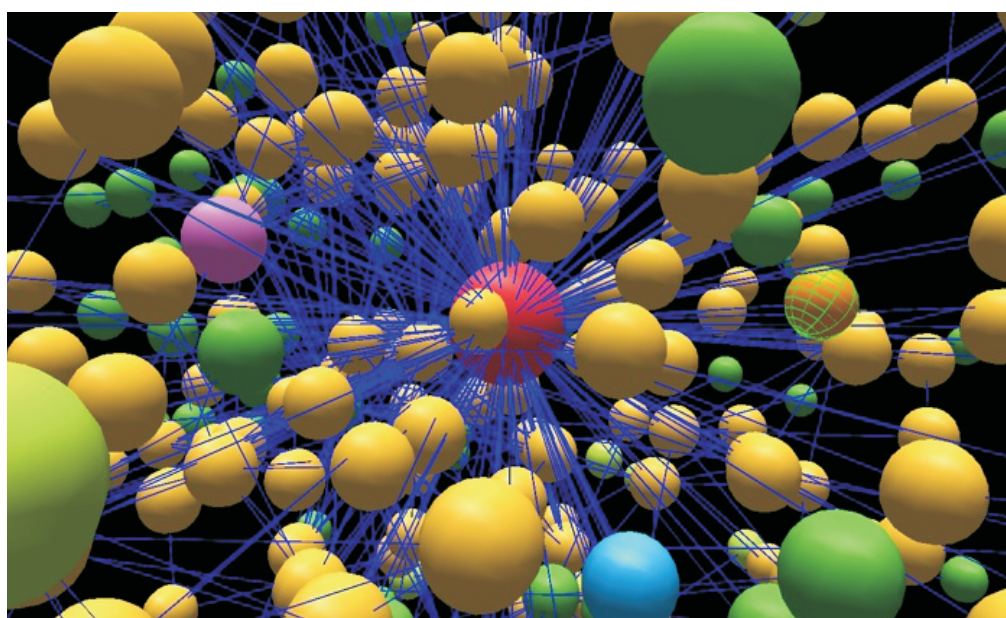


Physical Approach to Biology

Tetsuya Watanabe



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Preface

I wrote this book not only for biologists but also physicists and chemists who are interested in biology where a computational modeling is applied. I hope this book becomes a bridge between physics and biology.

In the Boltzmann model, the distribution law is derived from the number of states given by counting the number of ways for placing certain number of indistinguishable particles in the possible number of different energy cells. It is also important to know how the given total amount of energy is distributed among the certain number of independent individuals. Energy was assumed countable. His idea was thought to be peculiar at his time, but was well understood and accepted later in the time of quantum mechanics. Boltzmann also gave a statistical basis to the fact that pure different independent particles tend to be mixed spontaneously and occupy more space individually whereby increasing its randomness. Entropy is maximized at equilibrium in the isolated system. Chemical process proceeds toward the state of lowered Gibbs free energy usually accompanied by increasing randomness. Atoms bond together because the resultant bonding is more stable than the separate atoms. If electrons in outermost shell of atoms interact, they will form bonding only when their molecular orbitals become in lower energy state, and you will have more chance to find electrons in the close vicinity between each nucleus of the atoms. Negatively charged electron cloud between the nuclei will shield the positive nuclei of atoms and hold atoms together to form a molecule that is the neutral collection of atoms held by covalent bonds. If the resultant orbital is in the higher energy state, the bonding will never occur. If atoms are activated, they never stay at higher state. Instead, they will release the activated energy to the surrounding and become more stable. The quantum theory is applied to chemistry to explain chemical bonding, and reactions. Partial ionic character of covalent bond and hydrogen bond is extremely important for determining the shape of large

