1. Which of the following reactions is correct for the standard enthalpy of formation ($\Delta H_f^\circ$) for sulfur dioxide?

A. $\text{S(s)} + \text{O}_2(g) \rightarrow \text{SO}_2(g)$
B. $\text{S(s)} + 2 \text{O}(g) \rightarrow \text{SO}_2(g)$
C. $\text{S}^{2+}(s) + 2 \text{O}^2-(g) \rightarrow \text{SO}_2(g)$
D. $\text{S(s)} + \frac{1}{2} \text{O}_2(g) \rightarrow \text{SO}(g)$
E. $2 \text{S(s)} + \frac{1}{2} \text{O}_2(g) \rightarrow \text{S}_2\text{O}(g)$
F. None of the above are correct.

2. Using the heats of formation ($\Delta H_f^\circ$) data provided in the table below, calculate the change in enthalpy ($\Delta H$) for the following reaction of the combustion of nitromethane, a common racing fuel.

$$4 \text{CH}_3\text{NO}_2(l) + 3 \text{O}_2(g) \rightarrow 2 \text{N}_2(g) + 6 \text{H}_2\text{O}(g) + 4 \text{CO}_2(g)$$

<table>
<thead>
<tr>
<th>Substance (state)</th>
<th>$\Delta H_f^\circ$ (kJ/mol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{CH}_3\text{NO}_2(l)$</td>
<td>-434</td>
</tr>
<tr>
<td>$\text{CO}(g)$</td>
<td>-111</td>
</tr>
<tr>
<td>$\text{CO}_2(g)$</td>
<td>-394</td>
</tr>
<tr>
<td>$\text{H}_2\text{O}(l)$</td>
<td>-286</td>
</tr>
<tr>
<td>$\text{H}_2\text{O}(g)$</td>
<td>-242</td>
</tr>
</tbody>
</table>

3. A Twinkie is sent to the lab for determination of calorie content. It is burned in bomb calorimeter with a heat capacity of 5,431 kJ/°C. The initial and final temperatures were 23.0°C and 138.0°C respectively. Calculate the heat (in food calories or Calories) in one Twinkie?

A. 5.431
B. 21.18
C. 149.3
D. 624.6
E. 749.5
F. 4184

4. As demonstrated in class, strontium salts burn with a brilliant red flame. The wavelength of the light given off is 655 nm. Calculate the frequency (sec$^{-1}$) of the red light.

A. $1.95 \times 10^2$
B. $6.55 \times 10^2$
C. $4.58 \times 10^5$
D. $4.58 \times 10^{14}$
E. $2.18 \times 10^{-15}$
F. None of the above are correct.
5. Which of the following orbital shapes can be described by \( n = 4, l = 0 \).

![Orbital Shapes]

E. These quantum numbers do not describe any orbital shape described above.

6. How many electrons in an atom can have the following set of quantum numbers?

\[ n = 3, \ m_s = +1/2 \]

A. 1  
B. 3  
C. 5  
D. 9  
E. 18  
F. None of the above are correct.

7. Which of the following statements are true?

A. In Bohr’s atomic theory, when an electron moves from one energy level to another energy level more distant from the nucleus, energy is emitted.  
B. The principal quantum number determines the size and the shape of the orbitals.  
C. Mendeleev assembled the periodic table according to the element’s electron configuration.  
D. An s-orbital can accommodate more than two electrons when the atom is large.  
E. **The Pauli Exclusion Principle states that no two electrons in an atom can have the same four quantum numbers.**  
F. None of the above statements are true.

8. Which of the following sets of quantum numbers are not possible?

A. \( n = 2, l = 1, m_l = 0, m_s = +1/2 \)  
B. \( n = 2, l = 0, m_l = -1, m_s = -1/2 \)  
C. \( n = 3, l = 2, m_l = +1, m_s = +1/2 \)  
D. \( n = 3, l = 2, m_l = +2, m_s = -1/2 \)  
E. \( n = 3, l = 1, m_l = 0, m_s = +1/2 \)
Problems (60 pts)

9. (12 pts) Calculate the $\Delta H^\circ$ for the following reaction:

$$\text{P}_4\text{O}_{10} (s) + 6 \text{PCl}_5 (g) \rightarrow 10 \text{Cl}_3\text{PO} (g)$$

when the following heats of reaction at 25ºC are known.

P4(s) + 6 Cl2(g) → 4 PCl3(g) \hspace{1cm} \Delta H = -1225.6 \text{ kJ}

P4(s) + 5 O2(g) → P4O10(s) \hspace{1cm} \Delta H = -2967.3 \text{ kJ}

PCl3(g) + Cl2(g) → PCl5(g) \hspace{1cm} \Delta H = -84.2 \text{ kJ}

PCl3(g) + \frac{1}{2} O2(g) → Cl3PO (g) \hspace{1cm} \Delta H = -285.7 \text{ kJ}

$\Delta H^\circ = -610.1 \text{ kJ}$

10. (8 pts) Using a Born-Haber process and the information provided below, calculate the heat of sublimation ($\Delta H_{\text{sub}}$) for solid magnesium. For full credit, either provide a Born-Haber Cycle diagram or a complete set of chemical equations to explain the process of forming the ionic Mg-F bond.

