Spontaneous Assembly of Straws

Enthalpy, Entropy, and Free Energy

Introduction

Spontaneous has a special definition in chemistry. Observe and model it using straws.

Concepts

- Enthalpy
- Entropy
- Gibbs Free Energy
- Spontaneous Reaction

Materials

Water, tap

Straws, plastic, 3–4

Beaker, 600-mL

Procedure

1. Cut the straws into several 1.5 cm pieces.
2. Fill the beaker to the 3-cm height (~200 mL) with tap water
3. Place the straw pieces into the beaker. *Note:* Cover only $^1/_2$ to $^2/_3$ of the water surface in the beaker.
4. Push the straws down to fill with water. They will still float.
5. Gently swirl or tap the beaker.
6. Observe the behavior of the straw pieces

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory wastes. The straws may be thrown in the trash and the water may be poured down the drain.

Discussion

Many biological processes rely on the correct assembly of macro molecules. For example, proteins must be folded in a certain way to function properly and lipids in cell membranes must be orientated just so in order to provide an effective semipermeable barrier to the cytoplasm. Self assembly of the particles into functional clusters plays an essential role in the growing field of nanotechnology.

Fortunately, these processes usually occur without intervention. Spontaneous assembly of particles happens in many places in nature, and depends on the nature and strength of the attractive forces between the particles.

In this demonstration, straw pieces will assemble into regular patterns, side-to-side and end-to-end, but not side-to-end. Because they assemble on their own, without requiring additional energy, the process is called *spontaneous*. The energy change of a reaction is best understood using the Gibbs free energy equation:

$$\Delta G = \Delta H - T\Delta S \qquad \textit{Equation 1}$$

Where G = Gibbs free energy

ΔH = Enthalpy change

T = Temperature

ΔS = Entropy change

For a spontaneous reaction, ΔG is negative, which means that energy does not need to be put into the system for the reac-

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tion to proceed. S, called *entropy*, is best understood as degrees of freedom. For example, the same volume of gas in two different sized containers will have more entropy in the larger container. For simplicity's sake, entropy is often explained as "disorder". In this reaction, the entropy change is negative, as the straws are becoming more ordered. With ΔG and ΔS both negative, ΔH must also be negative. ΔH, called the *enthalpy change*, is understood as the amount of heat gained or lost by the system during a reaction. Endothermic reactions have a positive ΔH where heat energy is gained by the system. A negative ΔH is an exothermic reaction and heat energy is lost by the system. An analogy can be made by comparing the spontaneous assembly of soda straws to the crystallization of liquids. Molecules in liquid form have more degrees of freedom and more ways they can move than molecules in a solid. Therefore, crystallization has a negative entropy change. Crystallization is both exothermic because heat energy is released and spontaneous since it will occur at the proper temperature without the addition of more heat energy.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Systems, order, and organization
Evidence, models, and explanation
Content Standards: Grades 5–8
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, properties and changes of properties in matter, understanding of motions and forces, transfer of energy
Content Standards: Grades 9–12
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, structure and properties of matter, chemical reactions, motions and forces, conservation of energy and increase in disorder, interactions of energy and matter

Reference

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Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *Spontaneous Assembly of Straws* activity, presented by Jamie Benigna, is available in *Enthalpy, Entropy, and Free Energy*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series

Materials for the *Spontaneous Assembly of Straws* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP1819	Straws, Plastic, Pkg. 50
GP1030	Beaker, 600-mL

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.