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Himadri B. Bohidar

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Fundamentals of Polymer Physics and Molecular Biophysics

Himadri B. Bohidar
Jawaharlal Nehru University



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Contents

<i>List of Figures</i>	<i>xi</i>
<i>List of Tables</i>	<i>xvii</i>
<i>Preface</i>	<i>xix</i>
1. Essential Thermodynamic and Statistical Concepts	
1.1. Irreversible thermodynamics	1
1.2. Postulates in irreversible thermodynamics	4
1.3. Phenomenological forces and fluxes	4
1.4. Gibbs–Duhem equation	5
1.5. Statistical parameters	8
1.6. Probability distributions	9
1.6.1. Binomial distribution	10
1.6.2. Gaussian distribution	12
1.6.3. Poisson distribution	13
1.6.4. Multi-variable distributions	15
<i>Bibliography</i>	17
<i>Exercises</i>	17
2. Polymer Structure and Nomenclature	
2.1. Basic structures	18
2.2. Some common polymers	21
2.3. Molecular weight and polydispersity	27
2.4. Forces and interactions	31
2.4.1. Covalent bond	31
2.4.2. Ionic bond	31
2.4.3. Coulomb forces	31
2.4.4. Charge–dipole force	31
2.4.5. Lennard–Jones potential	32
2.4.6. Hydrogen bond	32
2.5. Polymer gels and networks	33
<i>Summary</i>	37
<i>References</i>	37
<i>Exercises</i>	38

3. Polymer Solutions	
3.1. Basic concepts	40
3.2. Ideal solution model	41
3.3. Real polymer solutions	42
3.4. Flory–Huggins model	44
3.5. Change in Gibbs free energy	47
3.6. Determination of X_1 from osmotic pressure	49
3.7. Dilute polymer solutions	50
<i>Summary</i>	53
<i>References</i>	53
<i>Bibliography</i>	53
<i>Exercises</i>	54
4. Phase Stability and Phase Transitions	
4.1. Phase transitions	56
4.2. Thermodynamic stability	57
4.3. Entropy of mixing	59
4.4. Internal energy of mixing	60
4.5. UCST and LCST	61
<i>Summary</i>	64
<i>Bibliography</i>	65
<i>Exercises</i>	65
5. Static Properties of Single Chains	
5.1. Radius of gyration and hydrodynamic radius	66
5.2. Freely jointed chain model	68
5.3. Random flight chain model	70
5.4. Concept of segments and persistence length	72
5.5. Distribution of end-to-end length	76
5.6. Ideal chain behaviour	79
5.7. Good solvent behaviour	80
5.8. Excluded volume effect	80
5.9. Gaussian chain	86
<i>Summary</i>	87
<i>References</i>	88
<i>Bibliography</i>	89
<i>Exercises</i>	89

6. Diffusion

6.1. Diffusion and irreversible thermodynamics	92
6.2. Fick's laws	99
6.3. Osmotic pressure	102
6.4. Diffusion in different solvents	104
6.5. Concentration dependence	108
6.6. Diffusion in three component systems	111
6.7. Temperature dependence	112
6.8. Langevin equation of diffusion	113
6.9. Smoluchowski equation of diffusion	115
6.10. Determination of molecular structure	117
<i>Summary</i>	118
<i>References</i>	119
<i>Bibliography</i>	119
<i>Exercises</i>	119

7. Viscosity of Polymer Solutions

7.1. Einstein relation	121
7.2. Brinkman relation	123
7.3. Einstein–Simha relation	124
7.4. Staudinger–Mark–Houwink relation	126
7.5. Intrinsic viscosity of polymer chains	126
7.6. Free-draining chain	128
7.7. Impermeable chain	131
7.8. Huggins equation	132
7.9. Kraemer equation	132
7.10. Flory–Fox equation	133
7.11. Krigbaum equation	134
7.12. Stockmayer–Fixman equation	134
7.13. Peterlin equations	135
7.14. Scheraga–Mandelkern relation	136
<i>Summary</i>	136
<i>References</i>	136
<i>Bibliography</i>	137
<i>Exercises</i>	137

8. Sedimentation	
8.1. Svedberg equation	139
8.2. Irreversible thermodynamic and sedimentation	141
8.3. Mark–Houwink–Kuhn–Sakurada equation	146
8.4. Wales–van Holde ratio	146
8.5. Scaling in dilute solutions	147
<i>Summary</i>	148
<i>References</i>	148
<i>Bibliography</i>	148
<i>Exercises</i>	148
9. Concentration Regimes and Scaling	
9.1. General description	151
9.1.1. Dilute solutions	151
9.1.2. Semi-dilute solutions	151
9.1.3. Concentrated solutions	152
9.2. Dilute solution regime	153
9.2.1. Semi-dilute solutions	153
9.2.2. Sedimentation coefficient	156
9.2.3. Intrinsic viscosity	157
9.3. Semi-dilute solution regime	158
9.3.1. Good solvents	158
9.3.2. Theta solvents	159
9.3.3. Osmotic pressure	159
9.3.4. Analysis of dynamic phenomena	160
9.3.5. Cooperative sedimentation	163
9.3.6. Sedimentation: Theta solutions	164
9.3.7. Cooperative diffusion	164
9.3.8. Dynamic regions in diffusion	166
<i>Summary</i>	167
<i>References</i>	167
<i>Bibliography</i>	167
<i>Exercises</i>	168
10. Internal Dynamics	
10.1. Rouse model: Theta solvent	170
10.2. Zimm model: Theta solvent	173
10.3. Zimm model: Good solvent	174
10.4. Reptation model	175

<i>Summary</i>	176
<i>References</i>	177
<i>Exercises</i>	177
11. Dynamics in Polymer Gels	
11.1. Dynamics in networks	179
11.2. Renewal time	179
11.3. Experimental data	181
11.4. Swelling of gels	182
11.5. Kinetics of swelling	183
11.6. Swelling of polyelectrolyte gels	184
11.7. Density fluctuations in gels	186
11.8. Scaling and phase diagram in Θ Gels	188
<i>Summary</i>	190
<i>References</i>	190
<i>Bibliography</i>	191
<i>Exercises</i>	191
12. Molecular Biophysics	
12.1. Chirality of biomolecules	193
12.2. Polyelectrolytes and polyampholytes	196
12.3. Debye–Hückel theory	197
<i>Summary</i>	204
<i>References</i>	205
<i>Bibliography</i>	205
<i>Exercises</i>	205
13. Structure of Biopolymers	
13.1. Nucleic acids	206
13.2. Proteins and amino acids	212
13.3. Peptide bond	216
13.4. Structure of proteins	217
13.5. Carbohydrates	220
13.5.1. Monosaccharides	221
13.5.2. Oligosaccharides	224
13.5.3. Disaccharides	224
13.5.4. Polysaccharides	224
<i>Summary</i>	229
<i>Bibliography</i>	230

14. Physics of Proteins

14.1. Charge on protein molecules	231
14.2. Protein folding: Helix–coil transition	238
14.2.1. Thermodynamic treatment	238
14.3. Kinetics of protein folding	248
14.3.1. Presence of intermediate states	248
14.3.2. Three step process	253
14.4. Polymerization of amino acids	255
14.4.1. Linear growth	256
14.4.2. Helical growth	258
14.5. Energetic of ligand binding	260
14.6. Enzymatic reactions	262
14.6.1. Single intermediate step process	262
14.6.2. Two intermediate step process	265
<i>Summary</i>	268
<i>References</i>	268
<i>Bibliography</i>	269
<i>Exercises</i>	269

15. Physics of Nucleic Acids

15.1. DNA stacking	272
15.2. Misfolding and loop formation	275
15.3. Tertiary structures of DNA	277
15.4. Stoichiometry of stacking	279
15.5. Ligand binding	283
15.5.1. Scatchard equation	284
15.5.2. Hill constant	288
15.6. Genetic code and protein biosynthesis	293
15.6.1. What is a genetic code?	293
15.6.2. Universality of the genetic code	295
15.6.3. Transfer of information via codons	295
15.6.4. Steps involved in information transfer	295
15.6.5. Protein biosynthesis summary	298
15.6.6. Mutations	299
<i>Summary</i>	300
<i>References</i>	300
<i>Bibliography</i>	301
<i>Exercises</i>	301

16. Special Topics	
16.1. Coacervation	303
16.1.1. Liquid-liquid phase transition	304
16.1.2. Simple coacervation	305
16.1.3. Complex coacervation	306
16.2. Diffusion in dense medium	307
16.3. How do bacteria eat: A diffusion problem	308
16.4. Biopolymeric micro- and nano-particles	313
16.4.1. Preparation of nano-particles	314
16.4.2. Preparation of micro-particles	314
16.4.3. Particle size characterizations	315
<i>References</i>	317
<i>Index</i>	319

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Himadri B. Bohidar
Frontmatter
[More information](#)

List of Figures

2.1	A monomer with functionality $f = 3$ can form a three-dimensional network.	20
2.2	Conformation of some common polymers.	20
2.3	(A) Branched polymer; (B) network cluster (microgel) and (C) gel state. In (C) all the chains are part of the same giant network that pervades through the whole volume unlike in (A) or (B).	34
2.4	Divergence of viscosity is a signature of the incipient gel phase; once the gel state is realized, the system develops an equilibrium modulus G_e .	36
3.1	Lattice model of the solution.	45
4.1	Possible states of ordering of monomers: (A) amorphous; (B) crystalline.	56
4.2	Thermodynamic mixing curve of two components.	58
4.3	Depiction of second virial coefficient A_2 , free energy of mixing ΔG_m and the corresponding upper critical solution temperature (UCST) and lower critical solution temperature (LCST).	62
4.4	Depiction of second virial coefficient A_2 , free-energy of mixing ΔG_m and the corresponding upper critical solution temperature (UCST) and lower critical solution temperature (LCST).	63
5.1	Representation of (A) R_g ; (B) dry and hydrodynamic radii (R_d and R_h) and (C) contour length (R_m).	68
5.2	A freely jointed polymer chain of N monomer vectors represented by \vec{r}_n and position vectors shown as \vec{R}_n ; R_e is the end-to-end length of this chain.	69
5.3	A polymer chain in the random flight model of N monomer vectors represented by \vec{r}_n ; R_e is the end-to-end length of this chain.	70
5.4	A C–C bond is located in a solid angle defined by angle α .	72
5.5	Original chain coarse-grained into segments keeping the end-to-end length unchanged.	74
5.6	Excluded volume interactions: (A) flexible chain; (B) rigid spheres.	81
5.7	Lennard–Jones potential showing hard sphere repulsion and weak attraction components.	82
5.8	Gaussian chain with bead spring representation.	87
5.9	Polymer chain in different solvent environments.	88
6.1	Particle flux in an elementary volume.	92

