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Book review

PHYSICAL CHEMISTRY FOR THE LIFE SCIENCES,

Peter Atkins, Julio de Paula,
Oxford University Press, Oxford, UK,
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The treatise **Physical Chemistry for Life Sciences**, written by Peter Atkins and Julio de Paula is structured in four parts: I. *Biochemical Thermodynamics*; II. *The Kinetics of Life Processes*; III. *Biomolecular Structure*; IV. *Biochemical Spectroscopy*. Also, it contains four appendixes: 1 – Quantities and units, 2 – Mathematical techniques, 3 – Concepts of physics, 4 – Review of chemical principles.

At the beginning it is presented the first law of the classical thermodynamics together with the fundamental concepts: systems and surroundings, work and heat, energy conversion in living organisms, measurement of work and heat, internal energy and enthalpy. The internal energy describes how biological processes can store and release energy. The authors focused on the use of the enthalpy as a useful bookkeeping property for tracing the flow of energy as heat during physical processes and chemical reaction at constant pressure. The discussion was directed towards a quantitative treatment of the factors that optimize the suitability of fuels, including *biological fuels*, the foods that are ingested to meet the energy requirements of daily life.

Chapter 2 – **The Second Law** – explains the spontaneous and non spontaneous changes of energy. These concepts are necessary to guide the study of bioenergetics and structure in biological systems. For this reason, fundamentals on entropy and second law of thermodynamics are presented.

Many phase changes are common everyday phenomena, and their description is an important part of the physical chemistry. Some of the thermodynamics concepts developed in chapter 3 – **Phase Equilibria** – form the basis of important experimental techniques in biochemistry. More specifically, the authors consider important the methods for determination of the molar masses of proteins and nucleic acids and the investigation of the binding of small molecules to proteins.

Chemical thermodynamics is used to predict whether a mixture of reactants has a spontaneous tendency to change into products, to predict the composition of the reaction mixture at equilibrium, and to predict how that composition will be modified by changing the conditions. All these aspects were presented in chapter 4 – **Chemical Equilibrium**.

The information included in this part is of crucial importance for understanding the mechanisms of oxygen transport in blood, metabolism, and all the processes going on inside organisms.

Chapter 5 – **Thermodynamics of Ion and Electron Transport** – presents experimental data that are very useful for discussing the characteristics of electrolyte solutions and the migration of ions across biological membranes. Also, experimental results and evidence are used to discuss the details of the propagation of signals in neurons and the synthesis of ATP. The final part of this section analyzes the redox reactions, the proton transfer typical of acid-base reactions, processes in which electrons are transferred.

The second part of this book is dedicated to the kinetics of life processes. Chemical kinetics can predict how rapidly reactants are consumed and products formed, how reaction rates respond to changes in the conditions or the presence of a catalyst, and the identification of the steps by which a reaction takes place.

In the chapter 6 – **The Rates of Reactions -** the experimental techniques and methods for investigation of reaction rate and determination of reaction order are presented. Because the rate of chemical reactions are sensitive to temperature, the Arrhenius equation is introduced and the parameters of this equation are determined.

The chapter 7: **Accounting for the Rate Laws** presents aspects regarding reaction mechanisms and dynamics, emphasizing their complexity and importance. The study of reactions rates can give deep insights into the way that reactions actually take place. As was previously mentioned, the rate laws can be considered as a window onto the mechanisms, the sequence of elementary molecular events that leads from the reactants to the products, of the reactions they summarize. In this chapter, it can be seen how analysis of a mechanism leads to insight into the dependence of the rate on the concentrations of reactants or products.

Chapter 8 – **Complex Biochemical Processes** – describes the transport across biological membranes, the enzymes and the electron transfer in biological systems. Many cellular processes, such as propagation of impulses in neurons and the synthesis of ATP by ATPases, are controlled by the transport of molecules and ions across biological membranes. *Passive transport* is the spontaneous movement of species down concentration and membrane potential gradients, whereas *active transport* is no spontaneous movement against these gradients driven by ATP hydrolysis. In the section **Enzymes** it is presented the Michaelis-Menten mechanism of enzyme catalysis, the catalytic efficiency of enzymes, the analysis of the complex mechanisms enzyme-substrate and enzyme inhibition. In the last chapter of this part, the crucial importance of electrons transfer in biological system is discussed. Electron transfer between protein-bound co-factor or between proteins also plays a role in biological processes, such as photosynthesis, nitrogen fixation, the reduction of atmospheric nitrogen to NH_3 by certain microorganism, and the mechanism of action of oxidoreductases, which are enzymes that catalyze redox reactions. The authors examine the features of a theory that describes the factors governing the rates of electron transfer. Then they discuss the theory in the light of the experimental results on a variety of systems including protein complexes.

