7.7 ENERGY AND EQUILIBRIUM: THE LAWS OF THERMODYNAMICS

PRACTICE

(Page 498)

Understanding Concepts

1. (a) negative
   (b) negative
   (c) positive
   (d) positive

Explore an Issue: Take a Stand: Can We Do Anything About Pollution?

(Page 501)

(There are a variety of positions that students can take as they argue the inevitability of pollution. The following argument is one possible scenario.)

At first glance, manufacturing new complex goods from simpler raw materials appears to contradict the second law of thermodynamics. However, when you consider the energy required to produce these products and the volume of waste materials the process generates, it becomes obvious that the second law remains valid. While the generation of waste materials may be inevitable, we can nevertheless control the type of waste a process generates. For example, an internal combustion engine and a hydrogen fuel cell arguably contribute a similar amount of entropy to the universe. However, the waste product of the fuel cell (steam) is much less harmful to the environment than the combustion products of gasoline.

Try This Activity: Stretching a Point

(Page 503)

(a) Forward reaction (stretching)
$\Delta G > 0, \Delta H < 0, \Delta S < 0$

(b) Reverse reaction (relaxing)
$\Delta G < 0, \Delta H > 0, \Delta S > 0$

(c) The rubber molecules become more ordered as the rubber band is stretched (the forward reaction). Stretching the rubber band forces the molecules to align parallel to each other, much like strands of spaghetti in a box. When the rubber band is relaxed, the long rubber molecules become more disordered since the force holding them into regular pattern has been removed.

(d) Bonds are forming between the polymer chains when the rubber band is being stretched. Conversely, bonds between the polymer chains are broken when the rubber band is relaxed.

(e) London forces are being affected during the changes.

(f) The spontaneous contraction of the rubber band is driven by entropy. Since ΔH is positive, the $T\Delta S$ term in the Gibbs free energy equation must be larger than ΔH in order for ΔG to be negative.

(g) Since $T\Delta S$ is always negative regardless of temperature, ΔG will always be negative as well. Consequently, the contraction process should be spontaneous at all temperatures.

(h) (Answers may vary. Sample investigation might include students testing their prediction by using rubber bands that have been warmed in a water bath or cooled in the freezer.)

PRACTICE

(Page 508)

Understanding Concepts

2. (a) $NH_{3(g)} + HCl_{(g)} \rightarrow NH_4Cl_{(s)}$

$$\Delta H^\circ = [\Delta H^\circ_{f(NH_4Cl_{(s)})}] - [\Delta H^\circ_{f(NH_{3(g)})} + \Delta H^\circ_{f(HCl_{(g)})}]$$
$$= [1 \text{ mol } (-314.4 \text{ kJ/mol})] - [1 \text{ mol } (-45.9 \text{ kJ/mol}) + 1 \text{ mol } (-92.3 \text{ kJ/mol})]$$
$$= [-314.4 \text{ kJ}] - [-45.9 \text{ kJ} - 92.3 \text{ kJ}]$$
$$= [-314.4 \text{ kJ}] - [-138.2 \text{ kJ}]$$