**Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Hess’ Law Lab**

**Guiding Question:** Experimentally determine the enthalpy of formation of NH4Cl using Hess’ law. (ΔHfº)

**Background Information:** The heat of formation is the difference in enthalpy between the substance and the enthalpies of the stable elements that constitute that substance. All substances are considered to be in their stable form at 25C and 1 atm. The enthalpy of formation of ammonium chloride is too difficult to determine directly because the elements that constitute the ammonium chloride are gases which do not combine easily. Therefore, the enthalpy will have to be found indirectly, using a series of related reactions. Some of these reactions and their enthalpies are found below. The reactions that do not have given enthalpies will be found in the lab.

 NH3(aq) + H+ 🡪 NH4+ ΔH1

 NH4Cl(s) 🡪 NH4+ + Cl- ΔH2

 ½ N2(g) + 3/2 H2(g) 🡪 NH3(g) ΔH3 = -46.0kJ/mol

 NH3(g) 🡪 NH3(aq) ΔH4 = -34.7kJ/mol

 ½ H2(g) + ½ Cl2(g) 🡪 HCl(g) ΔH5 = -92.4kJ/mol

 HCl(g) 🡪 H+ + Cl- ΔH6 = -74.9kJ/mol

**Pre-Lab:**

1. Read the procedure. Why is it important to rinse all the lab equipment between solutions?
2. Why should you measure 5.35 grams of ammonium chloride? (How many moles does it contain?)
3. Describe in detail how to create the 500–mL 1.0M HCl solution from a stock solution of 6.0M HCl.
4. Show how the given equations can be combined to give the desired equation of the formation of ammonium chloride from its elements.

**Materials:** Calorimeter, balance, graduated cylinder, thermometer, 1.0M HCl, 1.0M NH3, solid NH4Cl.

**Procedure:**

1. Find the calorimeter’s mass (with top).
2. Using a graduated cylinder pour 50mL of 1.0M HCl into the calorimeter and find the initial temperature of the solution.
3. Rinse the graduated cylinder and thermometer. Measure 50mL of 1.0M aqueous ammonia. Find the initial temperature of the solution.
4. Pour the ammonia into the HCl in the calorimeter, stir with the thermometer and find the maximum temperature of the solutions combined.
5. Find the mass of the calorimeter with both solutions.
6. Rinse the calorimeter, thermometer and cylinder.
7. Place 100.0mL of water into the calorimeter and find the temperature of the water to the nearest 0.1C.
8. Measure 5.35 grams of ammonium chloride and add it to the water.
9. Find the constant (max or min) temperature of the solution.
10. Find the mass of the calorimeter and new solution.

**Data:** Be sure to record ALL measured values.

**Questions:**

1. Find the enthalpy of reaction for ΔH1. Assume the specific heat of water equals the specific heat of solution. **Convert to kJ mol-1**. (Use moles of NH3 and the average initial temperature of HCl and NH3).
2. Find the enthalpy of reaction for ΔH2. Assume the specific heat of water equals the specific heat of solution. **Convert to kJ mol-1**. (Moles of NH4Cl)
3. In pre-lab one you showed how the equations can be combined to give the desired enthalpy of ammonium chloride. Using the given values and the lab values, calculate the enthalpy of formation of ammonium chloride.
4. Write the reaction for the standard heat of formation of ammonium chloride including your experimental heat on the correct side.
5. Using a textbook, find the accepted value for the heat of formation of ammonium chloride. Calculate your percent error and explain any errors over 15%. 