**EXERCISE 6**

**THERMODYNAMICS**

**Theoretical topics**

state function, heat capacity, molar and specific heat, enthalpy of reaction, internal energy of reaction, Hess's law, Kirchhoff’s law, the first law of thermodynamics, the second law of thermodynamics, entropy of a system, work, heat, internal energy, isothermal process, isochoric process, isobaric process, calorimeter

**Experimental Part – 6.1.**

**Topic:**  
Enthalpy of dissolution and neutralization of NaOH.

**Objective:**  
To determine the enthalpy of dissolution of 1 mole of sodium hydroxide depending on the molar ratio of hydroxide to water and to measure and compare the enthalpy of neutralization of sodium hydroxide with a strong and weak acid.

**Apparatus:**  
calorimetric vessel, temperature probe with reader (from conductometer), beaker, automatic pipette

**Reagents:**  
phenolphthalein, Solid NaOH, 2M HCl, 2M CH3COOH

**Procedure:**

1. Weigh the inner beaker of the calorimeter using an analytical balance and record its weight in the table, then pour 100 cm³ of distilled water into it (NOTE: do not weigh the beaker with the water; assume the mass of water is 100 g).
2. Weigh out three portions of NaOH (approximately 0.5 g, 1 g, and 1.5 g) on watch glasses using the analytical balance, recording the exact amounts. Record the exact weights of the samples.
3. Measure the temperature of the water in the inner beaker using a temperature probe, waiting for the temperature to stabilize, and record the results in the table. NOTE: Once the temperature probe is placed in the beaker, it should not be removed until the full measurement cycle is complete!
4. After the water temperature stabilizes, add the first portion of sodium hydroxide (0.5 g) to the inner beaker of the calorimeter, stir the solution gently, and read the temperature after it stabilizes.
5. Add the second portion of sodium hydroxide (1 g) to the solution prepared in step 4, stir again, and read the temperature after it stabilizes.
6. Then add the third portion of sodium hydroxide (1.5 g), stir again, and read the temperature after it stabilizes.
7. After the temperature stabilizes following the third addition, add a few drops of phenolphthalein to the solution.
8. Titrate the NaOH solution, adding 1 cm³ of 2M acetic acid at a time until the solution decolorizes. Record the volume of acid added and the final neutralization temperature.
9. After completing the measurements, remove the temperature probe and empty the beaker.
10. Refill the beaker with 100 cm³ of distilled water, weigh out, and add a new 3 g portion of NaOH all at once.
11. Stir the solution during the dissolution of NaOH and read the temperature after it stabilizes.
12. After the temperature stabilizes, add a few drops of phenolphthalein to the solution.
13. Titrate the NaOH solution, adding 1 cm³ of 2M hydrochloric acid at a time until the solution decolorizes. Record the volume of acid added and the final neutralization temperature.

NOTE: For the initial temperature of the acid, use the measured temperature of the water.

**Report:**

1. Present the results in Table 1.
2. Calculate the following (for NaOH dissolution):
   * The amount of moles of sodium hydroxide in each portion and the total number of moles
   * Temperature increases for each portion (∆T)
   * Enthalpies of dissolution for each portion of NaOH and the total molar enthalpy of dissolution (∆Hr)
   * Calorimeter constant K  
     Present the results in Table 2.
3. Calculate the following (for acid neutralization):
   * The amount of moles of acid added during neutralization
   * Temperature increases (∆T) for the acid and base
   * Enthalpy of neutralization (∆Hz) and molar enthalpy of neutralization  
     Present the results in Table 3.
4. Provide conclusions for the experiment.

**Experimental Part – 6.2.**

**Topic:**  
Determining the heat of dissolution based on the calorimeter constant.

**Objective:**  
To determine the heat of dissolution of substances with endothermic and exothermic characteristics using the calculated calorimeter constant K.

**Apparatus:**  
calorimetric vessel, temperature probe with reader (from conductometer), beaker

**Reagents:**  
oxalic acid, calcium chloride, sodium nitrate, methanol

**Procedure:**

1. Pour 100 cm³ of distilled water into the inner beaker of the calorimeter and measure the temperature of the water using a temperature probe, waiting for the temperature to stabilize.
2. Weigh 3 g of calcium chloride in a plastic weighing vessel using the analytical balance and record the exact weight.
3. Add the weighed portion of calcium chloride to the inner beaker of the calorimeter, stir the solution until the substance is fully dissolved, and read the temperature after it stabilizes.
4. After emptying the beaker, repeat steps 1-3 for two more portions of calcium chloride.
5. After finishing the experiment with calcium chloride, repeat the measurements for sodium nitrate and oxalic acid in three repetitions.
6. After working with solid substances, perform similar measurements for methanol, adding 3 cm³ of alcohol to the inner beaker of the calorimeter and repeating the experiment three times.

NOTE: If you have difficulty dissolving the substances, use a stirring rod.

**Report:**

1. Present the results in Table 4.
2. Calculate the following:
   * The amount of moles of the substances added
   * Temperature changes (∆T)
   * Enthalpies of dissolution of the substances
   * Molar enthalpies of dissolution of the substances  
     Present the results in Table 5.
3. Provide conclusions for the experiment.