Name: _____ Date: _____

Problem Solving: Enthalpy Calculations

Learning goals
After completing this activity, you will be able to …

- Determine how much heat is released when a given amount of reactant is used in a chemical reaction.
- Use the specific heat equation to determine how much heat is produced in a calorimeter.

Introduction
Chemists often try to measure the heat produced in a reaction. The amount of heat is usually given per mole of reactant or product. For example, the equation below indicates that 65.2 kJ of heat is produced when 1 mole of calcium oxide reacts with 1 mole of water:

$$CaO\ (s) + H_2O\ (l) \rightarrow Ca(OH)_2\ (s) \qquad \Delta H = -65.2\ kJ$$

In these equations, a negative value of ΔH indicates that heat is released and the reaction is exothermic. A positive value of ΔH indicates heat is absorbed and the reaction is endothermic.

To determine how much heat is released or absorbed for a given mass of reactant or product, it is necessary to convert the mass of the substance (in grams) to *moles* of substance. To do this, first find the mass of one mole of the substance by adding up the atomic masses (u) of each atom in the chemical formula and converting to grams.

For example, calcium has an atomic mass of 40.08 u and oxygen has a mass of 16.00 u. Therefore, the mass of one molecule of calcium oxide (CaO) is 40.08 u + 16.00 u = 56.08 u. The mass of one mole of CaO is 56.08 grams.

[Note: You will need a periodic table to look up atomic masses as you do these problems.]

Sample problem

When 2 moles of hydrogen is combined with 1 mole of oxygen to produce 1 mole of water, 483.6 kilojoules of heat are released:

$$2H_2 + O_2 \rightarrow 2H_2O \qquad \Delta H = -483.6\ kJ$$

How much energy is released when 8 grams of hydrogen react with excess oxygen?

Solution: The equation states that 2 moles of hydrogen yield 483.6 kJ of heat. A mole of hydrogen has a mass of 2.02 grams. The heat produced by 8 grams of hydrogen is therefore:

$$\text{Heat} = \frac{483.6\ \text{kJ}}{2\ \text{mol}} \cdot \frac{1\ \text{mol}}{2.02\ \text{g}} \cdot 8.0\ \text{g} = 957.6\ \text{kJ}$$

Problems

Calculator recommended

1. The decomposition of sodium bicarbonate ($NaHCO_3$) requires 129.0 kJ of heat to produce 1 mole of soda ash (Na_2CO_3):

   $2NaHCO_3\ (s) \rightarrow Na_2CO_3\ (s) + H_2O\ (g) + CO_2\ (g) \qquad \Delta H = 129.0\ kJ$

   How much heat is required to decompose 100.0 grams of sodium bicarbonate? _____

   Show your work here:

2. Is the decomposition of sodium bicarbonate described above an exothermic or an endothermic reaction? How do you know?

   _____

   _____

3. The combustion of methane (CH_4) produces 890.0 kJ of heat per mole of CH_4:

   $CH_4\ (g) + 2O_2\ (g) \rightarrow 2H_2O\ (l) + CO_2\ (g) \qquad \Delta H = -890.0\ kJ$

   How much heat is produced by the combustion of 10.00 grams of methane? _____

   Show your work here:

4. The reaction of hydrochloric acid (HCl) and sodium chloride (NaCl) produces 54.0 kJ per mole of HCl:

   $HCl\ (aq) + NaOH\ (aq) \rightarrow NaCl\ (aq) + H_2O\ (l) \qquad \Delta H = -54.0\ kJ$

   How much heat is produced when 100.0 mL of 0.5-M HCl solution reacts with excess NaOH?

   (Hint: There are 0.5 moles of HCl in a liter of 0.5 M HCl solution.) _____

   Show your work here:

Reaction calorimetry

The enthalpy of a reaction is often measured by placing the reactants in an insulated, water-filled container called a *calorimeter*. By measuring the temperature change of the water, the amount of heat released in the reaction can be determined. It takes 4.185 joules of heat energy to heat 1 gram of water by 1 °C. The total heat absorbed by a given amount of water can by calculated using the equation:

$$q = (4.185 \text{ J/g}\cdot\text{°C}) \cdot m\Delta T$$

In this equation, q is heat (in joules), m is the mass of water (in grams) and ΔT is the temperature change of the water (in degrees Celsius).

1. Two grams (2.00 g) of pure magnesium are burned in a calorimeter to produce magnesium oxide. There are 500 grams of water in the calorimeter, and during the reaction the water temperature changes from 22.0 °C to 45.6 °C.

   How much heat was produced in the reaction, in joules? _____

   How much heat was produced in the reaction, in kilojoules? _____

   Show your work here:

2. The reaction of magnesium and oxygen has the following formula: $2Mg + O_2 \rightarrow 2MgO$.

   What is the ΔH value for this reaction, in kilojoules? _____

   Show your work here: