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Specific Heat of Solution of HCl-NaOH Reaction by a Simple Handmade Calorimeter

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Abstract

A research study was performed by couple of students under the research project of bachelor in chemistry. The main goal to perform this project was to determine the changes in temperature of solution when an acid and a base were mixed together inside the cups of handmade calorimeter and their reaction was proceeded under the lab conditions and to determine either reaction would be exothermic or endothermic. Basically, from these changes in temperature of solution, the specific Heat of solution or Heat of reaction was determining. Temperature changes were observed using analytical thermometer with stop watch and all changes were noted on datasheet, while after completion of the whole experimental work, a thermodynamic equation of specific Heat was applied to calculate the Specific Heat of solution mathematically in numeric value which was 3214.72476 J or 3.21472 KJ. It was seen that as the base was mixed into acid, the temperature of solution was increased to maximum rapidly showing the exothermic reaction. After reaching to maximum range, the temperature decreased gradually to its minimum range being constant and consistent. The consistent temperature range terminated the reaction. All variations in temperature ranges were recorded very carefully and a table with a graph showing all ups and downs in temperature ranges was drawn on MS Excel Data Sheet.

Keywords: Enthalpy; Exothermic; Thermodynamic; Specific heat; Handmade calorimeter

Introduction

Every chemical reaction is established by a variation in energy, generally in the form of heat. The energy variation of a reaction that take place at persistent pressure is called "Heat or Enthalpy change". Heat change may happens either exothermically or endothermically. In case of heat liberation, exothermic reaction happened. While, in case of heat absorption endothermic reaction happened.

In research studies, a tool named as calorimeter must be operated to determine the amount of Heat of proceeding reaction.

Isothermal calorimeters were worked in the second 50% of the 1960s to think about synthetic responses [1]. Amid the 1970s, the affectability of instruments was in the scope of mJ, and other first applications were produced, for example, the investigation of (metal + ligand) buildings [2] and the adsorption of sweet-smelling mixes by sub-atomic strainers [3].

Calorimetry is utilized to quantify measures of Heat exchanged to or from a substance [4]. To do as such, the Heat is traded with an aligned protest (calorimeter) [5]. The adjustment in temperature of the measuring some portion of the calorimeter is changed over into the measure of Heat (since the past alignment was utilized to set up its Heat limit) [6]. The estimation of Heat exchange utilizing this approach requires the meaning of a framework (the substance or substances experiencing the synthetic or physical change) and its environment (alternate parts of the estimation device that serve to either give Heat to the framework or assimilate heat from the framework) [7]. Information of the heat limit of the environment, and cautious estimations of the majority of the framework and environment and their temperatures previously, then after the fact the procedure enables one to figure the Heat exchanged [8].

A calorimeter is a gadget used to gauge the measure of Heat associated with a substance or physical process [9]. At the point when an exothermic response happens in arrangement in a calorimeter [10], the Heat delivered by the response is consumed by the arrangement, which builds its temperature. At the point when an endothermic response happens [11], the Heat required is retained from the warm vitality of the arrangement [12], which diminishes its temperature. The temperature change, alongside the particular Heat and mass of the arrangement [13], would then be able to be utilized to figure the measure of Heat included [14].

Structurally, a simple handmade calorimeter consists of two polystyrene cups nested together, which are then placed in a 400-mL beaker. A cardboard square is adjusted on top to preserve the heat of solution or heat of reaction proceeding inside that calorimeter and to alleviate the thermometer which juts out of the cardboard into the solution below.

The heat liberated in the acid-base reaction happening inside the calorimeter makes an increase in temperature of the solution and also of that calorimeter to be used. If the calorimeter was perfect, then no heat would be radiated to the laboratory.

In order to determine the amount of heat absorbed by the calorimeter, we must irst determine the heat capacity of the calorimeter. The heat capacity is the amount of heat required to raise its temperature by 1 Kelvin, or 1 degree Celsius, which are equivalent increments. However, the heat capacity must be found using standard solutions. In this case, tap water will be used to ind the heat capacity of the calorimeter as outlined in the Procedure (Figure 1).

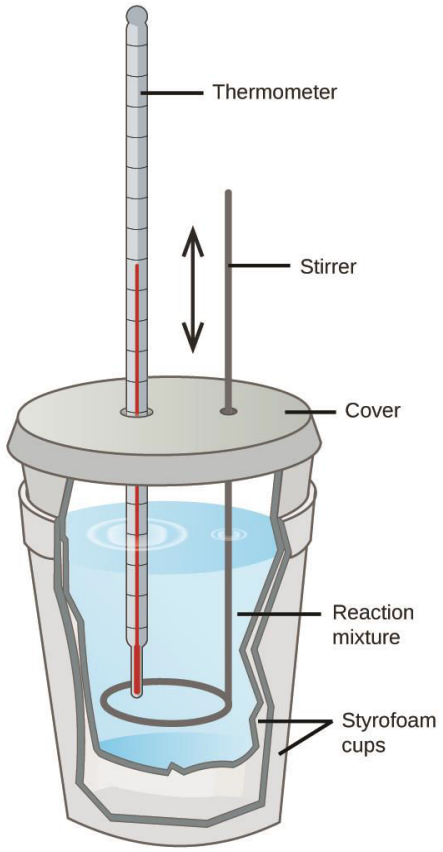

Figure 1: Calorimeter's Diagram.

