Advances in Planar Lipid Bilayers and Liposomes

Volume 19

VOLUME NINETEEN

ADVANCES IN PLANAR LIPID BILAYERS AND LIPOSOMES

Edited by

PROFESSOR DR. ALEŠ IGLIČ
Laboratory of Biophysics, Faculty of Electrical Engineering, University of Ljubljana, Ljubljana, Slovenia

DR. CHANDRASHEKHAR V. KULKARNI
Centre for Materials Science, University of Central Lancashire, Preston, United Kingdom

藏书章

Founding Editor

PROFESSOR DR. H.T. TIEN
Department of Physiology, Michigan State University, East Lansing, Michigan, USA

PROFESSOR DR. A. OTTOVA-LEITMANNOVA
Department of Physiology, Michigan State University, East Lansing, Michigan, USA

ELSEVIER

Amsterdam • Boston • Heidelberg • London • New York • Oxford
Paris • San Diego • San Francisco • Singapore • Sydney • Tokyo
Academic Press is an imprint of Elsevier

Academic Press is an imprint of Elsevier
225 Wyman Street, Waltham, MA 02451, USA
525 B Street, Suite 1800, San Diego, CA 92101-4495, USA
The Boulevard, Langford Lane, Kidlington, Oxford, OX5 1GB, UK
32 Jamestown Road, London, NW1 7BY, UK
Radarweg 29, PO Box 211, 1000 AE Amsterdam, The Netherlands

First edition 2014

Copyright © 2014 Elsevier Inc. All rights reserved

No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopy, recording, or any information storage and retrieval system, without permission in writing from the publisher

Permissions may be sought directly from Elsevier's Science & Technology Rights Department in Oxford, UK: phone (+44) 1865 843830, fax: (+44) 1865 853333; E-mail: permissions@elsevier.com. You may also complete your request online via the Elsevier homepage (http://www.elsevier.com), by selecting "Support & Contact" then "Copyright and Permission" and then "Obtaining Permissions"

Notice
No responsibility is assumed by the publisher for any injury and/or damage to persons or property as a matter of products liability, negligence or otherwise, or from any use or operation of any methods, products, instructions or ideas contained in the material herein. Because of rapid advances in the medical sciences, in particular, independent verification of diagnoses and drug dosages should be made

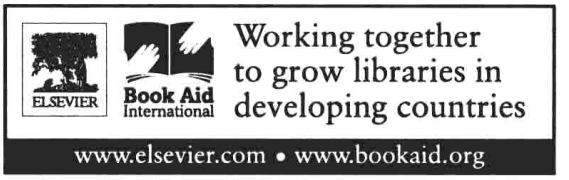
Library of Congress Cataloging-in-Publication Data
A catalog record for this book is available from the Library of Congress

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library

ISBN: 978-0-12-418699-6
ISSN: 1554-4516

For information on all Academic Press publications visit our website at www.store.elsevier.com

Printed and bound in USA
14 15 16 10 9 8 7 6 5 4 3 2 1



VOLUME NINETEEN

ADVANCES IN PLANAR LIPID BILAYERS AND LIPOSOMES

EDITORIAL BOARD

Prof. Dr. Aleš Iglič (*University of Ljubljana, Slovenia*)
Prof. Dr. Bernhard Schuster (*University of Natural Resources and Life Sciences, Vienna, Austria*)
Dr. Chandrashekhar V. Kulkarni (*University of Central Lancashire, United Kingdom*)
Dr. Habil. Rumiana Dimova (*Max Planck Institute of Colloids and Interfaces, Germany*)
Prof. Dr. Ian R. Peterson (*Coventry, United Kingdom*)
Prof. Dr. A. Leitmannova Liu (*USA*)
Prof. Dr. Masao Sugawara (*Tokyo, Japan*)
Prof. Dr. Mathias Winterhalter (*Jacobs University Bremen, Germany*)
Prof. Dr. Michael Rappolt (*University of Leeds, United Kingdom*)
Prof. Dr. Nir Gov (*The Weizmann Institute of Science, Israel*)
Prof. Dr. Philip J. White (*Wellesbourne, United Kingdom*)
Prof. Dr. Philippe Meleard (*Ecole Nationale Superieure de Chimie de Rennes, France*)
Prof. Dr. Reinhard Lipowsky (*MPI of Colloids and Interfaces, Potsdam, Germany*)
Prof. Dr. Roland Benz (*University of Würzburg, Germany*)
Prof. Dr. P.B. Sunil Kumar (*Indian Institute of Technology Madras, India*)
Prof. Dr. Sylvio May (*North Dakota State University, USA*)
Prof. Dr. Thomas Heimburg (*Niels Bohr Institute, University of Copenhagen, Denmark*)
Prof. Dr. Tibor Hianik (*Comenius University, Slovakia*)
Prof. Dr. Wojciech Gozdz (*Institute of Physical Chemistry Polish Academy of Sciences, Poland*)
Prof. Dr. Wolfgang Knoll (*Max-Planck-Institut für Polymerforschung, Mainz, Germany*)
Prof. Dr. Yoshinori Muto (*Gifu, Japan*)
Prof. Dr. Yoshio Umezawa (*Tokyo, Japan*)

此为试读,需要完整PDF请访问: www.ertongbook.com

CONTRIBUTORS

Manohar V. Badiger
Polymer Science and Engineering Division, CSIR-National Chemical Laboratory, Pune, India

Apolonija Bedina Zavec
Laboratory of Clinical Biophysics, Faculty of Health Sciences, University of Ljubljana, and National Institute of Chemistry, Ljubljana, Slovenia

Tatjana Blažič
Laboratory of Clinical Biophysics, Faculty of Health Sciences, University of Ljubljana, and Department of Orthopaedic Surgery, Ljubljana University Medical Centre, Ljubljana, Slovenia

Špela Bračun Vnuk
Department of Orthopaedic Surgery, Ljubljana University Medical Centre, and Laboratory of Clinical Biophysics, Chair of Orthopedics, Faculty of Medicine, University of Ljubljana, Ljubljana, Slovenia

Marileen Dogterom
FOM Institute AMOLF, Amsterdam, The Netherlands

Abdelbary Elhissi
Institute of Nanotechnology and Bioengineering, and School of Pharmacy and Biomedical Sciences, University of Central Lancashire, Preston, United Kingdom

Ines Hribar Ignaščenko
Clinical Department of Gastroenterology, Ljubljana University Medical Centre, Ljubljana, Slovenia

Rado Janša
Clinical Department of Gastroenterology, Ljubljana University Medical Centre, Ljubljana, Slovenia

Ulrich F. Keyser
Cavendish Laboratory, University of Cambridge, Cambridge, United Kingdom

Gijsje Hendrika Koenderink
FOM Institute AMOLF, Amsterdam, The Netherlands

Veronika Kralj-Iglič
Laboratory of Clinical Biophysics, Faculty of Health Sciences, University of Ljubljana, Ljubljana, Slovenia

Abhijit Mishra
Materials Science and Engineering, IIT Gandhinagar, Ahmedabad, India

Manca Pajnič
Laboratory of Clinical Biophysics, Faculty of Health Sciences, University of Ljubljana, Ljubljana, Slovenia

Oliver J. Pambos
Cavendish Laboratory, University of Cambridge, Cambridge, United Kingdom

Antigoni Papapanou
School of Pharmacy and Biomedical Sciences, University of Central Lancashire, Preston, United Kingdom

Magda Peruško
Laboratory of Clinical Biophysics, Faculty of Health Sciences, University of Ljubljana, and Department of Orthopaedic Surgery, Ljubljana University Medical Centre, Ljubljana, Slovenia

Šárka Perutková
Laboratory of Biophysics, Faculty of Electrical Engineering, University of Ljubljana, Ljubljana, Slovenia

Sonja Peternelj
Laboratory of Clinical Biophysics, Faculty of Health Sciences, University of Ljubljana, and Department of Orthopaedic Surgery, Ljubljana University Medical Centre, Ljubljana, Slovenia

Sophie Roth
FOM Institute AMOLF, Amsterdam, The Netherlands

Karin Schara
Department of Orthopaedic Surgery, Ljubljana University Medical Centre, Ljubljana, Slovenia

Aarti S. Shedge
LUNAM Universite, Laboratoire Polymeres, Colloïdes et Interfaces, UMR CNRS 6120, Universite du Maine, Le Mans cedex 9, France

Roman Štukelj
Laboratory of Clinical Biophysics, Faculty of Health Sciences, University of Ljubljana, Ljubljana, Slovenia

Vid Šuštar
Laboratory of Clinical Biophysics, Chair of Orthopedics, Faculty of Medicine, University of Ljubljana, Ljubljana, Slovenia

