Fundamentals of Polymer Physics and Molecular Biophysics

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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

the chemical structures with great care. Further, I acknowledge her support during the proofreading of various drafts of the manuscript which was done with much diligence. I am also deeply thankful to my wife, Dr Chetna and daughter, Dr Pareedhi for their encouragement and cooperation without which this endeavour would not have been successful.

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