

In the previous problems, and on your homework, you've been calculating changes in free energy to get the available work done in a process. In problem 3, you've also seen that the free energy of a system is a *minimum* in equilibrium (as opposed to the *total entropy* (system + environment), which is a *maximum* in equilibrium). In this problem, you'll take a deep breath and step back from all the calculations... now's your chance to think as a group to explain some things that happen in real life in terms of free energy.

a) Start by writing out the definition of free energy (F) in terms of the internal energy change of the system, the entropy change of the system, and the temperature of the environment.

$$F = U_{\text{system}} - T_{\text{environment}} S_{\text{system}}$$

b) Talk with your group members about the following situations. For each one, explain what's going on in terms of each term in the free energy (temperature, internal energy, and entropy) – your answers will probably be *increases*, *decreases*, or *stays the same*. If there are competing effects, which term wins? How do you know?

i) If you drop a salt cube into water, the cube dissolves.

Dissolving breaks up the Na<sup>+</sup> and Cl<sup>-</sup> attraction => U increases

I can rearrange the Na<sup>+</sup> and Cl<sup>-</sup> ions freely now => S increases

Sometimes, there is enough heat of solution to raise the temperature, but not here.

=> T stays the same

Since it actually dissolves, TS wins at this temperature.

ii) If you pour vegetable oil into a cup of water, the vegetable oil won't mix with the water.

If it were to dissolve => S increases

and (because the oil drop wants to stick together) => U increases

However, nothing happens (U dominates), so U and S stay the same.

iii) When you heat a stretched rubber band, it shortens, even if that lifts a weight.

Presumably, the heating increases the system temperature => U increases

This polymer has more arrangements when it's folded up => S increases

You are raising the temperature: => T increases

Since it shortens, the TS term must be larger. This means a cold rubber band won't shorten.

iv) When you open a pressurized gas bottle, the gas rushes out into the room.

Ideal gas: => U stays the same.

Also: => T stays the same

Volume increases: => S increases