molecules in aqueous solution. The recent molecular biology and biophysics is based on the physical chemistry. On one hand experimental approach to molecular biology has demonstrated that functions of living cells are regulated by charged or polar signaling small molecules called ligands. Some ligands can change the conformation of the ion channels in the cell membrane when they bind specifically to the receptors on the surface of the pore columnar protein, and open the channels for ions such as Na^+ , K^+ , Ca^{2+} , and Cl^- to be able to pass through the membrane. Some ligands can relay signals down to the cell interior and operate via second messengers such as cyclic AMP when they bind selectively to the G protein-coupled receptors. On the other hand physical approach to biology explains the selective permeability of membrane which causes osmosis and the membrane potential. Axon of nerve can generate action potentials when the membrane potential is raised above the threshold since it has special voltage gated channels, and conducts its action potential in the way that action potentials are renewed at each point along the axon. In the nucleus of the living cell there are chromosomes made of DNA. The x-ray diffraction images of DNA led to the model of the DNA double helix. DNA is a double-stranded polymer of four kinds of nucleotides, and the genetic code on DNA is carried out by messenger RNA which provides the basic instructions for production of proteins in the cytoplasm. Messenger RNA gives a clue of protein structure in the living cell. Because enzymes are proteins, their activity as a catalyst might be changed if the code marked on DNA is changed by mutation that could cause diseases.

Discovery of structure and semiconservative replication of DNA, and the mechanism of protein synthesis in the living cell have contributed the development of biotechnology and medicine. This book will also give the recent history of science.

It is my pleasure to thank many people who helped me publish this book. First I would like to say thank Dr. Akio Yoshida for checking and offering helpful

suggestions though he has been too busy for other projects. He and I have been very close friends on studying physics and mathematics since both were high school students. Though we went to different universities, he often visited me for studying physics and swimming during summer time because I lived near the beach. I became interested in physics under his influence. Dr. Haruo Ito is my brilliant teacher who gave me an opportunity to do research in the effects of Ach and Epinephrine on phosphorylase activities on rat heart when I was a student. He introduced me to Dr. Domingo Aviado at medical school, University of Pennsylvania, where I did research in pharmacology. Dr. Osamu Nishimura was a graduate student of economics at Penn. We became friends because we both love statistical mathematics. He helped me check the chapter one. Thank Dr. Yosuke Shirakura for correcting mathematical calculation of the chapter one and chapter three.

Tetsuya Watanabe

Contents

Preface	III
Chapter 1 Boltzmann Probability Distribution and Entropy.....	1
1.1 Introduction	3
1.2 Finding the Boltzmann Probability Distribution	7
1.3 Interacting System	14
1.4 Partition Functions and Degeneracy	19
1.5 Translational Distribution of Gasses	20
1.6 Changes in Energy and Enthalpy in Relation to Changes in States of the System.....	22
1.6.1 Internal Energy as a State Function	22
1.6.2 Joule Free Expansion of Gasses	24
1.6.3 Enthalpy as a State Function.....	26
1.7 Changes in Entropy and Gibbs Free Energy.....	28
1.7.1 Entropy as a State Function	28
1.7.2 Spontaneous Changes	30
1.8 Definition of Entropy	33
1.9 Entropy Expressed by Partition Function.....	36
1.10 Entropy as the Function of Microstates and Probability of Finding a Particular Microstate of a Molecule.....	38
1.11 Separation of Partition Functions	41
1.12 Application to Monatomic Gas with Translational Energy	42
1.13 Calculation of Entropy Change Microscopically	44
1.13.1 Free Expansion of a Gas	44
1.13.2 Ideal Gas Mixture.....	46
1.13.3 Ideal Liquid Mixture	48
1.14 Double-stranded Polymer Model.....	49
1.15 Activation Energy.....	51

Chapter 2 Beginning of Quantum Mechanics.....	55
2.1 The Classical Wave Equation	57
2.2 Standing Waves	60
2.3 Travelling Wave.....	61
2.4 The Standing Wave as the Result of a Superposition of Two Traveling Waves	63
2.5 Superposition of Two Travelling Waves of Slightly Different Wave Length	63
2.6 Light as a Wave	64
2.7 Discovery of Electron.....	66
2.8 Blackbody Radiation	71
2.9 Photoelectric Effect Suggesting Light as a Particle.....	74
2.10 Light as a Particle Supported by Compton Effect	76
2.11 Figuring a Model of an Atom	79
2.12 Discovery of X-ray and Application for Structural Analysis of Solids.....	80
2.12.1 X-ray Spectra	81
2.12.2 X-ray Diffraction and Structural Analysis of Cubic Crystal Systems	84
2.13 Packing Density of Cubic Crystals	94
2.14 Wavelike Properties of Electrons.....	96
 Chapter 3 Quantum Mechanics of Electrons and Diatomic Molecules.....	 99
3.1 Wavelike Property of Particles	101
3.2 Derivation of Time Independent Schrodinger Equation.....	103
3.3 Classical Mechanical Quantities Represented by Linear Operators.....	104
3.4 Translational Motion of a Particle in a One-dimensional Box	105
3.5 Probability Amplitude and Probability Density.....	108
3.6 The Expected Value of Momentum of a Particle in a Box	111
3.7 Heisenberg Uncertainty Principle.....	112
3.8 Three-dimensional Systems.....	112