Kevin M.G. Taylor
Institute of Nanotechnology and Bioengineering, University of Central Lancashire, Preston, and Department of Pharmaceutics, UCL School of Pharmacy, University College London, London, United Kingdom

Feng-Ching Tsai
FOM Institute AMOLF, Amsterdam, The Netherlands

Israr Ul Hassan
Dhofar University, Salalah, Oman

Nimrah Zeb
School of Pharmacy and Biomedical Sciences, University of Central Lancashire, Preston, United Kingdom

CONTENTS

Contributors *ix*

1. Charged Particles can Mediate Attraction Between Equally Charged Membranes—Theoretical Study **1**

Šárka Perutková

1. Biological Systems in Electrolyte Solutions 2
2. Theoretical Basis 5
3. Theoretical Methods and Simulation 12
4. Application of Methods to Different Biological Systems 22
5. General Discussion 42
6. Conclusions 45

References 46

2. Cationic Liposomes as Model Nonviral Vectors for Pulmonary Delivery of DNA **53**

Abdelbary Elhissi, Israr Ul Hassan, Antigoni Papapanou, Nimrah Zeb, and Kevin M. G. Taylor

1. Introduction 54
2. Viral Versus Nonviral Vectors of Genes 54
3. Cellular Uptake of Lipoplexes 56
4. Gene Therapy via Pulmonary Delivery 56
5. DNA Expression in the Lung 58
6. Factors Influencing Expression of Gene in the Lung Using Lipoplexes 59
7. Novel Strategies for Pulmonary Delivery of Genes 62
8. Conclusions 63

References 63

3. Giant Unilamellar Vesicles and Suspended Nanobilayers as Model Systems for Biophysical Research **67**

Oliver J. Pambos and Ulrich F. Keyser

1. Introduction 68
2. Giant Unilamellar Vesicles 69
3. Case Study: Nanobilayers on Glass Supports 77
4. Summary 86

Acknowledgments 86
References 87

4. Hydrophobically Modified Chitosan: Solution Properties by Rheology and Light Scattering 91

Aarti S. Shedge and Manohar V. Badiger

1. Introduction 92
2. Experimental 94
3. Results and Discussion 96
4. Conclusions 101

Acknowledgments 101
References 101

5. Structural Transitions in Lipid Membranes: Mechanism for Cell-Penetrating Peptides 103

Abhijit Mishra

1. Introduction 104
2. Structure of Lipids 105
3. Polymorphism of Lipids in Aqueous Solution 107
4. Cubic Phases in Lipids 111
5. Characterization of Lipid Phases 113
6. Cell-Penetrating Peptides 115
7. Proposed Cellular Uptake Mechanisms 116
8. Experimental Methods 119
9. Peptide–Lipid Interactions 123
10. Conclusion 130

References 131

6. Biomimetic Liposome Model Systems to Study Cell Shape Control by the Cytoskeleton 139

Feng-Ching Tsai, Sophie Roth, Marileen Dogterom, and Gijsje Hendrika Koenderink

1. Introduction 140
2. Creating Cell-Sized Liposomes Encapsulating Cytoskeletal Polymers 144
3. Toward Complex Cytoskeletal Model Systems 153
4. Conclusion and Perspective 159

Acknowledgments 160
References 160

7. Role of Blood Sampling in Assessment of Concentration of Extracellular Nanovesicles in Isolates from Peripheral Blood 175

Roman Štukelj, Ines Hribar Ignaščenko, Sonja Peternelj, Magda Peruško, Tatjana Blažič, Manca Pajnič, Špela Bračun Vnuk, Vid Šuštar, Apolonija Bedina Zavec, Karin Schara, Rado Janša, and Veronika Kralj-Iglič

1. Introduction 176
2. Material and Methods 179
3. Theory 180
4. Experimental Results on the Free Flow 182
5. Discussion 184

References 187

Index *191*

CHAPTER ONE

Charged Particles can Mediate Attraction Between Equally Charged Membranes—Theoretical Study

Šárka Perutková[1]

Laboratory of Biophysics, Faculty of Electrical Engineering, University of Ljubljana, Ljubljana, Slovenia
[1]Corresponding author: e-mail address: sarka.perutkova@fe.uni-lj.si