xii | List of Figures

6.2	Volume element representing particle flux transport.	100
6.3	The top panel shows how a drop of dye spreads over a period of time due to the diffusion of dye molecules in the solvent. Concentration of dye molecules $c(x,t)$ is plotted as function of x in the bottom panel. After a long time, $c(x,t)$ evolves as a Gaussian function.	101
6.4	Two chambers I and II separated by a semi-permeable membrane (SPM) are filled with solvent and solution respectively. This causes an osmotic pressure difference π between the two chambers. After equilibrium, the meniscus in chamber II is located higher than in chamber I due to net flow of solvent to balance this excess pressure.	102
6.5	Typical variation of the translational diffusion coefficient D and the self diffusion coefficient D_s of a polymer chain in a solution as function of polymer concentration; the translational diffusion coefficient normally increases in a good solvent whereas the self diffusion coefficient decreases with polymer concentration.	105
6.6	Excluded volume between pairs of monomers as function of temperature, T .	106
6.7	Typical chain swelling and conformation of a flexible polymer chain in: (A) theta; (B) marginal and (C) good solvent environment.	107
6.8	$D(c)$ versus c : Plot for good solvent, theta solvent and poor solvent dispersions; note that under poor solvent condition there is a possibility of phase separation.	109
7.1	Representative effect of particle size on relative viscosity.	122
7.2	Intrinsic viscosity of polymer solutions.	122
7.3	Relative viscosity of polymer solution at higher concentrations.	124
7.4	Ellipsoids of rotation describing rotational motion of equivalent polymer chains.	125
7.5	Typical variation of relative viscosity with axial ratio.	125
7.6	Concept of viscosity in fluids.	126
7.7	Free-draining and impermeable chain in dispersion.	128
7.8	Free-draining chain in viscous liquids.	129
7.9	Representation of a non-free-draining chain as an effective sphere of radius R_{ef} .	131
8.1	Schematic depiction of the principle of a ultracentrifugation: A cylindrical cell containing a polydisperse solution is rotated about the rotor axis with angular speed ω . (A) at $t = 0$, the sample was a homogeneous solution with say, one particle located at r_0 ; (B) at $t_1 > 0$, heavier particles drift away from the rotation axis and $r_1 > r_0$ and (C) at $t_2 > t_1$, particles of similar weight assemble close to each other forming bands, $r_2 > r_1$. Steady state is established in the particle motion.	140

8.2	An elementary volume of the solution is shown as a cuboid of length dr and cross-sectional area dA . Pressure on the cuboid face closer to the rotation axis is P and on the opposite face, the same is $P+dP$. Pressure increases towards the rim of the container of the liquid.	142
9.1	Different concentration regimes of polymer solutions.	150
9.2	Definition of correlation length or mesh size of a network.	152
9.3	Free diffusion in dilute solutions of polymers.	153
9.4	Re-normalized representation of a chain in dilute theta solution in the blob model. The corresponding representation for semi-dilute solution is shown in Fig. 9.5.	154
9.5	Blob representation of semi-dilute solutions.	158
9.6	Blob representation of semi-dilute solutions: (A) Θ solvent and (B) good solvent.	159
9.7	Characteristic length scale phase diagram.	166
10.1	Gaussian polymer chain.	170
10.2	Different dynamic modes of a chain: (A) $p = 0$, the translation of the centre of mass (CM); (B) $p = 1$, the rotation about the centre of mass and; (C) $p = 2$, higher order complex internal modes, etc.	172
10.3	(A) Depiction of a chain pinned on a 2-D plane by obstacles (circles); (B) conceptual confinement of the chain (dotted curve) in a tube of length L and diameter d .	175
11.1	Gel network in a good solvent; Cross-links are the reticulation points and the dangling chain ends are mechanically inactive; the mesh size is a characteristic of the network.	178
11.2	Gel network in a theta solvent; note the excessive self-knotting of the chains.	182
11.3	Gel network before and after swelling.	182
11.4	Concentration elastic moduli phase diagram.	189
12.1	Representation of L- and D- forms of an amino acid molecule. The “handedness” is defined by the location of the H- atom and the thumb.	194
12.2	Racemic representation of the amino acid alanine.	194
12.3	Example of polyampholyte and polyelectrolyte chains.	197
12.4	Ion environment around the macro ion. The Stern layer defines the electric double layer which is tightly bound to the macro ion surface. The diffuse layer extends beyond the double layer.	198
12.5	Depiction of potential $\psi(r)$ around the spherical macro ion: In the Stern layer, the potential falls rapidly as a reciprocal of the distance; in the diffuse layer, the potential decays exponentially with a characteristic decay length κ^{-1} called the Debye screening length.	203
13.1	Representation of sugar molecule found in DNA and RNA.	207

