PHYSICAL CHEMISTRY

What Is Physical Chemistry?

By David H. Magers

What is physical chemistry? *Chemistry* is usually referred to as the central science while *physics* is called the fundamental science. Thus, physical chemistry is a study of the fundamentals underlying the central science. To put it another way, physical chemistry is the study of the underlying physical principles that govern the properties and behavior of chemical systems. A scientist can be a chemist without studying physical chemistry, but at the price of never really knowing why the chemistry he or she does works. An analogous example would be a student of mathematics who studied derivatives and integrals without ever studying the concept of limits. The formulas could be memorized and problems worked, but a complete understanding of why would not be possible. Thus, physical chemistry is the course which tells chemists why chemistry works, not just how.

A chemical system can be studied from either a *microscopic viewpoint* or a *macroscopic viewpoint*. The microscopic viewpoint makes explicit use of the concept of atoms and molecules. The macroscopic viewpoint studies large-scale (bulk) properties of matter without the explicit use of the concept of molecules. The term **chemical physics** denotes those aspects of physical chemistry that study phenomena at the molecular level.

Physical chemistry is often divided into **four main areas**: *thermodynamics*, *quantum chemistry*, *statistical mechanics*, and *kinetics*. Of these areas, only thermodynamics may be studied strictly from a macroscopic viewpoint. Thermodynamics studies the interrelationships of the various equilibrium properties of a system and the changes in equilibrium properties in processes.

Molecules and the electrons and nuclei that they comprise do not obey *classical mechanics* as objects in our everyday macroscopic world do. Instead, their motions are governed by the laws of *quantum mechanics*. Application of quantum mechanics to atomic structure, molecular bonding, and spectroscopy yields quantum chemistry.

The macroscopic science of **thermodynamics** is a consequence of what is happening at the molecular (microscopic) level. The molecular and macroscopic levels are related to each other by the branch of science called *statistical mechanics* (or statistical thermodynamics). This field of study gives insight into why the laws of thermodynamics hold from a molecular viewpoint and allows calculation of macroscopic thermodynamic properties from molecular properties.

Kinetics is part of the science of motion. In physics, the science of motion is termed dynamics and is subdivided into kinematics, which treats the motion of bodies,

and kinetics, which deals with the effect of forces on motion. In chemistry, we usually make no such distinction.

Chemical kinetics is concerned fundamentally with the details of the process whereby a system gets from one state to another and with the time required for the transition. It is the study of rate processes such as chemical reactions, diffusion, and the flow of charge in an electrochemical cell.

This list of four main areas may be supplemented with at least two other fields of study: *electrochemistry* and *crystallography*. Electrochemistry could be considered to be an extension of thermodynamics, but it is certainly a field of study in its own right and usually introduced to students more than once in their undergraduate careers. Crystallography is actually just one part of the study of the structure of condensed phases. In the past, very little of this branch of science has been introduced to chemists at the undergraduate level, but the fields of material science and polymer science have greatly grown in the fast few decades. Therefore, chemists need a better understanding of condensed phases to keep abreast of these fields.

One final note to this introduction - just because we have divided physical chemistry into branches does not mean that they are not very ***interrelated***. The dividing lines are often extremely obscure just as they often are between the major branches of chemistry as a whole. As stated above, the principles of physical chemistry provide a framework for all branches of chemistry.