1. In the CHM 151 lab, you are given a 25.00 mL sample of phosphoric acid, $\text{H}_3\text{PO}_4(aq)$, of unknown concentration. Your assignment is to determine the concentration of the phosphoric acid by titrating it with a 0.09785 $M$ sodium hydroxide, $\text{NaOH}(aq)$, solution. You use phenolphthalein as an indicator, and it takes 20.30 mL of sodium hydroxide to titrate to the end point of the titration. What is the molarity of the phosphoric acid solution? [5 pts]

   \[ \text{H}_3\text{PO}_4(aq) + 3 \text{NaOH}(aq) \rightarrow 3 \text{H}_2\text{O}(l) + \text{Na}_3\text{PO}_4(aq) \]

   \[
   \frac{0.09785 \text{ mol NaOH}}{1 \text{ L}} \times 0.02030 \text{ L} = 0.001986 \text{ mol NaOH}
   \]

   \[
   0.001986 \text{ mol NaOH} \times \frac{1 \text{ mol } \text{H}_3\text{PO}_4}{3 \text{ mol NaOH}} = 6.620 \times 10^{-4} \text{ mol } \text{H}_3\text{PO}_4
   \]

   \[
   M_{\text{H}_3\text{PO}_4} = \frac{\text{mol } \text{H}_3\text{PO}_4}{\text{L soln}} = \frac{6.620 \times 10^{-4} \text{ mol } \text{H}_3\text{PO}_4}{0.02500 \text{ L}} = 0.02648 \text{ M}
   \]

2. True or False [2 pts each]

   a) The universe is composed of the surroundings and the system.
   
   TRUE

   b) Enthalpy is a measure of the heat flow in chemical changes at constant volume.
   
   FALSE, enthalpy is a measure of the heat flow in chemical changes at constant pressure.

   c) Temperature is the transfer of thermal energy between two bodies at different temperatures.
   
   FALSE, heat is the transfer of thermal energy between two bodies at different temperatures.

3. Given the three statements below, which answer is correct? [3 pts]

   1) In an endothermic reaction, heat is transferred from the surroundings to the system.
   2) The sign of $\Delta H$ for an endothermic reaction is positive.
   3) An exothermic reaction releases heat.

   a) 1 and 2 are true, 3 is false
   b) 1 and 3 are true, 2 is false
   c) 1, 2, and 3 are false
   d) 1, 2, and 3 are true
   e) 2 and 3 are true, 1 is false

4. Pentaborane-9, $\text{B}_5\text{H}_9$, is a colorless, highly reactive liquid that will burst into flame or even explode when exposed to oxygen. The reaction is

   \[
   2 \text{B}_5\text{H}_9(l) + 12 \text{O}_2(g) \rightarrow 5 \text{B}_2\text{O}_3(s) + 9 \text{H}_2\text{O}(l) \quad \Delta H = -9036.6 \text{ kJ}
   \]

   Calculate $\Delta H^\circ$ for the above process when a 15.0 g sample of $\text{B}_5\text{H}_9$ is burned at constant pressure. [4 pts]

   \[
   \frac{15.0 \text{ g } \text{B}_5\text{H}_9}{63.12 \text{ g } \text{B}_5\text{H}_9} = 0.2376 \text{ mol } \text{B}_5\text{H}_9
   \]

   \[
   0.2376 \text{ mol } \text{B}_5\text{H}_9 \times \frac{-9036.6 \text{ kJ}}{2 \text{ mol } \text{B}_5\text{H}_9} = -1074 \text{ kJ}
   \]
5. Use the data given below to calculate the standard enthalpy change, $\Delta H^\circ_{\text{rxn}}$, for the following reaction:

$\text{Fe}_2\text{O}_3 (s) + 6 \text{HCl} (g) \rightarrow 2 \text{FeCl}_3 (s) + 3 \text{H}_2\text{O} (g)$

$\Delta H^\circ_{\text{rxn}}$ [HCl(g)] = −92.3 kJ/mol  
$\Delta H^\circ_{\text{rxn}}$ [FeCl$_3$(s)] = −341.8 kJ/mol  
$\Delta H^\circ_{\text{rxn}}$ [Fe$_2$O$_3$(s)] = −822.2 kJ/mol  
$\Delta H^\circ_{\text{rxn}}$ [H$_2$O(l)] = −285.8 kJ/mol  
$\Delta H^\circ_{\text{rxn}}$ [H$_2$O(g)] = −241.8 kJ/mol  
$\Delta H^\circ_{\text{rxn}}$ [FeCl$_3$(s)] = −400.0 kJ/mol

Circle the correct answer.

a) −149.4 kJ/mol  
b) −281.4 kJ/mol  
c) −1257 kJ/mol  
d) +149.4 kJ/mol  
e) +281.4 kJ/mol

$\Delta H^\circ_{\text{rxn}} = \sum n\Delta H^\circ_f(\text{prod.}) - \sum n\Delta H^\circ_f(\text{reac.})$

$\Delta H^\circ_{\text{rxn}} = [(2)(-400.0 \text{ kJ/mol}) + (3)(-241.8 \text{ kJ/mol})] - [(1)(-822.2 \text{ kJ/mol}) + (6)(-92.3 \text{ kJ/mol})] = -149.4 \text{ kJ/mol}$

6. Consider the following reaction. What is the standard enthalpy of formation, $\Delta H^\circ_f$, of CO(g)? [2 pts]

$2 \text{C}(s) + \text{O}_2(g) \rightarrow 2 \text{CO}(g) \quad \Delta H = -221 \text{ kJ}$

The standard enthalpy of formation is the enthalpy change when one mole of a compound is formed from its elements. The above reaction represents the formation of two moles of a compound from its elements.

$\Delta H^\circ_f(\text{CO}) = \frac{-221 \text{ kJ}}{2 \text{ mol}} = -110.5 \text{ kJ/mol}$

7. Given the following data, [4 pts]

<table>
<thead>
<tr>
<th>Reaction</th>
<th>$\Delta H^\circ_{\text{rxn}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{N}_2 (g) + \text{O}_2 (g) \rightarrow 2 \text{NO} (g)$</td>
<td>$+180.7 \text{ kJ}$</td>
</tr>
<tr>
<td>$2 \text{NO} (g) + \text{O}_2 (g) \rightarrow 2 \text{NO}_2 (g)$</td>
<td>$-113.1 \text{ kJ}$</td>
</tr>
<tr>
<td>$2 \text{N}_2\text{O} (g) \rightarrow 2 \text{N}_2 (g) + \text{O}_2 (g)$</td>
<td>$-163.2 \text{ kJ}$</td>
</tr>
</tbody>
</table>

use Hess’s law to calculate $\Delta H$ for the reaction:

$\text{N}_2\text{O} (g) + \text{NO}_2 (g) \rightarrow 3 \text{NO} (g)$

$\Delta H^\circ_{\text{rxn}} = ?$

$\Delta H = \frac{1}{2}(180.7\text{ kJ}) - 163.2 \text{ kJ} = -81.6 \text{ kJ}$

Potentially Useful Information

$\Delta H^\circ_{\text{rxn}} = \sum n\Delta H^\circ_f(\text{prod.}) - \sum n\Delta H^\circ_f(\text{reac.})$