Part I. Multiple Choice:

1. Which of the following pairs of atoms/ions is isoelectronic?
   ___ A. O\(^{-2}\), S\(^{-2}\)
   ___ B. Na, Na\(^{+1}\)
   X_ C. Br\(^{-1}\), Kr
   ___ D. Cu, Zn
   ___ E. none of these

2. Which of the following quantum number sets describes a 4f orbital?
   ___ A. n=2, l=0, m\(_l\)= 0
   ___ B. n=3, l=1, m\(_l\)= -1
   ___ C. n=3, l=2, m\(_l\)= -1
   ___ D. n=4, l=2, m\(_l\)= +1
   X_ E. n=4, l=3, m\(_l\)= +2

3. Which element below has the largest atomic radius?
   ___ A. S
   X_ B. P
   ___ C. N
   ___ D. B
   ___ E. F

4. Which element below has the highest electronegativity?
   ___ A. C
   ___ B. P
   X_ C. N
   ___ D. B
   ___ E. Be

5. Order the elements S, Cl, and F in terms of increasing atomic radii.
   ___ A. S, Cl, F
   ___ B. Cl, F, S
   ___ C. F, S, Cl
   X_ D. F, Cl, S
   ___ E. S, F, Cl

6. Which of the following statements is true?
   ___ A. Electrons are never found in an antibonding MO.
   ___ B. All antibonding MOs are higher in energy than the atomic orbitals of which they are composed.
   ___ C. Antibonding MOs have electron density mainly outside the space between the two nuclei.
   ___ D. None of the above is true.
   X_ E. Two of the above statements are true. (B and C)
Part II. Short Answers and Calculations To get full credit you must show all your work!

7. Give the electron configuration for the following atoms and ions (condensed notation is OK).

\[
\text{Zr} \quad \underline{\text{[Kr] \, 5s}^2\text{4d}^2} \quad \text{(or \, 4d}^2\text{5s}^2) \quad \text{______________________________}
\]

\[
\text{V}^{+3} \quad \underline{\text{[Ar] \, 3d}^2} \quad \text{______________________________________}
\]

8. Circle the correct answer for each of the following:

a) The lowest (least endothermic) 1st ionization energy: \text{Li, Na, Mg}

b) The greatest (most exothermic) electron affinity: \text{As, Se, Br}

9. Rank the following orbitals in an atom of hydrogen from lowest to highest energy (list them below in order using the < symbol and the = symbol if any orbitals are the same energy): 1s, 2s, 2p, 3s

\[\text{lowest energy \quad 1s < 2s = 2p < 3s} \quad \text{highest energy}\]

10. Rank the following orbitals in an atom of sodium from lowest to highest energy (list them below in order using the < symbol and the = symbol if any orbitals are the same energy): 1s, 2s, 2p, 3s

\[\text{lowest energy \quad 1s < 2s < 2p < 3s} \quad \text{highest energy}\]

11. How many electrons can be accommodated in the \(n = 4\) quantum shell? \underline{32}

12. In one sentence, clearly explain why NO has a small bond dipole (polar compound) and the oxygen has a partial negative charge. You can draw a picture to support your answer.

\text{Oxygen is more electronegative than nitrogen, so the bond dipole points toward the O.}
13. In one sentence, clearly explain why CO has a small bond dipole (polar compound) and the oxygen has a partial positive charge. You can draw a picture to support your answer.

Although oxygen is more electronegative than carbon, CO has a +1 formal charge on O and a -1 formal charge on C, which causes a slight bond dipole toward the C.

\[ \text{CO} \]

14. In one sentence, clearly explain why MgO has a much higher lattice energy than NaF.

It takes more energy to separate ions with larger charges due to increased coulombic attraction.

15. For laughing gas, N₂O

a) Draw a valid Lewis structure below (connectivity N\text{–}N\text{–}O). Assign formal charges to all atoms.

\[ \text{N} \text{N} \text{O} \]

b) Draw two additional resonance structures of the structure you drew in part (a). Assign formal charges to all atoms.

\[ \text{N} \text{N} \text{O} \]

\[ \text{N} \text{N} \text{O} \]

\[ \text{N} \text{N} \text{O} \]

c) Circle the single structure above (from the three structures in parts (a) and (b)) that most closely represents the true structure of N₂O and briefly explain your choice.

*Formal charges are minimized and the -1 formal charge is on the most electronegative atom.*
16. Phosgene (COCl₂) was used as a chemical warfare agent in World War I. It can be synthesized by reacting carbon monoxide with chlorine as shown below. Use the table of bond enthalpies to estimate the heat of reaction ($\Delta H_{rxn}$) for the formation of phosgene.

$$\text{CO} + \text{Cl}_2 \rightarrow \text{COCl}_2$$

<table>
<thead>
<tr>
<th>Bond type</th>
<th>$BE$ (kJ/mol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-O</td>
<td>360</td>
</tr>
<tr>
<td>C=O</td>
<td>750</td>
</tr>
<tr>
<td>C≡O</td>
<td>1070</td>
</tr>
<tr>
<td>C-Cl</td>
<td>330</td>
</tr>
<tr>
<td>Cl-Cl</td>
<td>240</td>
</tr>
</tbody>
</table>

$\Delta H_{rxn} = $ bonds broken - bonds formed

$= (1070 + 240) - (750 + 2(330)) = -100 \text{ kJ/mol}$
17. Complete the following Table:

<table>
<thead>
<tr>
<th>Chemical Formula: SiF$_4$</th>
<th>Chemical Formula: NO$_2^+$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lewis Structure:</strong></td>
<td><strong>Lewis Structure:</strong> (nitrogen is the central atom)</td>
</tr>
<tr>
<td><img src="image" alt="Lewis Structure of SiF$_4$" /></td>
<td><img src="image" alt="Lewis Structure of NO$_2^+$" /></td>
</tr>
<tr>
<td>Molecular Geometry: (words only, you do not have to draw the molecule in three dimensions)</td>
<td>Molecular Geometry: (words only, you do not have to draw the molecule in three dimensions)</td>
</tr>
<tr>
<td><em>tetrahedral</em></td>
<td><em>linear</em></td>
</tr>
<tr>
<td>Molecular Polarity (yes/no):</td>
<td>Molecular Polarity (yes/no):</td>
</tr>
<tr>
<td>Hybridization of the Si atom:</td>
<td>Hybridization of the N atom:</td>
</tr>
<tr>
<td>$sp^3$</td>
<td>$sp$</td>
</tr>
<tr>
<td>Bond Angle for F–Si–F</td>
<td>Bond Angle for O–N–O</td>
</tr>
<tr>
<td>$109.5^\circ$</td>
<td>$180^\circ$</td>
</tr>
<tr>
<td>Number of $\sigma$ bonds for SiF$_4$</td>
<td>Number of $\sigma$ bonds for NO$_2^+$</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Number of $\pi$ bonds for SiF$_4$</td>
<td>Number of $\pi$ bonds for NO$_2^+$</td>
</tr>
<tr>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>