xiv | List of Figures

13.2	(A) Various nitrogenous bases, the phosphate diester and the deoxyribose molecules; (B) nucleotide produced when these three components join.	207
13.3	Sugar, phosphate and base linkage in DNA molecule.	209
13.4	Stacking of amine bases through hydrogen bonding yields DNA double helix structure; A–T and G–C are connected through two and three hydrogen bonds, respectively—this makes the G–C binding much stronger.	209
13.5	Common hairpin structure of RNA molecule.	212
13.6	Basic structure of an amino acid and charged state shown as a function of pH.	213
13.7	Dipolar character of an amino acid.	213
13.8	Molecular structure of hydrophobic amino acids.	215
13.9	Molecular structure of hydrophilic amino acids.	215
13.10	Molecular structure of polar amino acids.	216
13.11	Formation of a peptide bond through condensation reaction.	216
13.12	Planar structure of a peptide bond and its dipolar representation.	216
13.13	Typical β -sheet structure representation of a protein molecule.	218
13.14	Quaternary structure of hemoglobin molecule: It contains four polypeptide chains—two alpha chains, each with 141 amino acids and two beta chains, each with 146 amino acids; thus hemoglobin has the quaternary representation $\alpha_2\beta_2$.	219
13.15	Aldose and ketose sugar molecules.	221
13.16	Sugar monomers: (A) triose: glyceraldehydes; (B) tetrose: threose, erythrose; (C) pentose: ribose, arabinose, xylose, lyxose; (D) hexose: allose, gulose, altose, idose, galactose, mannose, glucose, tallose.	221
13.17	Alpha and beta forms of D-glucose.	222
13.18	(A) α -D-glucose in the pyranose form; (B) α -D-ribose in the furanose ring form; (C) aldose structure of D-glucose; (D) aldose structure of D-ribose.	222
13.19	Linear and cyclic forms of D-glucose.	223
13.20	Glycosidic bond and the chemical structure of starch and cellulose.	223
13.21	Common monomers of natural polysaccharides.	227
13.22	Common monomers of natural polysaccharides.	228
13.23	Chemical formula of sucrose (cane or beet sugar).	229
13.24	Chemical formula of amylose.	229
14.1	General representation of an amino acid.	231
14.2	Formation of a dipeptide molecule through condensation reaction.	231
14.3	pH- pK_a balance in a solution.	234
14.4	Variation of solubility as a function of pH.	237

- 14.5 Six dihedral rotation angles are required to be immobilized to establish the first hydrogen bond, while only two such angles are needed to be immobilized in making an adjacent bond. 240
- 14.6 A typical representation of helix–coil transition; the melting temperature T_m corresponds to [helix]:[coil]=1:1. 243
- 14.7 Variation of the equilibrium constant as a function of temperature. 247
- 14.8 Depiction of protein folding funnel: The free energy landscape shown is replete with several local minima; if the primary structure while folding gets trapped in any of these, it leads to misfolding; the minimum free energy state is located at the bottom of the landscape where the native protein resides. 249
- 14.9 Exponential decay of the fractional concentration of an initial state during a folding process. Two step processes are characterized by such decay. 253
- 14.10 Double exponential decay of the fractional concentration of an initial state during a folding process. Three step processes are characterized by such decay. 255
- 14.11 Addition polymerization and growth of a linear polypeptide molecule. The step-wise addition of monomers produces a highly polydisperse polypeptide preparation. 257
- 14.12 Addition polymerization and growth of a helical polypeptide molecule. The step-wise addition of monomers produces only a single helical polypeptide molecule. 258
- 14.13 Schematic variation of free monomers, monomers in oligopeptides and average helix size as a function of monomer concentration. 260
- 14.14 Free energy level diagram for ligand binding to a two-binding site protein molecule; standard free energy change without cooperativity is designated as (1) and with cooperativity as (2). 261
- 14.15 Michaelis–Menten plot representing growth of product as a function of substrate concentration. 264
- 15.1 A typical DNA strand showing base pairing between complementary nucleotides. 273
- 15.2 A typical DNA strand showing base pairing, mismatch and second initiation of base pairing between complementary nucleotides. 273
- 15.3 Schematic depiction of a hairpin loop connected to a duplex structure. 275
- 15.4 A double strand DNA is linearly displaced to generate a monomer; two monomers join to give a dimer (A), and when one monomer is bent into a circle to yield a circular DNA structure (B). 277
- 15.5 Representative plot of variation of absorbance A as a function of concentration of poly T for poly A mixing with poly T . The change in slope at a concentration 0.5 implies that there is a stoichiometric binding ratio of 1:1 between the two polynucleotides (arrow). 281