3.9	Particle in a Three-Dimensional Box	113
3.10	A Harmonic Oscillator as the Model of a Diatomic Molecule	115
3.11	Approximation of a Diatomic Molecule as a Harmonic Oscillator About Its Minimum of the Internuclear Potential.....	116
3.12	Solution of the Quantum Mechanical Harmonic Oscillator	118
3.13	Quantum Mechanical Operators	119
3.14	The Commutators of Two Operators	122
3.15	Operator Method Solution of a Harmonic Oscillator	123
3.16	Spectroscopic Predictions of a Diatomic Molecule.....	128
3.17	Vibrational Heat Capacity of a Diatomic Molecule	129
3.18	The Rigid Rotator as a Model of Rotating Diatomic Molecule.....	131
3.19	Angular Momentum Operator	132
3.20	Determination of the Eigenvalues of \hat{L}^2 and \hat{L}_z	135
3.21	Vector Analysis	137
	3.21.1 Product Rules	137
	3.21.2 Spherical Polar Coordinates.....	140
	3.21.3 Displacement by Extension and Rotation	144
3.22	Solving Schrodinger Equation of a Rigid Rotator	146
3.23	Spectroscopic Determination of a Diatomic Molecule.....	150
Chapter 4 Hydrogen Atom		153
4.1	The Schrodinger Equation for a Hydrogen Atom.....	156
4.2	Solution of the Radial Equation.....	159
4.3	Wave Functions of the Hydrogen Atom	162
4.4	Energy Level Diagram for Hydrogen Atom	168
4.5	Photon Emission	169
4.6	Radial Distribution Function of Hydrogen Atom	170
4.7	Probability Distribution Accompanied by Angular Momentum.....	174
4.8	Magnetic Field Effect	178
4.9	Otto Stern and Walther Gerlach Experiment	181
4.10	Intrinsic Spin Angular Momentum of an Electron	182

