Teaching Thermochemistry with Two Simple Experiments in Constructivistic Context

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Abstract. *This paper presents two experiments on thermochemistry. The teaching sequence consists of a theoretical study of the subject, a first experiment "estimating the heat of dissolution of $CaCl_2$" and a second experiment "estimating the heat of combustion of butane". Experimental procedure proved to be more fruitful in revealing misconceptions or alternative conceptions than the theoretical part. In addition experimental procedure appeared to be more effective in helping the students change their misconceptions to scientifically correct concepts. The proposed experiments are simple and easy to perform, the experimental set up is not complex and the students have enough time to think and discuss in a "minds-on" procedure as well.*

Keywords. Thermochemistry, Heat of combustion of butane, Heat of dissolution calcium chloride, Alternative conceptions

1. Introduction

This paper presents two experiments on thermochemistry. In the second class of our experimental high school, students of age 16-17 attended a teaching sequence in thermochemistry, which consisted of three stages: A) The theoretical study of the subject B) The first experiment in which the students estimated the heat of dissolution of $CaCl_2$ in a styrofoam cup calorimeter C) The second experiment in which the students estimated the heat of combustion of butane in ordinary camping gas apparatus. The first theoretical part is not presented here as the conventional method and content was followed. The two experimental stages are analyzed and special emphasis is being put on the benefits of the second.

2. Experimental procedure

The experiments are as follows:

First Experiment :

We pour 150 cm^3 of water into a styrofoam cup calorimeter. We register the temperature measured by a thermometer, we add 2 g of $CaCl_2$ and we register the higher temperature reached. From the above data we estimate the heat of dissolution of $CaCl_2$. We use the equation: $Q = m \times c \times \Delta\theta$ where Q stands for the estimated heat that is released during the dissolution, m stands for the mass of the water in the calorimeter, c for specific heat of water and $\Delta\theta$ for the change in temperature of the water before and after the dissolution of $CaCl_2$. With the proper calculations per mol the enthalpy of dissolution derives. This estimation is based on the principle that, the total heat produced from the dissolution of the salt is absorbed by the water in the calorimeter. It is worth noted that when the salt re-crystallizes in an endothermic process, a rapid decrease of the temperature is observed.

Second Experiment:

We pour 100 cm^3 of water into an empty aluminium refreshment can, which hangs over a butane camping gas apparatus. We register the temperature of the water in the refreshment can. We weigh the camping gas apparatus and then we light it and heat the can until the water's temperature increases up to 60-70 ^oC. We register the exact increased temperature and we weigh the gas apparatus again. The heat produced from the combustion of butane is rapidly absorbed by the mass of the water in the metal can. We use the equation $Q = m \times c \times \Delta\theta$ in order to estimate the heat produced during the combustion of the butane gas. The change of the mass of the butane gas apparatus gives the total mass of the gas burnt. We use this mass and the heat we have already found in order to calculate the heat produced per mole and the enthalpy of the combustion of butane.

Fig. 1 depicts both simple experimental setups.

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Figure 1. Experimental setups: (1) left (2) right

3. Alternative conceptions and difficulties

Some of the data concerning the alternative ideas and difficulties derived from the theoretical part and the first experiment are summarised below:

1. Students think that the temperature of the water in the calorimeter before the dissolution of the salt is much lower than the temperature of the surrounding atmospheric air.
2. Students can not distinguish between the "system" of the reactants and the surroundings. They have the idea that the total amount of water in the Styrofoam calorimeter belongs to the system and that the atmospheric air forms the surroundings.
3. Students cannot give coherent explanation of the energy changes during dissolution and are surprised when they observe the endothermic procedure.

The second experiment in the sequence offers the following opportunities

1. The students are able to distinguish between the "system" of the reaction and the "surroundings" because the reactants are enclosed in the camping gas vessel and the water that absorbs the exhausted heat is in a totally separated area, in the refreshment can.
2. The clear separation of the two areas gives teachers the opportunity to make students transcend from the macro-level of the empirical observation to the symbolic level of the written chemical equation of the combustion. With a proper computer simulation and three-D modelling teachers can help students to transcend to the micro-level of the reactants and products of the reaction, without having the "noise" of other substances included.
3. The higher or lower quantities of heat that is lost according to different parameters of the experimental setup give students the opportunity to repeat the procedure in order to find the best parameters as well as to reach to a good accuracy, following the scientific method.

4. Discussion

The evolution of each of the three stages led to the reveal of alternative conceptions or misconceptions [2], some have already been included in former works [3]. It is worth noted that both experimental procedures were more fruitful in revealing misconceptions than the theoretical part of the procedure. At the same time each experimental procedure appeared to be effective in helping the students change their misconceptions to scientifically correct concepts. It is obvious that this is one more reason among others [4] [5] of which hands-on-practice is of great value in chemistry teaching.

The teaching sequence proposed may become more creative if the two experiments are embedded in a different mode. For the first experiment we may construct a working sheet in a rather guided mode, and the second experiment may be given in an open procedure of scientific method. For the second experiment the students may be asked to use former knowledge which derives from both, their experience of the theoretical part and of the first experiment and invent a way of estimating the heat of combustion of butane.

Both experiments are convenient in discussing inter- and intra- molecular forces, as the first includes an ionic substance and the second a covalent substance, as well as energy changes that take place during the reactions that these two substances are involved.

They are also offer to the students the opportunity to trace the scientific background of everyday experiences and actions, as dissolution and combustion, and to give explanations of phenomena in the world around them.

The first experiment is not included in the formal curriculum. However, the curriculum suggests a similar to the first experiment, in which NaOH is used. By using $CaCl_2$ we have the benefit of observing an endothermic phenomenon as well. Modification is suggested as a practical alternative to completely laboratory activities in ways constructivism suggests [1].

The proposed experiments are simple and easy to perform with available and inexpensive materials. The time constraints do not affect the procedure because the experimental set up is not complex and the students have enough time to make the proper calculations, as well as to think and discuss [6]. This means that there is a "minds-on as well as hands-on practice" being carried out [5].

Of course certain precautions must be taken to protect the students because $CaCl_2$ is slightly irritating and butane is extremely flammable.

5. References

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