The chapter 9 – **The Dynamics of Microscopic Systems**- describes the principal concepts of quantum mechanics, the application of quantum theory, the most fundamental description of matter that currently are possess and the only way to account for the structures of atoms. Such knowledge is applied to rational drug design when computational chemists use quantum mechanical concepts to predict the structures and reactivities of drug molecules. Quantum mechanical phenomena form also the basis for virtually all types of spectroscopy and microscopy that are now as a core for investigations of composition and structure in both chemistry and biology. Present day techniques for studying biochemical reaction have progressed to the point where the information is so detailed that quantum mechanics has to be used in its interpretation.

The Chemical Bond – chapter 10 – is central to all aspects of chemistry and biochemistry. There are two major approaches to the calculation of molecular structure, *valence bond theory* (VB) and *molecular orbital theory* (MO). Almost all modern computational work makes use of MO theory, and the authors concentrate on that theory in this chapter. VB theory is very significant for the language of chemistry, being also important to know the significance of terms that chemists use every day. In this chapter, it is first presented a few concepts common to all level of description. Then, the VB and MO theories are presented for understanding of bond formation. Finally the authors notice how computational techniques pervade all current discussions of molecular structure, including the prediction of physiological properties of therapeutics agents.

Chapter 11 – **Macromolecular and Self-assembly** – includes analyses on the determination of size and shape, the control of shape and levels of structure of molecules. The first section explores important methods used in modern biochemical research to determine the molar mass and structure of very large molecules. The most powerful points of these techniques are based on the diffraction of X-rays from crystalline samples that can reveal the position of almost every heavy atom even in very large molecules. The conformation of a biological molecule that has been determined by one of the techniques described in this chapter is of crucial importance for its function, and it is necessary to understand forces that bring about the shape of macromolecules. The interactions between molecules include the attractive and repulsive interactions between the partial electric charges of polar molecules and of polar functional groups in macromolecules and the repulsive interactions that prevent the complete collapse of matter to densities as high as those characteristic of atomic nuclei. In the last section the authors explore the molecular interactions responsible for the different levels of structure of biological macromolecules and the consequences for their properties. Computational techniques are described that can help to predict the three-dimensional structure of polypeptides and polynucleotides.

Statistical Aspect of Structure and Change is presented in the chapter 12. A problem with the description of the bulk properties in terms of molecular properties is that the calculations require a lot of mathematical manipulations and many derivations – even the most fundamental – beyond the scope of this text. In the section **An introduction to molecular statistics**, some of the fundamental ideas of probability theory and statistics are introduced. Also, their relevance to biology by using them to develop a molecular view of diffusion is illustrated. The section **Statistical thermodynamics** presents the Boltzmann distribution, the partition function and thermodynamics properties based on calculation statistic. At the end of the chapter the authors assembled the insights and procedures necessary for understanding the molecular basis of biological processes, from the unfolding of a polypeptide to the myriad chemical reaction in the all.

In the last chapter – **Optical Spectroscopy and Photobiology** - general features of spectroscopy, vibrational spectra, ultraviolet and visible spectra, radiative and non-radiative decay and photobiology are presented. The authors focus on vibrational spectra, which report on molecular vibration excited by the absorption or scattering of electromagnetic radiation, and ultraviolet and visible spectra, which prove the electronic distribution in a molecule and result from the absorption or emission of ultraviolet and visible radiation. Understanding the ability of molecules to absorb light is essential for understanding how light can induce physical and chemical change. The authors end the chapter with description of light as a reactant that initiates many biochemical reactions.

The book is addressed to students of the life sciences, including biology and biochemistry, being an indispensable material for conducting theoretical and practical studies.

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