Exercise 8: Thermochemistry - Hess's Law

The exercise is conducted using the Virtual Lab program and a spreadsheet. The online version of the application is available on the website:

<http://chemcollective.org/vlab/vlab.php>

The data obtained in the Virtual Lab program and the calculated values should be recorded in the appropriate tables under the 'ex8' tab in the spreadsheet "Physical Chemistry ".

**IMPORTANT!!!**

* For aqueous solutions of most reagents under consideration, it should be assumed that their specific heat capacity is dominated by the specific heat capacity of the solvent (water), which is **Cw =** **4,18 J/gK**
* It is necessary to use an isolated system during the measurements.
* For all aqueous solutions, the density is set to **d =** **1 g/cm3** The initial temperature of the reagents for all chemical reactions is set to **25 °C**.

**I. Problem 1**

To launch the relevant task, select the following tabs:

# File → Load an Assignment → Thermochemistry → ATP Reaction

Determine the enthalpy of the reaction (**ΔH**) of adenosine triphosphate with water in the presence of an enzyme, leading to the formation of adenosine diphosphate and phosphoric acid (V).

**ATP + H2O ⬄ ADP + H3PO4**

* In isolated conditions, we conduct the hydrolysis reaction of ATP. A chosen volume of the solution (VATP) of several dozen cm³ is added to the beaker, along with 1 cm³ of the enzyme solution.
* After the reaction, we record the temperature change of the reaction system.
* The obtained value is used to calculate the amount of heat released during the reaction.

***QR = m ∙ Cw ∙ ∆T***

**m** – mass of the solution (**m = VSOL ∙ d**)

**Cw** – heat capacity

**∆T** – registered temperature change of the reaction system

* We determine the number of moles of adenosine triphosphate in the reaction.

(**n ATP = CATP∙VATP**) (volume is expressed in dm3)

* We determine the molar heat of reaction (**QMR**) based on the proportion.

***QR → n ATP***

***QMR → 1***

**Report**  
The collected data should be compiled in Table 1, and the calculated values in Table 2. Present the calculations and provide conclusions.

**II. Problem 2**

To launch the relevant task, select the following tabs:

File → Load Assignment → Thermochemistry → Measuring Heat of Reaction Problem

2a. Using the reagents available in the exercise, determine the enthalpy of the reaction.

**A + B = C**

* In isolated conditions, we conduct a synthesis reaction using equal volumes of solutions of substances A and B with similar concentrations.
* After the reaction, we record the temperature change of the reaction system.
* The obtained value is used to calculate the amount of heat released during the reaction.

***QR = m ∙ Cw ∙ ∆T***

**m** – mass of the solution (m = VSOL ∙ d)

**Cw** – heat capacity

**∆T** – registered temperature change of the reaction system

* We determine the amount of moles of substance A or B used during the reaction

(**n A = CA∙VA**) (volume expressed in dm³)

* We calculate the molar heat of the reaction (**QMR**) based on the proportion.

***QR → n A***

***QMR → 1***

**2b.** Using water and the available solutions of substances A and B, prepare two solutions of the reagents being considered (T = 25°C) that, when mixed in equal volumes, will cause the temperature of the system to rise to 50°C.

The factor determining the amount of heat released during the chemical reaction is the concentration of the reactants in the solution. Therefore, the primary goal of this stage of the task is to determine the concentrations of solutions A and B that will be used to conduct the chemical reaction.

We start by establishing the conditions under which we will conduct the chemical reaction:

* We assume the volumes of the solutions **A** and **B** that we want to mix are **VA = VB**
* We determine the amount of heat that we must release during the reaction for the resulting post-reaction mixture to reach a temperature of **50°C.**

***Q = m ∙ Cw ∙ ∆T***

***Q –*** Heat required to raise the temperature of the reaction system

***m –*** Mass of the reaction system ( (VA + VB)∙d )

**∆T –** Temperature difference between the final temperature (50 °C) and the temperature of the reagents before the chemical reaction begins.

* Based on the molar heat of the reaction determined in the first stage of the exercise, we determine the number of moles of substances **A** and **B** necessary to achieve the desired thermal effect.

***QMR → 1mol***

***Q→ x mol***

* We determine the molar concentration of solutions **A** and **B** (!!! the accuracy of recording the molar concentration is to 4 significant figures, 0.0001 mol/dm³).

***CA =* nA/VA**

* Through the dilution of concentrated solutions, we prepare solutions of substances **A** and B according to the concentrations obtained in the previous stage (remember the assumed volumes of substances **A** and **B**).
* We conduct an experiment in VLAB to confirm the correctness of the calculations performed **(remember to insulate the reaction system!!!).**

**Report**  
The collected data should be compiled in Tables 3 and 5, and the calculated values in Tables 4 and 6, respectively for points 2a and 2b. For both points, present the calculations and provide conclusions.

