3.1: Where we are headed

Introducing Particle Models to Matter

As previously noted, we are pursuing two goals in Physics 7A. On the one hand, we want to get a solid understanding of energy and how we can use this understanding to get answers and make predictions about interesting phenomena. In Chapter 2 we got through the basics of introducing work and potential energy and applied these concepts to mostly macroscopic phenomena. Now to achieve the second goal of 7A, in Chapter 3, we turn to the development of particle models of matter. We would like to be able to answer questions such as: Why do things melt and/or vaporize at different temperatures? What determines heat capacities of different substances? What aspects of these thermal properties are common to many substances and which are unique to particular substances? What common things can we say about all kinds of chemical bonding? Some of the most important ideas in our particle models of matter are related to the behavior of the spring-mass motion introduced in Chapter 2. We extend these ideas to understand the motion of atoms using a model that has at its core the idea that atoms and molecules in liquids and solids act like they oscillate exactly the way the spring-mass system oscillates. The relation between force and potential energy allows us to really make sense of the forces that act between atoms and molecules in terms of their equilibrium spacing and to understand the differences between solids, liquids, and gases in a much more fundamental way.

With start with a famous quote by Nobel laureate in physics, Richard P. Feynman, from the first chapter of an introductory physics book he wrote for Cal Tech students back in the late 50's, claiming that the *Particle Model of Matter* is *the most* important or powerful model in science. Here is what he said:

> *"If, in some cataclysm, all of scientific knowledge were to be destroyed, and only* ***one sentence*** *passed on to the next generations of creatures, what statement would contain the most information in the fewest words? I believe it is the* ***atomic hypothesis*** *(or the atomic fact, or whatever you wish to call it) that* ***all things are made of atoms—little particles that move around in perpetual motion, attracting each other when they are a little distance apart, but repelling upon being squeezed into one another.*** *In that one sentence, you will see, there is an enormous amount of information about the world, if just a little imagination and thinking are applied." -The Feynman Lectures on Physics, Volume I, page 1-2*

Your job over the next couple of weeks is to use "*a little imagination*" and apply "*a little thinking*" to the content of this powerful statement.

In This Chapter

The heart of the content in Chapter 3 is the development of a full understanding of the details contained in the Feynman quote. You already have a lot of useful ideas about this model. Much of it you have studied in chemistry. Keep consciously trying to integrate this new material with things you already know. It will take mental effort, but the understanding you gain will help your see chemical and biological concepts in a new light.

One of the areas in which our particle model of matter really shines is in explaining the experimentally observed thermal properties of matter, e.g., the values and trends of the specific heats of many substances in the gas, liquid, and solid phases. One of the interesting things about science is that it is in trying to resolve discrepancies as we push ahead and make breakthroughs. One of the discrepancies we will meet as we look at specific heats is that values for gases as well as solids are often lower than we would predict, especially at lower temperatures, but tend to rise to the predicted values as the temperature rises. The changes we need to incorporate in our model are due to the quantum mechanical nature of matter on a microscopic scale. We introduce some quantum ideas here and will continue to return to them throughout the course. Of course, you already know a lot about some of the central notions of quantum mechanics from your study of chemistry. For example, you have encountered the notion of orbital, or quantized energy levels for the electrons swirling about the nuclei of atoms. When you get to the discussion in this *chapter* on how quantum mechanics alters things, you should definitely connect it to what you already know about quantization.

The particulate nature of matter provides a model that allows explanations of a large range of phenomena that simply cannot be explained without invoking this fundamental idea regarding what matter is. In this chapter much of the focus will be simply developing a basic particle model, *Intro Particle Model of Matter*, sufficiently far so that, with a *Particle Model of Bond Energy* and a *Particle Model of Thermal Energy* it will be possible to develop explanations for many of the empirically determined thermal properties of matter encountered in Chapter 1. Specifically, how do we make sense of the range of thermal and bond energies we encountered in Chapter 1? In addition to the sampling of heat capacity data and heats of fusion and vaporization presented in Chapter 1, we would expect our models to provide us with the capability of explaining the heat capacity values, both at constant pressure and at constant volume for a large range of substances.