Contents

1. Biological Systems in Electrolyte Solutions 2
   1.1 Cell membrane structure and its electric properties 2
2. Theoretical Basis 5
   2.1 Electric double layer theory 5
   2.2 Some important parameters in the electrostatics of membranes 10
3. Theoretical Methods and Simulation 12
   3.1 Poisson–Boltzmann equation with additional boundary conditions 12
   3.2 Functional density theory for spherical counterions and co-ions 14
   3.3 Monte Carlo simulations 18
4. Application of Methods to Different Biological Systems 22
   4.1 Attraction between negatively charged vesicles in contact with a solution of plasma proteins 22
   4.2 Electrostatic interactions between osteoblasts and an implant surface 27
   4.3 Influence of ionic strength on β_2 glycoprotein I-induced vesicle agglutination 33
5. General Discussion 42
6. Conclusions 45
References 46

Abstract

Electrostatic interactions are one of the leading interactions in all biological systems. In this chapter, we present a possible mechanism which can lead to attractive interaction between two like-charged biological surfaces. We show three different modeled systems of charged biological surfaces in the solution containing charged macro-ionic particles which were inspired by experimental observations. In our proposed mechanism, we take into consideration the orientational entropy of the system. Namely, when the

Advances in Planar Lipid Bilayers and Liposomes, Volume 19
ISSN 1554-4516
http://dx.doi.org/10.1016/B978-0-12-418699-6.00001-1

© 2014 Elsevier Inc.
All rights reserved.

此为试读，需要完整PDF请访问：www.ertongbook.com

macro-ionic particles in solution have distinctive internal distribution of charge, the additional degrees of freedom for rotation are involved in the entropic contribution to the total free energy. The contribution is negative and thus lowers the free energy. Under certain conditions, this can lead to attractive force between like-charged surfaces. In the study, we use analytical as well as numerical methods—modifications of Poisson–Boltzmann equation and Monte Carlo simulations. We studied rod-like and spherical geometry of particles which can mediate the attraction. The macro-ionic particles can represent different kinds of proteins or various metallic nanoparticles in aqueous surrounding.

1. BIOLOGICAL SYSTEMS IN ELECTROLYTE SOLUTIONS

Cells, macromolecules, and all other components in biological systems are embedded in aqueous media (Fig. 1.1) with a high dielectric constant ($\varepsilon_r \cong 80$). The salt concentration of the electrolyte in the cell's environment is around 0.15–0.2 mol/l [1,2]. The electrostatic properties of such electrolyte solutions have a considerable effect on the different processes occurring in biological systems. The functioning of various processes (transport through ion channels, DNA–protein interactions, action and mechanism of biological molecules, etc.) would fail to work without them. Because of their long-range character, electrostatic interactions are of fundamental importance in understanding many biological processes. Many membrane properties such as structure, rigidity, and dynamics are directly affected by electrostatics [1].

1.1. Cell membrane structure and its electric properties

The main function of the biological membrane is to enclose the cell and the interior of the cell's organelles and separate them from their surroundings, both in prokaryotes and eukaryotes. The backbone of a biological membrane is built up of membrane lipids self-assembled into the lipid bilayer. The forces holding the bilayer together originate from the amphiphatic nature of membrane lipids. The heads of membrane lipids are polar (hydrophilic) and the tails (or chains) are nonpolar (hydrophobic). The hydrophobic forces lead membrane lipids to hide their tails from water and, on the other hand, to expose their heads to water (Fig. 1.2). Other components of the biological membrane are various kinds of proteins (integral proteins, peripheral proteins, structural proteins, etc.), glycoproteins, and glycolipids embedded in the lipid bilayer.

