
   d) microwaves
   e) radio waves

5. Which of the following ionic compounds possesses the smallest magnitude lattice energy?
   a) NaF
   b) NaCl
   c) NaBr
   d) NaI
   e) CsI
6. Which of the following sets of quantum numbers \((n, l, m, m_s)\) describes the highest energy electron of potassium in its ground state?

   a) \(4, 0, 0, +\frac{1}{2}\)
   b) \(3, 0, 0, +\frac{1}{2}\)
   c) \(3, 2, -2, -\frac{1}{2}\)
   d) \(4, 3, +3, +\frac{1}{2}\)
   e) \(4, 2, -2, -\frac{1}{2}\)

7. Which of the following bonds is most ionic?

   a) H-Cl
   b) F-Cl
   c) O-Cl
   d) Cs-Cl
   e) Li-Cl

8. Write the electron configuration of the following species:

   Cr: \([\text{Ar}] 4s^{1} 3d^{5}\)

   Zr^{4+}: \([\text{Kr}] 3d^{1}\)

Part II. Problems: answer ALL questions; you must show your work for partial credit

9. For the molecular anion \(\text{ICl}_4^-\),

   a) Draw a plausible Lewis dot structure

   \[
   \begin{array}{c}
   \vdots \vdots \\
   \vdots \vdots \\
   \vdots \vdots \\
   \vdots \vdots \\
   \end{array}
   \]

   b) Identify the electron domain geometry: \text{octahedral}

   c) Identify the molecular geometry: \text{square planar}

   d) Identify the hybridization about the central atom: \(d^2sp^3 (sp^3d^2)\)
10. A photon strikes the surface of a block of metal and an electron is ejected.
   a) What is the velocity of this electron if its de Broglie wavelength is $8.7 \times 10^{-11}$ m?
   \[
   \lambda = \frac{h}{mv} \Rightarrow v = \frac{h}{\lambda m} \\
   v = \frac{6.626 \times 10^{-34} J s}{(9.11 \times 10^{-34} kg)(8.7 \times 10^{-11} m)} = 8.4 \times 10^6 m/s
   \]
   b) What is the kinetic energy of this photoelectron?
   \[
   E_k = \frac{1}{2} mv^2 = \frac{1}{2} (9.11 \times 10^{-34} kg)(8.4 \times 10^6 m/s)^2 \\
   = 3.2 \times 10^{-17} J
   \]

11. What is the bond dissociation enthalpy of an oxygen-to-oxygen double bond if the enthalpy of combustion for one mole of ethane gas ($C_2H_6$) is approximately $-1.911 \times 10^3$ kJ?
   
   \[
   C_2H_6 + \frac{7}{2} O_2 \rightarrow 2CO_2 + 3H_2O
   \]

   Bond Dissociation Energies (kJ/mol)
   
   \[
   \begin{align*}
   C=O & \quad 1072 \\
   C=O & \quad 799 \\
   C-O & \quad 358 \\
   C-C & \quad 348 \\
   C-H & \quad 413 \\
   O=O & \quad 146 \\
   O-H & \quad 463 \\
   H-H & \quad 436
   \end{align*}
   \]

   \[
   \Delta H_{\text{comb}} = \sum \Delta H(\text{bonds broken}) - \sum \Delta H(\text{bonds formed})
   \]

   \[
   \Delta H_{\text{comb}} = D(C-C) + 6D(C-H) + \frac{7}{2} D(O=O) - 4D(C=O) - 6D(O-H)
   - 1911 \text{ kJ/mol} = 348 \text{ kJ/mol} + 6(413 \text{ kJ/mol}) + \frac{7}{2} D(O=O) - 4(1072 \text{ kJ/mol}) - 6(146 \text{ kJ/mol})
   \]

   \[
   1237 \text{ kJ/mol} = \frac{7}{2} D(O=O)
   \]

   \[
   D(O=O) = 353.4 \text{ kJ/mol}
   \]
12. An electron in monatomic hydrogen atom moves from a 1s orbital to a 3d orbital...
   (14 pts)
   a) Is this transition more likely to correspond to the absorption or emission of a photon?
   *Absorption*

   b) What is the wavelength of the photon?
   \[
   \Delta E = -2.178 \times 10^{-18} \text{ J} \left( \frac{1}{n_f^2} - \frac{1}{n_i^2} \right) = -2.178 \times 10^{-18} \text{ J} \left( \frac{1}{3^2} - \frac{1}{1^2} \right) \\
   = +1.938 \times 10^{-18} \text{ J} = \varepsilon_{\text{photon}} \\
   \varepsilon_{\text{photon}} = \frac{hc}{\lambda}, \quad \lambda = \frac{hc}{\varepsilon_{\text{photon}}} = \frac{(6.626 \times 10^{-34} \text{ J} \cdot \text{ s})(3.00 \times 10^{8} \text{ m/s})}{1.938 \times 10^{-18} \text{ J}} \\
   \lambda = 1.026 \times 10^{-7} \text{ m} = 102.6 \text{ nm}
   
   c) If this *hydrogen* electron moves from the 3d orbital to a 3p orbital, what is the \( \Delta E \)?
   \[ \Delta E = 0 \]

   d) What is the potential energy of the electron when it is no longer associated with the atom?
   \[ PE = 0 \]

13. For the nitrate anion (NO₃)... (14 pts)
   a) Draw the three most likely resonance forms as Lewis dot structures

   ![Lewis structures](image)

   b) How many ‘pi’ bonds does each structure have?
   \[ 1 \ \text{Ti bond} \]

   c) What is the average bond order for the N-O bonds?
   \[ 1 \ \frac{1}{3} \]

   d) How many unhybridized p-orbitals remain on the central atom?
   \[ 1 \]