CONTENTS

SECTION 1. THERMODYNAMICS IN BIOLOGY

1

102

CHAPTER	1	Work, Heat, and Energy Thermochemistry: Applications of Exact Differentials	3
CHAPTER	2	Chemical Potential	17
		 A. Phases and Phase Transitions. 1. How Many Phases Are There? (Gibbs 	23
		Phase Rule). 2. Phase Transitions in Biological	23
		Membranes. B. Semipermeable Membranes and Neutral Species in Solution: Osmotic Pressure, Types	25
		of Average Molecular Weight in Poly- disperse Systems. C. Semipermeable Membranes and Charged	32
		Species in Solution: Donnan Equilibrium,	
		Dialysis, Equilibrium Dialysis.	41
CHAPTER	3	Chemical Reactions and Equilibrium Constants	51
		A. Existence of Equilibrium Constants.	51
		1. Activity: Thermodynamic "Concentration."	53
		B. Macromolecular Solubility.	58
		1. "Salting-In" and "Salting-Out."	58
		2. Hydrophobicity: Noncovalent Association	
		Between Nonpolar Molecules. Protein	
		Chain-Folding; Micelles.	63
		C. Binding of Small Molecules or Ions to Macro-	
		molecules: Titrations, Buffer Capacity,	
		Scatchard Plot. Cooperative Binding:	
		Hill Plot.	70
CHAPTER	4	Chemical Reaction Spontaneity: Temperature- Dependence of Equilibrium Constants and	
		Reaction Rates.	87
		A. Criteria for Chemical Reaction Spontaneity.	88
		B. Variation of Equilibrium Constants with	
		Temperature: Determination of Enthalpy and	
		Entropy of Reaction; Phase Transitions from	
		Differential Scanning Calorimetry of Macro- molecules in Solution.	0.0
		C. Temperature-Dependence of Individual Re-	93
		action Rate Constants: Activation Energy.	98
		1. Collision Theory: Origin of First-Order	30
		Reaction Rates.	99
		2. Transition-State Theory of Chemical Re-	00
		action Rates.	102

-

CHAPTER	5	Electrochemical Potential	111
		 A. Concentration Cells: Trans-Membrane Potential; Ion-Selective Electrodes. B. Fuel Cells. 1. Analytical Applications: Electrochemical Determination of ΔG_{rx}, ΔH_{rx}, ΔS_{rx}, and K_a. 2. Preparative Applications: Electroplating and Batteries. 	111 118 119 123
		SECTION 2 SUCCESS AND FAILURE	131
CHAPTER	6	The Random Walk Problem	133
		 A. Even Odds: Walking for Distance. Random Coil; Dimensions of Polymers in Solution. B. Translational Diffusion. Diffusion Equation. 	140
		Immunodiffusion.	148
CHAPTER	7	Forced March	163
		 A. Electrophoresis. Gel-, Immuno-, and Discontinuous Electrophoresis; Isoelectric Focusing; Isotachophoresis. B. Sedimentation. Sedimentation Rate. Sedimentation Equilibrium. Density Gradient Sedimentation. C. Viscosity. Flow of Fluid in a Capillary. Viscosity Measurement. Viscosity, Friction Coefficient, and Macromolecular Shape in Solution. D. Polarography: Diffusion at a Spherical Boundary. Analysis for Metal Ions; Determination of Number of Electrons Transferred in Chemical Reactions; Determination of Standard Half-Reaction Potentials. 	163 181 182 185 189 193 194 197 205
CHAPTER	8	Bad Odds: Poisson Distribution	219
		 A. Radioactive Counting. Isotopic Dilution and Tracer Methods in Medicine. B. Electrical Noise. Shot Noise. Resistor Noise. Flicker Noise. Getting Rid of Noise: Signal Averaging. C. Did the Treatment Help the Patients? D. Chromatography: Isolation and Characteriza- 	219 229 231 232 232 232 234

tion of Biologically Interesting Substances.

Gas-Liquid, Gel-, Ion-Exchange, and Affinity Chromatography.

235

257

259

277

277

277

279

280

281

282

283

292

292

294

295

301

301

303

308

SECTION 3 GROWTH AND DECAY

First-Order Rate Processes. Bacterial Growth; Radio- and Chemical-Dating; Radioactive

CHAPTER 9

CHAPTER 10

CHAPTER 11

Fallout. Catalysts Michaelis-Menten (Steady-State) Kinetics. Α. Need for a Steady-State Hypothesis. 1. 2. Single Forward Reaction. 3. Forward and Back Reactions. 4. Consecutive Reactions. 5. Uncatalyzed Reaction with One Intermediate. Catalyzed Reaction with One Intermediate. 6. Removal of Michaelis-Menten Restrictions on **B**. **Enzyme-Catalyzed Reactions.** 1. Back-Reaction Permitted. 2. More Than One Intermediate. 3 Two Substrates. **Regulation of Enzyme-Catalyzed Reaction Rates** Α. Drugs, Poisons and Hormones: Types of Enzyme Inhibition and Activation. 1. Competitive Inhibition. 2. Non-Competitive Inhibition. Mixed Inhibition. 3.

- 3. Mixed Inhibition.310B. Further Types of Enzyme Regulation.3161. pH Control of Enzyme-Catalyzed Reactions.3172. Why Do Enzymes Have Subunits?3203. Self-Inhibition by Substrate.328
- 4. Activation by Metal Ions.330C. Chemical Oscillations: Quirk or Chemical
Basis for Biological Clocks?332

CHAPTER 12	Pharmacokinetics: Chemical Reaction Kinetics with Renamed Variables	343
	A. Time Course of Drug Action: Intake and Elimination of Drugs.	949
	0	343
	B. Theories of Drug-Effect Connection.	347
	1. Graded Response: Occupancy Theory; Rate	
	Theory.	347

Theory.3472. All-or-None Response: Sleep and Death.353

SECTION 4 WEIGHT ON A SPRING

359

CHAPTER 13 The Driven, Damped Weight on a Spring: One of the Most Important Models in Physical Science 361362 Vocabulary for Wave Motion. Α. The Driven, Damped Weight-on-a-Spring **B**. Steady-State Response. 369 Scattering Limit: Negligible Damping 1. 374 and/or Far from Resonance. **Rayleigh Limit: Driving Frequency** a. 375Smaller Than Natural Frequency. Thomson Limit: Driving Frequency b. Larger Than Natural Frequency. 376 Lorentz Limit: Driving Frequency Near 2. Natural Frequency, Absorption and Dis-376persion. The Damped Weight-on-a-Spring: Transient C. 381Response. Zero Mass on a Damped Spring: Relaxation D. 383 Phenomena. **CHAPTER 14** Absorption and Dispersion: Steady-State Response 391 of a Driven, Damped Weight on a Spring Absorption and Refractive Index: Basis for Α. Spectroscopy and Microscopy. 392Dichroism and Birefringence: Detection of В. 405Linear Order in Molecular Arrays. Circular Dichroism and Optical Rotation: C. Optical Activity and "Handedness" of 410 Molecules. Magnetic Resonance Absorption and Dis-D. persion: Nuclear Tetherball; "Spin-Labels" as Probes of Molecular Flexibility; Selective pH Meter. 419 E. Electronic Circuits as Spring Models: Capacitance, Resistance, Inductance; Resonance, and Relaxation. 434F. Dielectric Relaxation: Zero-Mass-on-a-Spring. Rotational Diffusion of Macromolecules. 438Ultrasonic Absorption and Velocity Dispersion: G. Zero-Mass-on-a-Spring Again – A New Tool for 444 Medical Diagnosis and Treatment. CHAPTER 15 Scattering Phenomena: Steady-State Response of 463 a Driven, Undamped Weight on a Spring Small Objects, Big Waves, Lenses Don't Help: Α. Rayleigh Light Scattering. Turbidity, Radius of Gyration, Zimm Plot: Size, Shape, and Mo-

lecular Weight of Macromolecules in Solution. 470

.

	 B. Big Objects, Small Waves, No Lenses Available: X-ray Scattering; Detailed Molecular Shape C. Big Objects, Small Waves, Lenses Available: Electron Scattering and the Various Electron Microscopes. 	480 487
CHAPTER 16	Transient Phenomena: Initial Response of a Suddenly Displaced Weight on a Spring	507
	 A. Damped Spring with Zero Mass: Rate of Return to Equilibrium. 1. Fast-Reaction Transient Chemical Kinetics: T-jump, E-jump, P-jump, Concention 	508
	 tration-jump (Stopped-flow). Simplified Analysis of Complicated Kinetic Schemes. 2. Cybernetics: Black-Box Models for 	508
	Physiology. B. Damped Spring with Finite Mass: Ringing a	523
	Bell.	528
	1. Fluorescence Depolarization: Site-Directed Macromolecular Probes.	528
	2. Gamma-Ray Directional Correlations:	535
	Same Experiment for Opaque Media.3. Magnetic Relaxation: The Spectroscopic	
	Molecular Yardstick.	540
CHAPTER 17	Coupled Springs	551
	 A. Coupling Constants and Spectral Splittings. B. Directly Connected Springs: Normal Modes. C. Amplitude Modulation: Raman Spectroscopy. 	551 553 555
	SECTION 5 QUANTUM ME- CHANICS: WHEN IS IT REALLY NECESSARY?	561
CHAPTER 18	Generalized Geometry: Existence and Positions of Spectral Power Absorption "Lines." Quantum Me- chanical Weight on a Spring.	563
	 A. Spin Problems: The Simplest Quantum Mechanical Calculations. The "AX" Spectrum; Karplus Relation and Determination of Chemi- 	
	cal Bond Angles in Molecules. B. Molecular Orbital Theory and Drug Activity.	583
	 B. Molecular Orbital Theory and Brug Retry P. Energy Levels; Electron Density. C. Biological Iron: Mossbauer Spectroscopy. 	$\begin{array}{c} 599 \\ 612 \end{array}$
CHAPTER 19	Putting the Marbles in the Right Bags: Boltzmann Distribution	621
	A. Lanthanide NMR Shift Reagents and Molecular Configuration in Solution.	626

į

•

ł

•

	 B. Transitions Between Energy Levels. 1. General Formulae. 	629 629
	 Population Inversion: Lasers and Their Applications. Saturation Phenomena and Spectral Lifetimes: Saturation Transfer as a Meas- ure of Communication Between Molecules; Fluorescent Energy Transfer as a Spectro- 	637
	scopic Ruler. 4. Intensities of Spectral Absorption "Lines."	647
	"Selection" Rules and Examples.	654
	SECTION 6 HARD PROBLEMS INTO SIMPLE PROBLEMS: TRANSFORMS, A PICTURE BOOK OF APPLICATIONS.	661
CHAPTER 20	Weights on a Balance: Shortcuts to Spectroscopy. Multichannel and Multiplex Methods.	663
	 A. Hadamard Transform Encoding-Decoding (Multiplex) Spectrometers. B. Fourier Transform Spectroscopy: Nuclear Magnetic Resonance, Ion Cyclotron Resonance, 	668
	Infra-red Spectroscopy	674
CHAPTER 21	Fourier Analysis of Random Motions: Auto- correlation and Spectral Density. Noise as a Radiation Source.	697
	 A. Random Jumps Between Two Sites of Different "Natural" Frequency: Chemical "Exchange" Rates from Spectral Line Shapes. B. Random Rotational Motion: Rotational Dif- fusion Constants from Dielectric Relaxation, 	704
	Magnetic Resonance, and Fluorescence De- polarization.	709
	 C. Random Translational Motion: Translational Diffusion. 1. Light Scattering: Translational Diffusion Coefficients for Macromolecules (or Bac- 	721
	teria) in Solution.	721
	2. Electrophoretic Light Scattering: Elec- trophoresis Without Boundaries.	733
CHAPTER 22	Reconstruction of Objects from Images.	741
	 A. X-Ray Crystallography: Determination of the Carbon Skeleton of a Macromolecule. 1. The Diffraction Image: The Lens as a 	741
	Fourier Transform Device. 2. (Pictorial) Fourier Synthesis.	$742 \\ 744$

	3. Location of Atoms in the Unit Cell:	
	Patterson Synthesis.	749
	4. Structure Determination for Large Mole-	
	cules: Solutions to the Phase Problem.	751
В.	Neutron Diffraction: Location of Hydrogen	
	Atoms; Hydrogen bonding.	763
	Image Reconstruction from Projections. Medi-	
	cal Imaging.	768
	1. X-Ray Tomography.	768
	2. Magnetic Resonance "Zeugmatography."	771
		779

Index

Appendix

ł

.

:

•

785