$\Delta H_{\text{dissociation F}_2(g)}$ \hspace{1cm} + 154 \text{ kJ/mol}

Electron Affinity F(g) \hspace{1cm} -328 \text{ kJ/mol}

First Ionization Energy Mg(g) \hspace{1cm} +735 \text{ kJ/mol}

Second Ionization Energy Mg(g) \hspace{1cm} +1445 \text{ kJ/mol}

$\Delta H^\circ$ MgF2(s) \hspace{1cm} -2088 \text{ kJ/mol}

lattice energy (U) \hspace{1cm} -3916 \text{ kJ/mol}

$\Delta H_{\text{sub}} = +150. \text{ kJ}$

11. (10 pts) Using the energy formula below, where $n$ is the principal quantum number and $Z$ is the atomic number, calculate the wavelength (in nanometers) when an electron falls from $n = 3$ to $n = 1$ in a Li$^{2+}$ cation.

$$E_n = -2.18 \times 10^{-18} \frac{Z^2}{n^2} \text{ Joules}$$

$\lambda = 11.4 \text{ nm}$
12. (20 pts) From the following list, select the atom that most appropriately describes the statement. Atoms may be used more than once or not at all.

Li, B, C, N, O, F, Kr, Na, K, Rb, Cs

A. largest atomic radius
   - Cs

B. nonmetal with the most unpaired electrons
   - N

C. lowest ionization energy
   - Cs

D. 4 valence electrons
   - C

E. most easily forms a 2\(^{-}\) anion
   - O

F. ns\(^2\)np\(^3\) electron configuration
   - N

G. most positive electron affinity (\(\Delta H=\)most negative)
   - F

H. least reactive element
   - Kr

I. least reactive alkali metal
   - Li

J. metalloid (semi-metal)
   - B

13. (8 pts) Write the electron configuration for the following atoms/ions. DO NOT use the noble gas inner core abbreviation. Show the arrangement (orbital box diagram) of all the electrons in the partially filled orbitals.

   P: \(1s^22s^22p^63s^23p^3\)  

   Cr: \(1s^22s^22p^63s^23p^64s^1\)  

   Se\(^{2-}\): \(1s^22s^22p^63s^23p^64s^23d^{10}4p^6\)  

   Zn\(^{2+}\): \(1s^22s^22p^63s^23p^64s^24d^{10}\)

14. (2 pts) Circle the atoms/ions below that would be predicted to have magnetic behavior.

   P  Cr  Se\(^{2-}\)  Zn\(^{2+}\)
Important Constants

- \( R = 0.08206 \text{ L-atm/mole-K} \)
- 1 atmosphere = 760 torr = 760 mm Hg (exactly)
- density of \( \text{H}_2\text{O} \) = 1.00 g/mL
- specific heat \( \text{H}_2\text{O} \) = 4.184 J/g°C
- density of \( \text{H}_2\text{O} \) = 1.00 g/mL
- specific heat \( \text{H}_2\text{O} \) = 4.184 J/g°C
- speed of light \( c = 3.00 \times 10^8 \text{ m/s} \)
- Planck's constant \( h = 6.626 \times 10^{-34} \text{ J-s} \)

Solubility Rules (apply in order)

1. All \( \text{Na}^+, \text{K}^+, \text{and NH}_4^+ \) salts are soluble.
2. All \( \text{NO}_3^-, \text{C}_2\text{H}_3\text{O}_2^-, \text{ClO}_3^-, \) and \( \text{ClO}_4^- \) salts are soluble.
3. All \( \text{Ag}^+, \text{Pb}^{2+}, \) and \( \text{Hg}_2^{2+} \) salts are insoluble.
4. All \( \text{Cl}^-, \text{Br}^-, \) and \( \text{I}^- \) salts are soluble.
5. All \( \text{CO}_3^{2-}, \text{O}_2^-, \text{S}_2^-, \text{OH}^-, \text{SO}_3^{2-}, \text{CrO}_4^{2-}, \text{Cr}_2\text{O}_7^{2-}, \) and \( \text{PO}_4^{3-} \) salts are insoluble, except \( \text{CaS}, \text{SrS}, \text{BaS}, \) and \( \text{Ba(OH)}_2 \).
6. All \( \text{SO}_4^{2-} \) salts are soluble except \( \text{Ca}^{2+}, \text{Sr}^{2+}, \) and \( \text{Ba}^{2+} \).

Vapor Pressure of Water at Various Temperatures

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<th>T (°C)</th>
<th>P (torr)</th>
<th>T (°C)</th>
<th>P (torr)</th>
<th>T (°C)</th>
<th>P (torr)</th>
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