

 WILEY

# SURFACTANT SCIENCE AND TECHNOLOGY

Third Edition



DREW MYERS

0647  
M996  
E.3

# **SURFACTANT SCIENCE AND TECHNOLOGY**

---

**THIRD EDITION**

**Drew Myers**



E200602380

 **WILEY-INTERSCIENCE**

**A JOHN WILEY & SONS, INC., PUBLICATION**

Copyright © 2006 by John Wiley & Sons, Inc. All rights reserved.

Published by John Wiley & Sons, Inc., Hoboken, New Jersey.  
Published simultaneously in Canada.

No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording, scanning, or otherwise, except as permitted under Section 107 or 108 of the 1976 United States Copyright Act, without either the prior written permission of the Publisher, or authorization through payment of the appropriate per-copy fee to the Copyright Clearance Center, Inc., 222 Rosewood Drive, Danvers, MA 01923, 978-750-8400, fax 978-646-8600, or on the web at [www.copyright.com](http://www.copyright.com). Requests to the Publisher for permission should be addressed to the Permissions Department, John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, (201) 748-6011, fax (201) 748-6008.

**Limit of Liability/Disclaimer of Warranty:** While the publisher and author have used their best efforts in preparing this book, they make no representations or warranties with respect to the accuracy or completeness of the contents of this book and specifically disclaim any implied warranties of merchantability or fitness for a particular purpose. No warranty may be created or extended by sales representatives or written sales materials. The advice and strategies contained herein may not be suitable for your situation. You should consult with a professional where appropriate. Neither the publisher nor author shall be liable for any loss of profit or any other commercial damages, including but not limited to special, incidental, consequential, or other damages.

For general information on our other products and services please contact our Customer Care Department within the U.S. at 877-762-2974, outside the U.S. at 317-572-3993 or fax 317-572-4002.

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print, however, may not be available in electronic format.

***Library of Congress Cataloging-in-Publication Data:***

Myers, Drew, 1946-

Surfactant science and technology/Drew Myers. – 3rd ed.  
p. cm.

Includes bibliographical references and index.

ISBN-13 978-0-471-68024-6 (cloth)

ISBN-10 0-471-68024-9 (cloth)

1. Surface chemistry. 2. Surface active agents. I. Title.

QD506.M94 2006

541'.33-dc22

2005007004

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

# **SURFACTANT SCIENCE AND TECHNOLOGY**

*To friends gone, but not forgotten—*

*Johnny B.*

*Paul G.*

*Alan B.*

## Preface to the Third Edition

When a book reaches the third edition, it must be assumed that (1) the work has been useful to someone or (2) the publisher has lost its collective mind. As a simple matter of ego, I must assume that reason 1 is true in this case. For that reason, I have tried to maintain the same basic philosophy with regard to the style and content of the book, while endeavoring to incorporate new material where indicated. A good deal of the information presented is “old” in the sense that it represents work done many years ago by the virtual founders of the science of surface and colloid chemistry. In the mid-1950s a few names stood out as the “gurus” of the field—today the names are too numerous to mention, and the body of published literature is enormous. Surfactants and their applications continue to fill books and patents.

Important advances in the tools available for studying the activity of surfactants has significantly increased our understanding of what is happening at interfaces at the molecular level in both model and practical systems, although there is still a lot to be learned. New knowledge obtained in the years since the publication of the second edition has added greatly to our understanding of the nature of the molecular interactions of surface-active materials and the consequences of their presence on system characteristics and performance. The basic concepts and principles, however, remain pretty much the same.

In this edition, some topics have been reduced or moved around and several new themes added. Two cases, those of phase transfer catalysis (PTC) and aerosols, are not directly related to surfactants, but their real or potential importance prompted me to include some introductory material related to them.

Without changing the fundamental philosophy and goals of the previous editions, this third edition was prepared with three major ideas in mind: (1) to maintain the basic content of the work, (2) to maintain the “readability” of the book for non-specialists, and (3) to improve the book’s utility as a source of basic concepts concerning surfactants and their applications. A limited number of problems are provided at the end of each chapter (except Chapter 1) to illustrate some of the concepts discussed. In some cases, the problems provided may not have a unique solution, but are posed to stimulate imaginative solutions on the part of the reader. Some may also require some searching on the part of the problem solver to find missing pieces. While exact literature references are not provided, the Bibliography at the end of the book includes many of the better resources for more detailed information on each specific subject. It should serve as a useful guide to more detailed coverage for the interested reader.

