Contents

21

21

1)	Introd Molec	uction: Physics in the World of Giant ules 1	
2	What	Does a Polymer Molecule Look Like? 5	
	2.1	Polymers Are Long Molecular Chains 5	
	2.2	Flexibility of Polymer Chains 7	
	2.3	Flexibility Mechanisms 9	
	2.4	A Portrait of a Polymer Chain 11	
	2.5	Heteropolymers, Branched Polymers, and Charge Polymers 12	ed
	2.6	Ring Macromolecules and Topological Effects	15

16

How Are Polymers Made?

What Kinds of Polymer Substances Are There?

Possible States of Polymer Substances

"Traditional" States of Matter and Polymers

Foreword by P. G. de Gennes

xiii

Preface

2.7

3.1

3.2

•	120
■ /	Contents
6	Contents

3.3 Plastics

3.4

26 Polymeric Fibers 28

3.5	Polymeric Liquid Crystals and Superstrong Fibers 33
3.6	Polymer Solutions 35
3.7	Polymer Blends and Block-Copolymers 36
3.8	Ionomers and Associating Polymers 38
4 Polymo	ers in Nature 43
4.1	A Few Words about Water and the Love or Fear of It 43
4.2	Head-and-Tail Molecules 45
4.3	Molecular Biology and Molecular Architecture 50
4.4	Molecular Machines: Proteins, RNA, and DNA 52
4.5	The Chemical Structure of Proteins, DNA, and RNA 53
4.6	Primary, Secondary, and Tertiary Structures of Biopolymers 54
4.7	Globular Protein Enzymes 60
4.8	Tertiary Structures of Other Biopolymers 63
4.9	Physics and Biology 63
5 The M	athematics of a Simple Polymer Coil 65
5.1	Mathematics in Physics 65
5.2	Analogy between a Polymer Chain and Brownian Motion 66
5.3	The Size of a Polymer Coil 69
5.4	Derivation of the Square Root Law 71
5.5	Persistent Length and Kuhn Segment 73
5.6	The Density of a Polymer Coil and Concentration Ranges of a Polymer Solution 75
5.7	The Gaussian Distribution 77

6 The Physics of High Elasticity 8:

- 6.1 Columbus Discovered... Natural Rubber 81
- 6.2 High Elasticity 82
- 6.3 The Discovery of Vulcanization 84
- 6.4 Synthetic Rubber 86
- 6.5 High Elasticity and Stretching of an Individual Polymer Chain 87

94

- 6.6 Entropy 92
- 6.7 Entropic Elasticity of an Ideal Gas
- 6.8 Free Energy 97
- 6.9 Entropic Elasticity of a Polymer Chain 98
- 6.10 Entropic Elasticity of a Polymer Network 99
- 6.11 The Guch–Joule Effect and Thermal Phenomena During the Deformation of Rubber 105

The Problem of Excluded Volume 109

- 7.1 Linear Memory and Volume Interactions 109
- 7.2 Excluded Volume: Formulating the Problem 112
- 7.3 The Density of a Coil and Collisions of Monomer Units 114
- 7.4 Good and Bad Solvents, and Θ Conditions 117
- 7.5 The Swelling of a Polymer Coil in a Good Solvent 118
- 7.6 The Excluded Volume Effect in a Semi-diluteSolution 120
- 7.7 The Compatibility of Polymer Blends 123

8 Coils and Globules 127

- 8.1 What Is a Coil-Globule Transition? 127
- 8.2 The Free Energy of a Globule 129

8.3	The Energy of Monomer Interactions 130
8.4	The Entropy Contribution 131
8.5	The Swelling Coefficient α 133
8.6	The Coil-Globule Transition 136
8.7	Pretransitional Swelling 138
8.8	Experimental Observation of the Coil-Globule Transition 139
8.9	Dynamics of the Coil-Globule Transition 141
8.10	Some Generalizations 142
8.11	The Collapse of Polymer Networks 143
8.12	The Globular State of the DNA Double Helix 147
8.13	Globular Structure of Proteins and Conformational Transitions in Globular Proteins 149
8.14	In Vivo, in Vitro, in Virtuo 154
	nics of Polymeric Fluids 157
9.1	Viscosity 157
9.2	Viscoelasticity 158
9.3	The Reptation Model 161
9.4	The Longest Relaxation Time 163
9.5	Young's Modulus of a Network of Effective Cross-links 167
9.6	The Tube 168
9.7	The Dependence of the Longest Relaxation Time on the Chain Length 170
9.8	The Viscosity of a Polymer Melt and the Self-Diffusion Coefficient 172
9.9	Experimental Tests of the Theory of Reptation 173
9.10	Reptation Theory and the Gel-Electrophoresis of DNA 174
9.11	The Theory of Reptation and the Gel Effect During Polymerization 178

ix

Contents

1	1
ч	v
	U

The Mathematics of Complicated Polymer Structures: Fractals 179

- 10.1 A Bit More About Math in Physics: How Does a Physicist Determine the Dimensionality of a 179 Space?
- 10.2 Deterministic Fractals, or How to Draw Beautiful 180 Patterns
- **Self-Similarity** 10.3 182
- 10 4 Natural Fractals 184
- **Simple Polymer Fractals** 10.5 187
- Why Worry About Fractals? (What the Two Authors 10.6 Said to Each Other One Day) 189
- 10.7 Why Is Self-Similarity Described by Power Laws, and What Use Can Be Made of This in Polymer Physics? 191
- Other Fractals in Polymers, and Polymers in 10.8 Fractals 193
- Fractal Texts in DNA 195 10.9

Polymers and the Origin of Life 199

- Why Do We Write About the Origin of Life in a Book 11.1 on Polymers? 199
- The Picture of Biological Evolution from a Molecular 11.2 Point of View 200
- The Conception of Life and the Evolution of the 11.3 Universe 203
- Chemical Evolution on the Early Earth 11.4 204
- Prebiological Evolution: Polymers "Scoff" Each 11.5 Other's Food 206
- Primary Polymerization: Can War and Peace Be 11.6 Written by Chance? 208
- Spontaneous Symmetry Breaking and the 11.7 Memorizing of a Random Choice 210
- Right- and Left-Handed Symmetry in Nature 212 11.8

- 11.9 The Memorizing of a Random Choice, the Creation of New Information, and Creativity 213
- 11.10 Conclusion: What Is Still Unclear? 214



Appendix: Application Polymer Program on the CD ROM 217

- A.1 Introduction 217
- A.2 Simplest Movies 218
- A.3 Toy Atoms and Toy Molecules 219
- A.4 Physics of the Toy World 221
- A.5 The Individual Movies 227
- A.6 How to Play with the Application Polymer 239

Suggested Readings 243