
Contents

Preface *page xi*

Chapter 1 | Energy transformation

A. Introduction	1
B. Distribution of energy	5
C. System, boundary, and surroundings	8
D. Animal energy consumption	11
E. Carbon, energy, and life	14
F. References and further reading	15
G. Exercises	16

Chapter 2 | The First Law of Thermodynamics

A. Introduction	21
B. Internal energy	24
C. Work	26
D. The First Law in operation	29
E. Enthalpy	32
F. Standard state	35
G. Some examples from biochemistry	36
H. Heat capacity	40
I. Energy conservation in the living organism	43
J. References and further reading	43
K. Exercises	45

Chapter 3 | The Second Law of Thermodynamics

A. Introduction	49
B. Entropy	52
C. Heat engines	56
D. Entropy of the universe	59
E. Isothermal systems	60
F. Protein denaturation	62
G. The Third Law and biology	63
H. Irreversibility and life	64
I. References and further reading	67
J. Exercises	69

Chapter 4 | Gibbs free energy – theory

A. Introduction	73
B. Equilibrium	76
C. Reversible processes	80
D. Phase transitions	82
E. Chemical potential	85

F. Effect of solutes on boiling points and freezing points	89
G. Ionic solutions	90
H. Equilibrium constant	93
I. Standard state in biochemistry	96
J. Effect of temperature on K_{eq}	98
K. Acids and bases	100
L. Chemical coupling	102
M. Redox reactions	104
N. References and further reading	108
O. Exercises	110

Chapter 5 Gibbs free energy – applications

A. Introduction	119
B. Photosynthesis, glycolysis, and the citric acid cycle	119
C. Oxidative phosphorylation and ATP hydrolysis	123
D. Substrate cycling	129
E. Osmosis	130
F. Dialysis	136
G. Donnan equilibrium	139
H. Membrane transport	140
I. Enzyme–substrate interaction	144
J. Molecular pharmacology	146
K. Hemoglobin	151
L. Enzyme-linked immunosorbent assay (ELISA)	154
M. DNA	155
N. Polymerase chain reaction (PCR)	159
O. Free energy of transfer of amino acids	161
P. Protein solubility	163
Q. Protein stability	165
R. Protein dynamics	171
S. Non-equilibrium thermodynamics and life	173
T. References and further reading	174
U. Exercises	178

Chapter 6 Statistical thermodynamics

A. Introduction	185
B. Diffusion	188
C. Boltzmann distribution	192
D. Partition function	198
E. Analysis of thermodynamic data	200
F. Multistate equilibria	204
G. Protein heat capacity functions	209
H. Cooperative transitions	210
I. ‘Interaction’ free energy	212
J. Helix–coil transition theory	214
K. References and further reading	217
L. Exercises	220

Chapter 7 | Binding equilibria

A. Introduction	223
B. Single-site model	225
C. Multiple independent sites	226
D. Oxygen transport	231
E. Scatchard plots and Hill plots	235
F. Allosteric regulation	240
G. Proton binding	242
H. References and further reading	245
I. Exercises	247

Chapter 8 | Reaction kinetics

A. Introduction	251
B. Rate of reaction	254
C. Rate constant and order of reaction	255
D. First-order and second-order reactions	257
E. Temperature effects	259
F. Collision theory	261
G. Transition state theory	262
H. Electron transfer kinetics	265
I. Enzyme kinetics	267
J. Inhibition	271
K. Reaction mechanism of lysozyme	273
L. Hydrogen exchange	275
M. Protein folding and pathological misfolding	278
N. Polymerization	281
O. Muscle contraction and molecular motors	284
P. References and further reading	286
Q. Exercises	288

Chapter 9 | The frontier of biological thermodynamics

A. Introduction	293
B. What is energy?	293
C. The laws of thermodynamics and our universe	296
D. Thermodynamics of small systems (e.g. molecular motors)	297
E. Formation of the first biological macromolecules	298
F. Bacteria	303
G. Energy, information, and life	304
H. Biology and complexity	314
I. The Second Law and evolution	319
J. References and further reading	323
K. Exercises	327

Appendix A. General references	331
Appendix B. Biocalorimetry	335
Appendix C. Useful tables	341

Appendix D. BASIC program for computing the intrinsic rate of amide hydrogen exchange from the backbone of a polypeptide	347
<i>Glossary</i>	363
<i>Index of names</i>	373
<i>Subject index</i>	375