4.1: Where We Are Headed

We continue our pursuit of an energy conservation approach, which looks at the state of a system before an interaction and then looks at the state of the system after the interaction, trying to avoid the messy details that occur in between. With our understanding of heat, work, thermal energy and heat capacities in terms or our particle model of matter, we are in a position to make explicit connections to the traditional field of thermodynamics. Thermodynamics is a very practical discipline. Scientists from all fields (chemistry, physics, biology, earth sciences, environmental sciences) find thermodynamics to be a very useful approach to determining values of physical variables. Our goal is to demystify thermodynamics as much as we can. In particular, we make direct connection to our particulate models of matter and our *Energy-Interaction Model.* The connection of entropy and energy to particulate models of matter helps to make thermodynamics much less mysterious to most of us. We can more readily see why so many things in nature "are they way they are" in terms of our models.

We will actually spend very little time, relatively, on thermodynamics. We can't expect to become experts in such a short time. But what we do hope is that you will develop some understanding of how traditional thermodynamics relates to what we have been doing. Perhaps, when you run across thermodynamics later in your studies or work, it won't seem so mysterious. The idea of entropy and its connection to statistical arguments should make the second law of thermodynamics much more understandable. The ideas expressed in the second law are very general. They apply to all systems composed of many particles. That takes in just about everything, since essentially everything is made up of little particles.

Kinds of Questions and Explanations

First kind of Question

- Why is thermodynamics such a useful tool throughout all the sciences?
- Why does almost everything you look up in a chemistry or biochemistry reference have a "ΔH" associated with it? And why is it so often negative?
- What the heck is "entropy," anyway? Does the 2nd law of Thermo have anything to do with the perpetual state of my desk? My hectic life?
- Why does Gibbs Energy seem to be such an important idea? And what is it that is "free" about it anyway."

The kinds of questions listed above will be the focus of much of our short and intense involvement with our *Intro Model of Thermodynamics*. Combined with the *Intro Statistical Model of Thermodynamics*, you should be able to feel pretty comfortable regarding your answers to these types of questions. But in addition, you should also be able to make a lot of sense and construct convincing explanations for questions like those in the second category below.

Second kind of Question

- What are the differences when water evaporates from your skin on a warm summer day in California and from the surface of a pot of nearly boiling water in an open pot on the stove?
- What is the temperature of the water vapor as it leaves either surface? Which evaporation process, if either, produces more cooling?
- Which "ΔH" is different, if either, in the two cases? Give a numerical prediction for the difference.

We won't have time to practice constructing answers to too many of these second kinds of questions, but in your own work in advanced science courses and making sense of research papers you are likely to get ample opportunities, provided you get a good foundation with some of the basic underlying ideas. That is the learning outcome we are aiming far.

Phenomena and Data Patterns

Although thermodynamics can be applied to physical systems as large as galaxies and even our entire universe, it really comes into its natural power when we have questions and need answers about what is going on *internally* in rather controlled environments. This might be in a biochemistry lab or in the cells in the human body. Thermodynamics (and the additional insight and understanding obtained from a statistical approach to entropy and Gibbs energy) connect the real world of empirical data with an extremely powerful approach to analysis that enables scientists to get answers to questions and make numerical predictions when it would seem that it is impossible to get the necessary data to do so. That is, often our questions are of a nature that we would normally believe that the only way they could be answered would by doing specific experiments directly on the phenomenon in question. Frequently, however, these experiments are either impossible to do directly or they are extremely difficult/expensive/illegal, etc. But here is where thermodynamics comes to the rescue.

How does this work? Well, the simple short answer is that for most physical systems, there might be tens, maybe even close to a hundred various physical parameters that characterize that physical system and distinguish it from a similar physical system. But, (here is the short answer) *all of these parameters are not independent of each other*! Thermodynamics is the *tool* that tells us how to determine the values of the ones we *can't directly measure* (and which no one else has measured and tabulated either) from values of parameters that have been measured and tabulated. At first it seems almost like magic. And to an "outsider" to the field, it is very analogous to magic, in the sense that you know there must "be a trick," but you can't imagine what it is. When you are reading and making judgments on scientific papers, you don't want to be like the "jaw-dropped-open in amazement" spectator, but rather "the insider," who at least knows where the "trick" is occurring, even if you don't have the skill to perform it yourself.

A tremendous amount of data has been collected and tabulated on the seemingly infinite variety of biochemical compounds and interactions among these compounds. Thermodynamics is the tool that lets you get maximum benefit from all the work so many thousands of scientists have done on so many different physical systems. So, in a sense, the data patterns of thermodynamics are mostly all of the data that has ever been collected and tabulated on the properties of every imaginable kind of substance or composite material.

In this chapter, we don't really even scratch the surface. With more and more data becoming accessible on-line, "doing thermodynamics" is getting easier every day. Don't forget its power when you need it.
