

AP CHEMISTRY

TOPIC 9: THERMODYNAMICS, PART A,

EXAMPLES, PART II

Day 108:

- Laws of Thermodynamics
- Enthalpy
- Specific Heat

Example #1: An unknown metal, with a mass of 30 grams, is in a beaker of boiling water, at a temperature of 102 °C, after a few minutes, the metal IS QUICKLY moved (and in our “perfect lab set-up” no heat was lost to the surroundings) to the calorimeter with 120 grams of water at a temperature of 19 °C. After a small amount of time the temperature of the water in the calorimeter changed (and stopped changing) to 21.3 °C. What is the specific heat of the metal?

	H ₂ O	Metal
m	120 g	30 g
T _i	19 °C	102 °C
T _f	21.3 °C	21.3 °C
c	4.184	?

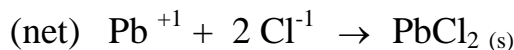
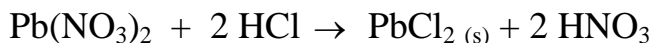
$$q_{H_2O} = mc\Delta T ; q_{H_2O} = (120 \text{ g}) \left(\frac{4.184 \text{ J}}{\text{g } ^\circ\text{C}} \right) (21.3^\circ\text{C} - 19^\circ\text{C}) = 1154.784 \text{ J}$$

$$q_{\text{metal}} = mc\Delta T ; q_{\text{metal}} = -1154.784 \text{ J} = (30 \text{ g})(c)(21.3^\circ\text{C} - 102^\circ\text{C})$$

$$c_{\text{metal}} = \frac{-1154.784 \text{ J}}{(30 \text{ g})(21.3^\circ\text{C} - 102^\circ\text{C})} = 0.477 \frac{\text{J}}{\text{g } ^\circ\text{C}}$$

In this second type of sample, the enthalpy of a reaction can be determined from the heat of the reaction, which will take place at constant atmospheric pressure.

Example #2, In this problem, 75.0 mL of 0.10 M Pb(NO₃)₂ and 50.0 mL of 0.23 M HCl are mixed together. First, will this reaction occur? If so what is the NET equation of this reaction?



The initial temperature of the solution was 25 °C, and the final temperature was 25.8 °C. Determine the enthalpy, in kJ / mol, for the formation of the product (if there is one ???). The volume of the final solution was 125 mL, and it had a density of 1.05 g/mL. The specific heat of water is 4.18 J / g °C.

$$\frac{125 \text{ mL}}{1 \text{ mL}} \times \frac{1.05 \text{ g}}{1 \text{ mL}} = 131.25 \text{ g}$$

$$q_{H_2O} = (131.25 \text{ g}) \left(\frac{4.18 \text{ J}}{\text{g } ^\circ\text{C}} \right) (25.8^\circ\text{C} - 25^\circ\text{C}) = \frac{438.9 \text{ J}}{1000 \text{ J}} \times \frac{1 \text{ kJ}}{1000 \text{ J}} = 0.4389 \text{ kJ}$$

Limiting Reactant STEP:

$$\frac{75 \text{ mL}}{1000 \text{ mL}} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{0.10 \text{ mol Pb}(\text{NO}_3)_2}{\text{L}} \times \frac{2 \text{ mol HCl}}{1 \text{ mol Pb}(\text{NO}_3)_2} \times \frac{\text{L}}{0.23 \text{ mol HCl}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 65.2 \text{ mL HCl}$$

HCl is the Limiting Reactant. If one used 75 mL of 0.1 M Pb(NO₃)₂ one would **NEED** 65.2 mL of 0.23 M HCl. There is **ONLY** 50 mL of HCl, there is **NOT ENOUGH** HCl to completely react with the Pb(NO₃)₂, therefore HCl is the Limiting Reactant.

$$\frac{50 \text{ mL}}{1000 \text{ mL}} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{0.23 \text{ mol HCl}}{\text{L}} \times \frac{1 \text{ mol PbCl}_2}{2 \text{ mol HCl}} = 0.00575 \text{ mol PbCl}_2$$

$$\Delta H = \frac{0.4389 \text{ kJ}}{0.00575 \text{ mol PbCl}_2} = 76.3 \frac{\text{kJ}}{\text{mol}}$$