

International Journal of Human Sciences Research

ELABORATION OF A BASIC CALORIMETER APPLIED IN THE DETERMINATION OF THE ENTHALPY OF CHEMICAL REACTIONS

Annabelle Malaquias

Faculdade Campo Limpo Paulista
Campo Limpo Paulista, SP, Brasil

Camila Ribeiro

Faculdade Campo Limpo Paulista
Campo Limpo Paulista, SP, Brasil

Caroline Queiroz

Faculdade Campo Limpo Paulista
Campo Limpo Paulista, SP, Brasil

Luana Bispo

Faculdade Campo Limpo Paulista
Campo Limpo Paulista, SP, Brasil

Michelle S. Liberato

Faculdade Campo Limpo Paulista
Campo Limpo Paulista, SP, Brasil

All content in this magazine is licensed under a Creative Commons Attribution License. Attribution-Non-Commercial-Non-Derivatives 4.0 International (CC BY-NC-ND 4.0).



Abstract: In thermodynamics, calorimetry studies the energies between the energy content between the products and reactant of an enthalpy reaction, which can occur with both compounds in liquid, solid and gaseous states. For the accomplishment of this work, products called acids and bases were used in their liquid form, resulting in a neutralization reaction. In this article, experimental data will be presented in order to demonstrate the enthalpy variations of an acid-base reaction from the construction of a low cost calorimeter, built with easily accessible materials, aiming to concentrate this energy, so that there was the lowest possible dissipation of it, seeking to reach the most plausible possible results compared to the parameters already pre-established for each reaction. We used an expanded polystyrene container (styrofoam), a conventional thermometer, the products and reagent, and at the end thermochemical equations were applied, such as the determination of the heat capacity of the measurement object and finally the appropriate transformations of the neutralization enthalpy calculations. , taking into account the possible interventions of the environment and the parameters not efficiently and accurately of the materials.

Keywords: Enthalpy changes, acid-base reaction, calorimeter, energy.

INTRODUCTION

In general terms, enthalpy is related to the amount of energy contained in a system, which can be absorbed and released during chemical reactions..^[1] Such energies come from chemical bonds, rotation, vibration and translation movements, and thus can be expressed by the heat of formation, combustion, binding, neutralization and dissociation. ^[1]. Therefore, the change in enthalpy (ΔH) of a reaction can be expressed using the following formula:

$$(\Delta H) = H_p - H_r$$

Being:

(ΔH) energy variation

H_p = enthalpy of products

H_r = enthalpy of the reactants

The energies of each enthalpy variation can change according to factors related to the physical state of matter, such as the combustion of methane, which can occur in two ways: in the liquid or gaseous state, where the same reagents are used and forms the same product, changing only the state of matter and the change in energy (ΔH) of the reaction ^[2]. Thermochemical equations are determined from kilojoules per mol, (KJ/mol), the unit of measurement responsible for representing calorific concepts. ^[2]

Other factors that influence the moment of junction and the formation of a product are the internal energies of each compound and the ambient temperature, with each element having its energy value determined in each state, values that are tabulated. ^[2]. The ambient temperature directly influences the timing of the reactions, which can be classified as endothermic (pulls energy) or exothermic (releases energy). The contact with the ambient temperature, at the time of the reaction, can cause some variations in the measurement of the enthalpy variation, because if it occurs in a place where the system and surroundings are in contact, the heat can dissipate very quickly, resulting in an inaccurate measurement. ^[2]

ENDOTHERMIC REACTION

EXOTHERMIC REACTION

Uma reação é tida como exotérmica quando as energias dos produtos são menores do que a dos reagentes, havendo a liberação de energia do sistema para a vizinhança, caso contrário essa reação é tida como endotérmica, que retira calor da vizinhança e

por consequência diminui a temperatura do sistema. O valor da variação de energia dessa reação pode mudar dependendo do meio em que ocorre, pois, se ocorrer em um sistema de fronteiras adiabáticas, a energia dessa reação é parte liberada para o ambiente e o valor final da variação de energia (ΔH) é menor do que o esperado, porém não faz com que a reação deixe de ser endotérmica ou exotérmica, no entanto, se ocorrer em uma fronteira diatérmicas, não há contato com o ambiente, e a variação de energia (ΔH) é maior. Ocorrendo uma reação de formação exotérmica o ΔH é sempre negativo (-), e quando é endotérmico o sinal do H é positivo (+).^[4]

