1. (2 points) **Enthalpy of Formation** Which of the following equations represents an equation for the standard molar enthalpy of formation of a compound?

(a) $\text{CH}_4(g) + \frac{1}{2} \text{O}_2(g) \rightarrow \text{CH}_3\text{OH}(g)$  
(b) $\text{C(graphite)} + 2 \text{H}_2(g) \rightarrow \text{CH}_4(g)$  
(c) $2 \text{CO}_2(g) \rightarrow 2 \text{CO}(g) + \text{O}_2(g)$  
(d) $\text{Pb(s)} + \text{Cl}_2(g) \rightarrow \text{PbCl}_2(s)$

2. (2 points) What is the standard molar enthalpy of formation for $\text{C}_2\text{H}_6(g)$? _________________ kJ/mol

3. (4 points) Using the enthalpy data below, and Hess’s Law, calculate the standard molar enthalpy change for the formation of magnesium carbonate from MgO, CO$_2$, and O$_2$.

\[
\begin{align*}
\text{MgO(s)} + \text{CO}_2(g) &\rightarrow \text{MgCO}_3(s) \quad \Delta H_{\text{rxn}} = ? \\
\text{Mg(s)} + \frac{1}{2} \text{O}_2(g) &\rightarrow \text{MgO(s)} \quad \Delta H^* = -601.7 \text{ kJ} \\
\text{Mg(s)} + \text{CO}_2(g) + \frac{1}{2} \text{O}_2(g) &\rightarrow \text{MgCO}_3(s) \quad \Delta H^* = -702.3 \text{ kJ}
\end{align*}
\]

(a) $\Delta H_{\text{rxn}}^* = +1304.0 \text{ kJ/mol}$  
(b) $\Delta H_{\text{rxn}}^* = -1304.0 \text{ kJ/mol}$  
(c) $\Delta H_{\text{rxn}}^* = +100.6 \text{ kJ/mol}$  
(d) $\Delta H_{\text{rxn}}^* = -100.6 \text{ kJ/mol}$  
(e) I don’t think it is any of these.

My calculations indicate the reaction is **(endothermic)**(exothermic) _________________

4. (5 points) Methane ($\text{CH}_4$) and propane ($\text{C}_3\text{H}_8$) are used as fuels.

$\text{CH}_4(g) + 2 \text{O}_2(g) \rightarrow \text{CO}_2(g) + 2 \text{H}_2\text{O}(\ell) \quad \Delta H = -890.3 \text{ kJ}$

$\text{C}_3\text{H}_8(g) + 5 \text{O}_2(g) \rightarrow 3 \text{CO}_2(g) + 4 \text{H}_2\text{O}(\ell) \quad \Delta H = -2220 \text{ kJ}$

Part 1: If you burn 25 g of methane, what quantity of heat is evolved?

(a) $\Delta H_{\text{rxn}}^* = -356 \text{ kJ}$  
(b) $\Delta H_{\text{rxn}}^* = -570 \text{ kJ}$  
(c) $\Delta H_{\text{rxn}}^* = -719 \text{ kJ}$  
(d) $\Delta H_{\text{rxn}}^* = -1390 \text{ kJ}$

Part 2: Which fuel provides more heat energy **per gram**, methane or propane? _________________
5. (3 points) Use the table of standard enthalpies of formation in your textbook to calculate the enthalpy change for the combustion of 1.00 mol of butane, \( \text{C}_4\text{H}_{10} \). (Use Table 6.2 or Appendix L to find the required \( \Delta H^\circ_f \) values.)

\[
\text{C}_4\text{H}_{10}(g) + 13/2 \text{ O}_2(g) \rightarrow 4 \text{ CO}_2(g) + 10 \text{ H}_2\text{O}(l)
\]

\begin{align*}
\text{a)} & \quad \Delta H^\circ_{rxn} = +200.7 \text{ kJ} \\
\text{b)} & \quad \Delta H^\circ_{rxn} = -888 \text{ kJ} \\
\text{c)} & \quad \Delta H^\circ_{rxn} = -4306 \text{ kJ} \\
\text{d)} & \quad \Delta H^\circ_{rxn} = -5320 \text{ kJ} \\
\text{e)} & \quad \text{Not a one of them!}
\end{align*}