4.11 Pauli Exclusion Principle..... 185

Chapter 5 Multi-electron Atoms and Chemical Bonding 187

5.1 Characteristic Properties of Multi-electron Atoms 190

5.2 Shielding and Effective Atomic Number of He Atom 191

5.3 Comparison of Orbital Energy, E_{2s} , E_{2p} , E_{3s} , E_{3p} or E_{3d} 193

5.4 Electron Configurations and Valence Electrons 193

5.5 Photoelectron Spectroscopy 195

5.6 Periodic Table of Elements 196

5.7 Chemical Bonding 198

 5.7.1 Ionic Bond..... 198

 5.7.2 Covalent Bond 200

 5.7.3 Partial Ionic Character of Covalent Bond 201

 5.7.4 Hydrogen Bond..... 205

 5.7.5 London Dispersion Forces 206

 5.7.6 Van der Waals Forces 207

5.8 Shapes of Molecules 207

 5.8.1 Bonding Electrons and Lone-pair Electrons 207

 5.8.2 Valence Shell Electron Pair Repulsion(VSEPR) Theory..... 208

5.9 Free Radicals in Life, Oxygen Radicals and Nitric Oxide 210

Chapter 6 Molecular Orbital Theory and Its Application to Biochemistry 213

6.1 Molecular Orbital Formed by Linear Combination of s -Orbitals..... 216

6.2 Molecular Orbitals Originating from p -Orbitals..... 219

6.3 Molecular Orbital Diagram and Electron Configuration..... 221

6.4 Paramagnetism and Diamagnetism 227

6.5 Hybridization of Atomic Orbitals 228

 6.5.1 sp^3 Hybridization..... 228

 6.5.2 sp^2 hybridization..... 230

6.5.3	<i>sp</i> Hybridization.....	231
6.6	Resonance Structures.....	235
6.7	Proteins.....	236
6.7.1	Secondary Structure of Proteins.....	238
6.7.2	Tertiary Structure of Proteins.....	239
6.7.3	Quaternary Structure of Proteins.....	240
6.8	Lipids.....	240
6.8.1	Fats and Oils.....	240
6.8.2	Phospholipids.....	241
6.8.3	Steroids.....	242

Chapter 7 Equilibrium of Chemical Reaction and Phase Change..... 245

7.1	Introduction.....	247
7.2	Heat of Formation.....	248
7.3	Entropy for Reactions.....	249
7.4	Free Energy of Formation and for Reactions.....	249
7.5	Entropy and Gibbs Free Energy in Dilution.....	250
7.6	Kinetics and Chemical Equilibrium.....	252
7.7	Changes in Gibbs Free Energy for Reactions at Constant Temperature.....	252
7.8	Changes in Gibbs Free Energy in Relation to Reaction Quotient over Equilibrium Constant.....	254
7.9	Variation of Chemical Equilibrium Constant with Temperature.....	256
7.10	Variation of Vapor Pressure with Temperature.....	257
7.11	Non-expansive Reversible Work at Constant Temperature and Pressure.....	260
7.12	Cell Potential and Gibbs Free Energy.....	260
7.13	Nernst Equation.....	262

Chapter 8 Rate of Reaction and Population Growth..... 265

8.1	Nuclear Reaction.....	267
-----	-----------------------	-----

8.2	Introduction to Chemical Kinetics.....	270
8.3	First Order Chemical Reactions	270
8.4	Second Order Chemical Reactions	271
8.5	Determining Orders of Reactions from Experimental Data	273
8.5.1	Reactions with One Reactant ($A \rightarrow \text{Product}$).....	274
8.5.2	Reactions with More Than One Reactant ($A + B + C \rightarrow \text{Products}$).....	275
8.6	Complex Reactions and Mechanisms.....	276
8.6.1	Parallel First Order Reactions	276
8.6.2	Consecutive First Order Reactions.....	277
8.6.3	Reversible First Order Reactions	279
8.6.4	Series Reversible First Order Reactions	281
8.7	Enzymes as Catalyst of Life	285
8.7.1	Introduction.....	285
8.7.2	Enzyme Kinetics	286
8.7.3	Inhibition of Enzyme Activity.....	292
8.8	Population Model of Bacterial Growth	297
8.9	Pharmacokinetics.....	299
Chapter 9 Application to Physiology and Pharmacology		301
9.1	The Cell Membrane.....	303
9.2	Shape of protein in Aqueous Solution	306
9.3	Transmembrane Proteins	307
9.4	Discovery of Aquaporins	309
9.5	Osmotic Pressure	311
9.6	Primary Active Transport	312
9.7	Resting Membrane Potential	314
9.8	Goldman Equation.....	316
9.9	Action Potential	317
9.10	Graded Potential	320
9.11	Tissues with Voltage Gated Channels.....	321

9.11.1	Nerve Cell	321
9.11.2	Muscle Fibers and Receptors	323
9.12	Intracellular Messenger, Cyclic AMP.....	327
9.13	Inhibition of Acetylcholinesterase	329
9.14	Role of Adenosine Triphosphate (ATP) in Cell Metabolism	332
9.15	Nucleic Acids (DNA and RNA)	333
9.16	Semiconservative Replication of DNA	336
9.17	Protein Synthesis in the Living Cells	337
9.17.1	Transcription	338
9.17.2	Translation.....	339
9.18	Transfection of Foreign DNA into Host Cells and Restriction Enzymes	341
9.19	Plasmids as Vectors	341
9.20	Polymerase Chain Reaction.....	342
9.21	DNA Sequencing Reaction.....	344
9.22	Reverse Transcription Polymerase Chain Reaction.....	345
9.23	Mutations	347
	Index	351