LEI DE HESS

Hess's law is used to define the enthalpy change of any type of chemical reaction. Hess' law consists of the separation in the process of forming a product, divided into steps, regardless of the product used, where in the end there is the total sum of energy released, or received, during each step of the reaction. Being called global reaction, the main reaction, or final, and half reactions that occur in steps. For example the reaction with carbon dioxide:

The overall reaction being: $C (gr) + \frac{1}{2} O_2 (g) \rightarrow CO_2 (g)$

1^a half reaction: $C (g) + \frac{1}{2} O_2 \rightarrow CO (g) (\Delta H) = -100 KJ$

2^a half reaction: $CO (g) + \frac{1}{2} O_2 (g) \rightarrow CO_2 (\Delta H) = -210 KJ$

$C (g) + O_2 \rightarrow CO_2 (g) (\Delta H) = -310 KJ \quad (1^a + 2^a)$

CALORIMETER

A calorimeter is a device used to measure heat received or released from the system to the surroundings. This equipment normally consists of a reaction vessel or chamber, where

a thermometer and, in some cases, an agitator are needed together^[4] These equipment can be classified as adiabatic, or diathermic or isopebolic (ambient with constant temperature, having a small exchange of heat between the media).^[5] The calorimeter used in this article can be classified as isopebolic, as there is a minimum heat exchange between the system and the surroundings, so the material used for the assembly was expandable polystyrene.

EXPERIMENTAL PART

Based on all the information researched, a simple low-cost calorimeter was built in order to verify the enthalpy variation between: strong acid and strong base, weak acid and strong base, weak acid and weak base. The experiment was carried out in the laboratory, and all the correct and necessary notes and attire were made.

MATERIALS AND REAGENTS

In a styrofoam container, we cut a rectangular part along its length to get a better view of heat variations. To seal the cut made in the styrofoam, a rectangular piece was cut out of the PET bottle, the same size as the cut in the container. After that, the cut part of the bottle was placed in the styrofoam, forming a visor, and covering the possible adiabatic borders. The container was colored with gold spray paint, which is optional.

With the container already inserted with the visor and the optional coloring, a 250 mL beaker was placed inside the styrofoam to be added to the bases used in the experiment, namely: sodium hydroxide and potassium chloride. The beaker was changed at each experiment, so two beakers were used, each containing 100 mL of sodium hydroxide.

In the lid of the styrofoam container, two holes were made, one for the thermometer, and another for a 60 mL syringe with a connection

for the acid contained in the syringe to reach the base contained in the beaker. The syringes and connections were also changed according to the experiment, so two connections and two syringes were used, used twice in each experiment, in order to complete 100 mL. Each syringe containing 50 ml of acetic acid, 50 ml of hydrochloric acid at a time.

For the construction of the calorimeter, proceeded to the following assembly process illustrated in figures 1, 2, 3 and 4.



Figure 1: Expandable polystyrene container (styrofoam) and bottle pet, not yet cropped for the necessary modifications for the use.



Figure 2: Expandable polystyrene container (Styrofoam) with the beaker and thermometer, and the PET bottle. The beaker was used to mix the acid with the base.

After the step of inserting the beaker, the plastic bottle display, and the thermometer, another hole was made on the surface of the calorimeter, so that a syringe can be attached, responsible for throwing the acid into the base that is already inside the beaker.



Figure 3: Attaching the syringe and thermometer to the calorimeter cover.



Figure 4: Point-to-use calorimeter, with all the necessary materials attached to the expandable polystyrene container.

RESULT AND DISCUSSION

For the experimental determination of the enthalpy of neutralization in this work, the following expression was used (Equation 1), as described in the article [3].

Equation 1.

$$\Delta H = - \frac{[C_{\text{sal}} (T_f - T_2) + m_{\text{hx}} C_{\text{hx}} (T_f - T_{\text{hx}}) + m_{\text{oh}} C_{\text{oh}} (T_f - T_{\text{mOH}})]}{n_{\text{mOH}}}$$

Being:

T_{HX} = starting temperature of the acid solution

T_{mOH} = initial temperature of the base solution

T_f = Final temperature of calorimeter and salt solution

n_{mOH} = amount of base material in the solution used

m_{HX} e m_{OH} = are the masses of the acid and base solutions, respectively

C_{HX} e C_{mOH} are the specific heat capacities of these solutions, considered to be equal to the specific heat of water (4,182 J/g °C)

