

CHAPTER REVIEW

Summary

SECTION 11.1

Fossil fuels (coal, crude oil, and natural gas) are today's major sources of energy, but they are nonrenewable.

SECTION 11.2

The law of conservation of energy states that energy is converted from one form into another but is not created or destroyed. Measurement of the energy changes resulting from the breaking and making of chemical bonds is called thermochemistry. Energy is defined as the capacity to do work and can take many forms. Chemical energy is a form of potential energy that is stored in the bonds of substances.

SECTION 11.3

Alkanes, or saturated hydrocarbons, have the general formula C_nH_{2n+2} . Alkanes with $n = 1$ to 4 are constituents of natural gas. Condensed structural formulas are simpler than Lewis structures in that the C-H bonds are not drawn. In straight-chain hydrocarbons, the C-C bonds also may not be shown.

SECTION 11.4

The combustion of hydrocarbons produces H_2O and CO_2 and releases energy. This energy may be in the form of heat (q) or work (w) or both. A reaction or process under study is called a system. Everything else is called its surroundings. The amount of energy gained or lost by the system during a chemical reaction or physical change of state equals the amount of heat lost or gained by its surroundings. The study of energy flow into and out of a system is called thermodynamics. Changes that release energy are exothermic; those that absorb energy are endothermic. The transfer of energy to a system changes its internal energy by an amount $\Delta E = q + w$.

SECTION 11.5

The flow of heat during a chemical or physical change at constant pressure equals a change in enthalpy (ΔH).

Reversing a process changes the sign of its enthalpy change.

SECTION 11.6

The heat required to raise the temperature of a substance is related to the quantity of the substance, the molar heat capacity of the substance, and the difference between the initial and the final temperatures of the substance. The solid, liquid, and gaseous states of a substance have different molar heat capacities. The heat required to melt a quantity of a solid substance can be calculated from the quantity of the substance and its molar heat of fusion, ΔH_{fus} . The heat required to convert a liquid into vapor can be calculated from the quantity of the substance and its molar heat of vaporization, ΔH_{vap} .

SECTION 11.7

The energy required to break a chemical bond is its bond energy. The enthalpy change during a chemical reaction can be estimated from the difference in average bond energies of the products and reactants. The enthalpy change of a combustion reaction is called its heat of combustion, ΔH_{comb} .

SECTION 11.8

The enthalpy changes of chemical reactions such as combustion reactions can be measured with a bomb calorimeter, in which heat produced by the reaction warms its surroundings. Knowing the heat capacity and temperature change of the surroundings enables us to calculate the enthalpy change of the reaction.

SECTION 11.9

The standard enthalpy of formation of a compound, ΔH_f° , is the enthalpy change that takes place when 1 mole of the compound is formed under standard conditions from its elements in their standard states. The ΔH_f° of the most stable form of a pure element is defined as zero. The difference in enthalpies of formation of products minus reactants can be used to calculate the enthalpy change of a reaction.

SECTION 11.0

The fuel value of a substance is the enthalpy change that takes place when 1 gram of the substance undergoes combustion.

Key Terms

alkane (saturated hydrocarbon) (p. 516)
 bond energy (p. 532)
 calorimetry (p. 535)
 chemical energy (p. 515)
 endothermic (p. 519)
 energy (p. 513)
 enthalpy (p. 523)
 exothermic (p. 519)
 first law of thermodynamics (p. 518)
 fuel value (p. 540)

heat capacity (p. 526)
 Hess's law (p. 543)
 hydrocarbon (p. 515)
 internal energy (p. 520)
 law of conservation of energy (p. 515)
 molar heat capacity (p. 526)
 molar heat of combustion (p. 534)
 molar heat of fusion (p. 526)
 molar heat of vaporization (p. 527)

potential energy (p. 514)
 saturated hydrocarbon (alkane) (p. 516)
 standard enthalpy of formation (p. 537)
 standard state (p. 537)
 state function (p. 514)
 surroundings (p. 518)
 system (p. 518)
 thermochemistry (p. 513)
 thermodynamics (p. 518)

Key Skills and Concepts

SECTION 11.1

Understand that the energy requirements of the world economy are mostly being met by the combustion of finite supplies of fossil fuels.

