INTERFACES AND COLLOIDS: THE TWILIGHT ZONE

In 1915 Wolfgang Ostwald described the subject of interface and colloid science as that of a "world of neglected dimensions." The reason for that description was the unique nature of interfaces and related colloidal phenomena - they could not be readily interpreted based on “classical” atomic or solution theories, and the regions of space involved were beyond the reach of existent experimental techniques. Since that time science has developed a firm theoretical and experimental understanding of the nature of matter at its two extremes - at the molecular, atomic, and subatomic level, and in the area of bulk materials, their physical strengths and weaknesses, their chemical and electrical properties, etc. Legions of chemists, physicists, materials scientists, engineers, etc., are continuously striving to increase that knowledge in academic and industrial laboratories around the world. Between those two extremes still lies the “world” referred to by Ostwald, and even with the latest advanced analytical and computational techniques, a great many mysteries remain to be solved. For that reason, I like to think of the study of interfaces and colloids as entering the "twilight zone" - that “region” of the material world that bridges the gap between chemical and physical phases. However, beyond the theoretical aspects of the area we continually find that interfaces and colloids also play a vital but often unrecognized role in other areas of chemistry, physics, biology, medicine, engineering, etc.

Because of experimental and theoretical difficulties encountered in its study, our theoretical and practical understanding of the nature of the interfacial region and the transformations that occur in bridging from one chemical or physical phase to another has historically lagged behind that in many other scientific areas. That is not to say that we are ignorant when it comes to interfacial and colloidal phenomena. Great advances in the theoretical understanding of interactions at interfaces were made in the late 19th and early 20th centuries. More recently, new analytical and computational techniques have led to significant advances toward a better understanding of the unique nature of interfaces and the interactions that result from that uniqueness.

Never the less, the unusual and sometimes complex nature of interfaces and their associated phenomena, has hindered the development of a fully satisfying theoretical model. By "fully satisfying" is meant a theory that produces good agreement between theory and experiment in situations that are less than "ideal" or "model" systems.

The "satisfaction" obtained from a given theory is a subjective evaluation, of course, so that there exists a great deal of controversy in many areas related to colloids and interfaces. For the surface and colloid scientist (as in all science), such controversy is not bad, since it represents the fuel for continued fundamental and practical research. However, for the scientist or engineer who needs to apply the fruits of fundamental research to solve practical problems, such uncertainty can sometimes complicate life to no end.

For every trained surface and colloid scientist in academia and industry, there are hundreds if not thousands of scientists, engineers, and technicians whose work directly or indirectly involves some surface and/or colloidal phenomena. And of those, only a relative few have probably been formally introduced to the subject in more than a cursory way during their scientific training. It therefore becomes necessary for them to learn enough of the subject "on the fly" to allow them to attack their problems in a coherent way. The series of brief introductory articles on surface and colloid science to follow are designed to provide a conceptual introduction to the subject without the “baggage” of significant theoretical or mathematical derivations. A Bibliography of current texts is provided for anyone wishing to venture farther into the twilight zone.

By: Drew Myers, Chemistry Coordinator, www.cheresources.com

WHAT LIES IN THE TWILIGHT ZONE?

While it would be difficult to list all of the natural and technological processes that involve interfacial and colloidal phenomena, a small taste can be had from the few representative examples listed in Table 1.

Table. 1. Some common examples of interfacial and colloidal phenomena in industry and nature.

Surface phenomena	Colloidal phenomena
A. Products manufactured as colloids or surface-active materials:	
Soaps and detergents (surfactants)	Latex paints
Emulsifiers and stabilizers	Aerosols
(non-surfactant)	Foods, e.g., ice cream, butter, mayonnaise, etc.
Herbicides and pesticides	Cosmetics and topical ointments
Fabric softeners	Pharmaceuticals
	Inks
	Lacquers, oil-based paints
	Oil and gas additives
	Adhesives
B. Direct application of surface and colloidal phenomena:	
Lubrication	Control of rheological properties
Adhesion	Emulsions
Foams	Emulsion and dispersion polymerization
Wetting and waterproofing	Drilling muds
	Electrophoretic deposition
C. Use for the purification and/or improvement of natural or synthetic materials:	
Tertiary oil recovery	Mineral ore separation by flotation
Sugar refining	Grinding and communition
Sintering	Sewage and wastewater treatment
D. Physiological applications:	
Respiration	Blood transport
Joint lubrication	Emulsification and transport of nutrients
Capillary phenomena in liquid transport	Enzymes
Arteriosclerosis	Cell membrane processes