xvi | List of Figures

- 15.6 Representative UV mixing plot of poly *A* with poly *T*; note the change in slope at concentration 0.5 and at 0.66 implying the formation of multiple complexes with stoichiometric binding ratios 1:1 and 1:2 respectively (arrows). 281
- 15.7 Representative Scatchard plot depicting various determinable parameters. 287
- 15.8 An alternative representation of the Hill plot; the Hill constant α_H can be determined from the ν_{\max} and *X*-axis intercept values. 292
- 15.9 Schematic diagram of a protein biosynthesis process. 296
- 15.10 Process of translation where tRNA assembles the polypeptide chain. 298
- 16.1 (A) Coacervating solution and (B) precipitation. 304
- 16.2 Zeta potential of gelatin B molecule shown as a function of concentration; note that for the lowest protein concentration, zeta potential is zero at pI = 5. 305
- 16.3 Plot of zeta potential and turbidity as function of ethanol (EOH) concentration. %T represents transmittance in percentage; note that close to 50% (w/v) ethanol concentration, the zeta potential assumes zero value. 306
- 16.4 Zeta potential of gelatin A, chitosan and their complex shown as a function of solution pH. Inset depicts zeta potential distribution as a function at various pH. 307
- 16.5 Spherical bacterium of radius *a* is surrounded by an imaginary shell of radius *b*. The concentration of sugar molecules at the shell surface is constant = C_0 . 309
- 16.6 The electrical circuit equivalent diagram of Fig. 16.5. 312
- 16.7 Particle size distribution of nano- and micro-particles of mean diameter 50 nm, 260 nm and 500 nm dispersed in water. Corresponding TEM pictures are shown in Fig. 16.8. 315
- 16.8 Particle size from TEM data for nano- and micro-particles of mean diameter (left to right) 500 nm, 260 nm and 50 nm dispersed in water. 315
- 16.9 Huggins plot for gelatin nano- and micro-particles of mean diameter 50 nm and 500 nm dispersed in water; the same for gelatin chain is shown for comparison. Notice the significant increase in the k_H value as the size is reduced from micro- to nano-domain. 316

List of Tables

1.1	Physical attributes of various probability distribution functions.	17
2.1	Examples of heteropolymers and their constituent monomers.	18
2.2	Homochain polymers of unsaturated hydrocarbons, halogens, alcohols, aldehydes and ketones.	21
2.3	Acids their derivatives and nitrogen containing monomers.	22
2.4	Hetro chain polymers.	23
2.5	Starch and cellulose polymers.	24
2.6	Aromatic polymers.	25
2.7	Miscellaneous.	25
2.8	Conjugated-bond polymers.	26
2.9	Elemento-organic polymers.	27
2.10	A comparison of various bonds and their bond lengths.	32
2.11	Typical binding energy of some covalent bonds.	33
10.1	Summary of centre of mass diffusion coefficient D and relaxation time τ_{rela} .	176
13.1	Representation and abbreviations of various nucleosides, nucleotides of DNA.	208
13.2	Representation and abbreviations of various nucleosides, nucleotides of RNA.	208
13.3	Various forms of RNA, their abbreviated representations and biological functions.	211
13.4	Common amino acids.	214
13.5	Functionally important proteins.	219
13.6	Common disaccharides and their characteristic glycosidic bond assignments.	224
13.7	Some important mucopolysaccharides.	226
15.1	Standard genetic codes.	294
16.1	Eating efficacy as function of number of mouths.	313
16.2	Physical characteristics of gelatin chain and its nano and micro-particles measured at 20°C.	316

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Preface

The journey of a thousand miles begins with a single step. I have been offering a course on molecular biophysics to advanced master level students since 1992 (the students have a background of physics, physical chemistry, chemical engineering, etc.). These students have little exposure to biology and organic chemistry. However, research focus is shifting towards soft matter science which is highly interdisciplinary, and holds a promise of generating customized, smart and biocompatible materials. Therefore, the need for learning physics of polymers and biopolymers has increased many folds. This course is taught with the objective to provide a robust background in these topics to students. I have converted my lecture notes into this publication. There are no textbooks in the market till date that cover the topics discussed herein in a single volume. The content has been used in a one semester course that I teach to MSc Physics students. The mathematical prerequisites for this book are modest.