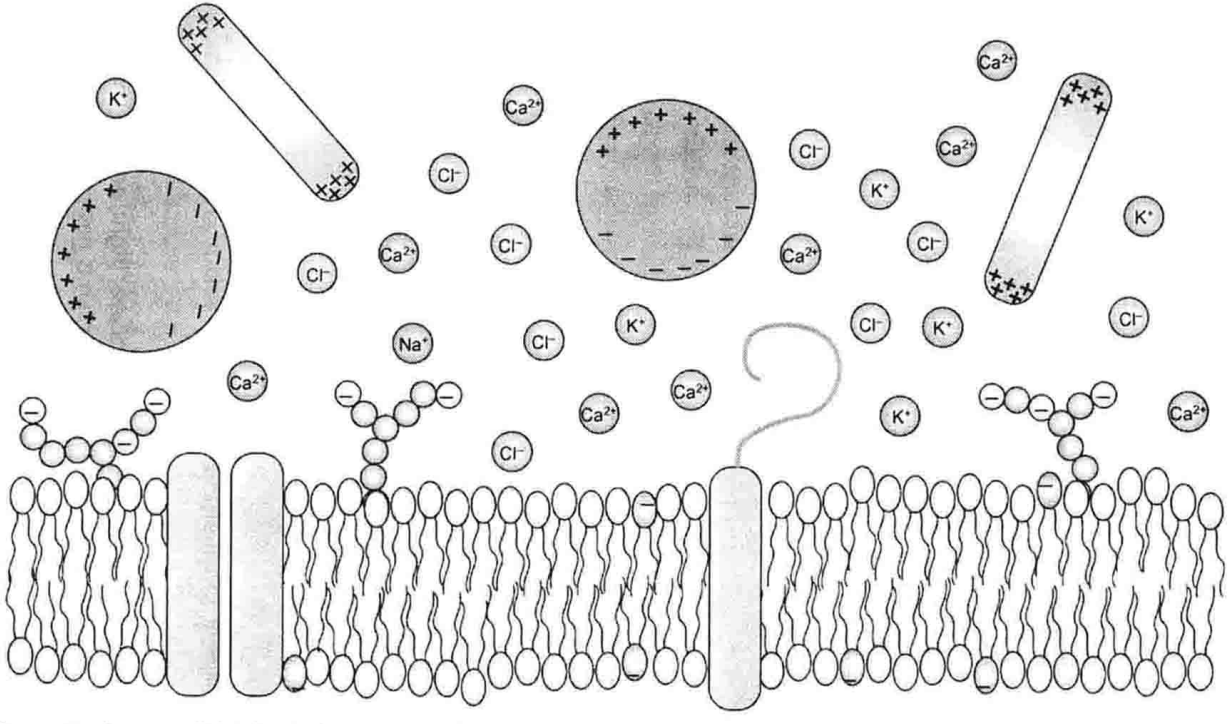


Figure 1.1 Schematic figure: all biological components are immersed in electrolyte solution. The interplay of electrostatic interactions between all of the components is of fundamental importance.

