1. (9 pts) At room pressure and temperature, a balloon, on a bottle containing liquid nitrogen, was observed to expand as liquid nitrogen vaporized to produce nitrogen gas.

\[ \text{N}_2 \text{(l)} \rightarrow \text{N}_2 \text{(g)} \]

Circle the correct answer for this process for each of the following quantities: \( q \), \( w \), and \( \Delta E \).

- \( q < 0 \)
- \( q > 0 \)
- \( q = 0 \)
- \( w < 0 \)
- \( w > 0 \)
- \( w = 0 \)
- \( \Delta E < 0 \)
- \( \Delta E > 0 \)
- \( \Delta E = 0 \)

2. (9 pts) A sample of ethane gas is heated from 25°C to 75°C under conditions of constant pressure.

Circle the correct answer for this process for each of the following quantities: \( q \), \( w \), and \( \Delta E \).

- \( q < 0 \)
- \( q > 0 \)
- \( q = 0 \)
- \( w < 0 \)
- \( w > 0 \)
- \( w = 0 \)
- \( \Delta E < 0 \)
- \( \Delta E > 0 \)
- \( \Delta E = 0 \)

3. (10 pts) Given the following data at 25°C:

\[
\begin{align*}
\text{C (graphite)} + \text{O}_2 \text{(g)} & \rightarrow \text{CO}_2 \text{(g)} & \Delta H^\circ = -393.5 \text{ kJ} \\
2\text{H}_2 \text{(g)} + \text{O}_2 \text{(g)} & \rightarrow 2\text{H}_2\text{O} \text{(l)} & \Delta H^\circ = -571.6 \text{ kJ} \\
2\text{C}_2\text{H}_2 \text{(g)} + 5\text{O}_2 \text{(g)} & \rightarrow 4\text{CO}_2 \text{(g)} + 2\text{H}_2\text{O} \text{(l)} & \Delta H^\circ = -2598.8 \text{ kJ}
\end{align*}
\]

Calculate the standard heat of formation, \( \Delta H_f^\circ \), for \( \text{C}_2\text{H}_2 \text{(g)} \).

\[ 2 \text{C (graphite)} + \text{H}_2 \text{(g)} \rightarrow \text{C}_2\text{H}_2 \text{(g)} \]
4. (10 pts) Consider the following reaction:

\[
2 \text{ Al (s)} + 3 \text{ Cl}_2 (g) \rightarrow 2 \text{ AlCl}_3 (s) \quad \Delta H^\circ = -1390.81 \text{ kJ}
\]

How many grams of Al are required to produce 1.00 kJ of heat?

5. (12 pts) The combustion of acetylene gas, C_2H_2 (g), with O_2 (g) produces CO_2 (g) and H_2O (g). Given the following standard heats of formation, calculate the change in enthalpy for the combustion of 1 mole of acetylene at 298 K and 1 atm.

<table>
<thead>
<tr>
<th>( \Delta H_f^\circ ) (kJ /mol)</th>
<th>C_2H_2 (g)</th>
<th>CO_2 (g)</th>
<th>H_2O (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>+ 226.7</td>
<td>- 393.5</td>
<td>- 241.8</td>
</tr>
</tbody>
</table>
6. (6 pts) In which case must a reaction be spontaneous at all temperatures?
   a) $\Delta H$ is positive, $\Delta S$ is positive
   b) $\Delta H = 0$, $\Delta S$ is negative
   c) $\Delta H$ is negative, $\Delta S$ is negative
   d) $\Delta H$ is negative, $\Delta S$ is positive
   e) None of these

7. One mole of liquid is vaporized at its boiling point, 80.0°C, and 1.00 atm. $\Delta H_{vap}$ for the liquid is 30.7 kJ/mol at 80°C.
   a) (10 pts) Calculate $w$

   b) (10 pts) Calculate $\Delta E$

8. (12 pts) An ideal gas is compressed isothermally.
   Circle the correct answer for each of the following quantities: $w$, $q$, $\Delta H$, $\Delta E$, $\Delta S$ and $\Delta G$.

   $w < 0$  $w > 0$  $w = 0$
   $q < 0$  $q > 0$  $q = 0$
   $\Delta H < 0$  $\Delta H > 0$  $\Delta H = 0$
   $\Delta E < 0$  $\Delta E > 0$  $\Delta E = 0$
   $\Delta S < 0$  $\Delta S > 0$  $\Delta S = 0$
   $\Delta G < 0$  $\Delta G > 0$  $\Delta G = 0$
9. (12 pts) In a coffee cup calorimeter, 200.0 mL of 0.862 M HCl is mixed with 200.0 mL of 0.431 M Ba(OH)$_2$. The heat capacity of the calorimeter is 453 J/°C. The initial temperature of both the HCl and Ba(OH)$_2$ solution is 20.48°C. Assume all solutions have a density of 1.00 g/mL and a specific heat capacity of 4.18 J °C$^{-1}$ g$^{-1}$. For the reaction,

\[ \text{H}^+ (\text{aq}) + \text{OH}^- (\text{aq}) \rightarrow \text{H}_2\text{O (l)} \]

the heat of neutralization is – 56.2 kJ. What is the final temperature of the mixed solution? Circle the correct answer. Show your work. **NO WORK = NO CREDIT**

a) 46.9 °C  
b) 25.0 °C  
c) 15.9 °C  
d) 20.5 °C  
e) 28.0 °C  
f) 22.8 °C  
g) 64.1 °C  
h) none of these