6. (3 points) (Study Question 6-69). The combustion of gaseous diborane, \( \text{B}_2\text{H}_6 \), proceeds according to the equation

\[
\text{B}_2\text{H}_6(g) + 3 \text{ O}_2(g) \rightarrow \text{B}_2\text{O}_3(s) + 3 \text{ H}_2\text{O}(g) \quad \Delta H^\circ_{rxn} = -1941 \text{ kJ}
\]

and 1941 kJ of heat energy is liberated per mole of \( \text{B}_2\text{H}_6(g) \) (at constant pressure). Calculate the molar enthalpy of formation of \( \text{B}_2\text{H}_6(g) \) using this information, the data in Table 6.2, and the fact that \( \Delta H^\circ_f \) for \( \text{B}_2\text{O}_3(s) \) is -1271.9 kJ/mol.

\begin{align*}
\text{a)} & \quad +56 \text{ kJ/mol} \\
\text{b)} & \quad -56 \text{ kJ/mol} \\
\text{c)} & \quad -427 \text{ kJ/mol} \\
\text{d)} & \quad +427 \text{ kJ/mol} \\
\text{e)} & \quad -1941 \text{ kJ/mol} \\
\text{f)} & \quad \text{None of the above?}
\end{align*}

7. (5 points) In the lab you measured the quantity of heat evolved when 0.20 g of Mg was placed in 100 mL of 1 M HCl in a coffee cup calorimeter.

\[
\text{Mg(s) + 2 HCl(aq) } \rightarrow \text{MgCl}_2(\text{aq}) + \text{H}_2(\text{g}) \quad \Delta H^\circ_f [\text{MgCl}_2(\text{aq})] = -801.15 \text{ kJ/mol}
\]

Suppose you drop 0.20 g of calcium metal into 100 mL of 1 M HCl in the same calorimeter.

\[
\text{Ca(s) + 2 HCl(aq) } \rightarrow \text{CaCl}_2(\text{aq}) + \text{H}_2(\text{g}) \quad \Delta H^\circ_f [\text{CaCl}_2(\text{aq})] = -877.13 \text{ kJ/mol}
\]

Will the temperature rise, \( \Delta T \), be greater for Mg or for Ca? \textit{Explain your answer briefly and support it with calculations.}
SPECTRA AND RADIATION

1. (3 points) *Spectra and Radiation*
   a) Which color of light in the visible spectrum has the shortest wavelength? _______
   b) Which color of light in the visible spectrum has the lowest energy? _______
   c) Is the energy of red light higher or lower than that of x-rays in the dentist’s office? _______

2. (5 points) Traffic signals are often now made of LEDs (light-emitting diodes)
   (a) The light from an amber signal has a wavelength of 595 nm, and that from a green signal is 500 nm. Which has the higher frequency? _____________________________
   (b) If a red traffic light emits radiation with a wavelength of 680 nm, what is the frequency of the light?
      i) $6.80 \times 10^{14}$ 1/s
      ii) $4.40 \times 10^5$ 1/s
      iii) $4.40 \times 10^{14}$ 1/s
      iv) $2.27 \times 10^{15}$ 1/s

3. (5 points) A cell phone sends signals at about 850 MHz (1 MHz = $1 \times 10^6$ Hz or cycles per second). What is the energy of 1.0 mol of photons with a frequency of 850 MHz?
   (a) 0.00040 J
   (b) 0.34 J
   (c) 5.6 J
   (d) 8.5 J
   (e) A whole lot!

   A cell phone emits energy that is *(greater than) (less than)* ______________________ the energy of red light.
4. (5 points) Consider only transitions involving the \( n = 1 \) through \( n = 4 \) electron energy levels for the hydrogen atom (where the line spacing are very approximate).

\[
\begin{array}{c}
\text{Energy} \\
\text{\( n = 1 \)} \\
\text{\( n = 2 \)} \\
\text{\( n = 3 \)} \\
\text{\( n = 4 \)}
\end{array}
\]

(a) How many emission lines are possible, considering only the four quantum levels? ________

(b) Photons of the lowest energy are emitted in a transition from the level with \( n = \) to a level with \( n = \).

(c) The emission line having the shortest wavelength corresponds to a transition from the level with \( n = \) to the level with \( n = \).

