Chapter 5: Thermochemistry

This lesson builds the basics of chemical thermodynamics, which will be dealt with more completely later in the course and in AP Chemistry.

- Understand what the *system,* the *surroundings,* and the *universe* mean.
- Be familiar with the units of energy.
- Understand what the *First Law of Thermodynamics* means.
- Be familiar with how the internal energy of a system is affected by exchanges of heat and work between the system and the surroundings.
- Understand what a *state function* is.
- Define *enthalpy,* and explain how heat transfer from or to the system at constant pressure changes it.
- Know what the sign of the enthalpy indicates about the reaction.
- Be able to sketch an enthalpy diagram for reactions given their enthalpy changes.
- Be able to calculate the amount of heat released or absorbed by a reaction, knowing the quantity of the reactants and the enthalpy of the reaction on a mole basis.
- Define *heat capacity* and *specific heat (capacity).*
- Be able to work problems on calorimetry.
- State and apply Hess's Law of Constant Heat Summation in calculating enthalpies of reaction from enthalpies of other reactions.
- Know what the *standard state* of an element or compound is.
- Define and illustrate what is meant by *standard enthalpy of formation.*
- Calculate the enthalpy change of a reaction using a table of standard enthalpies of formation.

Lab Objectives:

- Become familiar with the use of a calorimeter to measure the enthalpy change during a chemical reaction.
- Compare the molar enthalpy change for the neutralization of a strong and a weak acid.

Key Words:

- thermodynamics, p. 153
- thermochemistry, p. 153
- potential energy, p. 154
- kinetic energy, p. 154
- joule, p. 155
- calorie, p. 155
- system, p. 155
- surroundings, p. 155
- work, p. 156
- heat, p. 156
- energy, p. 157
- first law of thermodynamics, p. 158
- internal energy, p. 158
- endothermic, p. 160
- exothermic, p. 161
- state function, p. 162
- pressure-volume work, p. 163
- enthalpy, p. 163
- enthalpy of reaction, p. 166
- calorimeter, p. 169
- heat capacity, p. 169
- molar heat capacity, p. 169
- specific heat, p. 169
- bomb calorimeter, p. 171
- Hess's law, p. 174
- enthalpy of formation, p. 176
- standard enthalpy, p. 177
- standard enthalpy of formation, p. 177

Suggested Exercises:
Critical thinking questions and end-of-chapter activities are included in these exercises.

- pp. 188–197, # 1, 3, 11, 13, 17, 19, 21, 23, 25, 27, 29, 31, 33, 35, 39, 41, 43, 45, 47, 49, 51, 53, 55, 57, 59, 61, 63, 65, 67, 69, 71, 73, 75, 77, 90, 96.

Troubleshooting Tips/Error Traps:

- Section 5.8, Food and Fuels, is not *essential*
- Don't spend much time on ΔE, q, and w.
- Spend more time on enthalpy and specific heat.
- Remember that standard enthalpies of formation are molar.
- Balancing chemical reactions is essential and so are the physical states of all species in thermochemistry.

Thermochemistry – Concept Questions

This chapter introduces the basic concepts of thermochemistry, energy changes in chemical reactions. Energy in bond formation, heat flow, and work will be calculated. The first Law of Thermodynamics is discussed. This chapter provides the background necessary to deal with the energetics of bonding and phase transitions. The final sections in the chapter deal with sources of energy including the energy crisis and alternative fuels. It serves as a basis for further study of thermodynamics in Chapter 19 which are AP Chemistry topics.

Concepts:

1. State exactly what the enthalpy of a system measures.
2. How do endothermic reactions differ from exothermic reactions? How can you identify each by experimental observation? What would you look for if the reaction were written as a chemical equation including the enthalpy term? What would you look for if it were written in ΔH notation?
3. When a reaction is run in reverse, what happens to the numeral (magnitude) of ΔH? What happens to its sign?
4. State Hess's Law in both words and symbols. Define each symbol.
5. Hess's Law is one of the most important summaries of the First Law of Thermodynamics. You will apply it in many situations. The First Law, most simply stated is: Energy (and matter) cannot be created or destroyed (but they can be interchanged according to Einstein's relation). Explain how Hess's Law is related to the First Law.
6. Is fire walking "magic" or "science"? While explaining your answer, use the terms heat and temperature.
7. When doing calorimetry, it is the heat flow into the water that is actually measured. How does this quantity relate to the heat flow in the reaction you are really interested in?
8. In a bomb calorimeter the heat flow of the reaction is related to the heat flow into the water and into where else?
9. What is work? In what two ways does it differ from heat flow?
10. How do heat and work differ from energy?
11. Why is ΔE a state property while q and w are not?
12. Explain what is meant by The Green House Effect. How is it caused, what can society do to reduce this effect?

Energy Definitions

It should be noted that many of the energy definitions can be considered in the reverse direction with a corresponding change of sign for the energy.

Bond formation = exothermic ΔH negative
Bond cleavage = endothermic ΔH positive

Enthalpy of vaporization: The energy required to vaporize one mole of a liquid
Enthalpy of atomization: The energy required to produce one mole of gaseous atoms from an element in its standard state
Bond dissociation enthalpy: The energy change when one mole of a specific bond is broken or created
Bond enthalpy: The average energy change when one mole of a specific type of bond is broken or created.
Enthalpy of Combustion: The energy released when one mole of a compound is burned in excess oxygen
Enthalpy of formation: The energy change when one mole of a compound is formed from its constituent elements in their standard states
Enthalpy of solution: The energy change when one mole of a substance is dissolved in an infinite amount of water
Hydration enthalpy: The energy change when a particle is taken from infinite separation in the gaseous state to its position in an aqueous lattice
Ionization energy: The energy required to produce one mole of gaseous ions from one mole of gaseous atoms by removal of one mole of electrons
Lattice enthalpy: The energy change when one mole of an ionic substance is broken into its constituent atoms at infinite separation.