ACTIVITY 06-2

Internal Energy and Enthalpy

WHY?

The capability of a chemical system or machine to store and release energy or to do work is related to changes in the internal energy of the system or machine. The thermal energy stored or released when the pressure is kept constant is called the *enthalpy*. The concept of enthalpy will help you better understand the properties of chemical reactions and identify optimum systems for storing and releasing energy and producing work.

LEARNING OBJECTIVES

- Identify the relationships among internal energy, enthalpy, heat, and work
- Learn how to determine changes in internal energy and enthalpy through experimentation

SUCCESS CRITERIA

- Identify processes as endothermic or exothermic
- Determine the sign and magnitude of changes in internal energy and enthalpy

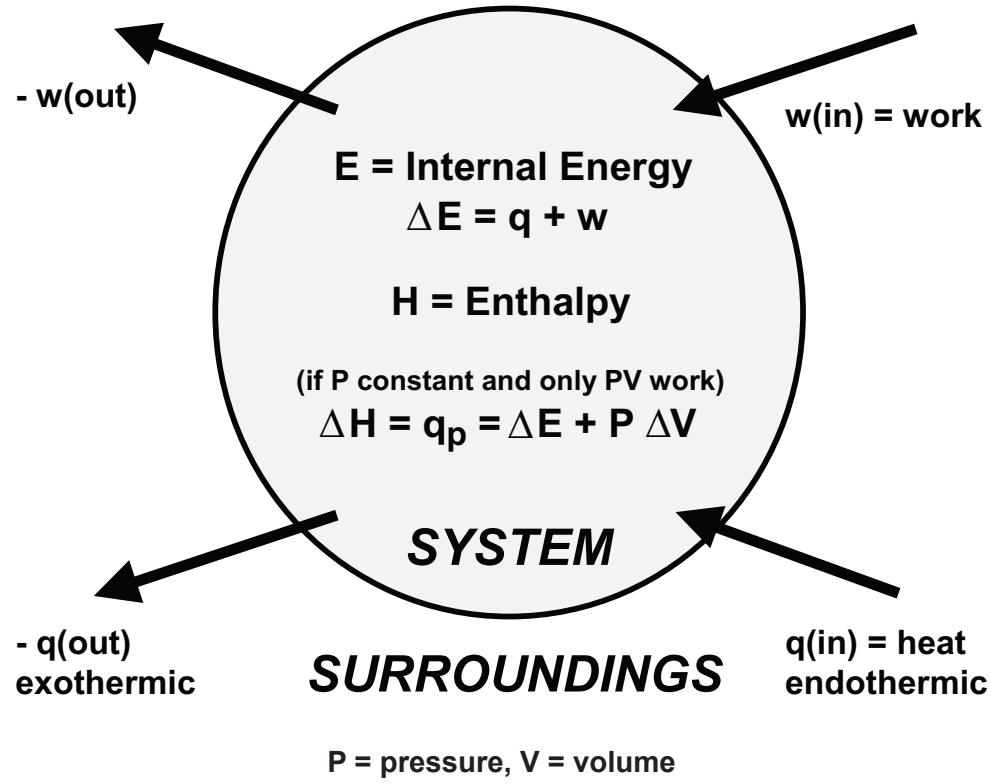
PREREQUISITE

- **Activity 06-1:** *Thermochemistry and Calorimetry*

INFORMATION

When physical and chemical changes occur in a system composed of atoms and molecules, energy is usually absorbed or released, and work is often done on or by the system. Energy is required to pull atoms apart and break chemical bonds. When bonds are formed, a more stable or lower energy situation is produced, so energy is released. When a chemical reaction involves both bond breaking and bond making, energy is either released or absorbed depending on the balance between the two. The energy change associated with a chemical reaction is usually in the form of thermal energy. The energy transferred in a reaction that takes place at a constant pressure is referred to by chemists as the *enthalpy of reaction*. The important relationships among heat, work, enthalpy, and internal energy of a system are represented in the Model.

MODEL: WHAT AFFECTS THE INTERNAL ENERGY AND THE ENTHALPY?



KEY QUESTIONS

1. According to the Model, if energy is introduced into a system from the surroundings, how does the internal energy of the system change?

2. According to the Model, if work is done on a system, e.g., by compressing it, how does the internal energy of the system change?

3. If a machine such as a steam engine produces work, how does the internal energy of the machine change?

4. Energy flows into or out of the system. What two terms describe the direction of energy flow? Write definitions of these terms.

5. What is the special name given to the energy (q_p) absorbed or released by a system when the pressure P is constant and the only work done is associated with a volume change?

6. In compressing a gas at constant pressure, work is done on the system and the internal energy increases. The work done is given by P times ΔV, where $\Delta V = V_{final} - V_{initial}$. Note that since the gas is compressed, V_{final} is smaller than $V_{initial}$. In calculating the change in internal energy, which of the following expressions should be used? Explain.

a) $w = P\,\Delta V$ b) $w = -P\,\Delta V$

7. Since most chemical reactions are conducted in containers open to the atmosphere, why is the energy transfer associated with a chemical reaction generally expressed as the change in enthalpy?

Exercises

1. If you do 1 J of work by pulling on a rubber band, by what amount does the internal energy of the rubber band change? Write your answer with a positive or negative sign as appropriate.

2. If your hot coffee loses 50 kJ of energy in cooling, what is the change in enthalpy of the coffee? Provide both the sign and the magnitude of ΔH.

3. Under what condition will the changes in enthalpy and internal energy be identical?

4. Identify each of the following as endothermic or exothermic. Explain.
   a) steam condensing

   b) ice melting

   c) two atoms combine to form a molecule: $2Cl(g) \longrightarrow Cl_2(g)$

   d) an electron is removed from an atom: $Na(g) \longrightarrow Na^+(g) + e^-$

e) a molecule is dissociated to produce two ions: $NaF(g) \longrightarrow Na^+(g) + F^-(g)$

5. Identify whether the sign of ΔH is positive or negative for each of the following. Explain. For any quantity, the change is determined by subtracting the initial from the final quantity, so

$$\Delta X = X_{final} - X_{initial}$$

a) steam condensing

b) ice melting

c) $Cl_2(g) \longrightarrow 2Cl(g)$

d) $Na(g) \longrightarrow Na^+(g) + e^-$

e) $Na^+(g) + F^-(g) \longrightarrow NaF(s)$

Problems

1. Your cup of hot coffee loses 50 kJ of energy in cooling, and the volume shrinks because of thermal contraction. For questions i) and ii), select an answer from the following list of possibilities, a) through f), and explain your reasoning.

a) exactly 50 kJ	c) less than 50 kJ	e) more negative than –50 kJ
b) more than 50 kJ	d) exactly −50 kJ	f) less negative than −50 kJ

i) How large is the change in enthalpy of the coffee?

ii) How large is the change in internal energy of the coffee?

iii) Justify your answers to i) and ii) by explaining why the change in internal energy must be larger/smaller than the change in enthalpy.

2. Burning butane (C_4H_{10}) produces gaseous carbon dioxide and water. The enthalpy of combustion of butane is – 2650 kJ/mole. Determine how much water you can heat from room temperature (22 ºC) to boiling with 1 lb of butane.

3. You are at your cabin in the woods. Will you be able to take a hot bath tonight if only 0.1 lb of propane remains in the tank? Explain. (Use your textbook for any additional data or information that you may need, and you may find it necessary to make assumptions or approximations as well.)