I would like to thank my two “best friends,” Adriana and Katrina, for their constant love and support, and the crew at ALPHA C.I.S.A.—Lucho, José, Guillermo, Lisandro, Gabriel, Soledad, Alberto, Carlos, Enrique, Rudi, and all the rest—for putting up with my presence and my absence. Gracias por haber soportado mi presencia y mi ausencia.

DREW MYERS

# Contents

<b>Preface to the Third Edition</b>	<b>xv</b>
<b>1 An Overview of Surfactant Science and Technology</b>	<b>1</b>
1.1 A Brief History of Surfactant Science and Technology	3
1.2 The Economic Importance of Surfactants	5
1.3 Some Traditional and Nontraditional Applications of Surfactants	7
1.3.1 Detergents and Cleaners	7
1.3.2 Cosmetics and Personal Care Products	8
1.3.3 Textiles and fibers	9
1.3.4 Leather and furs	10
1.3.5 Paints, Lacquers, and Other Coating Products	10
1.3.6 Paper and Cellulose Products	11
1.3.7 Mining and Ore Flotation	12
1.3.8 Metal-Processing Industries	12
1.3.9 Plant Protection and Pest Control	13
1.3.10 Foods and Food Packaging	13
1.3.11 The Chemical Industry	14
1.3.12 Oilfield Chemicals and Petroleum Production	14
1.3.13 Plastics and Composite Materials	15
1.3.14 Pharmaceuticals	15
1.3.15 Medicine and Biochemical Research	16
1.3.16 Other “Hi-Tech” Areas	16
1.4 Surfactant Consumption	17
1.5 The Economic and Technological Future	20
1.6 Surfactants in the Environment	21
1.7 Petrochemical versus “Renewable” Oleochemical-Based Surfactants	23
1.8 A Surfactant Glossary	25
<b>2 The Organic Chemistry of Surfactants</b>	<b>29</b>
2.1 Basic Surfactant Building Blocks	30
2.1.1 Basic Surfactant Classifications	31
2.1.2 Making a Choice	32



2.2	The Generic Anatomy of Surfactants	33
2.2.1	The Many Faces of Dodecane	34
2.2.2	Surfactant-Solubilizing Groups	38
2.2.3	Common Surfactant Hydrophobic Groups	39
2.2.3.1	The Natural Fatty Acids	40
2.2.3.2	Saturated Hydrocarbons or Paraffins	41
2.2.3.3	Olefins	41
2.2.3.4	Alkyl Benzenes	42
2.2.3.5	Alcohols	43
2.2.3.6	Alkyl Phenols	44
2.2.3.7	Polyoxypropylenes	44
2.2.3.8	Fluorocarbons	45
2.2.3.9	Silicone Surfactants	46
2.2.3.10	Miscellaneous Biological Structures	47
2.3	The Systematic Classification of Surfactants	47
2.4	Anionic Surfactants	48
2.4.1	Sulfate Esters	50
2.4.1.1	Fatty Alcohol Sulfates	51
2.4.1.2	Sulfated Fatty Acid Condensation Products	51
2.4.1.3	Sulfated Ethers	52
2.4.1.4	Sulfated Fats and Oils	54
2.4.2	Sulfonic Acid Salts	54
2.4.2.1	Aliphatic Sulfonates	55
2.4.2.2	Alkylaryl Sulfonates	56
2.4.2.3	$\alpha$ -Sulfocarboxylic Acids and Their Derivatives	58
2.4.2.4	Miscellaneous Sulfoester and Amide Surfactants	60
2.4.2.5	Alkyl Glyceryl Ether Sulfonates	63
2.4.2.6	Lignin Sulfonates	63
2.4.3	Carboxylate Soaps and Detergents	64
2.4.4	Phosphoric Acid Esters and Related Surfactants	65
2.5	Cationic Surfactants	66
2.6	Nonionic Surfactants	69
2.6.1	Polyoxyethylene-Based Surfactants	69
2.6.2	Derivatives of Polyglycerols and Other Polyols	70
2.6.3	Block Copolymer Nonionic Surfactants	73
2.6.4	Miscellaneous Nonionic Surfactants	73
2.7	Amphoteric Surfactants	74
2.7.1	Imidazoline Derivatives	74
2.7.2	Surface-Active Betaines and Sulfobetaines	76
2.7.3	Phosphatides and Related Amphoteric Surfactants	77
	Problems	78

