



Figure 7 illustrates the entropy change that takes place when solid sugar is dissolved in tea (an aqueous solution). In the sugar-water system shown in Figure 7a, the solid sugar has just been added to the tea, but most of it has not yet dissolved. The entropy is low because the majority of the sugar molecules are in one region at the bottom of the pitcher and the majority of the water molecules can be found everywhere else in the pitcher. After the sugar dissolves in the tea, shown in Figure 7b, the sugar molecules are thoroughly mixed throughout the tea solution. Sugar molecules and water molecules might be found anywhere in the solution, so the entropy, the randomness, of the system increases. This would give ΔS a positive value for this solid-liquid system. You can imagine the same series of events happening for a system of gases mixing with each other or a system of liquids mixing. In each case, ΔS would have a positive value once the solution was formed.

(b)

FIGURE 7 When a solid dissolves in a liquid, the entropy of the system increases.



extension

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Free Energy

Processes in nature are driven in two directions: toward least enthalpy and toward largest entropy. When these two oppose each other, the dominant factor determines the direction of change. As a way to predict which factor will dominate for a given system, a function has been defined to relate the enthalpy and entropy factors at a given temperature and constant pressure. *This combined enthalpy-entropy function is called the* **free energy**, *G*, *of the system*; it is also called *Gibbs free energy*. This function simultaneously assesses the tendencies for enthalpy and entropy to change. Natural processes proceed in the direction that lowers the free energy of a system.

Only the *change* in free energy can be measured. It can be defined in terms of changes in enthalpy and entropy. At a constant pressure and temperature, the **free-energy change**, ΔG , of a system is defined as the difference between the change in enthalpy, ΔH , and the product of the Kelvin temperature and the entropy change, which is defined as $T\Delta S$.

$$\Delta G^{0} = \Delta H^{0} - T \Delta S^{0}$$

Note that this expression is for substances in their standard states. The product $T\Delta S$ and the quantities ΔG and ΔH have the same units, usually kJ. The units of ΔS for use in this equation are usually kJ/K. If $\Delta G < 0$, the reaction is spontaneous.

 ΔH and ΔS in the free-energy equation can have positive or negative values. This leads to four possible combinations of terms.

Table 2 on the next page shows that if ΔH is negative and ΔS is positive, then both terms on the right in the free energy equation are