ChE 203 - Physicochemical Systems Laboratory

EXPERIMENT 1: HEAT OF SOLUTION

Before the experiment: *Read the booklet carefully. Be aware of the safety issues.*

Object

To determine the heat of solution of NaOH and KCl using a calorimeter.

Theory

Calorimetry, one of the oldest areas of physical chemistry, is the act of determining the heat transfer associated with changes, such as phase transitions, chemical reactions, or physical changes, of the state of a system by means of measuring these changes. Calorimeter is an instrument which can be utilized to determine the energy change of system by monitoring its temperature. Based on an energy balance around the system, the change of temperature is expressed as a function of the heat produced in a calorimeter [1].

The energy balance for a closed system containing *n* moles of a homogeneous fluid is [2]:

$$d(nU) = dQ + dW \tag{1}$$

Where total heat and work are denoted as *Q* and *W*, respectively. The work for a mechanically reversible, closed-system process is defined as:

$$dW = -Pd(nV) \tag{2}$$

Equations 1 and 2 combines:

$$d(nU) = dQ - Pd(nV) \tag{3}$$

For a constant-pressure process, when solved for *dQ*, Equation 3 becomes:

$$dQ = d(nU) + Pd(nV) \tag{4}$$

$$dQ = d(nU) + d(nPV) = d[n(U + PV)] \tag{5}$$

For convenience, the term $U + PV$, is defined as a new thermodynamic property called enthalpy. Mathematically, enthalpy is:

$$H = U + PV \tag{6}$$

Using molar or unit-mass values, the energy balance for a constant-pressure system can be written as:

$$dQ = d(nH) \tag{7}$$

$$Q = n\Delta H \tag{8}$$

Equation 8 states that, the heat transferred is equal to the enthalpy change of a mechanically reversible, constant-pressure, closed-system process.

The amount of heat transferred when a solute is dissolved in a solvent is called heat, or enthalpy, of solution. If dissolution is an exothermic process, heat is released, leading to an increase in temperature, and if it is an endothermic process, heat is absorbed by the solution leading to a decrease in temperature.

For a calorimeter, equation 8 can be written as:

$$Q = \Delta H_{total} = 0 = \Delta H_{water} + \Delta H_{calorimeter} + \Delta H_{solution} \tag{9}$$

$$\Delta H_{total} = m_{water} \times c_{water}\left(T_f - T_i\right) + c_{calorimeter}\left(T_f - T_i\right) + \Delta H_{solution} \tag{10}$$

T_i and T_f denote the initial and final temperature of the system, respectively.

$$\Delta H_{solution} = -m_{water} \times c_{water}\left(T_f - T_i\right) - c_{calorimeter}\left(T_f - T_i\right) \tag{11}$$

$$molar\ heat\ of\ solution = \frac{\Delta H_{solution}}{moles\ of\ solute} \tag{12}$$

Experimental Work

Apparatus: Beaker, calorimeter, stirrer, stopwatch, balance.