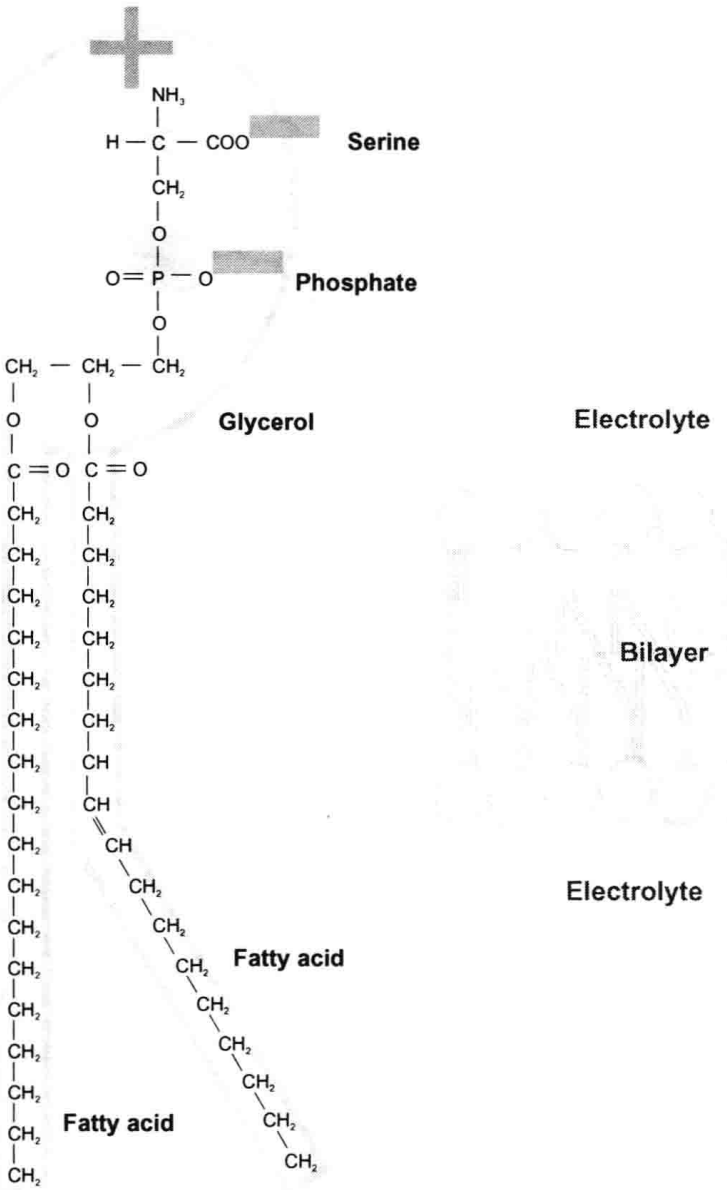


Figure 1.2 Schematic figure of a phospholipid bilayer (right) and the chemical structure of a single phospholipid (phosphatidylserine) which is negatively charged (left).

There exist various kinds of cell membrane lipids. One of the most important groups are phospholipids. The head of a phospholipid can be neutral with a nonzero dipole moment or negatively charged. It is rather mysterious that nature choose not to create positively charged membrane lipids. These can only be made artificially (e.g., a surfactant sterylamine is positively charged).

Neutral (zwitterionic) lipid heads have a dipole moment because the phosphate group carries a negative charge and the alcohol (or aminoalcohol) which esterifies the phosphate group usually has a positive charge. Zwitterionic lipids include, for example, phosphatidylcholines, phosphatidylethanolamines, sphingomyelin, and others. However, some alcohols esterifying the negatively charged phosphate group are neutral and thus the resulting charge of the lipid headgroup is negative (Fig. 1.2). The most known negatively charged phospholipids are phosphatidylserines, phosphatidylinositols, and phosphatidylglycerols (cardiolipin). The ratio between neutral and negatively charged lipids in plasma membranes is approximately 9:1 [3]. Phosphatidylserines are present, for example, in the inner part of the red blood cell membrane. Cardiolipin, which has four fatty acid chains, is very abundant in inner mitochondrial membranes. Though phosphatidylinositol is a minor component in biological membranes, it plays an important role in guiding membrane traffic and cell signaling [4].

Because of the presence of negatively charged lipids, the whole bilayer can also be negatively charged. The maximum surface charge density of a lipid bilayer is around -0.3 As/m^2 if the whole bilayer is composed only of negatively charged lipids [5]. In nature, however, the surface charge density of phospholipid bilayers is considerably lower (according to the ratio between negatively charged and neutral lipids in membranes). Negatively charged lipids usually occupy the inner part of the membrane.

Besides the negative charge from the lipid bilayer, the whole cellular surface can also be treated as uniformly charged because of the thick layer of negatively charged glycoproteins covering the plasmatic membrane. The average negative fixed charge on the cell surface is of the order of -0.001 As/m^2 [6].

As it was already mentioned, charged surfaces in biological systems can consist of macromolecules such as DNA, whole cells, liposomes created from a mixture of neutral and charged membrane lipids, surfaces of implants, and others. In this chapter, we focus on negatively charged liposome–liposome and negatively charged implant–cell interactions.

2. THEORETICAL BASIS

2.1. Electric double layer theory

The interaction between charged surfaces in an electrolyte solution is governed by the interplay between the electrostatic forces on the surfaces and the entropy of ions moving between them due to their thermal motion.

Entropy favors a uniform distribution of ions. On the other hand, electrostatics prefers all counterions to be clustered at the surface and all co-ions moved far away from it. The basic theory describing these interactions is the theory of the electric double layer. According to this theory, freely moving counterions from the solution are distributed mainly near the charged surfaces (without binding to them) and thus screen the surface electric potential, whereas co-ions are mostly depleted from the surfaces, as is described in Fig. 1.3.

The electric double layer has been the subject of extensive study since the pioneering work of Gouy [7] and Chapman [8] around 1910. The so-called Poisson–Boltzmann theory (PB theory) is the basic mean-field theory which relates the electric potential to the spatial distribution of charges, subjecting to the principles of statistical physics.