CALORIMETER HEAT CAPACITY

The determination of the calorific capacity of the calorimeter was also performed as described in the article [3]. The initial temperature of the calorimeter was measured, a volume of 200 mL of distilled water was added to 50 °C. Then, the temperature of the set (calorimeter + water) was measured after stabilization and, then, the following calculations were performed (equation 2):

$$C_{\text{cal}} = (m_{\text{água}}) \times c_{\text{água}} \times (T_{\text{cal}} + \text{água} - T_{\text{água}}) / (T_{\text{cal}} + \text{água} - T_{\text{cal}})$$

Considering that:

water density * = 0,986 g mL⁻¹

Calorimeter temperature (T_{cal}) = 22,0 °C

Water temperature (T_{water}) = 50,0 °C

Temperature (calorimeter + water) ($T_{\text{cal+water}}$) = 48,0 °C

Water volume = 200 mL

Heat capacity of water (C_{Water}) = 4,18 J/g °C

Water mass = 200 mL x 0,986 g/mL = 197,20 g

The heat capacity was:

(Equation 2)

$C_{\text{cal}} = 197,20 \times 4,18 \times (47 - 50) / (47 - 22)$

$C_{\text{cal}} = 63,4 \text{ J}^\circ\text{C}^{-1}$

The first experiment was carried out using hydrochloric acid and sodium hydroxide base, that is, base and strong acid. The initial temperature of hydrochloric acid and sodium hydroxide was 25.5°C. Temperature inside the calorimeter 22°C. When the hydrochloric acid was added by the syringe to the sodium hydroxide that was already in the beaker inside the calorimeter, the thermometer began to read 33.5°C. Both acid and base used were 1.5 mol L⁻¹ and 100 mL of each were used. The experiments were carried out in triplicate, and the values studied were:

Sodium hydroxide: m = 106.78 g

Initial = 25.5

Hydrochloric acid: m = 101.71 g

Initial = 25°C

Calorimeter: Initial = 22°C

Tfinal = 33.5° C

nOH = 0,15 mol

From these data, the calculation was performed using equation 1, obtaining the following result:

$$\Delta H = - [63,4 \times (33,5 - 22) + 101,7 \times 4,18 \times (33,5 - 25) + 106,78 \times 4,18 \times (33,5 - 25,5)] / 0,15$$

$\Delta H = - 52,75 \text{ KJ mol}^{-1}$

The second experiment was performed with sodium hydroxide with acetic acid, strong base with weak acid. 100 ml of each

solution was used, each one being 0,67 mol L⁻¹. As the experiment was done right after using it for other substances, the temperature inside the calorimeter became 23 °C. the acetic acid solution was at 23.0°C and the sodium hydroxide at 23.5°C. the same experiment was used in triplicate.

(Equation 1)

Sodium hydroxide: m = 102.37 g

Initial = 23.5

Acetic acid: m = 100.36 g

Initial = 23°C

Calorimeter: Initial = 23°C

T_{final} = 28.0°

C_nOH = 0,067 mol

$$\Delta H = - [63,5 \times (28 - 23) + 100,36 \times 4,18 \times (38 - 23) + 102,37 \times 4,18 \times (28 - 23)] / 0,067$$

$$\Delta H = - 50,0 \text{ KJ mol}^{-1}$$

CONCLUSION

The experiment carried out allows us to observe how enthalpy variation works and how this variation changes from reaction to reaction. Because it is a simple and low-cost experiment, it is an experiment that can be done by anyone interested in the subject, as it provides a basic explanation of how exothermic and endothermic reactions occur.

The final values that we were able to arrive at are not exact, as there are small spaces where the system made contact with the surroundings, causing an uncertain value, but close to the necessary one.

ACKNOWLEDGMENT

To the support of all the participants of the article, Professor Michelle Liberato, and laboratory technician Olin Hendrick.

REFERENCES

1. RUSSELL, John B. **Química geral**. 2. ed. São Paulo: Pearson Makron Books, 1994. 621p. (Volume 1).
2. ATKINS, Peter; JONES, Loretta. **Princípios de química: Questionando a vida moderna e o meio ambiente**. 5. ed. Porto Alegre: Bookman Companhia Ed, 2012. 924 p
3. ASSUMPCAO, M. H. M. T. et al . Construção de um calorímetro de baixo custo para a determinação de entalpia de neutralização. **Eclét. Quím.**, São Paulo, 2016.
4. WOLF, Lúcia Daniela et al. Construção de um calorímetro simples para determinação da entalpia de dissolução. **Eclét. Quím.**, São Paulo , v. 36, n. 2, p. 69-83, 2011 .
5. ATKINS, P.W.; JONES, Loretta. **Princípios de química: questionando a vida moderna e o meio ambiente**. 3.ed. Porto Alegre: Bookman, 2006. 965 p.