The examples noted have been divided into four main categories, each of which is further divided (somewhat arbitrarily, in some cases) into "colloidal" or "interfacial" categories. Although more precise definitions of what those two terms imply may be useful, for present purposes one can think of "colloidal" as being a state of subdivision of matter in which the particle (or molecular) size of the basic unit involved varies from just larger than that of "true" molecular solutions to that of coarse suspensions - that is between 10 and 10,000 nm. "Interfacial" phenomena may be defined, in this context, as those related to the interaction of at least one bulk phase (solid or liquid) with another phase (solid, liquid, or gas) or a vacuum in the narrow region in which the transition from one phase to the other occurs. As will become apparent as one enters the "zone", the two classes of phenomena are intimately related and often cannot be distinguished. By examining each subdivision in Table 1, it is apparent that interfacial and colloidal phenomena are ubiquitous. Our world, including ourselves, simply would not function or even exist as we know it in their absence.

Somewhat surprisingly considering its obvious importance, this "neglected dimension" has historically been shorthanded in terms of scientists and technicians formally trained in the theoretical and experimental aspects of the discipline. As a result, one can speculate that large amounts of time, money, and other resources have been wasted over the years simply because chemists, physicists, biologists, engineers, and technical operators were ignorant of certain basic ideas about interfaces and colloids that could have solved or helped solve many practical and theoretical problems.

Some important on-going areas of interface and colloid science research currently of interest include:

Theoretical studies - Interfacial energy and bulk material characteristics, interfacial tensions of solutions, thermodynamics of colloidal systems, electrical double layer theory, adsorbed polymer layers and steric stabilization.

"Practical" Surface chemistry - Equilibrium and dynamic wetting and spreading processes, adhesion, physical adsorption, chemisorption and heterogeneous catalysis, spectroscopic and optical studies of surfaces, flow through porous media, rheological and electrophoretic properties of colloids, demulsification and defoaming.

Inter-particle interactions and colloidal stability - Measurement of forces between surfaces, attractive forces, hydrodynamic and solvation forces, repulsive forces, coagulation and flocculation theory, emulsion stability, microemulsions, multiple emulsions, foam stability, the effects of adsorbed polymers on stability and flocculation.

Chemical reactions - Heterogeneous catalysis, chemical and biological reactions at interfaces and in colloidal systems, including those between body fluids and foreign surfaces.

Lyophilic colloids - Association colloids, gels, studies of polymers in solution and adsorbed at surfaces, microgels, liquid crystals.

Aerosols - Methods of formation, stabilization, and destruction.

Biocolloids – Biological membrane activity, cell and particle adhesion, cell-antibody interactions, drug delivery, drug and nutrient transport phenomena.

SERIES CONTENTS

While the series of articles presented covers a wide range of important topics in surface and colloid science, it is in no way claimed to be or intended to be comprehensive in coverage or specific content. The goal, more than anything, is to acquaint the reader with some of the basic terms and concepts involved and facilitate access to more in depth material that may be useful, especially for the understanding and solution of practical problems in engineering and technology. In some cases "approximate" explanations are given with the understanding that they are not theoretically exact, but do serve as useful tools for visualizing what is or may be occurring under various circumstances.

BIBLIOGRAPHY

The following books are recommended for the reader interested in delving deeper into the details of specific interfacial and colloidal interactions. The list is not exhaustive and includes references ranging from simple conceptual presentations to the most theoretically complete information currently available in book form. No specific research papers or reviews that may give the "latest" theories are included.

Myers, D.Y. "Surfaces, Interfaces, and Colloids, Principles and Applications," Second Edition, Wiley-VCH, New York, 1999.

Adamson, A.W; Gast A.P. "Physical Chemistry of Surfaces." 6th ed., Wiley-Interscience: New York, 1999.

Evans, D.F.; Wennerstrom, H. "The Colloidal Domain." VCH Publishers,Inc.: New York, 1994.

Hiemenz, P.C.; Rajagopalan, R. "Principles of Colloids and Surface Chemistry." 2nd ed., Marcel Dekker, Inc.: New York, 1997.

Israelachvili, J. "Intermolecular and Surface Forces." 2nd ed., Academic Press, Inc.: San Diego, 1991.