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SIMPLE DEMONSTRATIONS OF THE ENERGY EXCHANGE BETWEEN SYSTEM AND ITS SURROUNDING

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ABSTRACT: Demonstrating of energy changes is performed by observing physical or chemical changes that are started in the system in contact with the reaction vessel, in which heating or cooling takes place. The procedures for two short experiments in high school general chemistry course (age of 15) are described: (i) hydration of unslaked lime – melting of ice; and (ii) hydration of sulphuric acid – ether cannon. The demonstrations enable active acquiring of thermochemistry concepts. [*Chem. Educ. Res. Pract. Eur.*: 2001, 2, 329-332]

KEYWORDS: demonstrations; experiments in general chemistry; thermochemistry; energy transfer

INTRODUCTION

Numerous experimental demonstrations of heat changes in exothermic and endothermic processes have been published during last decades. Some of these experiments are designed for teacher's demonstrations requiring certain experimental adaptations to project the thermometer readings (Kato, Munson, & Kay, 1963; Hornbeck, 1966a; DuPre & Just, 1994; Hur, Solomon, & Wetzal, 1998; Papageorgiou & Xenos, 1999). Another very convenient way to demonstrate heat changes is to observe physical or chemical changes that are occurred in the system in contact with the reaction vessel, where heating or cooling takes place (Kato, Munson, & Kay, 1963; Hornbeck, 1966b; Boschmann, 1970; Philadelphia Quartz Co., 1970).

In this paper we describe two procedures for short experiments in high school general chemistry course (age of 15) that we found suitable for the demonstration of chemical and physical changes which are clearly accompanied with energy changes. These demonstrations enable students to construct the knowledge actively and to draw conclusions by themselves. Also, the students have an opportunity to improve their analytical thinking by considering cause-and-consequence relations, which take place within coupled experiments. At this point, it should be outlined that in the coupled experiment, triggered processes have to be carefully selected to avoid an overload of students' working memory (Johnstone, 1997). Otherwise, they could be an obstacle for observation and proper interpretation of the main experiment.

DEMONSTRATIONS

Hydration of lime – Melting of ice

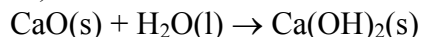
The reaction of the hydration of calcium oxide CaO (unslaked lime) has been often cited by the textbooks, laboratory manuals and articles (Kato, Munson, & Kay, 1963;

Hombeck, 1966a; Roesky & Mockel, 1996) as the demonstration of the highly exothermic chemical reaction. We present here a modification of this experiment that can be carried out using the laboratory equipment and chemicals available to most high schools.

| Apparatus | Chemicals |
|-------------------------|--|
| 250 mL glass beaker (3) | Calcium oxide CaO (lumps of fresh unslaked lime) |
| 100 mL glass flask | Distilled water |
| Dropping bottle | Phenolphthalein |
| Spoon | Ice cubes |
| Safety shield | |

Experimental procedure

Place a few lumps of fresh unslaked lime into the flask using a spoon. Add the ice cubes (edge length approximately 1cm) into the beaker #1 up to 1 cm in height. In a like fashion, add ice cubes into the beaker #2. Place the flask on ice in the beaker #1. From the dropping bottle, add a few drops of water in the flask (CARE: steam may shoot out the flask; avert face). The unslaked lime reacts with the water according to the following equation:



Add 3-4 drops of phenolphthalein in the flask (Figure 1a). After several minutes remove flask from the beaker #1. Pour the contents of the beakers #1 and #2 simultaneously in the beaker #3. One can observe that the water pours from the beaker #1, while ice cubes drop from the beaker #2 (Figure 1b).



FIGURE 1. (a) *Experimental setup*; (b) *final stage of experiment.*
NOTE: *This experiment can, also, be carried out with NaOH pellets.*

Hydration of sulphuric acid – Ether cannon

This demonstration, involving exothermic and endothermic processes, can help students to correlate the concept of enthalpy change with the concepts of internal energy and work being done on surroundings. It should be mentioned that the simple demonstration, illustrating work done by chemical reaction, has been reported recently by Brouwer (1996).

| Apparatus | Chemicals |
|---------------|-------------------------------|
| 250 mL beaker | Sulphuric acid (concentrated) |
| Test-tube | Ether |
| Glass rod | Distilled water |
| Stopper | |
| Safety shield | |

Experimental procedure

Pour the ether in the test-tube up to quarter of its volume. Cork the test-tube slightly using a stopper. Fill the beaker with distilled water up to half of its volume. Place the test-tube in the beaker. Using a glass rod, add the concentrated sulphuric acid slowly in the beaker and stir (Figure 2a). After a short time later the stopper will be pushed out slowly from the test tube (Figure 2b).



FIGURE 2. (a) *Experimental setup for the ether-canon experiment; (b) the ether cannon.*

RESULTS AND DISCUSSION

The setup of the first demonstration enables to observe heat evolution within both: reaction vessel and surrounding system where physical change - melting of ice (endothermic process) occurred. In addition, the change of phenolphthalein colour to purple indicates basic property of the reaction product. This experiment we use to combine with the well-known endothermicity demonstration (Radel & Navidi, 1990) with a moistened wooden block that adheres to the beaker in which $\text{Ba}(\text{OH})_2 \cdot 8 \text{H}_2\text{O}$ and NH_4SCN are being mixed.

In the second demonstration, hydration of sulfuric acid: $\text{H}_2\text{SO}_4 + \text{H}_2\text{O} \rightleftharpoons \text{HSO}_4^- + \text{H}_3\text{O}^+$, as an exothermic process, gives off the heat to the surrounding. A part of released heat is transferred to the system (test tube with ether) which is in contact with the solution of sulphuric acid. Consequently, the internal energy of ether rises and evaporates faster. The evaporation of ether is an endothermic physical change. The increase of ether vapor pressure results in work being done on the surroundings.

By our experience, these demonstrations help students to acquire easily thermochemistry concepts and to use them actively in class discussion that should answer the question: What is the source of the energy liberated in changes of substances?

Hazards

Skin contact with calcium oxide can cause burns. Sulfuric acid is extremely corrosive to eyes, skin and other tissues. Wear suitable eye and skin protection.

In preparation phase, ether should be checked because of the tendency to form shock sensitive peroxides. Ether is highly flammable. Extreme care must be taken to avoid fire hazard.

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