<b>3</b>	<b>Fluid Surfaces and Interfaces</b>	<b>80</b>
3.1	Molecules at Interfaces	83
3.2	Interfaces and Adsorption Phenomena	84
3.2.1	A Thermodynamic Picture of Adsorption	85
3.2.2	Surface and Interfacial Tensions	88
3.2.3	The Effect of Surface Curvature	90
3.3	The Surface Tension of Solutions	91
3.3.1	Surfactants and the Reduction of Surface Tension	94
3.3.2	Efficiency, Effectiveness, and Surfactant Structure	95
	Problems	105
<b>4</b>	<b>Surfactants in Solution: Monolayers and Micelles</b>	<b>107</b>
4.1	Surfactant Solubility	108
4.2	The Phase Spectrum of Surfactants in Solution	112
4.3	The History and Development of Micellar Theory	116
4.3.1	Manifestations of Micelle Formations	117
4.3.2	Thermodynamics of Dilute Surfactant Solutions	121
4.3.3	Classical Theories of Micelle Formation	122
4.3.4	Free Energy of Micellization	124
4.4	Molecular Geometry and the Formation of Association Colloids	125
4.5	Experimental Observations of Micellar Systems	129
4.5.1	Micellar Aggregation Numbers	129
4.5.2	The Critical Micelle Concentration	130
4.5.3	The Hydrophobic Group	131
4.5.4	The Hydrophilic Group	140
4.5.5	Counterion Effects on Micellization	142
4.5.6	The Effects of Additives on the Micellization Process	143
4.5.6.1	Electrolyte Effects on Micelle Formation	144
4.5.6.2	The Effect of pH	146
4.5.6.3	The Effects of Added Organic Materials	147
4.5.7	The Effect of Temperature on Micellization	149
4.6	Micelle Formation in Mixed Surfactant Systems	150
4.7	Micelle Formation in Nonaqueous Media	153
4.7.1	Aggregation in Polar Organic Solvents	153
4.7.2	Micelles in Nonpolar Solvents	154
	Problems	157
<b>5</b>	<b>Higher-Level Surfactant Aggregate Structures: Liquid Crystals, Continuous Biphases, and Microemulsions</b>	<b>160</b>
5.1	The Importance of Surfactant Phase Information	161
5.2	Amphiphilic Fluids	162

5.2.1	Liquid Crystalline, Bicontinuous, and Microemulsion Structures	163
5.2.2	“Classical” Liquid Crystals	166
5.2.3	Liquid Crystalline Phases in Simple Binary Systems	167
5.3	Temperature and Additive Effects on Phase Behavior	170
5.4	Some Current Theoretical Analyses of Novel Mesophases	171
5.5	Vesicles and Bilayer Membranes	172
5.5.1	Vesicles	174
5.5.2	Polymerized Vesicles	176
5.6	Biological Membranes	177
5.6.1	Some Biological Implications of Mesophases	178
5.6.2	Membrane Surfactants and Lipids	180
5.7	Microemulsions	182
5.7.1	Surfactants, Cosurfactants, and Microemulsion Formation	186
5.7.1.1	Ionic Surfactant Systems	187
5.7.1.2	Nonionic Surfactant Systems	188
5.7.2	Applications	188
	Problems	189
<b>6</b>	<b>Solubilization and Micellar and Phase Transfer Catalysis</b>	<b>191</b>
6.1	Solubilization in Surfactant Micelles	192
6.1.1	The “Geography” of Solubilization in Micelles	194
6.1.2	Surfactant Structure and the Solubilization Process	196
6.1.3	Solubilization and the Nature of the Additive	199
6.1.4	The Effect of Temperature on Solubilization Phenomena	201
6.1.5	The Effects of Nonelectrolyte Solutes	203
6.1.6	The Effects of Added Electrolyte	204
6.1.7	Miscellaneous Factors Affecting Solubilization	205
6.2	Micellar Catalysis	206
6.2.1	Micellar Catalysis in Aqueous Solution	206
6.2.2	Micellar Catalysis in Nonaqueous Solvents	208
6.3	Phase Transfer Catalysis	209
6.3.1	Cross-phase Reactions	210
6.3.2	Some Examples of PTC Applications	213
6.3.2.1	Alkyl nitrile Synthesis	213
6.3.2.2	Dihalocyclopropanes	215
6.3.3	Some Notes on the Use of PTC	216
6.3.4	Some Requirements for a Successful PTC Reaction	216
	Problems	218

