Thermodynamics—Enthalpy of Reaction and Hess's Law

Inquiry Guide and AP* Chemistry Curriculum Alignment

Introduction

The heat or enthalpy change for a chemical reaction is called the enthalpy of reaction, ΔH_{rxn}. This energy change is equal to the amount of heat transferred, at constant pressure, in the reaction. The enthalpy of a reaction represents the difference in enthalpy of the products and the reactants and is independent of the steps in going from reactants to products. According to Hess's law, if a reaction can be carried out in a series of steps, the sum of the enthalpies for each step equals the enthalpy change for the overall reaction.

Opportunities for Inquiry

The investigation of thermodynamics and the confirmation of Hess's law ties together principles and concepts from thermodynamics, stoichiometry, and chemical reactions. The Hess's law experiment draws upon students to develop science practice skills involving symbolic and graphical representations of energy changes for chemical reactions.

The classic AP chemistry experiment can be transitioned to guided inquiry by asking lots of very specific questions about the purpose and design of the lab.

- The central question in designing a Hess's law experiment is choosing an appropriate series of reactions that will "add up to" the final reaction. Provide a set of 5–6 possible reactions for this purpose and ask students to select the ones that may be used. That's the question!
- Introduce the lab by demonstrating the general setup for assembling a calorimeter and collecting data. Guide students to design the actual experimental procedure through a series of leading questions. What information (data) is needed to determine the heat capacity of the calorimeter? What information is needed to determine the molar heat of reaction for each reaction? What variables will influence the experimental data?
- Choose the independent and dependent variables for the experiment and describe how other variables that may affect the accuracy of the results can be controlled. Will stirring the solution during the reaction influence the measured temperature change? Is the maximum or minimum temperature that is reached stable over time, or should it be determined by extrapolation, that is, by graphing temperature versus time? What is a suitable scale for each reaction, and appropriate glassware for measuring reactant volumes, to ensure that the desired results can be obtained with a certain level of precision (three significant figures)?
- Take away the data tables and post-lab questions, replacing the worksheet calculations with a detailed overview of the purpose of the experiment and the thermodynamic quantities that must be reported.
- Make it a challenge lab! Once the students determine the heat of reaction, challenge them to design a reaction system that will produce a specific temperature change.
- Thermodynamics has many interesting applications in daily life, from instant cold packs to hand warmers or "MREs"—meals-ready-to-eat. Extend the lab to design an effective instant cold pack or hand warmer.

Alignment with AP Chemistry Curriculum Framework—Big Ideas 3 and 5

Enduring Understandings and Essential Knowledge

Chemical and physical transformations may be observed in several ways and typically involve a change in energy. (Enduring Understanding 3C)

3C2: Net changes in energy for a chemical reaction can be endothermic or exothermic.

Energy is neither created nor destroyed, but only transformed from one form to another. (Enduring Understanding 5B)

5B1: Energy is transferred between systems either through heat transfer or through one system doing work on the other system.

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5B2: When two systems are in contact with each other and are otherwise isolated, the energy that comes out of one system is equal to the energy that goes into the other system. The combined energy of the two systems remains fixed. Energy transfer can occur through either heat exchange or work.

5B3: Chemical systems undergo three main processes that change their energy: heating/cooling, phase transitions, and chemical reactions.

5B4: Calorimetry is an experimental technique that is used to measure the change in energy of a chemical system.

Learning Objectives

3.11 The student is able to interpret observations regarding macroscopic energy changes associated with a reaction or process to generate a relevant symbolic and/or graphical representation of the energy changes.

5.6 The student is able to use calculations or estimations to relate energy changes associated with heating/cooling a substance to the heat capacity, relate energy changes associated with a phase transition to the enthalpy of fusion/vaporization, relate energy changes associated with a chemical reaction to the enthalpy of the reaction, and relate energy changes to PΔV work.

5.7 The student is able to design and/or interpret the results of an experiment in which Calorimetry is used to determine the change in enthalpy of a chemical process (heating/cooling, phase transition, or chemical reaction) at constant pressure.

Science Practices

2.2 The student can apply mathematical routines to quantities that describe natural phenomena.

2.3 The student can estimate numerically quantities that describe natural phenomena.

4.3 The student can collect data to answer a particular scientific question.

5.1 The student can analyze data to identify patterns or relationships.

6.1 The student can justify claims with evidence.

The *Thermodynamics—Enthalpy of Reaction and Hess's Law—AP Chemistry Classic Laboratory Kit* is available from Flinn Scientific, Inc.

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