1. What is the oxidation number of the phosphorus atom in $\text{H}_3\text{PO}_3$?
   A) -1  B) +1  C) +3  D) +5  E) +7

2. What is $\Delta H$ for the net reaction below?
   \[
   \begin{align*}
   \text{H}_2(g) + \text{F}_2(g) &\longrightarrow 2 \text{HF}(g) & \Delta H = -537 \text{ kJ} \\
   \text{C}(s) + 2 \text{F}_2(g) &\longrightarrow \text{CF}_4(g) & \Delta H = -680 \text{ kJ} \\
   2 \text{C}(s) + 2 \text{H}_2(g) &\longrightarrow \text{C}_2\text{H}_4(g) & \Delta H = 52.3 \text{ kJ} \\
   \text{C}_2\text{H}_4(g) + 6 \text{F}_2(g) &\longrightarrow 2 \text{CF}_4(g) + 4 \text{HF}(g) & \Delta H = ?
   \end{align*}
   \]
   A) -2486 kJ  B) -1702 kJ  C) -1165 kJ  D) 234 kJ  E) 1165 kJ

3. Which Group 15 element has the highest metallic character?
   A) As  B) Bi  C) N  D) P  E) Sb

4. Which of the following is false?
   A) The energy of any electron in any atom depends only on $n$.
   B) A node (or nodal surface) is a place of zero electron density.
   C) In any atom, no two electrons may have the same four quantum numbers.
   D) The lowest energy state for an atom is its ground state.
   E) Orbitals are regions of space that are occupied by electrons.

5. Which of the following quantum numbers provides information about the orientation of orbitals in space?
   A) $\ell$  B) $m_\ell$  C) $m_s$  D) $n$  E) $o$

6. Which of the following species is isoelectronic to $\text{Sn}^{2+}$?
   A) $\text{Ge}^{2+}$  B) $\text{In}^+$  C) $\text{Sb}^-$  D) $\text{Sn}^{4+}$  E) $\text{Xe}$

7. Which form of light carries the least energy per photon?
   A) microwaves  C) ultraviolet  E) X-rays
   B) radiowaves  D) visible

8. Which of the following is an expanded octet molecule at the central atom?
   A) $\text{BF}_3$  B) $\text{C}_5\text{H}_5$  C) $\text{Na}_2\text{O}$  D) $\text{PCl}_3$  E) $\text{SF}_6$

9. What is the most likely element for $\text{Z}$ in $\text{C} = \text{Z} = \text{C}$?
   A) B  B) C  C) N  D) O  E) F
Discussion Questions: (You must show your work to receive credit.)

1. What is the molar heat capacity of copper metal if 635 J of heat energy is added to a sample of copper weighing 25.7 g causes it to warm by from 25.0º to 86.8 ºC? (8 points)

\[
\text{heat capacity} = \frac{635 \text{ J}}{(25.7 \text{ g})(\frac{1 \text{ mol}}{63.55 \text{ g}})(86.8 \text{ ºC}-25.0 \text{ ºC})} = \frac{635 \text{ J}}{(0.4044 \text{ mol})(61.8 \text{ ºC})} = 25.4 \text{ J/mol•ºC}
\]

2. Write the balanced equation for: aqueous sodium carbonate reacts with hydrochloric acid to produce gaseous carbon dioxide, aqueous sodium chloride, and water. (5 points)

\[
\text{Na}_2\text{CO}_3(\text{aq}) + 2 \text{HCl(aq)} \rightarrow \text{CO}_2(\text{g}) + 2 \text{NaCl(aq}) + \text{H}_2\text{O(ℓ)}
\]

3. Write out the electron configuration of the following and provide the number of unpaired electrons on each (10 points)

V: [Ar] 4s² 3d⁵  
Co²⁺: [Ar] 3d⁷

4. Calculate the wavelength and energy of light that has a frequency of 1.5 x 10¹⁵ Hz. What is the energy of a mole of these photons? (12 points)

\[
E_{\text{photon}} = (6.626 \times 10^{-34} \text{ J•s})(1.5 \times 10^{15} \text{ s}^{-1}) = 9.94 \times 10^{-19} \text{ J (per photon)}
\]

\[
E_{\text{mole}} = (6.626 \times 10^{-34} \text{ J•s})(1.5 \times 10^{15} \text{ s}^{-1})(6.022 \times 10^{23} \text{ photons/mol}) = 599,000 \text{ J (599 kJ)}
\]

\[
\lambda = \left(3.00 \times 10^8 \text{ m/s}\right) \left(\frac{1}{1.5 \times 10^{15} \text{ s}^{-1}}\right) = 2.00 \times 10^{-7} \text{ m}
\]

5. Explain how and why Z is different from Z_{eff}. (6 points)

Z is the total number of protons in an atom, while Z_{eff} is the nuclear charge experienced by an electron in that atom. They differ because electrons sometimes pass between the nucleus and other electrons. The inner electron blocks part of the nuclear charge experienced by the outer electron. This has the effect of electrons experiencing the pull of fewer protons than are actually in the nucleus. The further an electron is from the nucleus, the greater the charge reduction because the more electrons that are able to get between it and the nucleus.

6. Draw the Lewis structures of SF₄ and H₂PO₄. For each molecule, indicate which bonds are (functionally) polar and nonpolar. (10 points)

\[
\begin{align*}
\text{SF}_4: & \quad \begin{array}{ccc}
\vdots & \vdots & \vdots \\
F & S & F
\end{array} & \quad \begin{array}{ccc}
\vdots & \vdots & \vdots \\
\vdots & O & \vdots
\end{array} \\
\text{H}-\ddots & \text{P} & \ddots & \text{H}
\end{align*}
\]

All bonds are polar

7. Each pictured Lewis structure is invalid. Identify the error (wrong electron total or octet rule violation) in each case. (6 points)
8. For the following answer and explain your answer. (10 points)

   a) Rank the following in order of more exothermic electron affinity: Be, Mg, and Na.

      Na < Mg ≈ (>) Be. Magnesium has one more proton and electron than sodium. That
additional electron isn’t shielded by the other 3s electron well and so both 3s electrons
are pulled closer to the nucleus. The result is that an added electron would end up closer
to the nucleus and so magnesium would have the more exothermic electron affinity.
Electron affinity generally doesn’t change significantly down a group, but if it were to
follow the patterns of size and ionization energy, the electron affinity of beryllium wo
be more exothermic than magnesium because one row higher in the periodic table would
put the new electron in a smaller orbital, closer to the nucleus.

   b) List the isoelectronic species Ar, Cl⁻ and K⁺ in order of increasing radius.

      K⁺ < Ar < Cl⁻. This is an isoelectronic series, so each species has the same electron
configuration. The difference between them is the number of protons in the nucleus.
With the same number of electrons, electron-electron repulsion is the same, but on
moving from K⁺ to Ar to Cl⁻, the number of proton declines. This lowers the nuclear-
electron attraction and the electrons move further from the nucleus, increasing its radius.