Materials and Methods

Two Styrofoam cups, an analytical thermometer, an acid; HCl and a base; NaOH were used to determine the Heat of solution and exothermic or endothermic nature of proceeding reaction between acid and base. They were labelled as Cup-A and Cup-B. Cup-A was used for Acid (HCl) and Cup-B was used for Base (NaOH). Using analytical graduated cylinder, 40.0 mL of HCl was added in Cup-A, while 41.0 mL of NaOH was added in Cup-B. Then, two separate analytical thermometers were added in Cup-A and Cup-B separately, to determine the temperatures of both acid and base. When this temperature determination was completed, Base NaOH was poured into Cup-A containing Acid HCl, while placing the cleaned thermometer simultaneously into Cup-A. Changes in temperature at every 30 seconds were recorded very carefully until temperature became constant. After the completion of experimental work, drained the solution of acid and base with water, recorded all the experimental results on data sheet of MS Excel, and drawn the temperature versus time graph for heat of solution of acid-base reaction. To get the numerical value of Heat of solution of acid-base reaction, thermodynamic specific heat/Heat equation were applied, which is;

q=ms(Tf-Ti)

Where, q=Specific Heat Called Heat of solution that has to be determine.

m=mass of solution calculated from density equation.

s=specific heat capacity of solution.

Tf=Final or maximum temperature.

Ti=Initial or minimum temperature.

Results and Discussion

When the acid HCl was taken in Cup-A of handmade calorimeter and base NaOH in Cup-B, their temperature were measured by analytical thermometer since 30-minutes which was 25°C of acid and 45°C consistently. When acid and base were mixed together, the temperature of solution inside the cup-B of handmade calorimeter increased immediately, reached to maximum value and then decreased very slowly as reaction went toward its completion. The maximum temperature was 53°C. The fact was that an increase in temperature of solution resulted the exothermic reaction of acid-base reaction solution. As the reaction was completed and terminated, the temperature of solution became constant to 43.5°C. The consistency in temperature pointed that it was the terminating temperature of this acid-base reaction. All the variations in temperature with time were recorded on MS Excel datasheet to draw a table and graph showing the changes in temperature of solution (Table 1, Figure 2). A Thermodynamic equation of specific Heat was applied and all recorded values were put in equation and determined the Specific Heat of Solution of Acid-Base Reaction, which was 3.21471 KJ or 3214.72 J.

No.	Time (Sec)	Temperature (°C) of Acid	Temperature (°C) of Base
1	30	25	45
2	60	25	45
3	90	25	45
4	120	25	45
5	150	25	45
6	180	25	45

Table 1: Temperature changes against Time values.

Maximum Temperature as Final Temperature=53°C.

Minimum Temperature as Initial Temperature=43.5°C.

Density of HCl & NaOH Soultion=1.04 g/mL.

Specific Heat of HCl & NaOH Solution=4.017 J/g°C.

Volume used (v)=40+41= 81 mL.

m=dv

m=1.04 g/mL × 81 mL

m=84.24 g

Applying the Thermodynamic Heat equation;

$q=ms(T_f-T_i)$

=84.24×4.017 (53-43.5)

=3214.72476 J

=3.21472 KJ

So, the heat of HCl-NaOH solution is 3214.72476 J or 3.21472 KJ.

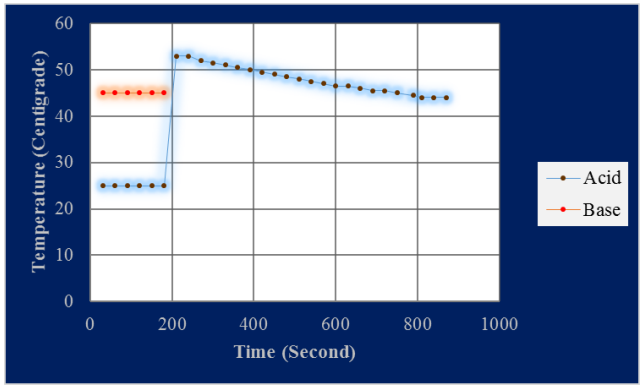

Figure 2: Temperature v/s Time graph for HCl-NaOH reaction.

The graph also shown these results, that curve first reaches to peak value then turned gradually to its minimum and consistent value, showing the completion and termination of acid-base reaction happening inside the cups of handmade calorimeter.

Conclusion

It is concluded that when the acid-base reaction proceeded, the temperature of solution changed from maximum to minimum. The maximum temperature was 53°C. The fact was that an increase in temperature of solution resulted the exothermic reaction of acid-base reaction solution. As the reaction was completed and terminated, the temperature of solution became constant to 43.5°C. The consistency in temperature pointed that it was the terminating temperature of this acid-base reaction. A Thermodynamic equation of specific Heat was applied, and all recorded values were put in equation and determined the Specific Heat of Solution of Acid-Base Reaction, which was 3.21471 KJ or 3214.72 J. It was seen that as the base was mixed into acid, the temperature of solution was increased to maximum rapidly showing the exothermic reaction. After reaching to maximum range, the temperature decreased gradually to its minimum range being constant and consistent. The consistent temperature range terminated the reaction. The graph also shown these results, that curve first reaches to peak value then turned gradually to its minimum and consistent value, showing the completion and termination of acid-base reaction happening inside the cups of handmade calorimeter.

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