1. In the CHM 151 lab, you are given a 25.00 mL sample of phosphoric acid, H₃PO₄(aq), of unknown concentration. Your assignment is to determine the concentration of the phosphoric acid by titrating it with a 0.1015 M sodium hydroxide, NaOH(aq), solution. You use phenolphthalein as an indicator, and it takes 19.57 mL of sodium hydroxide to titrate to the end point of the titration. What is the molarity of the phosphoric acid solution? [5 pts]

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

\[
\frac{0.1015 \text{ mol NaOH}}{1 \text{ L}} \times 0.01957 \text{ L} = 0.001986 \text{ mol NaOH}
\]

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

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

2. 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 true d) 1, 2, and 3 are false e) 2 and 3 are true, 1 is false

3. True or False [2 pts each]

a) 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.

b) The universe is composed of the surroundings and the system.

TRUE

c) 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.

4. Pentaborane-9, B₅H₉, is a colorless, highly reactive liquid that will burst into flame or even explode when exposed to oxygen. The reaction is

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

Calculate \( \Delta H^\circ \) for the above process when a 10.0 g sample of B₅H₉ is burned at constant pressure. [4 pts]

\[
10.0 \text{ g B}_5\text{H}_9 \times \frac{1 \text{ mol B}_5\text{H}_9}{63.12 \text{ g B}_5\text{H}_9} = 0.1584 \text{ mol B}_5\text{H}_9
\]

\[
0.1584 \text{ mol B}_5\text{H}_9 \times \frac{-9036.6 \text{ kJ}}{2 \text{ mol B}_5\text{H}_9} = -715.7 \text{ kJ}
\]
5. Consider the following reaction. What is the standard enthalpy of formation, $ΔH_f^o$, of CO(g)? [2 pts]

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

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.

$$ΔH_f^o(\text{CO}) = \frac{-221 \text{ kJ}}{2 \text{ mol}} = -110.5 \text{ kJ/mol}$$

6. Use the data given below to calculate the standard enthalpy change, $ΔH_{\text{rxn}}^o$, for the following reaction: [4 pts]

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

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

Circle the correct answer.

- a) $-281.4 \text{ kJ/mol}$
- b) $-149.4 \text{ kJ/mol}$
- c) $-1257 \text{ kJ/mol}$
- d) $+281.4 \text{ kJ/mol}$
- e) $+149.4 \text{ kJ/mol}$

$$ΔH_{\text{rxn}}^o = ΣnΔH_f^o(\text{prod.}) - ΣnΔH_f^o(\text{reac.})$$

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

7. Given the following data, [4 pts]

- $N_2 (g) + O_2 (g) \rightarrow 2 \text{NO (g)} \quad ΔH_{\text{rxn}}^o = +180.7 \text{ kJ}$
- $2 \text{NO (g)} + O_2 (g) \rightarrow 2 \text{NO}_2 (g) \quad ΔH_{\text{rxn}}^o = -113.1 \text{ kJ}$
- $2 \text{N}_2\text{O (g)} \rightarrow 2 \text{N}_2 (g) + O_2 (g) \quad ΔH_{\text{rxn}}^o = -163.2 \text{ kJ}$

use Hess’s law to calculate $ΔH$ for the reaction:

$$\text{N}_2\text{O (g)} + \text{NO}_2 (g) \rightarrow 3 \text{NO (g)} \quad ΔH_{\text{rxn}}^o = ?$$

<table>
<thead>
<tr>
<th>Reaction</th>
<th>$ΔH$</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{N}_2\text{O(g)} \rightarrow \text{N}_2(g) + 1/2\text{O}_2(g)$</td>
<td>$ΔH = \frac{1}{2}(-163.2 \text{ kJ}) = -81.6 \text{ kJ}$</td>
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<tr>
<td>$\text{NO}_2(g) \rightarrow \text{NO(g)} + 1/2\text{O}_2(g)$</td>
<td>$ΔH = \frac{1}{2}(+113.1 \text{ kJ}) = 56.55 \text{ kJ}$</td>
<td></td>
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<tr>
<td>$\text{N}_2(g) + \text{O}_2(g) \rightarrow 2\text{NO(g)}$</td>
<td>$ΔH = +180.7 \text{ kJ}$</td>
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$$\text{N}_2\text{O(g)} + \text{NO}_2(g) \rightarrow 3\text{NO(g)} \quad ΔH = -81.6 \text{ kJ} + 56.55 \text{ kJ} + 180.7 \text{ kJ} = 155.7 \text{ kJ}$$

**Potentially Useful Information**

$$ΔH_{\text{rxn}}^o = ΣnΔH_f^o(\text{prod.}) - ΣnΔH_f^o(\text{reac.})$$