

An Introduction to Interfacial Engineering

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Preface

In 2004 the first course on Interfacial Engineering was given at the chemical engineering department DelftChemTech of Delft University of Technology. Before that time, there was some coverage with colloidal systems in courses on physical chemistry and a voluntary course on “disperse systems”. The idea was to give a course that would deal with colloidal phenomena while giving a good perspective on technological applications. Hence the name Interfacial Engineering. The teaching goal of the course was set at a decent level: after studying the course, the students should be able to critically assess the relevant scientific literature.

This first course was developed simultaneously with prof. dr. Theo van de Ven (McGill University, Montreal), who was a visiting professor of the department at the time. A significant amount of course material was generated from which the students could study, but a textbook covering all topics of the course was not available. Over time, the idea developed to write one myself. The result of half a year writing text while teaching the course is what you are reading now. The book is still under construction. Many ideas have been put into this book and the coverage is not fully balanced yet. Also, the text will not be without flaws. Therefore, any suggestion or correction will be welcomed so that in a following print more accuracy will be attained.

The contents of the book can be roughly divided into two parts. The first part contains the basic knowledge required to deal with colloidal systems albeit that some technological issues are discussed. These are the chapters 1 - 5. With these chapters, there is a bundle of worked exercises, taken from the author’s own experience and from other textbooks, that will be available upon request. The chapters 6 - 8 deal with technologies such as emulsification, film formation and flotation. In these last chapters some new fundamental issues are discussed where necessary but the emphasis is on the application.

In a half-semester course – of weekly 2 consecutive lecture hours – one chapter is discussed per week, sometimes together with some exercises. The last three chapters are discussed in conjunction with scientific papers from the contemporary literature. This teaches the students how to use their knowledge with published material and how to extract key information for a given process. Particular attention is paid on how to read a scientific paper, how to extract information from it, and how to evaluate its significance. A method has been developed to do this systematically. Subsequently, some calculations are made with the material presented in the paper where it does occur that another conclusion is drawn than in the paper. The exam for the students consists of the assessment

of a – small – scientific paper and some relevant calculations.

Most of the information in this book is not mine. It is the accumulated knowledge of the field and I acknowledge all contributors: there are too many to name and I feel indebted to them all. My role has been to make a selection of topics and to organize and discuss these in such a way as to teach chemical engineers the essentials about colloid science and its technological applications.

Finally, I thank all who have helped me writing this book and Delft University of Technology for their support. Last but not least I thank my wife and children for their patience: they had to suffer my absence during long evenings of working to finish this work.

Ger Koper,
Leiden, 5 March 2007.

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Chapter 1

Introduction

1.1 Nature of the colloidal state

The challenge of Interfacial Engineering is the wide range of length scales that it deals with, see figure 1.1. On the one hand there are the molecules of which their typical length scale is in the Ångstroms. On the other hand there is the size of the mixing vessel or reactor of which the length scale is meters or more. In almost all practical situations, there is at least one particular length scale — the colloidal length scale — that is associated with the degree of dispersion in the system. This colloidal length scale is in the range of 10^{-9} – 10^{-3} m and encompasses the range that is currently exploited by the “nanoscientists”.

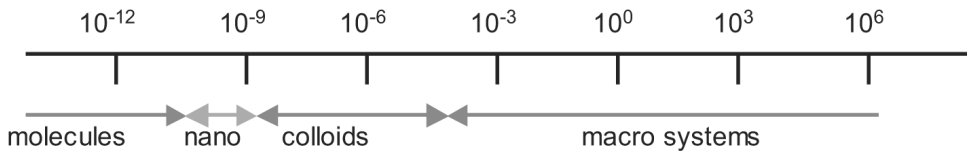


Figure 1.1 Length scales operative in Interfacial Engineering.

The term *colloid* stems from the greek word *κολλᾶ* that means glue and refers to classical colloids as protein or gelatin solutions. Using a membrane, colloids can be distinguished from molecules in the classical experiment depicted in figure 1.2.

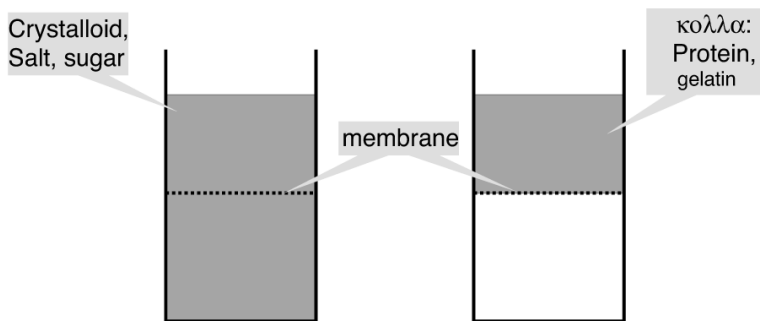


Figure 1.2 Classical experiment to distinguish colloids from molecular solutions.

A *colloidal system* or *colloid* is an essentially multiphase — usually two-phase — system, such as paint or milk, in which one of the phases is dispersed in the other. In such systems the *colloidal particles* have at least one dimension in the colloidal range. A

which is the expression given in eq. 1.1.

Care has to be taken in the usage of the term specific area. The one usage, discussed above, is the specific area per unit volume of dispersion. Another usage is the specific area per unit mass of *dispersed material*.

1.2 Microscopic colloidal behavior

The experienced interfacial engineer has some simple tools at hand to distinguish a molecular solution from a dispersion. The phenomena described below are both fundamental in nature but very practical in their application.

1.2.1 Osmotic pressure

The classical experiment to measure molar masses of polymers is of very good use to colloid scientists as it can provide in a relatively simple way information about the mass as well as the size of the dispersed particles. The set-up requires a semi-permeable mem-

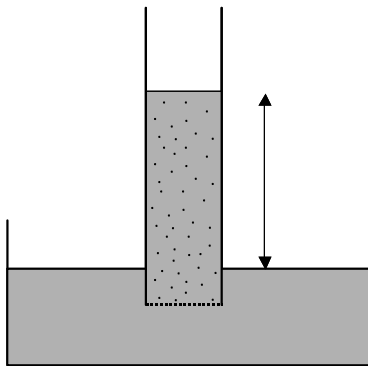


Figure 1.3 Osmotic pressure experiment.

brane that does not allow the dispersed particles to go from the vertical tube to the reservoir below, see figure 1.3. The height h is directly related to the osmotic pressure Π , due to the dispersion, by

$$\Pi = \rho gh$$

with ρ the mass density of the solvent and g the gravitational constant. Van 't Hoff's law relates this osmotic pressure to the mass concentration C of dispersed material by

$$\frac{\Pi}{RT} = \frac{C}{M} (1 + B_2 C + \dots) \quad (1.2)$$

where the second virial coefficient B_2 has been added. The molar mass M of the dispersion is related to the particle mass M_p by

$$M = N_A M_p$$