SECTION 11.2

Understand the meaning of *state function*.
 Understand that heat and work are interchangeable forms of energy.
 Be able to state the law of conservation of energy.

SECTION 11.3

Know the names, formulas, and structures of the C_1 to C_4 alkane hydrocarbons.
 Be able to convert condensed structural formulas into Lewis structures.

SECTION 11.4

Be able to complete and balance equations for hydrocarbon combustion reactions.
 Be able to identify a thermodynamic system and its surroundings.

SECTION 11.11

According to Hess's law, the enthalpy change for an overall process is the sum of the enthalpy changes for the constituent steps in the process.

Be able to state the first law of thermodynamics.
 Understand the meaning of *exothermic* and *endothermic*.
 Understand the relation between the energy change of a system, the heat flow to or from it, and the work done by or on it.

SECTION 11.5

Know the meaning of *enthalpy* and the relation between the change in enthalpy (ΔH) and heat flow at constant pressure.

SECTION 11.6

Understand the enthalpy changes associated with heating or cooling and with changes of state, and be able to calculate these changes for given amounts of substances.

SECTION 11.7

Be able to estimate the enthalpy changes for balanced combustion reactions (heats of combustion) of specified reactants from bond energies.

SECTION 11.8

Be able to calculate enthalpy changes from data obtained from a bomb-calorimeter experiment.

SECTION 11.9

Understand the concept of standard heat of formation (ΔH_f°). Be able to calculate the enthalpy change of a reaction from the heats of formation of the reactants and products.

SECTION 11.10

Be able to calculate the fuel value of a substance from its heat of combustion and molar mass.

SECTION 11.11

Be able to use Hess's Law to manipulate reactions and their associated enthalpy changes to obtain ΔH for a particular reaction.

Key Equations and Relations

SECTION 11.2

Mechanical work (w) equals force (F) times distance (d):

$$w = F \times d \quad (11.1)$$

The kinetic energy (K.E.) of an object with mass m moving at velocity u is

$$\text{K.E.} = \frac{1}{2} mu^2 \quad (11.2)$$

SECTION 11.4

The change in internal energy of a system (ΔE) is the sum of the heat (q) flow into the system and the amount of work done on the system:

$$\Delta E = q + w \quad (11.3)$$

When the volume of a system increases at constant pressure as a result of a chemical reaction, the change in internal energy of a system, ΔE , is

$$\Delta E = q - P\Delta V \quad (11.4)$$

SECTION 11.5

The enthalpy of a system is defined as the sum of its internal energy and its pressure times its volume:

$$H = E + PV \quad (11.5)$$

The change in enthalpy (ΔH) of a system undergoing a change in volume at constant pressure is

$$\Delta H = \Delta E - P\Delta V \quad (11.6)$$

An enthalpy change at constant pressure equals the flow of heat to the system:

$$\Delta H = q_p \quad (11.7)$$

SECTION 11.6

The amount of heat added or removed from a substance as its temperature changes by ΔT is

$$q = n c_p \Delta T \quad (11.8)$$

where n is the number of moles of substance and c_p is the molar heat capacity of the substance.

The amount of heat needed to melt (fuse) n moles of a solid substance is

$$q = n \Delta H_{fus} \quad (11.9)$$

where ΔH_{fus} is the substance's molar heat of fusion.

The amount of heat needed to vaporize n moles of a liquid substance is

$$q = n \Delta H_{vap} \quad (11.10)$$

where ΔH_{vap} is the substance's molar heat of vaporization.

The enthalpy change in a chemical reaction (ΔH_{rxn}) can be estimated from the difference in the average bond energies of the products minus the average bond energies of the bonds in the reactants.

SECTION 11.8

In calorimetry, the amount of heat released to the surroundings by a system is

$$q = C\Delta T \quad (11.11)$$

where C is the heat capacity and ΔT is the increase in the temperature of the surroundings.