The basic problem which can be solved within PB theory is shown schematically in Fig. 1.3. Two planar infinitely large equally charged surfaces are in contact with a 1:1 electrolyte solution (e.g., NaCl) with surface separation D, surface charge density σ, and bulk concentration of ions n_s (in units $1/m^3$). The electrostatic potential is constant in the yz plane and varies only with x. The so-called Poisson–Boltzmann equation for a 1:1 electrolyte when $\varphi(x, y, z) = \varphi(x)$ is [1,9,10]:

$$\frac{d^2\varphi(x)}{dx^2} = \frac{2n_s e_0}{\varepsilon_r \varepsilon_0} \sinh \frac{e_0 \varphi(x)}{kT}, \tag{1.1}$$

where e_0 is the elementary charge, k the Boltzmann constant, T the thermodynamic temperature, and ε_0 and ε_r the vacuum permittivity and the relative permittivity, respectively. Equation (1.1) can be solved for some approximate cases (e.g., in linearized form) analytically [1]. Without simplifications, it can be solved only numerically. The solution of the equation depends on the boundary conditions at the two charged surfaces. The boundary conditions are derived from the condition of electroneutrality of the whole system:

$$\frac{d\varphi}{dx}(x=0) - \frac{\sigma}{\varepsilon_r \varepsilon_0} \quad \text{and} \quad \frac{d\varphi}{dx}(x=D) = +\frac{\sigma}{\varepsilon_r \varepsilon_0} \tag{1.2}$$

From PB theory, the pressure between two surfaces can be derived. The pressure is uniform across the gap between the surfaces and depends only on the total concentration of ions in the midplane position $\Sigma_i n_{mi}(D)$ and on the bulk ion concentration $\Sigma_i n_{mi}(\infty)$ for a certain value of D [1,10]:

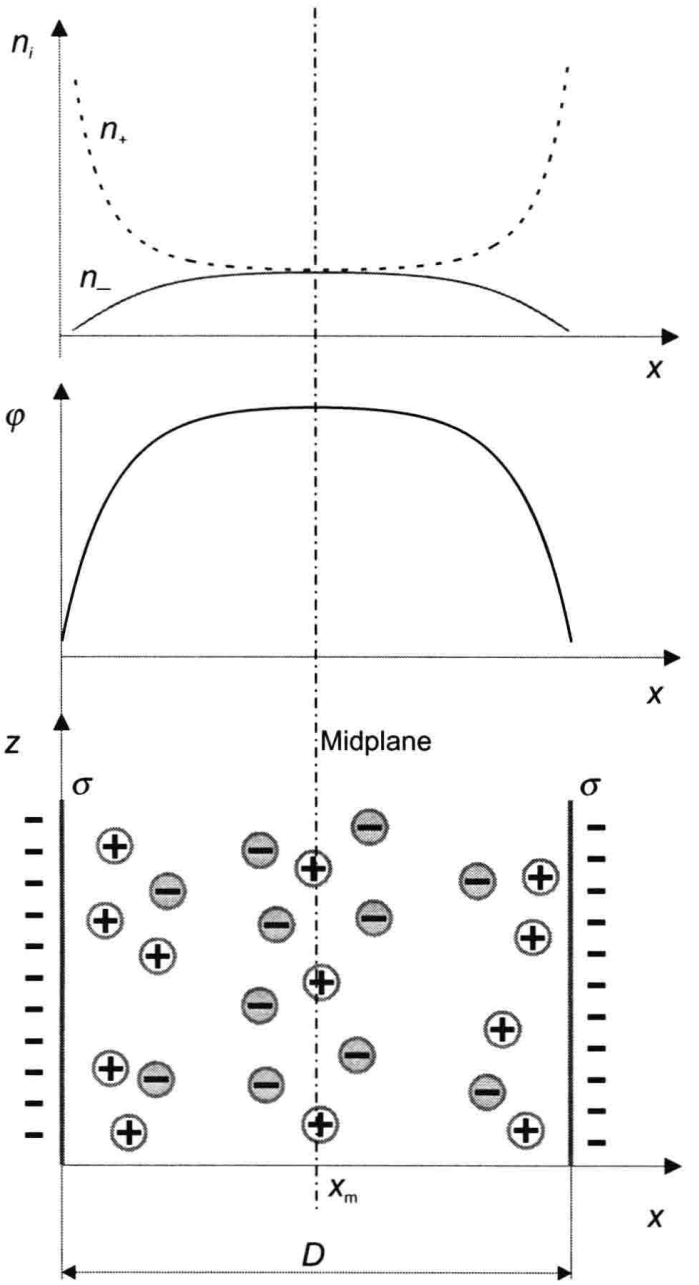


Figure 1.3 Schematic figure of the standard electric double layer problem. Two equally charged surfaces are immersed in electrolyte solution. The number density distribution of counterions and co-ions and the electric potential calculated from Eq. (1.1) are also shown.

此为试读,需要完整PDF请访问: www.ertongbook.com