5. (3 points) Place the following types of radiation in order of increasing energy per photon:

(a) yellow light from a sodium lamp
(b) x-rays from an instrument in a dentist’s office
(c) microwaves in a microwave oven
(d) your favorite FM music station at 91.7 MHz

Least energetic ____________ ____________ ____________ Most energetic

\textit{QUANTUM NUMBERS}

1. (6 points)

(a) When \( n = 4 \), \( \ell = 2 \), and \( m = 2 \), to what orbital type does this refer? (Give the orbital label, such as 1s.) ______________

(b) How many orbitals occur in the \( n = 5 \) electron shell? ______________

(c) How many subshells occur in the \( n = 5 \) electron shell? ______________

(d) Explain briefly why the following is not a possible set of quantum numbers for an electron in an atom: \( n = 5 \), \( \ell = 2 \), \( m = 5 \)

(e) Which one or ones of the following orbitals cannot exist according to the quantum theory: 2s, 2d, 3p, 3f, 4f, and 5s. ________________

(f) A particular orbital has \( n = 4 \) and \( \ell = 2 \). This orbital must be: (a) 3p, (b) 4p, (c) 5d, or (d) 4d.
2. (8 points) More on atomic structure

a) What quantum number is related to the shape of an atomic orbital? __________

b) For a 3d orbital, the value of \( n \) is _________ and the value of \( \ell \) is _________.

c) Indicate what type of orbital is illustrated below.

\[
\begin{array}{lll}
\text{letter} & \text{_______} & \text{_______} & \text{_______} \\
\end{array}
\]

d) How many electrons can be associated with each of the following sets of quantum numbers?

<table>
<thead>
<tr>
<th>Quantum Number Set</th>
<th>Number of Electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>( n = 4 ) and ( \ell = 1 )</td>
<td>_________</td>
</tr>
<tr>
<td>( n = 3, \ell = 2, m_\ell = -1 )</td>
<td>_________</td>
</tr>
</tbody>
</table>

---

4. (7 points) Electron Configurations

a) What element has the electron configuration \([\text{Ar}]\ 3d^84s^2\)? _________

b) What element has a 2+ ion with the configuration \([\text{Ar}]\ 3d^6\)? _________ Is the ion paramagnetic or diamagnetic? ___________________________

c) How many unpaired electrons are there in a Mn^{2+} ion? _________

d) Is a mercury(II) ion, Hg^{2+}, paramagnetic or diamagnetic? __________________________

e) What 2+ ions in the first series of transition elements (Sc through Zn) have two unpaired electrons? _______________

f) With what element is the \( n = 4 \) shell of electrons completed? _____________

---

5. (3 points) The configuration for an element is given here.

\[ [\text{Ar}] \ \begin{array}{llllllllllllllllllllllll}
\text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \\
\end{array} \ 3d \ 4s \]

(a) What is the identity of the element with this configuration? _______________

(b) Is a sample of the element paramagnetic or diamagnetic? _______________

(c) How many unpaired electrons does a 31+ ion of this element have? _______________
2. (8 points) Using the spectroscopic or spdf notation [e.g., 1s\(^2\)2s\(^2\)], write electron configurations for each of the following:
   - S (do NOT use the noble gas notation for this case)
   - Iron (do NOT use the noble gas notation for this case)
   - Uranium (please DO use the noble gas notation for this case)
   - V\(^{2+}\) (your choice)

3. (6 points) Using the orbital box notation, write electron configurations for the following atoms or ions. Please use the noble gas notation in all three!
   - Cl
   - Ni\(^{2+}\)
   - Se\(^{2-}\)
PERIODIC TRENDS

1. (12 points) Periodic Trends

a) Of the elements O, S, and F, which has the largest atomic radius? 

b) Which is larger, I or I⁻? 

c) What element in the alkaline earth metal group has the largest radius? 

d) What element in the second period has the largest affinity for an electron? 

e) What element in Group 3A has the largest ionization energy? 

f) Place the following elements in order of increasing ionization energy: F, Al, C

\[ \text{lowest IE} \quad \text{highest IE} \]

\[ \text{lowest IE} \quad \text{highest IE} \]

g) Which ion is larger, Rb²⁺ or Br⁻? 

h) Which of the following ions is (are) unlikely to exist: Ti⁵⁺, F⁻, Al³⁺, Sr²⁺, Pt⁴⁺?

i) Of the elements Na, O, F, Cl, which has the largest atomic radius and which has the largest ionization energy?

2. (5 points) Answer the questions below about the elements A and B, which have the electron configurations shown.

\[ A = [Kr]5s^1 \quad B = [Ar]3d^{10}4s^24p^4 \]

(a) Is element A a metal, nonmetal, or metalloid?

(b) Which element has the greater ionization energy?

(c) Which element has the smaller affinity for an electron?

(d) Which element has the larger atomic radius?

(e) Which is more likely to form an anion?