<b>7</b>	<b>Polymeric Surfactants and Surfactant–Polymer Interactions</b>	<b>220</b>
7.1	Polymeric Surfactants and Amphiphiles	220
7.2	Some Basic Chemistry of Polymeric Surfactant Synthesis	223
7.2.1	Modification of Natural Cellulosics, Gums, and Proteins	223
7.2.2	Synthetic Polymeric Surfactants	223
7.3	Polymeric Surfactants at Interfaces: Structure and Methodology	229
7.4	Interactions of “Normal” Surfactants with Polymers	230
7.4.1	Surfactant–Polymer Complex Formation	232
7.4.2	Nonionic Polymers	235
7.4.3	Ionic Polymers and Proteins	237
7.5	Polymers, Surfactants, and Solubilization	240
7.6	Surfactant–Polymer Interactions in Emulsion Polymerization	242
	Problems	243
<b>8</b>	<b>Foams and Liquid Aerosols</b>	<b>245</b>
8.1	The Physical Basis for Foam Formation	246
8.2	The Role of Surfactant in Foams	250
8.2.1	Foam Formation and Surfactant Structure	253
8.2.2	Amphiphilic Mesophases and Foam Stability	256
8.2.3	Effects of Additives on Surfactant Foaming Properties	257
8.3	Foam Inhibition	259
8.4	Chemical Structures of Antifoaming Agents	261
8.5	A Summary of the Foaming and Antifoaming Activities of Additives	262
8.6	The Spreading Coefficient	263
8.7	Liquid Aerosols	265
8.7.1	The Formation of Liquid Aerosols	265
8.7.1.1	Spraying and Related Mechanisms of Mist and Fog Formation	266
8.7.1.2	Nozzle Atomization	267
8.7.1.3	Rotary Atomization	268
8.7.2	Aerosol Formation by Condensation	270
8.7.3	Colloidal Properties of Aerosols	272
8.7.3.1	The Dynamics of Aerosol Movement	273
8.7.3.2	Colloidal Interactions in Aerosols	275
	Problems	277
<b>9</b>	<b>Emulsions</b>	<b>280</b>
9.1	The Liquid–Liquid Interface	281

9.2	General Considerations of Emulsion Stability	282
9.2.1	Lifetimes of Typical Emulsions	286
9.2.2	Theories of Emulsion Stability	289
9.3	Emulsion Type and Nature of the Surfactant	290
9.4	Surface Activity and Emulsion Stability	293
9.5	Mixed Surfactant Systems and Interfacial Complexes	298
9.6	Amphiphile Mesophases and Emulsion Stability	302
9.7	Surfactant Structure and Emulsion Stability	305
9.7.1	Hydrophile–Lipophile Balance (HLB)	306
9.7.2	Phase Inversion Temperature (PIT)	311
9.7.3	Application of HLB and PIT in Emulsion Formulation	312
9.7.4	Effects of Additives on the “Effective” HLB of Surfactants	314
9.8	Multiple Emulsions	315
9.8.1	Nomenclature for Multiple Emulsions	316
9.8.2	Preparation and Stability of Multiple Emulsions	316
9.8.3	Pathways for Primary Emulsion Breakdown	318
9.8.4	Surfactants and Phase Components	319
	Problems	321