**III. Problem 3**

To launch the relevant task, select the following tabs:

# File → Load Assignment → Thermochemistry → Camping III

**3a.** Based on the reagents available in the exercise, determine the enthalpy of the reaction:

**X + Y = Z**

* In isolated conditions, we conduct a synthesis reaction using equal volumes of solutions of substances X and Y with similar concentrations.
* After the reaction, we record the temperature change of the reaction system.
* The obtained value is used to calculate the amount of heat released during the reaction.

***QR = m ∙ Cw ∙ ∆T***

**m** – mass of the solution (m = VSOL ∙ d)

**Cw** – heat capacity

**∆T** – registered temperature change of the reaction system

* We determine the amount of moles of substance **X** or **Y** used during the reaction: (**n X = CX∙VX**) (volume expressed in dm³))
* We calculate the molar heat of the reaction (**QMR**) based on the proportion.

***QR → n X***

***QMR → 1***

**3b.** Based on the reagents available in the exercise, prepare two solutions with an initial temperature of 25 °C that, when added in equal volumes to 100 ml of H₂O, will cause the temperature of the mixture to rise to 60 °C.

We start by establishing the conditions under which we will conduct the chemical reaction:

* We determine the volumes of the solutions X and Y that we want to mix: **VX = VY****(IMPORTANT!!! The chosen volumes of solutions X and Y must be greater than 70 cm³).**
* We calculate the amount of heat that we need to release during the reaction for the resulting post-reaction mixture to reach a temperature of 60 °C

***Q = m ∙ Cw ∙ ∆T***

Q – heat required to raise the temperature of the reaction system

m – mass of the reaction system ( (VX + VY + 100) ∙ d ) (the mass of the solution is expressed in grams)

∆T – temperature difference between the final temperature and the temperature of the reagents before the chemical reaction begins.

* Based on the molar heat of the reaction determined in the first stage of the exercise, we determine the number of moles of substances X and Y necessary to achieve the desired thermal effect.

***QMR → 1mol***

***Q→ x mol***

* We determine the molar concentration of solutions X and Y **(!!! the accuracy of recording the molar concentration is to 4 significant figures, 0.0001 mol/dm³)**  
  ***CX =* nX/VX**
* Through the dilution of concentrated solutions, we prepare solutions of substances **X** and **Y** according to the concentrations obtained in the previous stage (remember the assumed volumes of substances **X** and **Y**).
* We conduct an experiment in VLAB to confirm the correctness of the calculations performed **(remember to insulate the reaction system!!!).**

**Report**  
The collected data should be compiled in Tables 7 and 9, and the calculated values in Tables 8 and 10, respectively for points 3a and 3b. For both points, present the calculations and provide conclusions.

**IV. Problem 4**

To launch the relevant task, select the following tabs:

# File → Load Assignment → Thermochemistry → Heats of Reaction-Hess Law

Using the available reagents, conduct the following reactions:

**1. NaOH(s)  Na+(aq) + OH-(aq) + ΔH1 [J]**

**Dissolving solid NaOH in water**

**2. NaOH(s) + H+(aq) + Cl-(aq) → H2O(l) + Na+(aq) + Cl-(aq) + ΔH 2 [J]**

**Dissolving solid NaOH in HCl**

**3. Na+(aq) + OH-(aq) + H+(aq) + Cl-(aq) → H2O(l) + Na+(aq) + Cl-(aq) + ΔH 3 [J]**

**Neutralization of NaOH with HCl**

* We conduct the chemical reactions in thermally isolated systems according to the above schemes, using the following quantities of reagents:
* Reaction 1 – 4 g of NaOH in 100 ml of water
* Reaction 2 – 4 g of NaOH in 100 ml of 1M HCl
* Reaction 3 – 100 ml of 1M NaOH + 100 ml of 1M HCl
* Based on the recorded temperature changes, we determine the heat of each reaction.

***QR = m ∙ Cw ∙ ∆T***

* m – mass of the solution. **NOTE:** Due to the limitations of the VLAB program, for Reactions 1 and 2, we assume the mass of the solution to be 100 g (Vsol⋅d)
* Cw ​ – specific heat capacity
* ∆T – registered temperature change of the reaction system
* Determine the number of moles of NaOH involved in each reaction, and then calculate the molar heat (**QMR**) of each reaction using proportions.

***QR →* Number of moles of NaOH in a given reaction**

***QMR → 1***

* Analyze the obtained values. What mutual dependencies can be indicated for the obtained molar enthalpies of the reactions?

**Report**  
The collected data should be compiled in Tables 11, 13, and 15, and the calculated values in Tables 12, 14, and 16, respectively for Reactions 1, 2, and 3. Present the calculations and provide conclusions.