Macromolecules in solutions can be distinctly characterized from their transport behaviour in the solution phase. The study of the transport processes yields coefficients like the diffusion coefficient, sedimentation coefficient, intrinsic viscosity, friction constant, etc. of the dissolved solute particles. These coefficients are dependent on two parameters. First is the size and shape of the solute particle. Second is the type of the solvent medium and its environment (pH, temperature, pressure, ionic strength, etc.). The solvent medium can force diffusing particles to assume a special shape and/or to get distributed in a special fashion in space through solvent–solute interactions. At the same time, a pair of solute molecules also influence each other's behaviour and/or physical shape and size. This process may or may not be mediated by the solvent. To account for all these mechanisms, we need to discuss the solute–solvent, solvent–solvent and solute–solute interactions. Interestingly enough, much of this information is contained in the transport coefficients of a solute and the physical parameters describing a solvent.

However, the question arises how to explicitly characterize the macromolecules from these data? We shall answer this question in this book. The answer lies in the physical interpretation of this data in the perspective of macromolecular transport phenomena occurring in a given system. This in turn is an interplay between thermodynamic and hydrodynamic forces active in a macromolecular solution. Apart from this, there can be external forces acting on the diffusing particles, like in electrophoresis experiments. In these situations, the diffusion process is very complex and depends on several physical

parameters, like the pH, ionic strength, temperature, pressure, external force and the nature of solvent, etc. This book attempts to address these issues in a simple and lucid manner. No discussion on polymers is complete without reference to the salient features of biopolymers. This volume addresses some important issues and concepts related to proteins and nucleic acids.

More precisely, we will be discussing the physical mechanisms of diffusion, viscosity, sedimentation, etc. of polymer solutions under different hydrodynamic and thermodynamic conditions. The important elucidation that we will be seeking all through the forthcoming discussions is how this information can be used to characterize the polymer molecules dispersed in a solvent.

The potential reader of this book may not necessarily be a physicist. Keeping this in mind, the presentation has been prepared to suit the requirements of readers with background in biological and interdisciplinary sciences. The mathematics in this book is presented from an experimentalist's point of view, which is why following the text is easy. The rigors of mathematics has been avoided as far as possible and no special skill or knowledge is required to follow the mathematics described here. Nonetheless, the physical concepts have not been sacrificed and more often than not, more emphasis has been given on physical interpretation of the equations.

We start the discussion from elementary thermodynamics, proceed to account for the static properties and continue onto the transport phenomena in solutions of macromolecules. Solutions are treated as isotropic and homogeneous. Different terms and concepts are introduced and defined, as these are encountered in the course of discussions.

It is possible to cover all the material contained in this book in 40 lectures of 90 minutes duration each.

Discovery is seeing what everybody sees, but learning what has not been taught. It is this unending thirst for discovery and knowledge that drives us forward towards a common goal—to understand our clandestine world. Our mind is our greatest tool, one that necessitates constant honing. So let us rise to the occasion and bring to light the enigma that is life in its entirety.

Humanity has never learnt how not to question. The answer might not always be as expected, but it does lead to something new. Humanity's greatest forte has always been never to just scratch the surface but to constantly delve in deeper. The world we live in is complex in many ways but is simpler in so many more ways. Nature strives for simplicity and so does man. In this aspect, a man of science is quite similar to a spiritual man. Both seek to unveil the secrets of our world, one to satisfy the mind and the other the soul.

My lecture notes were converted into this book due to the incessant persuasion of several batches of students, who took this course and received copy of the lecture notes, but could never find a textbook to fall back on. All of them deserve special thanks. I am thankful to Dr Kamla Rawat, my senior research student who painstakingly made all

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This book is dedicated to the memory of my mother whom I owe everything.