## **10 Solid Surfaces and Dispersions      323**

10.1	The Nature of Solid Surfaces	323
10.2	Liquid versus Solid Surfaces	327
10.3	Adsorption at the Solid–Liquid Interface	329
10.3.1	Adsorption Isotherms	329
10.3.2	Mechanisms of Surfactant Adsorption	331
10.3.2.1	Dispersion Forces	332
10.3.2.2	Polarization and Dipolar Interactions	333
10.3.2.3	Electrostatic Interactions	334
10.3.3	The Electrical Double Layer	335
10.4	The Mechanics of Surfactant Adsorption	337
10.4.1	Adsorption and the Nature of the Adsorbent Surface	338
10.4.2	Nonpolar, Hydrophobic Surfaces	338
10.4.3	Polar, Uncharged Surfaces	339
10.4.4	Surfaces Having Discrete Electrical Charges	340
10.5	Surfactant Structure and Adsorption from Solution	342
10.5.1	Surfaces Possessing Strong Charge Sites	343
10.5.2	Adsorption by Uncharged, Polar Surfaces	346
10.5.3	Surfactants at Nonpolar, Hydrophobic Surfaces	347
10.6	Surfactant Adsorption and the Character of Solid Surfaces	347
10.7	Wetting and Related Phenomena	349
10.7.1	Surfactant Manipulation of the Wetting Process	352

10.7.2	Some Practical Examples of Wetting Control by Surfactants	355
10.7.3	Detergency and Soil Removal	355
10.7.4	The Cleaning Process	355
10.7.5	Soil Types	357
10.7.6	Solid Soil Removal	357
10.7.7	Liquid Soil Removal	358
10.7.8	Soil Redeposition	360
10.7.9	Correlations of Surfactant Structure and Detergency	361
10.7.10	Nonaqueous Cleaning Solutions	363
10.8	Enhanced Oil Recovery	364
10.9	Suspensions and Dispersions	366
	Problems	367
	<b>Bibliography</b>	<b>370</b>
	<b>Index</b>	<b>375</b>

# 1 An Overview of Surfactant Science and Technology

Rapid evolution in the chemical-based nature of our modern society has made it increasingly difficult for scientists, engineers, regulators, and managers to remain abreast of the latest in the technologies impacting their work. The scientific and technical journals published worldwide number in the thousands, and this number increases yearly. Paralleling the proliferation of the scientific literature in general has been an apparent divergence into fields of “pure” science—studies in which the principal goal is a general advancement of human knowledge with no particular “practical” aim in mind—and “applied” science and technology, in which the research is driven by some anticipated application, quite often, but not always, profit-related. Few areas of chemistry have exhibited this growing dichotomy of purpose more than the study of surface and colloid science, especially as applied to surface activity and surface-active materials. Even the nomenclature used in discussing materials showing surface activity is widely varied, depending on the context of the discussion. It is not surprising, then, that the world of surface activity and surface-active agents, or surfactants, can appear complex and confusing to those not intimately involved in it on a day-to-day basis.

When one considers the impact of surface science in general, and emulsions, dispersions, foaming agents, wetting agents, and other related compounds in particular, in our day-to-day routines, the picture that develops reveals the great extent to which these areas of chemistry and chemical technology permeate our lives. From the fundamental aspects of biological membrane formation and function in living cells, which vividly illustrates the spontaneity and importance of colloidal phenomena, to the more “far out” problem of how liquids wet the walls of a rocket’s fuel tank in a low-gravity environment, the physical chemistry of the interactions among various phases at interfaces lies at the root of much of our modern lifestyle.

Industrial concerns, whose very lifeblood may be intimately linked to application of the basic principles of interfacial interactions, often ignore the potential benefits of fundamental research in these areas in favor of an empirical trial-and-error approach, which may lead to a viable process but that possibly could be better understood and even significantly improved by the application of more fundamental science. In many cases the prevailing philosophy seems to be, to paraphrase an old

adage, "A dollar in the hand is worth two in the laboratory." Unfortunately, such an approach often results in more dollars down the drain than many management-level decisionmakers care to admit. Academic researchers, on the other hand, are sometimes guilty of ignoring the potential practical aspects of their work in favor of experimental sophistication and the "Holy Grail" of the definitive theory or model. Neither philosophy alone truly satisfies the needs of our technological existence. Each approach makes its valuable contribution to the overall advancement of human knowledge; however, it sometimes appears that a great deal is lost in the communication gap between the two.