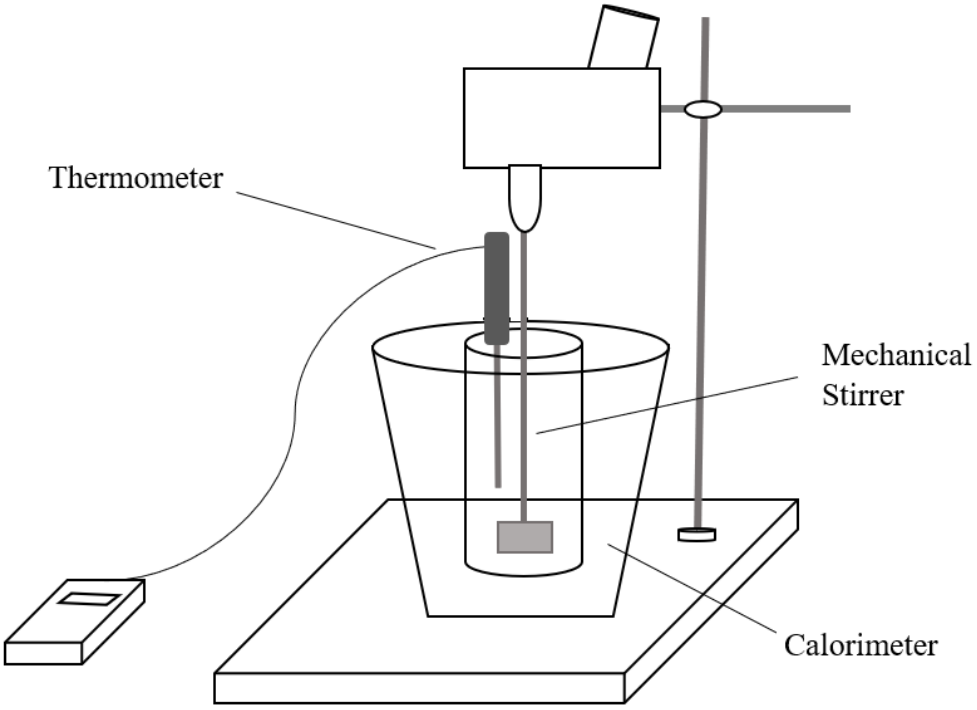

Figure 1. Calorimeter set-up.

Chemicals: NaOH, KCl, distilled water.

Procedure

1. Weigh an empty beaker and fill it with 400 g of water. When it is filled with water, weigh the beaker again.

2. Pour the water into the calorimeter, switch on the agitator, and read the initial temperature.

3. Prepare 5 g of NaOH, and 10 g of KCl samples.

4. Once the temperature of the calorimeter is stabilized, pour NaOH into the calorimeter and start the stopwatch.

5. Record temperature and time data at 10 second intervals for first 1 minutes and 20 second intervals until temperature reaches steady state.

6. Repeat step 4 and 5 by using KCl instead of NaOH.

7. Make sure you clean the calorimeter with distilled water between trials.

Safety Issues:

Potassium Chloride (KCl) [3]: Slightly hazardous in case of skin contact (irritant), of eye contact (irritant), of ingestion, of inhalation.

First Aid Measures:

Eye contact:

Check for and remove any contact lenses. In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. Cold water may be used. Get medical attention.

Skin Contact: Wash with soap and water. Cover the irritated skin with an emollient. Get medical attention if irritation develops. Cold water may be used.

Inhalation: If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention.

Ingestion: Do NOT induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. Loosen tight clothing such as a collar, tie, belt or waistband. Get medical attention if symptoms appear.

Sodium Hydroxide (NaOH) [4]: Non-flammable. Odorless. Solid. White. Easily soluble in cold water.

Routes of Entry: Absorbed through skin. Dermal contact. Eye contact. Inhalation. Ingestion. Very hazardous in case of skin contact (corrosive, irritant, permeator), of eye contact (irritant, corrosive), of ingestion, of inhalation.

First Aid Measures:

Eye Contact: Check for and remove any contact lenses. In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. Cold water may be used. Get medical attention immediately.

Skin Contact: In case of contact, immediately flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Cover the irritated skin with an emollient. Cold water may be used. Wash clothing before reuse. Thoroughly clean shoes before reuse. Get medical attention immediately.

Inhalation: If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention immediately.

Calculations

1. Calculate the molar amount of each solute, NaOH and KCl, present in the solution.

2. Calculate the total temperature change of the system and use the difference between initial and final temperatures to calculate total heat transferred. (Take $c_{calorimeter}$, the calorimeter constant, as 350 J/°C).

3. Calculate the enthalpy change of calorimeter and water.

4. Based on an energy balance around the system, calculate the enthalpy of solution of NaOH and KCl, and compare the results with those stated in the literature.

5. Plot temperature versus time.

References

[1] Zielenkiewicz, W. and Margas, E., Theory of Calorimetry, 1st Edition, Springer, Netherlands, 2002.

[2] Smith, J., Van Ness, H. C., Introduction to Chemical Engineering Thermodynamics, 7th Edition, McGraw-Hill,US, 2005.

[3] Sodium Hydroxide MSDS, http://www.sciencelab.com/msds.php?msdsId=9924998 (Retrieved September, 2017).

[4] Potassium Chloride MSDS, http://www.sciencelab.com/msds.php?msdsId=9927402 (Retrieved September, 2017).