The science and the technology of surfactants have possibly suffered a double blow from the functional divergence of academic and applied research. Academic interest in surfactants, while increasing, has generally concentrated on highly purified, homogeneous materials [quite often limited to a few materials such as sodium dodecylsulfate (SDS), or cetyltrimethylammonium bromide (CTAB)] and elegant analytical techniques. While providing a wealth of useful information related to the particular system under investigation, the application of such information to more complex practical materials and processes is often less than obvious, and is sometimes misleading. The sad fact of life is that real surfactant systems are almost always composed of mixed chemical isomers, contaminants, and added materials that can dramatically alter the effects of a given surfactant on a system. High purity is necessary for the interpretation of delicate laboratory experiments, but requires the use of techniques that may be impractical at the industrial level.

In the results-oriented industrial environment, with some significant exceptions, surfactant research is often carried out on a "Make it work and don't worry about why!" basis. The industrially interesting materials are usually complex mixtures of homologs and structural isomers, or contain impurities resulting from chemical side reactions, unreacted starting materials, residual solvents or byproducts, and so on. Such "contamination" of the desired product is not only common, but commonly variable from batch to batch. For example, particularly significant surface property changes can be induced by the presence of such impurities as inorganic salts or long-chain alcohols remaining after processing. While the presence of such impurities and mixtures will often produce superior results in practice, analysis of the process may be difficult because of the unknown or variable nature of the surfactant composition. Considering the limitations imposed by each school of surfactant research, it is not surprising to find that a practical fusion of the two approaches can be difficult to achieve.

The different views of surfactant science and technology have spawned their own distinctive terminologies and literatures. While the academic or fundamental investigator may probe the properties of surface-active agents, surfactants, tensides, or amphiphiles, the industrial chemist may be concerned with the characteristics of soaps, detergents, emulsifiers, wetting agents, and similar compounds. The former group may publish their results primarily in the *Journal of Physical Chemistry*, *Colloids and Surfaces*, *Langmuir*, or the *Journal of Colloid and Interface Science*, the latter in the *Journal of the American Oil Chemists Society*, the *Journal of Dispersion Science and Technology*, or one of the other technologically specialized



publications aimed at specific areas of application (foods, cosmetics, paints, etc.). All too often, the value of the results to each community can become lost in the sea of manuscripts and the philosophical and operational gulf that sometimes develops between the two, not to mention the almost impossible task of being abreast of all the information published in all the relevant literature.

Before beginning a discussion of specific aspects of the chemistry of surface-active materials and surfactant action, it may be useful to have some idea of the history of surfactants and how their synthesis and use have evolved through the years. Because of parallel developments in various areas of the world, the secrecy of industrial research efforts, and the effects of two world wars, the exact details of the evolution of surfactant science and technology may be subject to some controversy regarding the specific order and timing of specific developments. In any case, the major facts are (hopefully!) correct.

### 1.1. A BRIEF HISTORY OF SURFACTANT SCIENCE AND TECHNOLOGY

The pedigree of the synthetic surfactant industry is reasonably well documented, unlike that of the more ancient “natural” alkali soaps. However, it is not an easy task to pinpoint the exact time when the industry came into being. In a strictly chemical sense, a soap is a compound formed by the reaction of an essentially water-insoluble fatty acid with an alkali metal or organic base to produce a carboxylic acid salt with enhanced water solubility, sufficient to produce useful surface activity. Since the soaps require some form of chemical modification to be useful as surfactants, they could be considered to be synthetic; however, custom dictates that they not be classified in the same category as the materials prepared by more “elegant” synthetic routes.

The alkali metal soaps have been used for at least 2300 years. Their use as articles of trade by the Phoenicians as early as 600 B.C. has been documented. They were also used by the Romans, although it is generally felt that their manufacture was learned from the Celts or some Mediterranean culture. Early soap producers used animal fats and ashes of wood and other plants containing potassium carbonate to produce the neutralized salt. As the mixture of fat, ashes, and water was boiled, the fat was saponified to the free fatty acids, which were subsequently neutralized.

The first well-documented synthetic (nonsoap) materials employed specifically for their surface-active properties were the sulfated oils. Sulfonated castor oil, produced by the action of sulfuric acid on the castor oil, was originally known as “turkey red oil.” It was introduced in the late nineteenth century as a dyeing aid and is still used in the textile and leather industries today. The first surfactants for general application that have been traditionally classified as synthetic were developed in Germany during World War I in an attempt to overcome shortages of available animal and vegetable fats. Those materials were short-chain alkyl-naphthalene sulfonates prepared by the reaction of propyl or butyl alcohol with